# Goose Creek Watershed TMDLs
## *Final*

Prepared by

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Prepared for

**Wyoming Department of Environmental Quality**

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**WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY**
**WATER QUALITY DIVISION**
**GOOSE CREEK WATERSHED TMDLs**
**TMDL SUMMARIES**

| **Waterbody Name** | **Goose Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010209_01 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli*, Sediment, Habitat |
| **Impaired Designated Uses** | 2AB, Recreation, Aquatic Life, Cold-water Fish |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 2,270.2<br>Medium flow (21–54 cfs): 121.8<br>Low flow (< 21 cfs): 68.0<br>Weighted average: 750.2 |
| **Current Load (kg/day TSS)** | 17,992 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 469.3<br>Medium flow (21–54 cfs): 109.2<br>Low flow (< 21 cfs): 33.4<br>Weighted average: 192.9 |
| **Loading Capacity (kg/day TSS)** | 5,913 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 23.5<br>Medium flow (21–54 cfs): 5.5<br>Low flow (< 21 cfs): 1.7<br>Weighted average: 9.7 |
| **Margin of Safety (kg/day TSS)** | 407 |
| **Wastewater Treatment Plant Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 21.1<br>Medium flow (21–54 cfs): 21.1<br>Low flow (< 21 cfs): 21.1<br>Weighted average: 21.1 |
| **Wastewater Waste Load Allocations (kg/day TSS)** | City of Sheridan WWTP (WY0020010): 500<br>Big Horn Mountain KOA WWTP (WY0026441): 2<br>Powder Horn Ranch, LLC (WY0036251): 6<br>Royal Elk Properties, LLC (WY0054399): 5<br>Sheridan County School District (WY0056308): 3<br>Total: 516 |
| **Stormwater Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 7.7<br>Weighted average: 7.7 |
| **Stormwater Waste Load Allocations (kg/day TSS)** | 3,665 |

| **Waterbody Name** | **Goose Creek** |
|---|---|
| **Upstream Load Allocations (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 231.6<br>Medium flow (21–54 cfs): 54.6<br>Low flow (< 21 cfs): 10.7<br>Weighted average: 94.5 |
| **Upstream Load Allocations (kg/day TSS)** | 1,052 |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 174.1<br>Medium flow (21–54 cfs): 16.6<br>Low flow (< 21 cfs): <0.1<br>Weighted average: 48.5 |
| **Future Growth Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (> 54 cfs): 11.5<br>Medium flow (21–54 cfs): 11.5<br>Low flow (< 21 cfs): <0.1<br>Weighted average: 11.5 |
| **Future Growth Waste Load Allocations (kg/day TSS)** | 273 |
| **Defined Targets/Endpoints *E. coli*** | 126 cfu/100 mL |
| **Defined Targets/Endpoints TSS** | 50 mg/L |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land |
| **Regulated Point Sources** | City of Sheridan Municipal Wastewater (WY0020010)<br>Big Horn Mountain KOA (WY0026441)<br>City of Sheridan Stormwater |

| **Waterbody Name** | **Little Goose Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010208_01 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli*, Sediments, Habitat |
| **Impaired Designated Uses** | 2AB, Recreation, Aquatic Life, Cold-water Fish |
| **Current Load (G-cfu/day *E. coli*)** | High flow (>10 cfs): 149.4<br>Medium flow (1.4–10 cfs): 32.2<br>Low flow (< 1.4 cfs): 18.1<br>Weighted average: 63 .1 |
| **Current Load (kg/day TSS)** | 10,459 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (>10 cfs): 81.3<br>Medium flow (1.4–10 cfs): 18.6<br>Low flow (< 1.4 cfs): 3.5<br>Weighted average: 32.8 |
| **Loading Capacity (kg/day TSS)** | 2,902 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (>10 cfs): 4.1<br>Medium flow (1.4–10 cfs): 0.9<br>Low flow (< 1.4 cfs): 0.2<br>Weighted average: 1.6 |
| **Margin of Safety (kg/day TSS)** | 232 |
| **Wastewater Treatment Plant<br>Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (>10 cfs): 0.4<br>Medium flow (1.4–10 cfs): 0.4<br>Low flow (< 1.4 cfs): 0.4<br>Weighted average: 0.4 |
| **Wastewater Treatment Plant<br>Waste Load Allocations (kg/day TSS)** | Powder Horn Ranch, LLC (WY0036251): 6<br>Royal Elk Properties, LLC (WY0054399): 5<br>Sheridan County School District (WY0056308): 3<br>Total: 14 |
| **Stormwater Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (>10 cfs): 14.1<br>Weighted average: 14.1 |
| **Stormwater Waste Load Allocations (kg/day TSS)** | 2,086 |
| **Upstream Load Allocations (G-cfu/day *E. coli*)** | High flow (>10 cfs): 35.7<br>Medium flow (1.4–10 cfs): 10.7<br>Low flow (< 1.4 cfs): 2.9<br>Weighted average: 15.9 |
| **Upstream Load Allocations (kg/day TSS)** | 570 |

| **Waterbody Name** | **Little Goose Creek** |
|---|---|
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (>10 cfs): 27.0<br>Medium flow (1.4–10 cfs): 6.5<br>Low flow (< 1.4 cfs): 0.0<0.1<br>Weighted average: 0.8 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints *E. coli*** | 126 cfu/100 mL |
| **Defined Targets/Endpoints TSS** | 50mg/L as a monthly average |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Grazing on Public Lands<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | Powder Horn Ranch, LLC<br>Royal Elk Properties, LLC<br>City of Sheridan Stormwater |

| **Waterbody Name** | **McCormick Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010208_02 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 2.1 cfs): 81.4<br>Medium flow (0.3–2.1 cfs): 9.7<br>Low flow (< 0.3 cfs): 1.1<br>Weighted average: 28.6 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 2.1 cfs): 15.4<br>Medium flow (0.3–2.1 cfs): 3.7<br>Low flow (< 0.3 cfs): 0.5<br>Weighted average: 6.2 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 2.1 cfs): 0.8<br>Medium flow (0.3–2.1 cfs): 0.2<br>Low flow (< 0.3 cfs): <0.1<br>Weighted average: 0.3 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 2.1 cfs): 14.7<br>Medium flow (0.3–2.1 cfs): 3.5<br>Low flow (< 0.3 cfs): 0.5<br>Weighted average: 5.9 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| Waterbody Name | Park Creek |
|---|---|
| **Waterbody ID** | WYTR100901010204_01 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (>0.1 cfs): 0.6<br>Medium flow (0.03–0.1 cfs): 1.3<br>Low flow (<0.03 cfs): 0.0<0.1<br>Weighted average: 0.7 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (>0.1 cfs): 0.5<br>Medium flow (0.03–0.1 cfs): 0.1<br>Low flow (<0.03 cfs): 0.1<br>Weighted average: 0.2 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (>0.1 cfs): <0.1<br>Medium flow (0.03–0.1 cfs): <0.1<br>Low flow (<0.03 cfs): <0.1<br>Weighted average: <0.1 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (>0.3 cfs): 0.4<br>Medium flow (0.03–0.1 cfs): 0.1<br>Low flow (<0.03 cfs): 0.1<br>Weighted average: 0.2 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| **Waterbody Name** | **Rapid Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010204_02 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 1.4 cfs): 10.4<br>Medium flow (0.9–1.4 cfs): 8.3<br>Low flow (< 0.9 cfs): 3.0<br>Weighted average: 7.4 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 1.4 cfs): 13.9<br>Medium flow (0.9–1.4 cfs): 3.4<br>Low flow (< 0.9 cfs): 1.9<br>Weighted average: 6.1 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 1.4 cfs): 0.7<br>Medium flow (0.9–1.4 cfs): 0.2<br>Low flow (< 0.9 cfs): 0.1<br>Weighted average: 0.3 |
| **Waste Load Allocations(G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 1.4 cfs): 13.2<br>Medium flow (0.9–1.4 cfs): 3.2<br>Low flow (< 0.9 cfs): 1.8<br>Weighted average: 5.8 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Grazing on Public Lands<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| **Waterbody Name** | **Big Goose Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010205_01 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 258.9<br>Medium flow (7–26 cfs): 32.3<br>Low flow (<7 cfs): 41.5<br>Weighted average: 103.0 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 198.0<br>Medium flow (7–26 cfs): 48.1<br>Low flow (<7 cfs): 16.0<br>Weighted average: 83.5 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 9.9<br>Medium flow (7–26 cfs): 2.4<br>Low flow (<7 cfs): 0.8<br>Weighted average: 4.2 |
| **Stormwater Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 3.0<br>Weighted average: 3.0 |
| **Upstream Load Allocations (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 25.0<br>Medium flow (7–26 cfs): 6.9<br>Low flow (<7 cfs): 3.3<br>Weighted average: 11.3 |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 26 cfs): 160.2<br>Medium flow (7–26 cfs): 38.8<br>Low flow (<7 cfs): 11.9<br>Weighted average: 65.1 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Grazing on Public Lands<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | City of Sheridan Stormwater |

| **Waterbody Name** | **Beaver Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010205_02 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 3.8 cfs): 212.6<br>Medium flow (1.6–3.8 cfs): 17.4<br>Low flow (< 1.6 cfs): 2.6<br>Weighted average: 71.5 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 3.8 cfs): 29.1<br>Medium flow (1.6–3.8 cfs): 8.4<br>Low flow (< 1.6 cfs): 3.8<br>Weighted average: 13.2 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 3.8 cfs): 1.5<br>Medium flow (1.6–3.8 cfs): 0.4<br>Low flow (< 1.6 cfs): 0.2<br>Weighted average: 0.7 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 3.8 cfs): 27.6<br>Medium flow (1.6–3.8 cfs): 8.0<br>Low flow (< 1.6 cfs): 3.6<br>Weighted average: 12.6 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| **Waterbody Name** | **Sackett Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010207_01 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 44.2<br>Medium flow (0.4–1.1 cfs): 2.0<br>Low flow (< 0.4 cfs): 1.3<br>Weighted average: 14 .4 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 12.1<br>Medium flow (0.4–1.1 cfs): 1.9<br>Low flow (< 0.4 cfs): 0.8<br>Weighted average: 4.6 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 0.6<br>Medium flow (0.4–1.1 cfs): 0.1<br>Low flow (< 0.4 cfs): <0.1<br>Weighted average: 0.2 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 11.5<br>Medium flow (0.4–1.1 cfs): 1.8<br>Low flow (< 0.4 cfs): 0.8<br>Weighted average: 4.4 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| **Waterbody Name** | **Jackson Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010207_02 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 69.4<br>Medium flow (0.4–1.1 cfs): 6.5<br>Low flow (< 0.4 cfs): 0.2<br>Weighted average: 23.5 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 9.1<br>Medium flow (0.4–1.1 cfs): 2.4<br>Low flow (< 0.4 cfs): 0.5<br>Weighted average: 3.9 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 0.5<br>Medium flow (0.4–1.1 cfs): 0.1<br>Low flow (< 0.4 cfs): <0.1<br>Weighted average: 0.2 |
| **Wastewater Treatment Plant Waste Load Allocations (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 0.1<br>Medium flow (0.4–1.1 cfs): 0.1<br>Low flow (< 0.4 cfs): 0.1<br>Weighted average: 0.1 |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 1.1 cfs): 8.5<br>Medium flow (0.4–1.1 cfs): 2.2<br>Low flow (< 0.4 cfs): 0.4<br>Weighted average: 3.6 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Grazing on Public Lands<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | Sheridan County School District |

| **Waterbody Name** | **Kruse Creek** |
|---|---|
| **Waterbody ID** | WYTR100901010208_03 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (> 4.0 cfs): 85.6<br>Medium flow (1.3–4.0 cfs): 15.9<br>Low flow (< 1.3 cfs): 3.9<br>Weighted average: 33.2 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (> 4.0 cfs): 17.2<br>Medium flow (1.3–4.0 cfs): 7.9<br>Low flow (< 1.3 cfs): 2.5<br>Weighted average: 9.0 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (> 4.0 cfs): 0.9<br>Medium flow (1.3–4.0 cfs): 0.4<br>Low flow (< 1.3 cfs): 0.1<br>Weighted average: 0.5 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (> 4.0 cfs): 16.3<br>Medium flow (1.3–4.0 cfs): 7.5<br>Low flow (< 1.3 cfs): 2.4<br>Weighted average: 8.6 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

| Waterbody Name | Soldier Creek |
|---|---|
| **Waterbody ID** | WYTR100901010209_02 |
| **Location** | Sheridan County, Wyoming |
| **Causes of Impairment** | *E. coli* |
| **Impaired Designated Uses** | 2AB, Recreation |
| **Current Load (G-cfu/day *E. coli*)** | High flow (>1.6 cfs): 103.3<br>Medium flow (0.6–1.6 cfs): 5.8<br>Low flow (<0.6 cfs): 9.3<br>Weighted average: 36.1 |
| **Loading Capacity (G-cfu/day *E. coli*)** | High flow (>1.6 cfs): 17.2<br>Medium flow (0.6–1.6 cfs): 3.2<br>Low flow (<0.6 cfs): 1.1<br>Weighted average: 6.8 |
| **Margin of Safety (G-cfu/day *E. coli*)** | High flow (>1.6 cfs): 0.9<br>Medium flow (0.6–1.6 cfs): 0.2<br>Low flow (<0.6 cfs): 0.1<br>Weighted average: 0.3 |
| **Waste Load Allocations (G-cfu/day *E. coli*)** | None |
| **Nonpoint Source Load Allocations (G-cfu/day *E. coli*)** | High flow (>1.6 cfs): 16.3<br>Medium flow (0.6–1.6 cfs): 3.1<br>Low flow (<0.6 cfs): 1.1<br>Weighted average: 6.4 |
| **Future Growth Waste Load Allocations** | None |
| **Defined Targets/Endpoints** | 126 cfu/100 mL |
| **Watershed Nonpoint Sources** | On-site Wastewater Treatment (Septic Systems)<br>Pastured Animals on Private Land<br>Wildlife and Waterfowl<br>Domestic Animals |
| **Regulated Point Sources** | None |

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# ABBREVIATIONS

AFO - animal feeding operation
AP - Airport
BHNF - Big Horn National Forest
BMP - best management practice
BSLC - Bacteria Source Load Calculator
cfs - cubic feet per second
CWA - Clean Water Act
DMR - discharge monitoring report
GCDAG - Goose Creek Drainages Advisory Group
G-cfu - Giga colony forming units
GCWPC - Goose Creek Watershed Planning Committee
GIS - geographical information system
HKM - HKM Engineers Inc.
IDEQ - Idaho Department of Environmental Quality
I/E plan - information and education plan
kg - kilograms
LA - load allocation
lf - linear feet
m - meter
MGD - million gallons per day
mg/L - milligrams per liter
mL - milliliters
MOS - margin of safety
MS4 - municipal separate storm sewer systems
NRCS - Natural Resources Conservation Service
NTU - nephelometric turbidity units
ODEQ - Oregon Department of Environmental Quality
PCB - polychlorinated biphenyls
RIVPACS - River Invertebrate Prediction and Classification System
SCCD - Sheridan County Conservation District
SDVC- Spatial Data and Visualization Center
SSURGO - NRCS Soil Survey Geographic Database
SWCA - SWCA Environmental Consultants
SWMP - stormwater management plan
TMDL - total maximum daily load
TSS - total suspended soils

U.S. EPA - U.S. Environmental Protection Agency

USDA -U.S. Department of Agriculture

USFS - U.S. Forest Service

USGS - U.S. Geological Survey

WDEQ - Wyoming Department of Environmental Quality

WGFD - Wyoming Game and Fish Department

WLA - waste load allocation

WRCC - Western Regional Climate Center

WSII - Wyoming Stream Integrity Index

WSO - Weather Service Office

WWTP - wastewater treatment plant

WYDOT - Wyoming Department of Transportation

WYPDES - Wyoming Pollutant Discharge Elimination System

# APPENDICES

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# EXECUTIVE SUMMARY

This document represents the total maximum daily load (TMDL) analyses for the Goose Creek Watershed in fulfillment of the requirements by the Clean Water Act (CWA). The overall goal of the TMDL process is to restore and maintain water quality in the Goose Creek Watershed to a level that protects and supports the designated uses (e.g., drinking water, game and non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value). This TMDL was developed by SWCA Environmental Consultants under the direction of the Wyoming Department of Environmental Quality (WDEQ).

This TMDL represents the analysis of eleven impaired waters within the Goose Creek Watershed. All eleven waters were found to be impaired due to exceedances of Wyoming water quality standards for fecal coliform bacteria, and more recently for exceedances of *Escherichia coli*. Two of the waters (Goose Creek and Little Goose Creek) are also impaired due to excessive sediment loads and poor habitat, which affect aquatic life and the cold-water fishery.

The Goose Creek Watershed is in a semiarid and mountainous region of north-central Wyoming. Elevation in the watershed ranges from 3,828 feet (1,167 m) at Acme to 11,760 (3,584 m) in the Big Horn Mountains, although the majority of the land is at elevations of less than 5,000 feet (1,524 m). The Goose Creek Watershed drains approximately 258,100 acres, which encompasses forest, rural, and urban environments. Surface waters in the Goose Creek Watershed are used to provide irrigation water and water supply for some rural and urban residents. Numerous artificial diversions throughout the watershed result in interbasin water transfers and the mixing of waters from different areas of the watershed.

The City of Sheridan, located within the Goose Creek Watershed, was founded in 1884 and settled in the late 1800s to early 1900s. In 2007 the City of Sheridan had an estimated population of 16,719, with an estimated population of 3,273 people living outside the city but within the watershed. Sheridan County's population has increased at an average of 1.2% annually in recent years.

The Goose Creek Watershed includes three primary drainages: Big Goose Creek, Little Goose Creek, and Goose Creek (includes Soldier Creek). The headwaters of Big Goose Creek, the largest tributary to Goose Creek, are in the Cloud Peak Wilderness in the Big Horn National Forest at an elevation of approximately 11,760 feet (3,584 m). Big Goose Creek drains the southern portion of the Goose Creek Watershed and converges with Little Goose Creek in the City of Sheridan to form Goose Creek. Little Goose Creek originates approximately 0.5 mile above the Big Horn National Forest boundary by the joining of two streams, the East Fork and the West Fork of Little Goose Creek, which drain the southwestern portion of the watershed. Little Goose Creek flows north and west after leaving the Big Horn Mountains, and converges with Big Goose Creek in the City of Sheridan to form Goose Creek. Little Goose Creek also receives flow from several smaller impaired tributaries, including Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek. Land uses vary greatly in the Goose Creek Watershed, including agricultural, irrigated and non-irrigated hay meadows, wildlife habitat, and rangeland.

Hydrologic and climate data from 1985 to 2007 were used in this TMDL to describe seasonal patterns in the system, differentiate critical low-water seasons from spring melt periods and summer storms, calculate pollutant loads, and estimate variability in the system. In the Goose Creek Watershed, peak flows typically occur in May and June and are related to the snowmelt throughout the watershed.

In the upper Goose Creek Watershed, spring snowmelt is stored in five reservoirs (Cross Creek, Bighorn, Park, Dome Lake, and Sawmill) that provide irrigation and drinking water. Water is also diverted to and from these reservoirs through interbasin diversions. Below the reservoirs, water is also diverted in sixteen major irrigation diversion canals and ditches. Additional diversions and hydrologic modifications are used to supply drinking water and to provide flood control in the City of Sheridan.

Groundwater within the Goose Creek Watershed is present in shallow, unconfined, water table conditions. For this TMDL, shallow groundwater is of concern because it can be impacted by surface land uses and near-subsurface systems, such as septic systems and drainfields. Near surface, shallow groundwater decreases the travel distance pollutants take through unsaturated soils, in addition to reducing the filtration time needed for biologic attenuation (breakdown).

Water quality data from 1998 to 2005 were used for analysis in this TMDL. Data were obtained from the U.S. Geological Survey (USGS), the Sheridan County Conservation District (SCCD), and WDEQ. In 1998 and 1999, WDEQ collected water quality samples from 28 sites in the Goose Creek Watershed, 18 of which overlapped with SCCD water quality sites. In June 2000 the USGS conducted a synoptic water quality study that included 24 stations within the Goose Creek Watershed; 13 stations overlapped with SCCD water quality sites (sites within 300 m of each other are considered to be overlap). Water quality parameters that relate directly to the sediment and pathogen impairments were analyzed. They include fecal coliform, *E.Coli*, total suspended solids, and turbidity.

The pathogen TMDLs identify current *E. coli* load and the *E. coli* load capacity for each of the eleven impaired segments in the Goose Creek Watershed. Loads are described separately for high-, medium-, and low-flow periods, as defined by individual flow duration curves developed for each impaired segment. Overall *E. coli* load reductions range from a low of 17% for Rapid Creek to a high of 84% for Jackson Creek. The primary nonpoint sources identified for the *E. coli* impairments in the Goose Creek Watershed are septic systems, livestock (on public and private land), wildlife and waterfowl, and domestic animals. The primary point sources of *E. coli* in the watershed are from municipal separate storm sewer systems (MS4) in the City of Sheridan. These permitted MS4 stormwater outfalls discharge to Little Goose Creek, Big Goose Creek, and Goose Creek. There are also five permitted wastewater treatment plants that discharge *E. coli* to streams in the watershed.

The sediment TMDLs identify the current sediment load and load capacity from MS4 permitted stormwater outfalls in the City of Sheridan during a two-year, 24-hour design storm. Sediment load from sources upstream of the City of Sheridan were estimated using total suspended solids (TSS) data and stream flow data collected during high-flow periods. In addition, current and permitted sediment load in wastewater treatment plant discharges were incorporated into the analysis. The cumulative sediment TMDL for the sediment-impaired segments requires a load reduction from stormwater to the creeks of 13,194 kg/day, or 78%.

Based on the results of the TMDLs completed for the Goose Creek Watershed, a watershed-based implementation plan was developed. This plan outlines a strategy to reduce pathogen and sediment loads and to attain Wyoming's water quality standards for the impaired creeks and tributaries in the watershed. This implementation plan includes nine key elements identified by the United States Environmental Protection Agency (U.S. EPA).

Recommended management and implementation measures were defined for three management areas. These areas fall under the jurisdiction of the United States Forest Service, Sheridan County, and the City of Sheridan. However, some implementation measures are shared between the groups to address specific point and nonpoint sources. Point sources identified in the Goose Creek Watershed include the City of Sheridan stormwater flows and the City of Sheridan wastewater treatment plant. Additional point source discharges are from the Powder Horn Ranch, Royal Elk properties, the Sheridan County School District, and the Sheridan Big Horn Mountain KOA wastewater treatment plants. Nonpoint sources identified in the Goose Creek Watershed include on-site wastewater treatment (septic systems), grazing on public lands, pastured animals on private land, big-game wildlife, waterfowl, and domestic animals. Existing implementation measures to address these sources were identified, and recommendations were made for the implementation of future best management practices.

Because the implementation of a watershed-based plan requires collaboration among agencies, resources, and authorities, the technical and financial assistance needed to implement these plans is also included. Furthermore, an implementation schedule and interim milestones for nonpoint source management measures have also been established. These goals provide a general framework to track progress of watershed implementations geared toward improving water quality. In addition, each implementation measure should be monitored for effectiveness and a monitoring plan is included. This monitoring will influence future decisions based on the success or failure of past implementations and provide useful guidance.

# Foreword

Chapter 1 identifies water quality concerns, applicable water quality criteria and standards, and previous and on-going work in the watershed. The regional setting and watershed characterization (Chapters 2 and 3) summarizes the physical, biological, and cultural characteristics of the Goose Creek Watershed. Hydrologic patterns and relationships throughout the watershed are described in Chapter 4. The water quality component of the TMDL (Chapters 5) describes the water quality parameters, trends, and data summaries. The pathogen load analysis and source identification (Chapter 6) analyzes loading by catchment area and seasonality. Point and nonpoint sources are also identified. The pathogen TMDL analysis (Chapters 7) quantifies the current and projected load from the watershed and identifies water quality objectives, and load allocations and reductions required to meet Wyoming's water quality standards. The sediment TMDL analysis (Chapters 8) quantifies the current and projected load from the watershed and identifies water quality objectives, and negotiated load allocations and reductions required to meet water quality standards. Implementation and monitoring plans for the Goose Creek watershed (Chapter 9) describe existing and recommended measures and priorities to attain the TMDLs. The public participation process is presented in Chapter 10.

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# CHAPTER 1 INTRODUCTION

## 1.1 Purpose

This document presents the total maximum daily load (TMDL) study for the Goose Creek Watershed in fulfillment of requirements by the Clean Water Act (CWA).

A TMDL study describes the amount of an identified pollutant that a specific stream, lake, river, or other waterbody can contain while preserving its designated uses and state water quality standards. Once the state has identified the pollutant load from both point and nonpoint sources, controls can be implemented to reduce the daily load of pollutants until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL study, it is submitted to the U.S. Environmental Protection Agency (U.S. EPA) for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was further expanded and enhanced in 1972 and became known as the CWA. The CWA continues to be subject to change as new information, understanding of the natural systems, and human impacts (both positive and negative) are realized. A more thorough discussion of the CWA can be found in *The Clean Water Act: An Owners Manual* (Elder et al. 1999). The main purpose of the CWA is to improve and protect water quality through restoration and maintenance of the physical, chemical, and biological integrity of the nation's waterways. The CWA provides a mechanism for evaluating the nation's waters, establishing designated uses, and defining water quality criteria to protect those uses in specific waterbodies. Section 303(d) of the CWA requires that each state submit a list of waterbodies that fail state water quality standard to the U.S. EPA every two years. This list is known as the "303(d) list," and waterbodies identified on the list are referred to as "impaired waters." For each impaired waterbody, the CWA requires a TMDL study for each pollutant responsible for the impairment of its designated use (or uses).

In 1996 the Sierra Club Legal Defense Fund, on behalf of Biodiversity Associates, American Wildlands, and the Wyoming Outdoor Council, filed a lawsuit to require the U.S. EPA (Region 8) to implement the TMDL program in Wyoming. The lawsuit was filed based on the claim that the State of Wyoming had not adequately monitored its streams, had not developed sufficient point and nonpoint source TMDLs, and had not listed all impaired streams. The State of Wyoming created a TMDL Workplan in 1997 that established a five-year schedule for monitoring streams on the 1996 303(d) list and a 10-year schedule for incorporating TMDLs on those streams with data indicating that TMDLs need to be established.

Since the approval of the TMDL Workplan in 1997, practically all of the 1996-listed waters carried forward to the 1998 303(d) list in Wyoming were included in watershed planning efforts and given "low" priority for TMDL development. The Goose Creek Watershed TMDLs will be among the first TMDLs completed by the State of Wyoming with nonpoint source loading components.

## 1.2 Problem Identification

Residents in the Goose Creek Watershed use Goose Creek and its tributaries extensively for irrigation, recreation, and fishing (Map 1; all maps are in Appendix 1). The streams are very accessible to recreation users, especially in parks and recreation pathways in the City of Sheridan. Big Goose Creek flows through Kendrick Park, Little Goose Creek flows through Emerson and Washington parks, and Goose Creek passes through Thorne-Rider Park. Water quality impairments related to pathogens in the watershed affect a large user community.

## *1.2.1 Designated Uses and Associated Water Quality Standards*

Protection of waters under the CWA consists of three main components: 1) designating uses, 2) establishing water quality criteria to protect those uses, and 3) antidegradation policies and procedures. The State of Wyoming designates uses to all of the surface waters in the state according to the classes outlined in Table 1.1. Designated use categories were updated on April 25, 2007.

**Table 1.1** Designated Uses Related to Specific Surface Water Classes

| Class | Drinking Water | Game Fish | Non-game Fish | Fish Consumption | Other Aquatic Life | Recreation | Wildlife | Agriculture | Industry | Scenic Value |
|---|---|---|---|---|---|---|---|---|---|---|
| 1* | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2AB | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2A | Yes | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 2B | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2C | No | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 2D | No | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| 3A | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3B | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3C | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 3D | No | No | No | No | Yes | Yes | Yes | Yes | Yes | Yes |
| 4A | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |
| 4B | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |
| 4C | No | No | No | No | No | Yes | Yes | Yes | Yes | Yes |

Source: Wyoming Department of Environmental Quality (2001).

Notes: "Yes" indicates the use is protected for that water class, whereas "No" indicates that it is not protected for that water class.

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the national parks and wilderness areas are Class 1; however, all do not support fisheries or other aquatic life uses (e.g., hot springs, ephemeral waters, wet meadows).

The State of Wyoming has designated the uses of Goose Creek and most of its tributaries as Class 2AB (Table 1.2). Class 2AB surface waters are protected for all of the uses identified under Wyoming surface water use designations, including drinking water, game and non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value. Waters designated as Class 2AB are defined by the Wyoming Department of Environmental Quality (WDEQ) as follows in the Wyoming Surface Water Quality Standards:

> Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold-water or warm-water species present. All Class 2AB waters are designated as cold-water game fisheries unless

identified as a warm water game fishery by a "ww" notation in the "Wyoming Surface Water Classification List". Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses (WDEQ 2007).

**Table 1.2** Designated Use Class of Impaired Waters in the Goose Creek Watershed

| Surface Water Name | Description | Designated Use Class | Source |
|---|---|---|---|
| Goose Creek | Tributary to Tongue River | 2AB | Table A; WDEQ (2001) |
| Soldier Creek | Tributary to Goose Creek | 2AB | Table A; WDEQ (2001) |
| Big Goose Creek | Tributary to Goose Creek | 2AB | Table A; WDEQ (2001) |
| Beaver Creek | Tributary to Big Goose Creek | 2AB | 2008 Wyoming 303(d) list[1] |
| Park Creek | Tributary to Big Goose Creek | 2AB | Table B; WDEQ (2001) |
| Rapid Creek | Tributary to Big Goose Creek | 2AB | Table A; WDEQ (2001) |
| Little Goose Creek | Tributary to Goose Creek | 2AB | Table A; WDEQ (2001) |
| McCormick Creek | Tributary to Little Goose Creek | 2AB | 2008 Wyoming 303(d) list[2] |
| Kruse Creek | Tributary to Little Goose Creek | 2AB | 2008 Wyoming 303(d) list[2] |
| Jackson Creek | Tributary to Little Goose Creek | 2AB | Table A; WDEQ (2001) |
| Sackett Creek | Tributary to Little Goose Creek | 2AB | Table B; WDEQ (2001) |

[1] Beaver Creek is classified as 3B in the Wyoming Surface Water Classification List (WDEQ 2001a) and as 2AB on the 2008 303(d) list of impaired waters.

[2] Kruse Creek and McCormick Creek are not classified in the Wyoming Surface Water Classification List (WDEQ 2001a), although they are identified as Class 2AB on the 2008 303(d) list of impaired waters.

Wyoming water quality standards are specific to designated uses and consist of both numeric limits for individual pollutants and conditions, and narrative descriptions of desired conditions. Water quality standards applicable to the impaired uses in the Goose Creek Watershed are summarized in Table 1.3. *Escherichia coli* (*E. coli*) is the only parameter that has a numeric water quality standard. All other standards applicable to the impaired uses in the Goose Creek Watershed are narrative.

**Table 1.3** Narrative and Numeric Surface Water Quality Standards Applicable to the Designated Uses in the Goose Creek Watershed

| Parameter | Water Quality Standard Reference | Standard/Description (WDEQ 2007) |
|---|---|---|
| Settleable Solids | Section 15 | In all Wyoming surface waters, substances attributable to or influenced by the activities of man that will settle to form sludge, bank or bottom deposits shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife. |
| Floating and Suspended Solids | Section 16 | In all Wyoming surface waters, floating and suspended solids attributable to or influenced by the activities of man shall not be present in quantities which could result in significant aesthetic degradation, significant degradation of habitat for aquatic life, or adversely affect public water supplies, agricultural or industrial water use, plant life or wildlife. |

**Table 1.3** Narrative and Numeric Surface Water Quality Standards Applicable to the Designated Uses in the Goose Creek Watershed

| Parameter | Water Quality Standard Reference | Standard/Description (WDEQ 2007) |
|---|---|---|
| Turbidity | Section 23 | (a) In all cold water fisheries and drinking water supplies (classes 1, 2AB, 2A, and 2B), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than ten (10) nephelometric turbidity units (NTUs).<br>(b) In all warm water or nongame fisheries (classes 1, 2AB, 2B and 2C), the discharge of substances attributable to or influenced by the activities of man shall not be present in quantities which would result in a turbidity increase of more than 15 NTUs. |
| *E. coli* Bacteria | Section 27 | (a) Primary Contact Recreation. In all waters designated for primary contact recreation, during the summer recreation season (May 1 through September 30), concentrations of E. coli bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30-day period. All waters in Table A of the Wyoming Surface Water Classification List are designated for primary contact recreation unless identified as a secondary contact water by a "(s)" notation. Waters not specifically listed in Table A of the Wyoming Surface Water Classification List shall be designated as secondary contact waters. During the period October 1 through April 30, all waters are protected for secondary contact recreation only.<br>(b) Secondary Contact Recreation. In all waters designated for secondary contact recreation, and in waters designated for primary contact recreation during the winter recreation season (October 1 through April 30), concentrations of E. coli bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30-day period.<br>(c) Single-sample Maximum Concentrations. During the summer recreation season, on all waters designated for primary contact recreation, the following single-sample maximum concentrations of E. coli bacteria shall apply:<br>(i) High use swimming areas - 235 organisms per 100 milliliters<br>(ii) Moderate full body contact - 298 organisms per 100 milliliters<br>(iii) Lightly used full body contact - 410 organisms per 100 milliliters<br>(iv) Infrequently used full body contact - 576 organisms per 100 milliliters<br>Single-sample maximum values may be used to post recreational use advisories in public recreation areas and to derive single-sample maximum effluent limitations on point source discharges. An exceedence of the single-sample maxima shall not be cause for listing a water body on the State 303(d) list or development of a TMDL or watershed plan. The appropriate recreational use category (i through iv above) shall be determined by the administrator as needed, on a case by case basis. In making such a determination, the administrator may consider such site-specific circumstances as type and frequency of use, time of year, public access, proximity to populated areas, and local interests. |
| Fecal Coliform Bacteria[1] | Section 27 | During the entire year, fecal coliform concentrations shall not exceed a geometric mean of 200 organisms per 100 mL (based on a minimum of not less than 5 samples obtained during separate 24 hour periods for any 30 day period), nor shall the geometric mean of 3 separate samples collected within a 24 hour period exceed 400 organisms per 100 mL in any Wyoming surface water. |
| Biological Criteria | Section 32 | Class 1, 2, and 3 waters shall not have concentrations of substances that adversely affect aquatic life. |

Source: WDEQ (2007).

[1] Original impairments were based on the former fecal coliform bacteria standard listed in WDEQ 2001b.

To interpret narrative standards, WDEQ uses methods to assess the support status of surface waters in the state and to determine water quality condition, TMDL prioritization, and 303(d) listings of impairments (WDEQ 2008a).

Aquatic life uses are not fully supporting when “at least one component of the biological, physical, or chemical data indicate[s] modification to the aquatic community beyond the natural range of reference condition; and/or for any one pollutant, the acute or chronic criterion is [are] exceed[ed] more than once within a three-year period” (WDEQ 2008a).

Impairment of the aquatic life use is based primarily on macroinvertebrate data and quantitative measures of stream morphology. Chemical, physical, and other ancillary data and information also supplement these metrics in a weight-of-evidence approach for making a determination. The biological health of a stream is determined by comparing the biological potential of the stream to observed biological communities in the stream. This analysis is based on a regionally calibrated macroinvertebrate index called the Wyoming Stream Integrity Index (WSII) and a statewide macroinvertebrate-based predictive model called RIVPACS (River Invertebrate Prediction and Classification System). The results of these two analyses are used in the weight-of-evidence approach to determine whether biological narrative criteria are exceeded. If at least one of the two approaches indicates non-support, and the other is indeterminate or also indicative of non-support, then the narrative criteria are considered to be exceeded. If one approach indicates non-support and the other indicates full support, the support status is found to be undetermined. A stream is considered to meet narrative criteria when at least one approach indicates full support and the other indicates either indeterminate or full support. Once a stream is found to exceed biological criteria, the source of the exceedance is investigated. Stream geomorphology was used to determine whether in-stream habitat is affected by physical alterations to the stream channel, including changes in sediment loading. Supplemental studies, such as a stormwater study in the City of Sheridan (WDEQ 2008 305b report), were also used to identify impairment sources.

The recreational uses in Goose Creek and several of its tributaries were found to be impaired due to exceedances of Wyoming water quality standards for fecal coliform bacteria and more recently for exceedances of *E. coli*. These include four impaired segments in the Big Goose Creek subwatershed (main stem of Big Goose Creek, Park Creek, Rapid Creek, and Beaver Creek); five impaired segments in the Little Goose Creek subwatershed (main stem of Little Goose Creek, Jackson Creek, Sackett Creek, Kruse Creek, and McCormick Creek); and the lower section of Soldier Creek and Goose Creek itself (Map 2). Sediment impairments on the main stem of Little Goose Creek and Goose Creek in the City of Sheridan were also identified as impaired on the 2006 303(d) listings (see Map 2) for aquatic life/cold-water fishery uses.

## 1.2.2 Impaired Waters

The impaired waters in the Goose Creek Watershed (see Map 2) are summarized in Table 1.4 and described below. The Goose Creek Watershed was historically a Yellowstone cutthroat fishery, including what is now the City of Sheridan. The true (natural) trout fishery potential has been affected by the current degraded water quality conditions.

### 1.2.2.1 GOOSE CREEK

Goose Creek is a fifth order stream (Strahler 1957) that forms at the confluence of Little Goose Creek and Big Goose Creek near the intersection of Dow Street and Alger Street in the City of Sheridan’s downtown area. Goose Creek flows north to the Tongue River near Acme, Wyoming. Goose Creek is considered by the Wyoming Game and Fish Department (WGFD) to be a low-production trout water that is not likely to sustain a trout fishery (WGFD 1991). Goose Creek was first listed as impaired for exceedances of the fecal coliform standard in 2000. In 2008 the impairment cause was changed to *E. coli* to reflect the recent change in state water quality standards.

In 2006 the cold-water fishery use on Goose Creek was also listed as impaired for sediment and habitat. This impairment was based on a weight-of-evidence approach incorporating a biological assessment of Goose Creek conducted by WDEQ using the methodologies described above (WSII and RIVPACS). Both the pathogen and sediment impairments were identified by WDEQ for Goose Creek from the confluence of Big Goose Creek and Little Goose Creek to an undetermined distance downstream. The estimated length of impairment identified in the 2008 303(d) list for both impairments is 12.6 miles. Based on a study of stormwater water runoff in the City of Sheridan and on a sampling of storm drains along Little Goose Creek and Goose Creek, the identified source of sediment to Goose Creek was determined to be stormwater (WDEQ 2008 305b report).

#### 1.2.2.2 SOLDIER CREEK

Soldier Creek is a fourth order stream with headwaters in the Big Horn National Forest (BHNF). Soldier Creek drains directly to Goose Creek (Sheridan County Conservation District [SCCD] 2003). Goose Creek is considered by the WGFD to be a low-production trout water that is not likely to sustain a trout fishery (WGFD 1991). Soldier Creek, from the confluence with Goose Creek to an undetermined distance upstream, was first listed as impaired for exceedances of the fecal coliform standard in 2000. In 2008 the impairment cause was changed to *E. coli* to reflect the recent change in state water quality standards. The estimated length of impairment identified on the 2008 303(d) list is 2.8 miles.

#### 1.2.2.3 BIG GOOSE CREEK AND TRIBUTARIES

Big Goose Creek is a fifth order stream (Strahler 1957) that, together with Little Goose Creek, forms the main stem of Goose Creek in the City of Sheridan's downtown area (SCCD 2003). East Fork Big Goose Creek and West Fork Big Goose Creek join to form Big Goose Creek approximately 2.0 miles upstream of the BHNF boundary. Big Goose Creek along with three of its tributaries (Beaver Creek, Park Creek, and Rapid Creek) were listed as impaired for exceedances of the fecal coliform standard in 2000. In 2008 the impairment cause was changed to *E. coli* to reflect the 2007 change in state water quality standards. All of the creeks are considered low-production trout waters by WGFD. Rapid Creek is considered to have local fisheries importance but cannot sustain substantial fishing pressure (WGFD 1991). The estimated length of impairment identified for Big Goose Creek and its tributaries on the 2008 303(d) list is 30.2 miles.

#### 1.2.2.4 LITTLE GOOSE CREEK AND TRIBUTARIES

Little Goose Creek is a fourth order stream (Strahler 1957) that joins with Big Goose Creek to form the main stem of Goose Creek in the City of Sheridan's downtown area. The headwaters for Little Goose Creek are in the BHNF (SCCD 2003). Little Goose Creek was first listed as impaired for exceedances of the fecal coliform standard in 1996. Four tributaries to Little Goose Creek (McCormick Creek, Kruse Creek, Sackett Creek, and Jackson Creek) were also listed as impaired for exceedances of the fecal coliform standard in 2000. In 2008 the impairment cause was changed to *E. coli* to reflect the 2007 change in state water quality standards. In 2006 the cold-water fishery use on Goose Creek was also listed as impaired for sediment and habitat. The identified source of sediment to Little Goose Creek has been identified as stormwater (WDEQ 2008 305b report). The estimated length of impairment identified for Little Goose Creek and its tributaries on the 2008 303(d) is 29 miles. The upper segments of Little Goose Creek (downstream to the Highway 87 Bridge crossing) are classified as an important trout water and designated as a fishery of regional importance (Class 3) by WGFD (1991). The lower segments of the creek are classified as low-production trout waters as are the impaired tributaries to Little Goose Creek.

**Table 1.4** Wyoming's Final 2008 305(b) Integrated State Water Quality Assessment Report

| Name | Class | Location | Miles | Uses | Use Support | Causes | Sources | List Date |
|---|---|---|---|---|---|---|---|---|
| Goose Creek (tributary to Tongue River) | 2AB | From confluence of Big Goose Creek and Little Goose Creek an undetermined distance downstream | 12.6 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Goose Creek (tributary to Tongue River) | 2AB | From confluence of Big Goose Creek and Little Goose Creek an undetermined distance downstream | 12.6 | Aquatic life, cold-water fish | Not supporting | Habitat, sediment | Stormwater | 2006 |
| Soldier Creek (tributary to Goose Creek) | 2AB | From Goose Creek to an undetermined distance upstream | 2.8 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Big Goose Creek (tributary to Goose Creek) | 2AB | From the City of Sheridan to above Beckton | 18.7 | Recreation | Not supporting | *E. coli* | Unknown | 1996 |
| Beaver Creek (tributary to Big Goose Creek) | 2AB | From Big Goose Creek to an undetermined distance upstream | 5.7 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Park Creek (tributary to Big Goose Creek) | 2AB | From Big Goose Creek to an undetermined distance upstream | 2.6 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Rapid Creek (tributary to Big Goose Creek) | 2AB | From Big Goose Creek to an undetermined distance upstream | 3.2 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Little Goose Creek (tributary to Goose Creek) | 2AB | From the City of Sheridan upstream to above Big Horn | 15.3 | Recreation | Not supporting | *E. coli* | Unknown | 1996 |
| Little Goose Creek (tributary to Goose Creek) | 2AB | From the City of Sheridan upstream to above Big Horn | 15.3 | Aquatic life, cold-water fish | Not supporting | Habitat, sediment | Stormwater | 2006 |
| McCormick Creek (tributary to Little Goose Creek) | 2AB | From Little Goose Creek to an undetermined distance upstream | 2.1 | Recreation | Not supporting | *E. coli* | Unknown | 2004 |
| Kruse Creek (tributary to Little Goose Creek) | 2AB | From Little Goose Creek to an undetermined distance upstream | 2.5 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Jackson Creek (tributary to Little Goose Creek) | 2AB | From Little Goose Creek to an undetermined distance upstream | 6.1 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |
| Sackett Creek (tributary to Little Goose Creek) | 2AB | From Little Goose Creek to an undetermined distance upstream | 3 | Recreation | Not supporting | *E. coli* | Unknown | 2000 |

## 1.3 Previous and Ongoing Work in Goose Creek Watershed

Extensive work toward understanding the Goose Creek Watershed and improving water quality in stream segments is ongoing. This work has paved the way for a more defensible and adaptable TMDL. The extensive water quality datasets collected by SCCD will be critical to developing segment-specific loads and deriving load capacities for streams. The septic mapping efforts led by the City of Sheridan and Sheridan County were helpful in the source identification portion of the TMDL. SCCD (2006) will monitor the effectiveness of best management practices (BMP) by following implementation of BMPs on ranches, animal feeding operations (AFOs), and improvements to septic systems. This will help to prioritize BMP recommendations in the future.

The Goose Creek Drainages Advisory Group (GCDAG) was formed in 2000 as a collaborative partnership between SCCD, the Sheridan County Commission, and the City of Sheridan. Other stakeholders representing rural, urban, and other local interests also served on the GCDAG. Funding obtained through the GCDAG from the U.S. EPA was used to design and begin implementation of a comprehensive watershed assessment, the *Goose Creek Watershed Assessment* (SCCD 2003). Findings from this assessment are incorporated into the TMDL. The comprehensive watershed assessment of the Goose Creek Watershed was conducted in 2000 and 2002 with the following goals: 1) to identify impaired segments of Big Goose, Little Goose, and Goose Creek; and 2) to provide information and education to affected individuals and the general public to encourage public involvement in future planning and mitigation efforts. In addition to the watershed assessment, a *Goose Creek Watershed Management Plan* (SCCD 2004) was completed as part of this effort. Findings from the plan were also incorporated into the TMDL. As part of the *Goose Creek Watershed Management Plan*, SCCD outlined several initiatives to improve water quality in the watershed. Implementation of the recommendations of the Goose Creek Watershed Planning Committee (GCWPC) is ongoing and includes the following (see Chapter 9 for a comprehensive summary of existing implementation measures in the watershed):

- Reduce septic system contributions to local water quality.
- Develop and maintain a local working group for the SCCD septic system program to develop criteria.
- Administer the septic system cost share program for Goose Creek Watershed residents that have the potential to affect local water quality.
- Conduct an outreach campaign to educate watershed residents about the proper function of septic systems.

Numerous projects have been implemented in the Goose Creek Watershed. Since 2003 SCCD has completed 12 AFO improvement projects, nine septic improvement projects, one riparian buffer project, and storm drain stenciling in the Goose Creek Watershed. These projects have been distributed across the impaired watersheds and include five projects in the Big Goose Creek subwatershed, three projects in the Goose Creek subwatershed (including Soldier Creek), and 15 projects in the Little Goose Creek subwatershed. These projects were all partially funded through the 319 nonpoint source pollution reduction program and implemented by SCCD. Additional projects funded through other U.S. Department of Agriculture (USDA) programs include several irrigation upgrades and stock water, and grazing land improvements.

# CHAPTER 2 REGIONAL SETTING

## 2.1 History

Humans have inhabited the Goose Creek Watershed and surrounding Powder River Basin for over 12,000 years. American Indian tribes with historical ties to the area include the Arikara, Crow, Lakota/Dakota, Arapaho, Comanche, Blackfeet, Cheyenne, and Shoshone (Bureau of Land Management 2009). Euro-Americans began arriving in the area in the mid to late nineteenth century. As land battles between American Indians and Euro-Americans subsided, settlers began to colonize, mine, and farm north-central Wyoming.

Central to the Goose Creek Watershed, the City of Sheridan was founded in 1884 and settled in the late 1800s to early 1900s. The construction of the railroad, coal mining, and cattle ranching brought newcomers to the area, and in 1900 the population of the City of Sheridan totaled 1,559 (Sheridan County 2009). Although mining in the area has been subject to boom-and-bust cycles, agriculture remains a consistent and valued way of life for residents of the watershed. Today, the local municipalities in the area seek to find a balance between traditional land uses and new residential and commercial development (Sheridan County Chamber of Commerce 2009). The City of Sheridan has grown around and along Big Goose Creek, Little Goose Creek, and Soldier Creek, and flows are used for domestic and agricultural purposes. The creeks also flow through city parks and along recreational pathways (SCCD 2004).

In the 1950s, the City of Sheridan developed a three-stage flood control plan for Little Goose Creek and Big Goose Creek through the City of Sheridan, but Stage III for upper Big Goose Creek was never completed. Stage I was started in 1961 and completed in 1963. Stage I involved channel straightening and realignment and the addition of levees and a drop structure on Big Goose Creek upstream of Little Goose Creek to 8,000 linear feet downstream, and 2,000 linear feet of Little Goose Creek upstream of Big Goose Creek. Stage II construction began in 1965 and was completed in 1966, and included seven levees on 11,000 linear feet of Little Goose Creek upstream of Stage I. These channelization projects straightened and lowered the stream channel, and confined the creeks within steep levees (Steady Stream Hydrology 2006).

## 2.2 Socioeconomics

Sheridan County's economic base has traditionally centered on natural resource development, including ranching, mining and, more recently, energy development. However, based on recent employment and income measures, natural resource-dependant goods production has decreased and contributes little to the overall economy. In 2005 service-providing sectors, including trade, transportation, and utilities; education and health services; and leisure and hospitality employed 60% the people in Sheridan County. Government employment accounted for 24% of all employees and specifically local government employed 16% of the workforce. The largest goods-producing sector was construction with 9% of the total employment. Agriculture, forestry, fishing, and hunting accounted for 2% of total employment, and natural resources and mining employment totaled 5% (Headwaters Economics 2007). More generally, farm employment accounted for 762 jobs in 2005 and 4% of total employment.

The federal government is the highest paying sector in Sheridan County with an average annual wage of $61,068. Goods-producing sectors maintain a range of annual wages. Mining wages average $55,546, construction wages average $28,796, and agriculture, forestry, fishing, and hunting-related employment averages $28,288 annually. Of the total personal income earned in Sheridan County in 2005, less than 1% was related to agriculture, forestry, and fishing (Headwaters Economics 2007).

Although agricultural-related contributions to the local economy are quite low, the social connection to the historic land use is important in the local communities. Agriculture has and continues to provide a unique sense of place and visual quality to the rural Sheridan County. The county residents are invested in sustaining working farms and ranches, especially irrigated agricultural land (Sheridan County 2008). Land-use data indicate that 22,309 acres (8.4%) in the watershed are being used for agricultural production, including ranching. Approximately 6,425 acres (2.4%) have been classified as cultivated cropland and 15,884 acres (6.0%) are hay or pastureland. For more information on land-use acreages see Section 3.0.

## 2.3 Population and Growth

The majority of the Goose Creek Watershed lies in Sheridan County (see Map 1). The 267,645-acre watershed encompasses approximately 16% of the 2,516-square-mile (1,610,240 acres) county. Approximately 44,688 acres of the watershed are in Johnson County and 129 acres of the watershed are in Bighorn County. The amount of developed land with measurable population numbers (urban or irrigated cropland) within the watershed boundaries in Johnson and Bighorn counties is minimal and is not discussed with regard to population and socioeconomic conditions.

The largest urban area in the Goose Creek Watershed is the City of Sheridan. Smaller communities in the watershed include Beckton, Big Horn, and Acme. The majority of the population in the watershed resides in the City of Sheridan, with an estimated population of 16,719 in 2007. It is estimated that 3,273 people live outside the City of Sheridan but in the watershed. This population estimate was derived from the number of residential homes on septic systems outside of the city limits and the assumption that there is an average of 2.7 people per household in Sheridan County (Map 3).

The area's population has grown steadily in recent decades, and population forecasts anticipate continued growth through 2030. The population in Sheridan County has increased more than 53% since 1970. At an annual rate, the population increase has been 1.2% (Headwaters Economics 2007). Table 2.1 reflects the current and projected population for the Goose Creek Watershed and surrounding area. The State of Wyoming numbers are given for comparative purposes.

**Table 2.1** Population of Goose Creek Watershed and Surrounding Area

| | Population 2007 | Estimated Population 2015 | Estimated Population 2030 |
|---|---|---|---|
| Wyoming[a] | 533,830 | 560,000 | 621,160 |
| Sheridan County[a] | 27,998 | 30,020 | 33,560 |
| City of Sheridan[a] | 16,719 | 17,926 | 20,040 |
| Rural Residents in Goose Creek Watershed[b] | 3,273 | 3,510[c] | 3,923[c] |
| **Total Goose Creek Watershed** | **19,992** | **21,436** | **23,963** |

[a] Source: Wyoming Department of Administration and Information: Economic Analysis Division (2007).

[b] Estimated from septic density map for area outside of the City of Sheridan but in the watershed, multiplied by 2.31 (the average people per household in Sheridan County).

[c] Estimated using the percentage increase for Sheridan County, excluding the city, over the same time period.

## 2.4 Climate

The climate of the Goose Creek Watershed is typical of semiarid and mountainous regions in north-central Wyoming. Elevation in the watershed ranges from 3,644 feet (1,110 m) at Acme to over 11,760 feet (3,584 m) in the Big Horn Mountains, although the majority of the land is at elevations of less than 5,000 feet (1,524 m). Precipitation ranges from under 12 inches in the east-central portion of Sheridan County to more than 30 inches in the Bighorn Mountains. Winter snowfall accounts for the majority of this total annual precipitation.

Climate data for the Goose Creek Watershed are available from two climate sites maintained by the Western Regional Climate Center (WRCC): the Sheridan Weather Service Office (WSO) Airport (AP)-Station 488155, and the Sheridan Field Station, number 488160 (see Map 2).

The Sheridan WSO AP WRCC site is located at an elevation of 3,960 feet (1,207 m). The site is still in operation and has been in operation since August 1948; data are available through December 2007 (WRCC 2008). Average, minimum, and maximum temperatures and average total monthly precipitation and snowfall recorded over the period of record for the Sheridan WSO AP WRCC site are listed in Table 2.2.

**Table 2.2** Sheridan WSO AP WRCC Site: Monthly Climate Data Summary (1948–2008)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature (ºF) | 21.4 | 26.4 | 33.6 | 43.7 | 53.1 | 62 | 70.2 | 69.0 | 58.1 | 46.6 | 32.9 | 24.3 | 45.1 |
| Average Precipitation (inches) | 0.68 | 0.66 | 1.03 | 1.82 | 2.34 | 2.15 | 1.06 | 0.83 | 1.32 | 1.26 | 0.78 | 0.63 | 14.57 |
| Average Snowfall (inches) | 11 | 10.3 | 12.4 | 10.5 | 1.7 | 0.1 | 0 | 0 | 1.4 | 4.7 | 8.5 | 11.1 | 71.7 |

Source: WRCC (2008).

The Sheridan Field Station WRCC site is located at an elevation of 3,750 feet (1,143 m). The site is still in operation and has been operating from 1920; data are available through December 2007 (WRCC 2008). Average, minimum, and maximum temperatures and average total monthly precipitation and snowfall recorded over the period of record for the Sheridan Field Station WRCC site are listed in Table 2.3.

**Table 2.3** Sheridan Field Station WRCC Site: Monthly Climate Data Summary (1920–2008)

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Temperature (ºF) | 19.3 | 23.7 | 32.1 | 43.5 | 53.4 | 62.2 | 70.7 | 68.9 | 57.7 | 46.1 | 31.9 | 22.7 | 44.3 |
| Average Precipitation (inches) | 0.49 | 0.47 | 0.93 | 1.79 | 2.55 | 2.72 | 1.24 | 0.88 | 1.44 | 1.29 | 0.71 | 0.5 | 15.01 |
| Average Snowfall (inches) | 7.2 | 6.8 | 9.0 | 5.2 | 0.8 | 0.1 | 0 | 0 | 0.4 | 2.1 | 5.5 | 6.4 | 43.3 |

Source: WRCC (2008).

The elevation difference between the two sites is 210 feet (64 m), and the observed average temperature and precipitation for the two sites are relatively similar. For all data available at these stations, the annual precipitation ranges from 14.5 to 15.0 inches, and annual temperature ranges from approximately 44ºF to 45ºF. However, the Sheridan WSO AP site receives almost double the amount of snowfall relative to the Sheridan Field Station site.

More recent temperature and precipitation patterns from 1985 to 2008 (Figures 2.1 and 2.2) support the above trends. During this period, annual precipitation for the Sheridan WSO AP site has ranged from a minimum of 9.6 inches to a maximum of 17.8 inches, whereas annual precipitation for the Sheridan Field Station has ranged from 8.6 inches to 17.9 inches. Average annual temperatures for the two sites have also ranged from 41°F to 48°F.

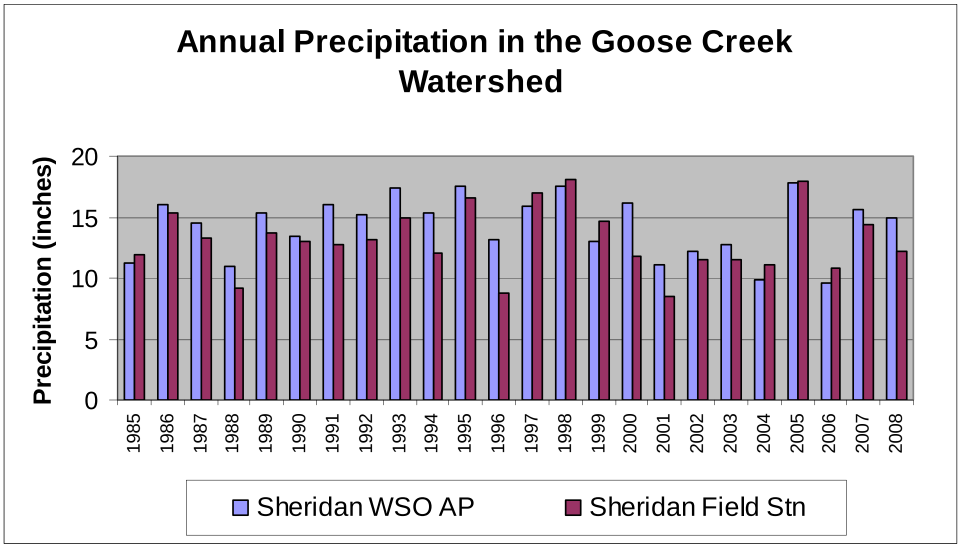


**Figure 2.1** Annual precipitation in the Goose Creek Watershed (1985–2008).

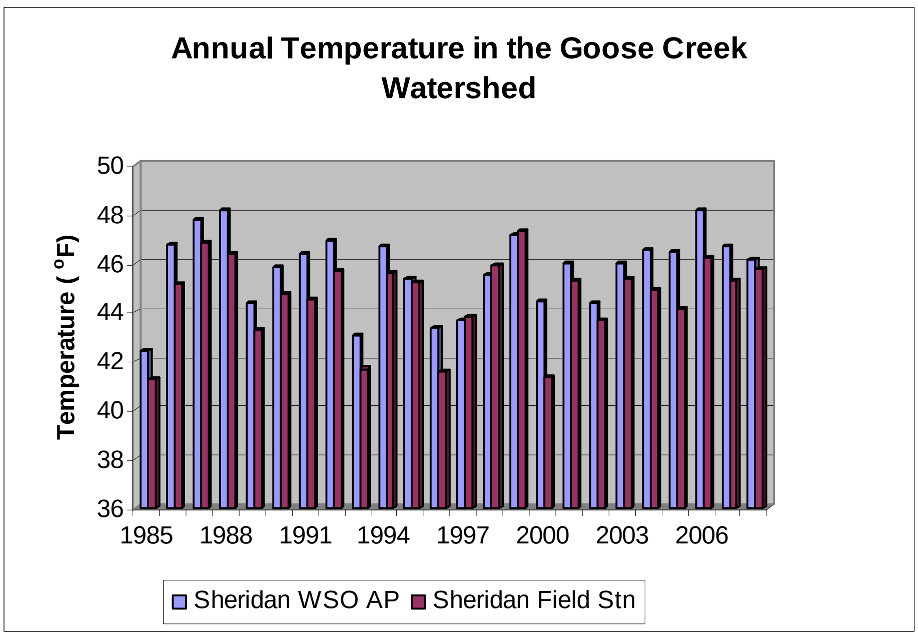


**Figure 2.2** Annual temperature in the Goose Creek Watershed (1985–2008).

# CHAPTER 3 WATERSHED CHARACTERIZATION

The Goose Creek Watershed is located in north-central Wyoming in Sheridan County (see Map 1). The watershed drains 418 square miles and encompasses the City of Sheridan and the communities of Acme, Beckton, and Big Horn; the BHNF; several rural subdivisions; and several ranches. In total, the BHNF makes up 43% of the drainage area (115,000 acres). It is managed as a multiple-use area for recreation, seasonal cattle grazing, logging, and wildlife. Half of the watershed (136,700 acres) is owned by private land holders, the majority of which owns and operates small and large ranches. These ranches have some irrigated hay and crop lands, as well as pastureland for cattle grazing and corrals for feeding. Habitat found on private lands also supports big game, waterfowl, and other wildlife species. The City of Sheridan is the largest and most developed urban area in the watershed (6,399 acres). Subdivisions, converted from rural areas, along Little Goose Creek and Big Goose Creek are becoming more common, especially in areas close to the City of Sheridan.

The watershed covers an elevation range from 3,644 feet (1,110 m) at Acme to approximately 11,760 feet (3,584 m) in the Big Horn Mountains (Map 4). Little Goose Creek and Big Goose Creek converge to form Goose Creek, which flows through the City of Sheridan and north into the Tongue River, a tributary to the Yellowstone River and eventually the Missouri River. The Goose Creek Watershed is therefore at the headwaters of the Mississippi River drainage basin.

The two largest streams in the Goose Creek Watershed are Little Goose Creek and Big Goose Creek. Soldier Creek is a smaller stream draining directly to Goose Creek downstream of the Big Goose Creek and Little Goose Creek confluence. These three streams provide irrigation water to ranches and make up a portion of the water supply to rural and urban residents in the watershed. Diversions from these creeks, as well as reservoirs in the upper segments of the watershed, result in interbasin water transfers and mixing of waters from different areas of the watershed.

For the purposes of the watershed characterization, the Goose Creek Watershed has been divided into three subwatersheds: Big Goose Creek, Little Goose Creek, and Goose Creek (including Soldier Creek) (see Map 1). Delineation of subwatersheds into smaller drainages for the load analysis portion of the TMDLs is discussed in Chapter 6.

## 3.1 Big Goose Creek

The Big Goose Creek subwatershed is the largest of the three subwatersheds with an area of 203 square miles. The headwaters of Big Goose Creek, the largest tributary to Goose Creek, are in the Cloud Peak Wilderness in the BHNF at an elevation of approximately 11,760 feet (see Map 4). The creek drains the southwestern portion of the Goose Creek Watershed and converges with Little Goose Creek in the City of Sheridan to form Goose Creek.

### *3.1.1 Land Ownership and Land Use*

The upper segments of the Big Goose Creek subwatershed are owned and managed by the BHNF for wilderness, recreation, grazing, and timber. In total, the U.S. Forest Service (USFS) owns and manages 41% of the subwatershed (Table 3.1). Private land represents the next largest percentage, accounting for 34% of all land ownership in this subwatershed (Map 5).

**Table 3.1** Land Ownership in the Big Goose Creek Subwatershed

| Land Owner | Total Acres | % of Total Acreage |
|---|---|---|
| USFS National Forest | 52,712 | 40.5% |
| Private Lands | 44,155 | 33.9% |
| USFS Wilderness Area/Scenic River | 28,266 | 21.7% |
| Wyoming State Land | 3,346 | 2.6% |
| Open Water | 1,141 | 0.9% |
| Bureau of Land Management | 445 | 0.3% |
| USFS Research Natural/Special Interest Area | 124 | 0.1% |
| Department of Defense | 3 | 0.0% |
| **Total** | **130,192** | **100.0%** |

The subwatershed is predominantly deciduous and evergreen forest (51.5%) and shrub/scrub/herbaceous (38.3%) land cover (Table 3.2 and Map 6). Privately owned lands comprise 44,155 acres (33.9%), mostly in the lower half of the subwatershed (see Table 3.1), and are predominantly shrub/scrub/herbaceous cover, residential and commercial development, and agricultural land uses. Agricultural operations include irrigated croplands and hay/pasturelands. Nearly all wetland/riparian habitats occur on private lands. Development is concentrated along the waterways, with the highest density development in the lowest portions of the subwatershed in the City of Sheridan at the confluence of Big Goose Creek and Little Goose Creek (see Map 6). The majority of the 67,077 acres of forested lands in the Big Goose Creek subwatershed are in BHNF.

**Table 3.2** Land Use in the Big Goose Creek Subwatershed

| NLCD Land Cover[1] | Total Acres | Percent of Total Acreage |
|---|---|---|
| Deciduous Forest/Evergreen Forest | 67,077 | 51.5% |
| Shrub/Scrub/Herbaceous | 49,868 | 38.3% |
| Hay/Pasture | 5,697 | 4.4% |
| Woody Wetlands/Emergent Herbaceous Wetlands | 3,961 | 3.0% |
| Cultivated Crops | 1,157 | 0.9% |
| Developed, Open Space | 1,075 | 0.8% |
| Developed, Low, Medium, or High Intensity | 600 | 0.5% |
| Open Water | 561 | 0.4% |
| Barren Land | 196 | 0.2% |
| **Total** | **130,192** | **100.0%** |

NLCD = National Land Cover Database

The lower segments of Big Goose Creek flow through the populated City of Sheridan and outlying residential communities. In the City of Sheridan, the creek flows through Kendrick Park, providing a recreational resource for residents. Between the City of Sheridan and the national forest boundary, the Big Goose Creek Valley is owned by private land holders and dominated by ranching and agriculture. Irrigated hayland, non-irrigated hayland, wildlife habitat, and cattle ranches are the predominant land uses found in the Big Goose Creek Valley. Several rural subdivisions have also been constructed along Big Goose Road and County Road 87.

### 3.1.2 Geology and Soils

Big Goose Creek Canyon consists primarily of igneous rocks such as quartz diorite and quartz monzonite The upper parts of the watershed also include sedimentary rocks including dolomite, limestone, and sandstones. Alluvium and colluvium are predominant along the Big Goose Creek Valley from the canyon mouth to the City of Sheridan (U.S. Geological Survey [USGS] 1985). This includes the Cody Shale, which contains gray shales, gray siltstones, and gray sandstones, as well as the Land Formation, which is a buff-colored sandstone with drab-green shales (USGS 1985; SCCD 2003; Table 3.3).

**Table 3.3** Geology of the Big Goose Creek Subwatershed

| Geologic Formation | Total Acres | Percent of Total Acreage |
|---|---|---|
| Plutonic Rocks | 67,649.8 | 52.0% |
| Fort Union Formation | 20,503.4 | 15.7% |
| Glacial Deposits | 12,047.4 | 9.3% |
| Lance Formation | 4,835.9 | 3.7% |
| Undivided Surficial Deposits | 4,285.9 | 3.3% |
| Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone | 3,882.6 | 3.0% |
| Cody Shale | 3,484.7 | 2.7% |
| Alluvium and Colluvium | 3,019.0 | 2.3% |
| Madison Limestone and Darby Formation | 2,430.0 | 1.9% |
| Tensleep Sandstone and Amsden Formation | 1,237.2 | 1.0% |
| Fox Hills Sandstone and Bearpaw Shale | 1,217.9 | 0.9% |
| Mesaverde Group | 1,033.2 | 0.8% |
| Cloverly, Morrison, Sundance and Gypsum Spring Formations | 1,009.6 | 0.8% |
| Landslide Deposits | 870.7 | 0.7% |
| Chugwater and Goose Egg Formations | 840.7 | 0.6% |
| Mowry and Thermoplis Shales | 741.8 | 0.6% |
| Wasatch Formation | 683.4 | 0.5% |
| Frontier Formation | 399.1 | 0.3% |
| Oldest Gneiss Complex | 19.2 | 0.0% |
| **Total** | **130,191.5** | **100.0%** |

Big Goose Creek subwatershed soils are dominated by sandy loam-textured soils at middle to higher elevations, whereas the plains below Big Goose Canyon mainly consist of shallow to deep loamy soils characteristic of mountain slopes, terraces, and alluvial fans (Table 3.4, Map 8).

**Table 3.4** Soil Texture in the Big Goose Creek Subwatershed

| Soil Texture | Total Acres | Percent of Total Acreage |
|---|---|---|
| Sandy Loam | 44,063.3 | 33.8% |
| Loam | 31,851.5 | 24.5% |
| Unweathered Bedrock | 23,137.6 | 17.8% |
| Channery Loam | 12,552.4 | 9.6% |
| Silt Loam | 12,188.4 | 9.4% |
| Very Fine Sandy Loam | 6,398.3 | 4.9% |
| **Total** | **130,191.5** | **100.0**% |

## *3.1.3 Surface Water Hydrology*

### 3.1.3.1 STREAM NETWORK

Big Goose Creek is formed by the convergence of the East Fork and West Fork of Big Goose Creek (Figure 3.1). Flows in the East Fork of Big Goose Creek are provided by releases from Cross Creek, Bighorn, and Park reservoirs. Flows in the West Fork of Big Goose Creek are provided by releases from Dome Lake and Sawmill reservoirs. The convergence of the East Fork and West Fork of Big Goose Creek is located approximately 2.0 miles upstream (southwest) of the national forest boundary where Big Goose Creek becomes a fifth order stream and flows northwest to the City of Sheridan where it converges with Little Goose Creek to form Goose Creek. The major tributaries to Big Goose Creek are Rapid Creek, Park Creek, and Beaver Creek. The largest tributary is Rapid Creek, which joins with Big Goose Creek near Beckton, Wyoming.

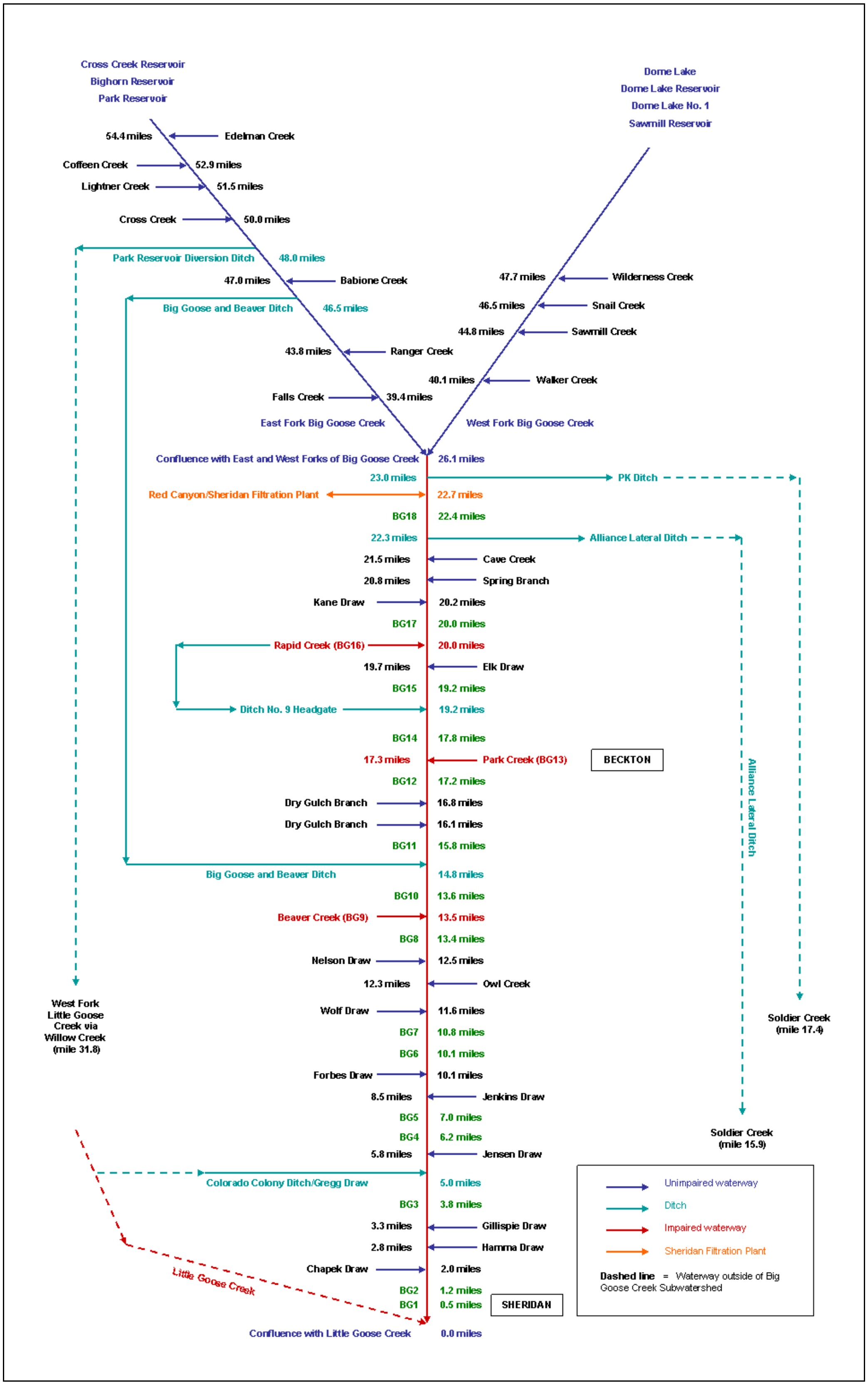


**Figure 3.1** Big Goose Creek from the headwaters to the confluence with Little Goose Creek.

#### 3.1.3.2 CANALS AND DITCHES

Water in Big Goose Creek is appropriated for irrigation use through several irrigation companies as well as for municipal use. The City of Sheridan is appropriated 16 cfs (cubic feet per second) or 11,591 acre-feet of water per year from Big Goose Creek water to serve as their primary water supply (1882 water right). In addition, there are numerous diversions ditches used to convey irrigation water in the Big Goose Creek subwatershed, as well as return flows. Some ditches are also used to convey water to adjacent subwatersheds in the Goose Creek Watershed. Water diversion ditches in the Big Goose Creek subwatershed are shown on Map 2, presented schematically in Figure 3.1, and discussed below.

Near the headwaters, the Park Reservoir Diversion Ditch and the Big Goose and Beaver Ditch divert water from the East Fork of Big Goose Creek just below Park Reservoir. Flows diverted into the Park Reservoir Diversion Ditch are transferred to the Little Goose Creek subwatershed via Willow Creek. They then enter the West Fork of Little Goose Creek. Flows diverted into the Big Goose and Beaver Ditch return to Big Goose Creek approximately 32 miles downstream (see Figure 3.1).

Approximately 3 to 4 miles below the confluence of the East and West forks of Goose Creek are the PK Ditch and Alliance Lateral Ditches. Both of these ditches divert flows to Soldier Creek. Further downstream water is diverted from Rapid Creek before entering Big Goose Creek, but returns to Big Goose Creek via Ditch No. 9 after passing through the Rapid Creek and Beaver Creek subwatersheds. An interbasin diversion from Little Goose Creek also flows into Big Goose Creek via the Colorado Colony Ditch. Other ditches along Big Goose Creek include Rocky Ditch, Elk Horn Ditch, Owl Ditch, Daisy Ditch, Robinson Hardee Ditch, Jensen Pump Ditch, Flume Ditch, and N.B. Held Ditch.

#### 3.1.3.3 STREAM GEOMORPHOLOGY

The upper segments of Big Goose Creek are confined “B” channels in steep mountain valleys in the Big Horn Mountains. As defined by Rosgen (1996), “B” type channels are moderately steep and entrenched, slightly incised, with rapids, riffles, and irregularly spaced scour pools. This channel type is characterized by low to moderate sensitivity to disturbance, low streambank erosion potential, and vegetation with moderate influence on channel stability. Once the creek exits Big Goose Canyon, it transitions to a meandering “C” type channel (Rosgen 1996) as it enters the transition zone from the foothills to the Great Plains Ecoregion (SCCD 2003). “D” type channels are slightly entrenched, lower gradient, and meandering (SCCD 2003). These channels have very high streambank erosion potential, and are highly sensitive to changes caused by streamflow and sediment. The lower sections of Big Goose Creek in and near the City of Sheridan have been channelized into concrete sections through the city for flood control (SCCD 2003).

Stream habitat assessments conducted from 2001 to 2002 indicate a decline in channel condition and habitat quality from upstream to downstream (SCCD 2003). The streambed was dominated by cobble and coarse gravel throughout, and silt deposition was low at most sampling sites. There was a general trend toward reduced habitat quality and channel condition from Big Goose Creek Canyon to the lowermost sampling site in the City of Sheridan. Channelization of Big Goose Creek in the city has reduced streambank stability, undercut banks, pools, and in-stream and riparian habitat structure.

### *3.1.4 Fisheries and Wildlife*

#### 3.1.4.1 FISHERIES

Wyoming fish fauna are classified by WDEQ as non-game species, warm-water game species, or cold-water game species and are used as the primary measure to classify Wyoming waterbodies (SCCD 2003). In the past, the fish population in Big Goose Creek was dominated by cold-water and warm-water game and non-game species, including brown trout, rainbow trout, longnose sucker, longnose dace, mountain sucker, stonecat, rock bass, mountain whitefish, white sucker, northern redhorse, and Snake River cutthroat. Yellowstone cutthroat trout are the only native trout in the watershed. No fish species were considered threatened, endangered, or of special concern (Williams et al. 1989 in SCCD 2003). Of the warm-water game fish and the cold-water game fish known to occur in Big Goose Creek, only stonecat and Yellowstone cutthroat trout are native to Wyoming.

Currently, the majority of Big Goose Creek is classified by WDEQ as a cold-water fishery. Fish species that are known to occur in Big Goose Creek include brook trout, black bullhead, brown trout, carp, flathead chub, fathead minnow, golden shiner, grayling, green sunfish, longnose dace, longnose sucker, mountain sucker, mountain whitefish, shorthead redhorse, rainbow trout, rock bass, smallmouth bass, stonecat, white crappie, white sucker, and yellow perch (personal communication via email between Audrey McCulley [SWCA Environmental Consultants] and Bill Bradshaw [WGFD] March 5, 2009). Warm-water game species occur less frequently in the upper Big Goose Creek drainage. The occurrence and relative abundance of cold-water game fish, including brown trout, rainbow trout, cutthroat trout, and mountain whitefish, varied along the longitudinal gradient of Big Goose Creek and occurred more frequently in the upper drainage (SCCD 2003). Fishery data indicate that the majority of Big Goose Creek contains populations of cold-water game fish, except in the City of Sheridan where extensive channelization has resulted in little to no fish habitat (SCCD 2003). The transition from a cold-water fishery to a warm-water fishery occurs approximately 1 to 2 miles downstream of the Beaver Creek confluence and continues downstream to the City of Sheridan. This transition zone yielded the highest diversity of cold-water and warm-water game species recorded in Big Goose Creek (SCCD 2003). Although cold-water game species occur in the warm to cold-water transition zone, limited data suggest their abundance is not high.

**Table 3.5** Fish Species Recorded at Big Goose Creek at T-T Ranch Lower Bridge, July 25, 2002

| Species | Total |
|---|---|
| Brown Trout | 61 |
| Rainbow Trout | 1 |
| Longnose Dace | NC |
| Mountain Sucker | NC |

Note: Data collection by WGFD
NC= not counted

Based only on the occurrence and abundance of cold-water game fish species in Big Goose Creek, the waterbody appears to be meeting its designated use for fish. The one exception to this is an unknown distance of stream between the warm- to cold-water transition zone and the confluence of Big Goose Creek with Little Goose Creek in the City of Sheridan (SCCD 2003).

### 3.1.4.2 WILDLIFE

Big-game species in the Big Goose Creek subwatershed include mule deer, white-tailed deer, elk, moose, and pronghorn antelope (Maps 9a, 9b, 9c). Mountain lions and black bear are also known to occur in the area. Table 3.6 lists habitat data for big-game species in Big Goose Creek, as designated by WGFD.

**Table 3.6** Big Goose Creek Subwatershed Big-game Habitat

| Big-game Species | Crucial Winter Habitat (acres) | Spring/Summer/Fall Habitat (acres) | Yearlong Habitat (acres) | Parturition (acres) | Migration Routes (miles) |
|---|---|---|---|---|---|
| Elk | 12,225.6 | 80,609.9 | – | 13,409.7 | 8.4 |
| Mule Deer | – | 70,338.1 | 7,325.1 | – | – |
| White-tailed Deer | – | – | 24,467.2 | – | – |
| Moose | 3,748.7 | 2,870.0 | 45,311.3 | 6,098.7 | – |
| Pronghorn | – | – | 10,862.0 | – | – |
| **Total*** | **15,974.3** | **153,818.0** | **87,965.6** | **19,508.4** | **8.4** |

*Big-game habitat acreages may overlap.

Common waterfowl species in the Big Goose Creek subwatershed likely include mallard, common goldeneye, wood duck, blue-winged teal, green-winged teal, common merganser, and Canada goose. These species are most common in lower elevations, from the mouth of Big Goose Canyon north to the confluence with the Tongue River (personal communication between Audrey McCulley [SWCA] and Tim Thomas [WGFD] March 4, 2009). Waterfowl data for upper tributaries in the Big Goose Creek subwatershed are not available.

# 3.2 Little Goose Creek

The Little Goose Creek subwatershed is the second largest of the three subwatersheds with an area of 151 square miles. The creek is formed approximately 0.5 mile above the BHNF boundary by the joining of two streams, the East Fork and the West Fork, whose headwaters originate in the national forest. The creek flows to the east and north after leaving the Big Horn Mountains, converging with Big Goose Creek to form Goose Creek in the City of Sheridan. Little Goose Creek also receives flow from several smaller tributaries that are impaired, including Sackett Creek, Jackson Creek, Kruse Creek, and McCormick Creek.

## *3.2.1 Land Ownership and Land Use*

Land ownership and land uses along Little Goose Creek are similar to those previously discussed for Big Goose Creek (see Map 5). Privately owned lands comprise 61,686 acres (64%) of the subwatershed. Little Goose Creek's upper segments are owned and managed by the BHNF for wilderness, recreation, grazing, and timber. In total, the USFS owns and manages 25% of the subwatershed. After leaving the BHNF and the Little Goose Canyon, the subwatershed is predominantly privately owned (Table 3.7).

**Table 3.7** Land Ownership in the Little Goose Creek Subwatershed

| Land Owner | Total Acres | Percent of Total Acreage |
|---|---|---|
| Private Lands | 61,686 | 64% |
| USFS National Forest | 24,304 | 25% |
| USFS Wilderness Area/Scenic River | 7,075 | 7.3% |
| Wyoming State Land | 2,830 | 2.9% |
| Bureau of Land Management | 635 | 0.8% |
| Open Water | 41 | <1% |
| **Total** | **96,572** | **100**% |

Agricultural land uses, consisting of irrigated hayland, non-irrigated hayland, cattle grazing, and wildlife habitat, are prevalent throughout the subwatershed. In the lower segments, as the creek nears the community of Big Horn, smaller acreage and rural residential land uses increase (Table 3.8). Additional land uses in the watershed include a feedlot, state bird farm, and a small gravel mining operation.

**Table 3.8** Land Use in the Little Goose Creek Subwatershed

| NLCD Land Cover | Total Acres | Percent of Total Acreage |
|---|---|---|
| Shrub/Scrub/Herbaceous | 38,910 | 40.3% |
| Deciduous Forest/Evergreen Forest | 36,206 | 37.5% |
| Hay/Pasture | 7,058 | 7.3% |
| Woody Wetlands/Emergent Herbaceous Wetlands | 5,633 | 5.8% |
| Cultivated Crops | 4,018 | 4.2% |
| Developed, Open Space | 2,578 | 2.7% |
| Developed, Low, Medium or High Intensity | 2,059 | 2.1% |
| Open Water | 61 | 0.1% |
| Barren Land | 49 | 0.1% |
| **Total** | **96,572** | **100**% |

The Little Goose Creek subwatershed is predominantly shrub/scrub/herbaceous (40.3%) and deciduous/evergreen forest (37.5%) land cover (see Map 6). Privately owned lands are predominantly shrub/scrub/herbaceous cover, residential and commercial development, and agricultural land uses. Agricultural operations include irrigated croplands and hay/pasturelands. A large portion of wetland/riparian habitats occurs on private lands. Development is concentrated along the waterways, with the highest density development in the lowest portions of the subwatershed in the City of Sheridan at the confluence of Little Goose Creek and Big Goose Creek.

After passing through Big Horn, a resort golf course, and several larger subdivisions downstream, Little Goose Creek segments the City of Sheridan. The creek flows through much of the city, including business areas, residential areas, and recreational areas, before meeting Big Goose Creek. Much of this stretch has been channelized for flood control and development purposes; the lowermost segment has been placed in a concrete lined channel.

### 3.2.2 Geology and Soils

The upper portion of the Little Goose watershed flows mainly over igneous rocks, such as quartz diorite or quartz monzonite As the creek enters Little Goose Creek Canyon, the predominant rocks are sedimentary and consist of dolomites, limestones, sandstones, siltstones, claystones, and shales (Table 3.9). The sedimentary formations include the Wasatch Formation, which comprises red to gray and brown sandstones and mudstones with conglomerate lenses (USGS 1985), and the Moncreiffe and Kingsbury Conglomerate Members of the Wasatch Formation, consisting of clasts interbedded with sandstones and claystones. Approximately 4 miles south of Big Horn, the creek enters a floodplain consisting of alluvium and colluvium and continues to its confluence with Big Goose Creek (USGS 1985).

**Table 3.9** Geology of the Big Goose Creek Subwatershed

| Geologic Formation | Total Acres | Percent of Total Acreage |
|---|---|---|
| Plutonic Rocks | 30,238.1 | 31.3% |
| Alluvium and Colluvium | 17,382.9 | 18.0% |
| Fort Union Formation | 10,574.9 | 11.0% |
| Madison Limestone and Darby Formation | 2,793.9 | 2.9% |
| Cody Shale | 2,699.8 | 2.8% |
| Glacial Deposits | 1,799.6 | 1.9% |
| Tensleep Sandstone and Amsden Formation | 1,699.5 | 1.8% |
| Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone | 1,612.0 | 1.7% |
| Lance Formation | 1,571.6 | 1.6% |
| Chugwater and Goose Egg Formations | 887.8 | 0.9% |
| Cloverly, Morrison, Sundance and Gypsum Spring Formations | 843.0 | 0.9% |
| Mesaverde Group | 667.5 | 0.7% |
| Mowry and Thermoplis Shales | 652.6 | 0.7% |
| Frontier Formation | 491.0 | 0.5% |
| Gravel, Pediment, and Fan Deposits | 450.8 | 0.5% |
| Landslide Deposits | 330.0 | 0.3% |
| **Total** | **96,571.7** | **100.0%** |

Little Goose Creek subwatershed soils are dominated by channery loam-textured soils at middle elevations. Soils in the plains below Little Goose Creek are dominated by loam-textured soils characteristic of terraces and alluvial fans (see Map 8). Near the Little Goose Creek confluence with Big Goose Creek, the most common soils are very fine sandy loam-textured soils typical of gently sloping floodplains and alluvial fans (Natural Resources Conservation Service [NRCS] 1998; Table 3.10).

**Table 3.10** Soil Texture in the Little Goose Creek Subwatershed

| Soil Texture | Total Acres | Percent of Total Acreage |
|---|---|---|
| Loam | 43,871.6 | 45.4% |
| Sandy Loam | 28,171.7 | 29.2% |
| Channery Loam | 10,406.5 | 10.8% |
| Very Fine Sandy Loam | 6,647.7 | 6.9% |
| Silt Loam | 3,828.0 | 4.0% |
| Clay | 3,353.8 | 3.4% |
| Unweathered Bedrock | 292.4 | 0.3% |
| **Total** | **96,571.7** | **100.0**% |

## *3.2.3 Surface Water Hydrology*

### 3.2.3.1 STREAM NETWORK

Little Goose Creek is formed by the convergence of the East Fork and West Fork of Little Goose Creek (Figure 3.2). Flows in the East Fork of Little Goose Creek are due to runoff from the Big Horn Mountains. Flows in the West Fork of Little Goose Creek are provided by releases from Cross Creek, Bighorn, and Park reservoirs. Additional flows are provided to the West Fork of Little Goose Creek via the interbasin Park Reservoir diversion from the East Fork of Big Goose Creek.

The East Fork and the West Fork of Little Goose Creek join approximately 0.5 mile upstream of the national forest boundary, after which the creek becomes a fourth order stream (Strahler 1957) and flows to the City of Sheridan where it converges with Big Goose Creek to form Goose Creek (Figure 3.2). The major tributaries to Little Goose Creek are McCormick Creek, Kruse Creek, Jackson Creek, and Sackett Creek. McCormick Creek and Kruse Creek enter Little Goose Creek near the intersection of Highways 87 and 335. Jackson Creek enters Little Goose Creek approximately 0.5 mile north of Big Horn community. All of the tributaries have a drainage area of approximately 10 square miles or less, and they are designated as third order streams (Strahler 1957).

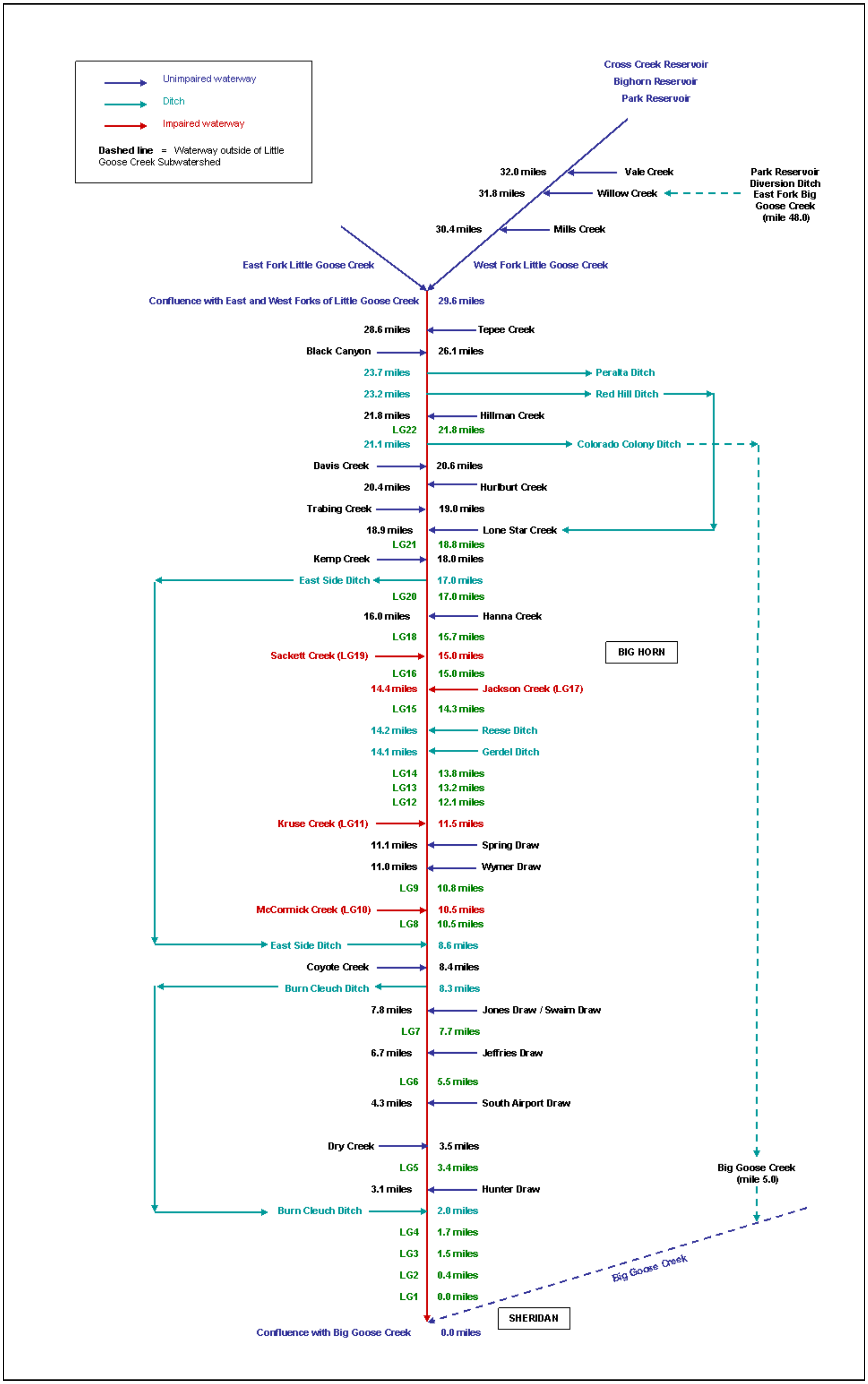


**Figure 3.2** Little Goose Creek from the headwaters to the confluence with Big Goose Creek.

#### 3.2.3.2 CANALS AND DITCHES

Little Goose Creek is a highly appropriated waterbody with approximately fourteen irrigation ditches taking water from Little Goose Creek. Water diversion ditches in the Little Goose Creek subwatershed are shown on Map 2 and in Figure 3.2.

At approximately 6 miles below the confluence of the East Fork and West Fork of Little Goose Creek, the Peralta Ditch and Red Hill Ditch take water from Little Goose Creek. Return flows from Red Hill Ditch re-enter Little Goose Creek via Lone Star Creek. In this section, the Colorado Colony interbasin diversion diverts flow through the Jackson Creek drainage and continues to Big Goose Creek. Further downstream, the East Side Ditch diverts water south of Big Horn through the middle of the McCormick Creek drainage. The Burn Cleuch Ditch also diverts water from Little Goose Creek and return flows occur approximately 6 miles downstream. Other diversion ditches along Little Goose Creek include Last Chance Ditch, Willow Ditch, Nameless Ditch, West Side Ditch, Gerdel Ditch, Hurricane Ditch, and Reed Ditch.

#### 3.2.3.3 STREAM GEOMORPHOLOGY

The upper segments of Little Goose Creek are confined, high gradient, entrenched, slightly incised channels in steep mountain valleys in the Big Horn Mountains. Once the creek exits Little Goose Canyon, it transitions from a higher gradient and confined “B” type channel to a lower gradient, meandering “C” type channel in the plains (Rosgen 1996) as it enters the transition zone from the foothills to the Great Plains Ecoregion (SCCD 2003). “C” type channels have very high streambank erosion potential, and are highly sensitive to changes caused by streamflow and sediment. The lowermost sections of Little Goose Creek, in and near the City of Sheridan, have been channelized into concrete sections for flood control and development purposes (SCCD 2003).

The SCCD (2003) stream habitat assessments indicate a general decline in channel condition and habitat quality from the uppermost sampling site to the lowermost sampling site in the City of Sheridan. However, this trend was not consistent. The lower segment (LG5 upstream of the Brundage Lane Bridge) was in good condition other than relatively high amounts of silt and sand, apparently originating from upstream sources. The poor condition of lower stream segments is due to artificial channelization that has eliminated some undercut banks, pools, and in-stream and riparian habitat structure. The streambed was dominated by cobble or coarse gravel, with silt and sand increasing from upstream to downstream.

### *3.2.4 Fisheries and Wildlife*

#### 3.2.4.1 FISHERIES

Historically, the fish population in Little Goose Creek was dominated by both cold-water and warm-water game and non-game species, including brown trout, rainbow trout, brook trout, mountain whitefish, longnose sucker, longnose dace, white sucker, and mountain sucker. In 1956 and 1958 channel catfish were stocked in Little Goose Creek. No fish species were considered threatened, endangered, or of special concern (Williams et al. 1989 in SCCD 2003).

Currently, the majority of Little Goose Creek is classified by WDEQ as a cold-water fishery. Fish species known to occur in Little Goose Creek include brook trout, brown trout, carp, creek chub, fathead minnow, flathead chub, lake chub, longnose dace, longnose sucker, mountain sucker, mountain whitefish, rainbow trout, rock bass, and white sucker (personal communication via email between Audrey McCulley [SWCA] and Bill Bradshaw [WGFD], March 5, 2009). Fish population trends are generally the same as those observed in Big Goose Creek for the abundance and distribution of cold-water and warm-water game species. Common warm-water game species present in Little Goose Creek downstream of Highway 87 include rock bass and green sunfish. The occurrence and relative abundance of cold-water game fish declines dramatically from the Gallatin Ranch Bridge downstream to the Highway 87 Bridge, and no cold-water game species were recorded by WGFD from the Woodland Park Bridge downstream to the City of Sheridan.

**Table 3.11** Fish Species Recorded at Little Goose Creek Near Woodland Park Bridge on June 28, 1994

| Species | Total Number |
|---|---|
| Brown Trout | 12 |
| Rainbow Trout | 2 |
| White Sucker | 114 |
| Longnose Dace | 276 |
| Mountain Sucker | 24 |
| Longnose Sucker | 6 |
| Rock Bass | 11 |
| Carp | 1 |

Note: These data are the most recent data available but are not reflective of current conditions in the creek as described by WGFD in 2009 via personal communication with SWCA.

Based only on the occurrence and abundance of cold-water game fish species, Little Goose Creek appears to be meeting its designated use as a cold-water fishery, with the exception of an unknown length of stream from the Woodland Park Bridge to the confluence with Big Goose Creek in the City of Sheridan (SCCD 2003).

### 3.2.4.2 WILDLIFE

Big-game species in the Little Goose Creek subwatershed include mule deer, white-tailed deer, elk and moose (see Maps 9a, 9b, 9c). Mountain lions and black bear are also known to occur in the area. Table 3.12 lists habitat data for big-game species in Little Goose Creek as designated by WGFD.

**Table 3.12** Little Goose Creek Subwatershed Big-game Habitat

| Big-game Species | Crucial Winter Habitat (acres) | Spring/Summer/Fall Habitat (acres) | Yearlong Habitat (acres) | Parturition (acres) | Migration Routes (miles) |
|---|---|---|---|---|---|
| Elk | 5,803.9 | 36,001.8 | – | 11,918.2 | 8.0 |
| Mule deer | – | 32,663.8 | 28,167.3 | – | – |
| White-tailed Deer | – | – | 48,285.6 | – | – |
| Moose | 7,681.2 | 2,985.5 | 21,148.8 | 2,590.9 | – |
| Pronghorn | – | – | 10,871.6 | – | – |
| **Total*** | **13,485.1** | **71,651.1** | **108,473.3** | **14,509.1** | **8.0** |

*Big-game habitat acreages may overlap.

Common waterfowl species in the Little Goose Creek subwatershed likely include mallard, common goldeneye, wood duck, blue-winged teal, green-winged teal, common merganser, and Canada goose.

These species are most common in lower elevations, from the mouth of Little Goose Canyon north to the confluence with the Tongue River (personal communication between Audrey McCulley (SWCA) and Tim Thomas (WGFD), March 4, 2009). Waterfowl data for upper tributaries in the Little Goose Creek subwatershed are not available.

# 3.3 Goose Creek

## 3.3.1 Land Ownership and Land Use

The Goose Creek subwatershed is the smallest of the three subwatersheds with an area of 61 square miles. Privately owned lands comprise 31,822 acres (81.4%) of the subwatershed (see Map 5; Table 3.13). Land uses vary greatly from the upper to lower segments of the Goose Creek Watershed. From Acme upstream to the City of Sheridan, the predominant land uses are agricultural, including irrigated and non-irrigated hay meadows, wildlife habitat, and rangeland.

**Table 3.13** Land Ownership in the Goose Creek Subwatershed

| Land Owner | Total Acres | Percent of Total Acreage |
|---|---|---|
| Private Lands | 31,822 | 81.4% |
| Wyoming State Land | 3,071 | 8.0% |
| Bureau of Land Management | 2,848 | 7.3% |
| USFS National Forest | 783 | 2.0% |
| Department of Defense | 493 | 1.3% |
| Open Water | 59 | 0.2% |
| **Total** | **39,076** | **100**% |

The Goose Creek subwatershed is predominantly shrub/scrub/herbaceous (69%) land cover (see Map 6; Table 3.14). Privately owned lands in the subwatershed are predominantly shrub/scrub/herbaceous cover, agricultural land uses (hay/pasture and cultivated crops), and various wetlands. Agricultural operations include mostly hay/pasturelands with some irrigated croplands. Development is concentrated along the waterways, with the highest density development in the upper segments of Goose Creek in the City of Sheridan.

**Table 3.14** Land Use in the Goose Creek Subwatershed

| NLCD Land Cover | Total Acres | Percent of Total Acreage |
|---|---|---|
| Shrub/Scrub/Herbaceous | 26,982 | 69.1% |
| Hay/Pasture | 3,129 | 8.0% |
| Woody Wetlands/Emergent Herbaceous Wetlands | 2,648 | 6.9% |
| Deciduous Forest/Evergreen Forest | 2,163 | 5.5% |
| Developed, Low, Medium or High Intensity | 1,667 | 4.3% |

**Table 3.14** Land Use in the Goose Creek Subwatershed

| NLCD Land Cover | Total Acres | Percent of Total Acreage |
|---|---|---|
| Cultivated Crops | 1,251 | 3.2% |
| Developed, Open Space | 1,158 | 3.0% |
| Barren Land | 49 | 0.1% |
| Open Water | 28 | 0.1% |
| **Total** | **39,076** | **100**% |

Goose Creek flows through the City of Sheridan’s residential, recreational, and retail business areas. Nearby land uses also include the city wastewater treatment plant (WWTP), a concrete plant, a sawmill, a livestock sale facility, a Veterans Administration hospital, and other small businesses.

### 3.3.2 Geology and Soils

Shales and light colored sandstones from the Fort Union Formation are the predominant geology in the Goose Creek subwatershed (Table 3.15). The predominant geology in the Goose Creek floodplain is alluvium and colluvium composed of clay, silt, sand, and gravel (USGS 1985; Map 7).

**Table 3.15** Geology of the Goose Creek Subwatershed

| Geologic Formation | Total Acres | Percent of Total Acreage |
|---|---|---|
| Fort Union Formation | 28,435.2 | 72.8% |
| Wasatch Formation | 2,712.7 | 6.9% |
| Alluvium and Colluvium | 2,316.4 | 5.9% |
| Undivided Surficial Deposits | 1,951.6 | 5.0% |
| Bighorn Dolomite, Gallatin Limestone, Gros Ventre Formation, and Flathead Sandstone | 1,080.8 | 2.8% |
| Madison limestone and Darby Formation | 493.0 | 1.3% |
| Lance Formation | 456.7 | 1.2% |
| Plutonic Rocks | 394.5 | 1.0% |
| Tensleep Sandstone and Amsden Formation | 331.7 | 0.8% |
| Chugwater and Goose Egg Formations | 237.7 | 0.6% |
| Cody Shale | 209.7 | 0.5% |
| Cloverly, Morrison, Sundance and Gypsum Spring Formations | 125.9 | 0.3% |
| Landslide Deposits | 93.3 | 0.2% |
| Mesaverde Group | 73.9 | 0.2% |
| Fox Hills Sandstone and Bearpaw Shale | 62.5 | 0.2% |
| Frontier Formation | 58.8 | 0.2% |
| Mowry and Thermoplis Shales | 41.1 | 0.1% |
| **Total** | **39,075.6** | **100.0%** |

Soils in the Goose Creek subwatershed are primarily dominated by deep, loam-textured soils typically found in floodplains, alluvial fans, and terraces (see Map 8). At its upper segments, soils associated with Soldier Creek consist primarily of shallow to deep loamy soils located on steep mountain slopes, ridges, and hills. Soils along Goose Creek and the mid to lower segments of Soldier Creek are dominated by very fine sandy loam-textured soils (NRCS 1998; Table 3.16).

**Table 3.16** Soil Texture in the Goose Creek Subwatershed

| Soil Texture | Total Acres | Percent of Total Acreage |
|---|---|---|
| Loam | 22,943.6 | 58.7% |
| Very Fine Sandy Loam | 11,359.0 | 29.1% |
| Channery Loam | 2,397.5 | 6.1% |
| Silt Loam | 2,260.9 | 5.8% |
| Sandy Loam | 114.6 | 0.3% |
| **Total** | **39,075.6** | **100.0**% |

## *3.3.3 Surface Water Hydrology*

### 3.3.3.1 STREAM NETWORK

Goose Creek is formed by the convergence of Little Goose Creek and Big Goose Creek near the City of Sheridan’s downtown area, south of the Dow Street and Alger Street intersection. Goose Creek a fifth order stream (Strahler 1957). It flows in a northerly direction to its intersection with the Tongue River, near Acme (Figure 3.3). Goose Creek’s primary tributary is Soldier Creek. Soldier Creek is a fourth order stream (Strahler 1957) with a total drainage area of approximately 33.3 square miles. Soldier Creek enters Goose Creek from the west approximately 1,000 feet upstream from the Fort Road Bridge. Several intermittent streams (Hammel, Warriner, and Hultz Draws) enter Soldier Creek along its course.


**Figure 3.3** Goose Creek from the confluence of Big Goose Creek and Little Goose Creek to the Tongue River.

#### 3.3.3.2 CANALS AND DITCHES

Irrigation of hay meadows, pastureland, and residential areas constitutes a great demand on surface waters in this subwatershed. However, most irrigation diversions take surface water from Big Goose Creek and Little Goose Creek and their associated tributaries upstream of Goose Creek. The Grinnell Livestock Company Ditch is the only major diversion that takes water from Goose Creek. Located approximately 0.5 mile downstream from the City of Sheridan WWTP, this diversion distributes surface waters to irrigated lands located between Highway 338 and Goose Creek north of the City of Sheridan. As described above, the PK and Alliance ditches divert water from Big Goose Creek for use in the Soldier Creek subwatershed.

#### 3.3.3.3 STREAM GEOMORPHOLOGY

Goose Creek is predominantly a low gradient, meandering "C" type channel (Rosgen 1996) located in the Great Plains Ecoregion (SCCD 2003). This meandering channel type has very high streambank erosion potential, and is highly sensitive to changes caused by streamflow and sediment. The meandering character of the creek, combined with the predominance of alluvium and colluvium comprised of clay, silt, sand, and gravel, has naturally increased the potential for clay and silt introduction and deposition in the creek (SCCD 2003). In addition, the area around Acme was historically developed to extract coal by surface and underground mining methods. During reclamation of an inactive mine, a portion of Goose Creek upstream from Acme was channelized and the banks were reinforced to prevent further channel erosion (SCCD 2003). In the upper segments of Goose Creek, the majority of the stretch has also been channelized (straightened) to protect the City of Sheridan from floods (SCCD 2003).

The SCCD (2003) stream habitat assessments on Goose Creek showed a general improvement in channel condition and habitat quality from the uppermost sampling location in the City of Sheridan to the lowermost sampling location near Highway 339 (GC1). The poor condition of lower stream segments is due to artificial channelization that has eliminated some undercut banks, pools, and in-stream and riparian habitat structure. The streambed was dominated by cobble or coarse gravel, with no silt deposition at the lowermost sampling location and increasing silt at the middle and uppermost sampling location (SCCD 2003).

### *3.3.4 Fisheries and Wildlife*

#### 3.3.4.1 FISHERIES

In the past, the fish population in Goose Creek was dominated by non-game species and to a lesser extent warm-water game species, including northern redhorse, longnose sucker, white sucker, carp, mountain sucker, rock bass, stonecat, and green sunfish. Brown trout and rainbow trout are the only two cold-water game species collected in Goose Creek, and their populations appear to have been marginal (SCCD 2003). Prior to 1959, pollution from gravel washing operations and improper treatment of domestic sewage eliminated the fishery of Goose Creek from below the City of Sheridan to the confluence with the Tongue River (WGFD 1964 in SCCD 2003). Discharge of pollutants into Goose Creek was reduced with the implementation of the Wyoming Pollutant Discharge Elimination System (WYPDES) program in the mid-1970s and upgrades to the Sheridan WWTP in 1983 (SCCD 2003). No fish species were considered threatened, endangered, or of special concern (Williams et al. 1989 in SCCD 2003).

A limited amount of fish species sampling has been conducted in Goose Creek since 1977, and it appears that warm-water game species still dominate fish populations in Goose Creek. Fish species that are currently likely to occur in Goose Creek between the confluence of Big Goose Creek and Little Goose Creek and the Tongue River include black bullhead, carp, flathead chub, fathead minnow, golden shiner, green sunfish, longnose dace, longnose sucker, northern redhorse, rock bass, smallmouth bass, stonecat, white crappie, white sucker, and yellow perch (personal communication via email between Audrey

McCulley [SWCA] and Bill Bradshaw [WGFD], March 5, 2009). Although Goose Creek is classified by WDEQ as a cold-water fishery, dominant game fish comprise warm-water species; therefore, Goose Creek more closely approximates a warm-water waterbody (SCCD 2003). Cold-water fish species occur throughout most of the length of Goose Creek; however, populations are low in abundance and marginal (SCCD 2003).

**Table 3.17** Fish Species Recorded at Goose Creek (Rice Ranch) on June 28, 1994

| Species | Total Number |
|---|---|
| White Sucker | 31 |
| Longnose Sucker | 4 |
| Longnose Dace | 110 |
| Mountain Sucker | 5 |
| Northern Redhorse | 1 |
| Rock Bass | 56 |
| Carp | 3 |
| Lake Chub | 1 |

Note: These data are the most recent data available but are not reflective of current conditions in the creek as described by WGFD in 2009 via personal communication with SWCA.

### 3.3.4.2 WILDLIFE

Big-game species in the Goose Creek subwatershed include mule deer, white-tailed deer, elk and moose (see Map 9a, 9b, 9c). Table 3.18 lists habitat data for big-game species in Goose Creek, as designated by WGFD.

**Table 3.18** Goose Creek Subwatershed Big-game Habitat

| Big-game Species | Crucial Winter Habitat (acres) | Spring/Summer/Fall Habitat (acres) | Yearlong Habitat (acres) | Parturition (acres) | Migration Routes (miles) |
|---|---|---|---|---|---|
| Elk | 3,330.4 | 837.8 | – | 1,754.6 | 2.8 |
| Mule Deer | – | 925.9 | 13,217.2 | – | – |
| White-tailed Deer | – | – | 15,628.9 | – | – |
| Moose | – | – | 2,261.7 | – | – |
| Pronghorn | – | – | 24,001.6 | – | – |
| **Total*** | **3,330.4** | **1,763.7** | **55,109.4** | **1,754.6** | **2.8** |

* Big-game habitat acreages may overlap.

Common waterfowl species in the Goose Creek subwatershed likely include mallard, common goldeneye, wood duck, blue-winged teal, green-winged teal, common merganser, and Canada goose. These species are most common in lower elevations, along Soldier Creek and Goose Creek, north to the confluence with the Tongue River (personal communication between Audrey McCulley [SWCA] and Tim Thomas [WGFD], March 4, 2009).

# CHAPTER 4 HYDROLOGY

## 4.1 Hydrologic Data Sources and Coverage

In general, hydrological data are used in this TMDL study to describe seasonal dynamics in the system, differentiate critical low-water seasons in the watershed, calculate pollutant loads, and estimate variability in the system.

Discharge is the measure of the amount of water flowing in a waterbody and is usually expressed as cubic feet per second (cfs). Discharge is often correlated with water quality parameters such as pathogens, nutrients, total suspended solids (TSS), and turbidity. Discharge is also used to estimate the total load of a pollutant in units of mass per time (kilograms/day) at a stream site.

The most complete hydrologic dataset for the watershed is the USGS Acme Station #6305700 (hereafter referred to as the USGS Acme Station), which reported average daily flow readings at the outlet of the watershed from May 1984 to September 2007. In addition, SCCD collected discharge measurements at water quality sampling sites from 2001 to 2002 and 2005 using a typical staff gage installation and discharge calibration (SCCD 2003; SCCD 2006). Discharge at sampling sites BG14 and LG22 was measured with a USGS wire-weighted gage and at sampling site LG3 with the bucket-time method. The methodology used to measure discharge at SCCD sites is discussed in detail by SCCD (2003 and 2006). The Wyoming State Engineer's Office tracks water diversions throughout the watershed; however, a detailed water budget for the Goose Creek Watershed is beyond the scope of this project.

## 4.2 Hydrologic Period of Study

The period of study for hydrology in the Goose Creek Watershed TMDLs is the 1985–2007 water years. This hydrologic period of study is represented at the USGS Acme Station that recorded average daily flow readings at the bottom of the watershed. This period of study represents a wide range of hydrologic conditions, including wet and dry precipitation years, as well as a range in irrigation withdrawals. Upstream discharge measurements are limited to 2001, 2002, and 2005 and correspond to SCCD sampling events. Data related to water diversions in the watershed are available for 2000–2007 and are assumed to represent current irrigation practices and seasonal diversion patterns. The recreation seasons defined for pathogens in the Wyoming water quality criteria are used as one method of summarizing hydrologic data within the period of study. The Wyoming water quality criteria define the summer recreation season as May to September and the winter recreation season as October to April.

## 4.3 Flow Characterization of Goose Creek at Watershed Outlet

### *4.3.1 Hydrologic Patterns*

There are several hydrologic patterns represented by the data recorded at the USGS Acme Station (the outlet from the Goose Creek Watershed). These patterns represent climatic and water use patterns in the Goose Creek Watershed. Data used in this characterization were collected by the USGS between May 1, 1984 and September 30, 2007 (the water years 1985–2007). The USGS Acme Station represents flow out of the Goose Creek Watershed, a drainage area of 267,645 acres (418.2 square miles). For this study, these data have been grouped into water years (October 1–September 30). Figure 4.1 shows monthly average discharge at the USGS Acme Station for the period of record (1985–2007). The hydrology of the

Goose Creek Watershed is characterized by a single large period of snowmelt (typically occurring between April and July) and an extended period of baseflow interspersed with small storm events.

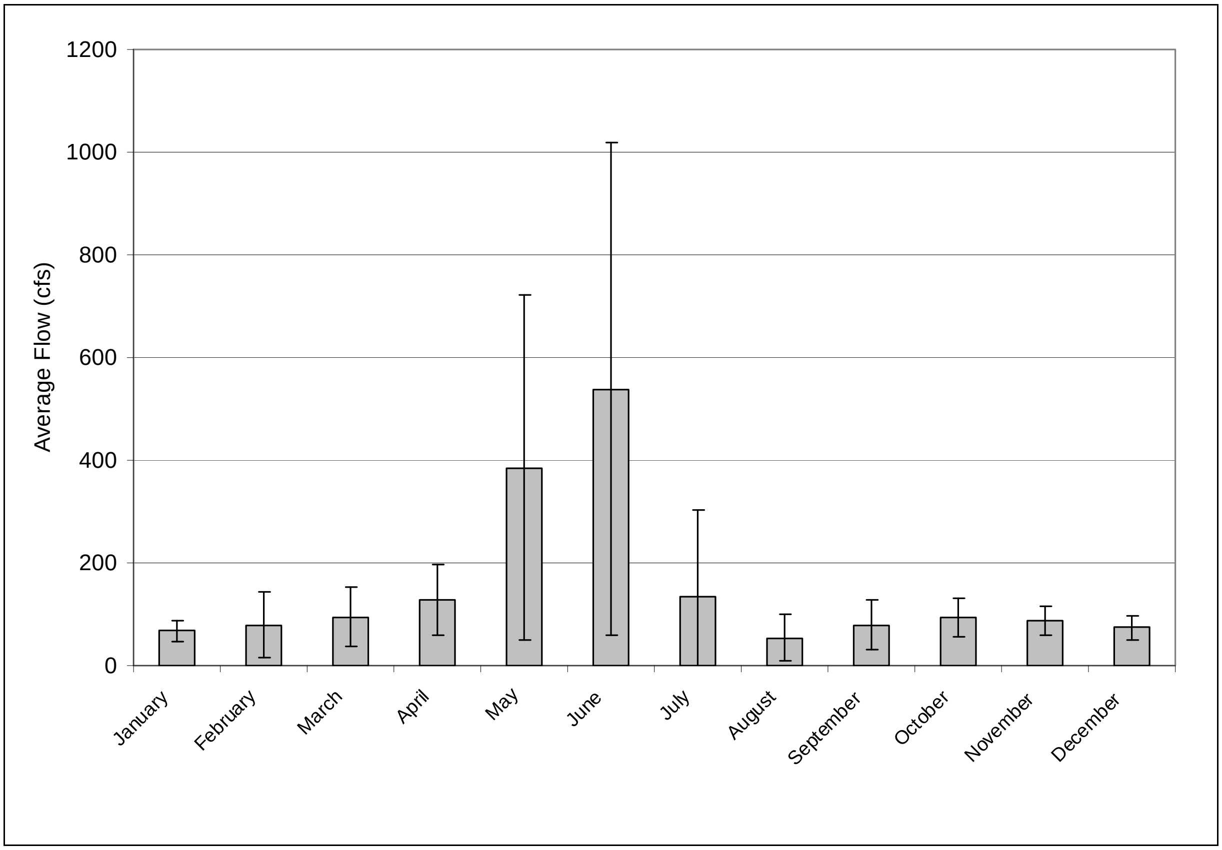


**Figure 4.1** Average monthly flow for the Goose Creek Watershed (USGS Acme Station #06305700) for period of record (water years 1985–2007).

Figure 4.2 shows the average daily discharge at the USGS Acme Station for the period of record (1985–2007), its wettest water year recorded (1995), and its driest water year (2002). As shown in Figure 4.2, baseflow conditions tend to be lower during dry years, and spring runoff tapers to baseflow conditions earlier in the summer. In addition, dry soils tend to produce fewer runoff events from spring and summer storms than the saturated soils common during wet years. Furthermore, return flow from irrigation on agricultural lands is lower during dry water years.

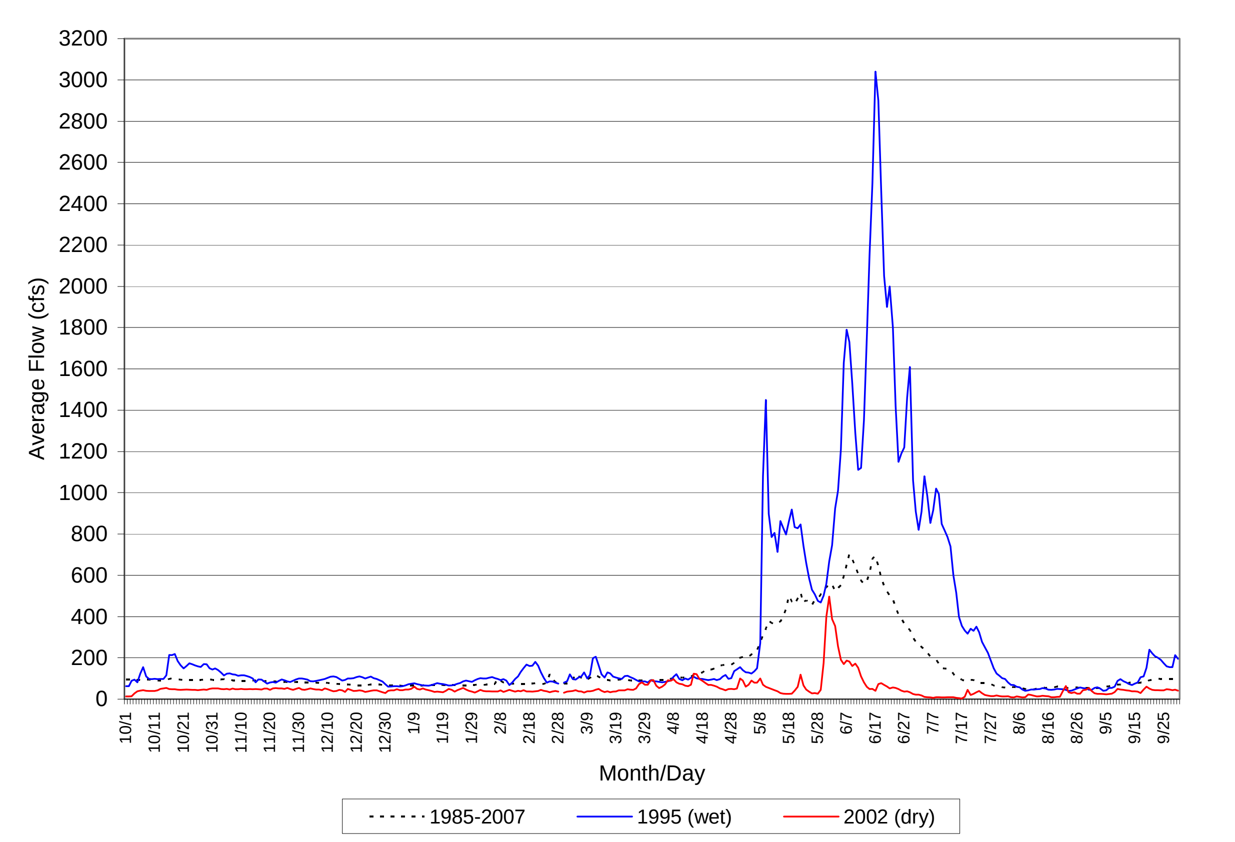


**Figure 4.2** Average flow for wet, dry, and average conditions in the Goose Creek Watershed (USGS Acme Station #06305700).

Average annual flows and quantitative comparisons relative to the average flow for the 23-year flow record at the USGS Acme Station are shown in Figure 4.3 and summarized in Table 4.1. The $50^{th}$ and $150^{th}$ percentiles of flow are shown on Figure 4.3 and used to identify wet and dry years. Wet years (those greater than the $150^{th}$ percentile) and dry years (those less than the $50^{th}$ percentile) were selected as the water years when average flows were highest and lowest during the period of record (1985–2007), respectively.

The 2001, 2002, 2004, and 2006 water years had the lowest flows recorded for the 23-year period of record. The 1995 water year had both the highest average flow (Figure 4.3) and highest peak flows (Table 4.1) for the 23-year period of record. The late 1980s are characterized by a relatively dry period followed by a wet period in the 1990s. Since 2000, flows have been relatively low with four years below the 23-year $50^{th}$ percentile value of 73 cfs and only two years above the 23-year average of 146 cfs. Peak flows during these dry years (2001 and 2002) were an order of magnitude below peak flows during normal and wet years (Table 4.1).

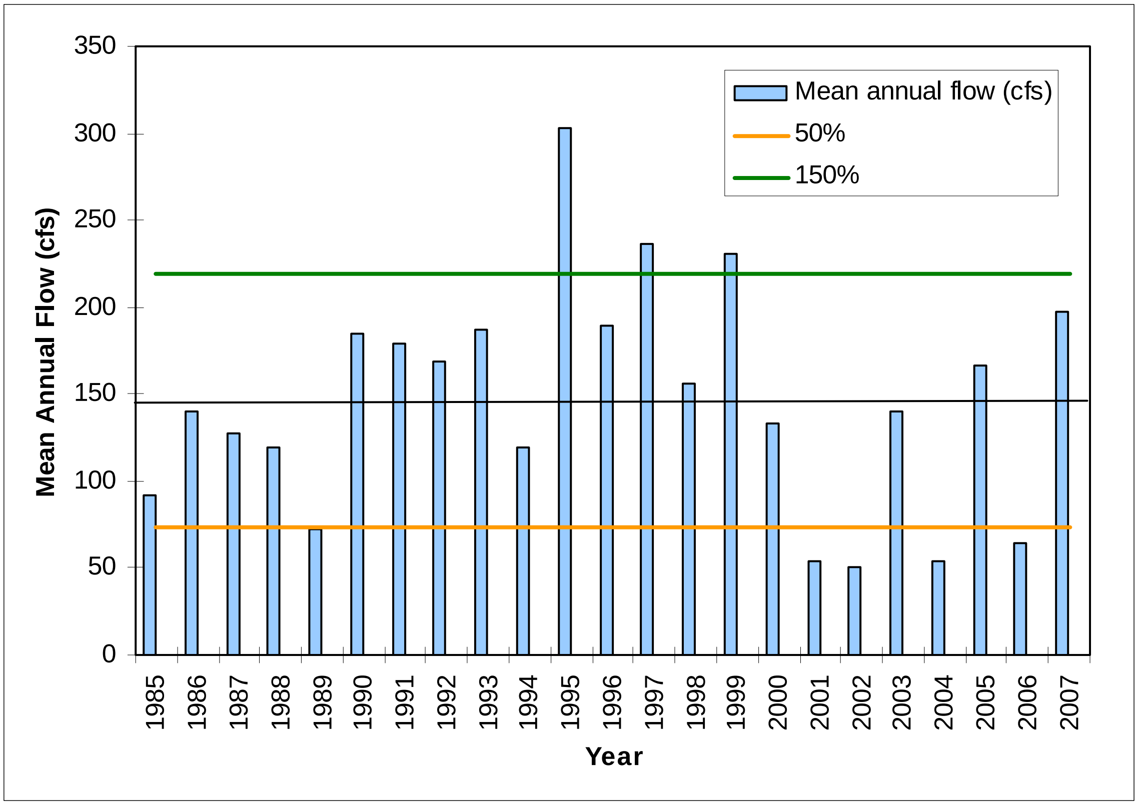


**Figure 4.3** Average annual flow at the bottom of the Goose Creek Watershed (USGS Acme Station #06305700).

**Table 4.1** Average Annual Flow Rates and Quantitative Comparisons Relative to the 23-year Period of Record Average for Goose Creek Watershed at USGS Acme Station #06305700

| Water Year | Peak Flow (cfs) | Average Flow (cfs) | Percent of Average Flow | Wet, Dry, or Normal Range |
|---|---|---|---|---|
| 1985 | 254 | 91 | 62% | Normal |
| 1986 | 1,370 | 140 | 96% | Normal |
| 1987 | 572 | 128 | 87% | Normal |
| 1988 | 958 | 119 | 81% | Normal |
| 1989 | 300 | 72 | 49% | Normal/dry |
| 1990 | 1,070 | 185 | 126% | Normal |
| 1991 | 1,600 | 179 | 123% | Normal |
| 1992 | 1,240 | 168 | 115% | Normal |
| 1993 | 1,170 | 187 | 128% | Normal |
| 1994 | 1,080 | 120 | 82% | Normal |
| 1995 | 3,040 | 304 | 207% | Wet |
| 1996 | 1,210 | 189 | 129% | Normal |
| 1997 | 1,730 | 236 | 161% | Wet |
| 1998 | 652 | 156 | 106% | Normal |
| 1999 | 1,630 | 231 | 158% | Wet |
| 2000 | 1,660 | 133 | 91% | Normal |
| 2001 | 159 | 54 | 37% | Dry |
| 2002 | 497 | 50 | 34% | Dry |
| 2003 | 1,210 | 140 | 96% | Normal |
| 2004 | 176 | 54 | 37% | Dry |
| 2005 | 2,000 | 167 | 114% | Normal |
| 2006 | 541 | 65 | 44% | Dry |
| 2007 | 1,940 | 198 | 135% | Normal |
| Period of Record Average | | 146.3 | 100% | – |

Note: <50% = Dry; 50–150% = Normal ;>150% = Wet

## *4.3.2 Flow Duration Curves*

### 4.3.2.1 METHODOLOGY

For the Goose Creek Watershed, the flow duration curve methodology was applied, as described by U.S. EPA (2007). A flow duration curve is a hydrologic analysis that calculates the cumulative frequency of a given flow value (percent of time a flow value has been met or exceeded) over a given historical period. Using this methodology, flow duration intervals are expressed as a percentage, with zero corresponding to the highest stream discharge in the record and 100 to the lowest. Flow duration curves combined with water quality data at different flow regimes provide a visual relationship between streamflow and water quality. The flow duration curves described in this section are combined with water quality data to create load duration curves at sites throughout the Goose Creek Watershed (Phase 2 of this TMDL study).

Three flow duration curves were developed for the Goose Creek Watershed using data from the USGS Acme Station. First, a flow duration curve that covers the entire period of record (water years 1985–2007) was developed. Second, separate flow duration curves were developed for the two recreation seasons identified by the Wyoming water quality standards for *E. coli* (October–April and May–September) using data from the entire period of record (water years 1985–2007). Flow duration curves for the Goose Creek Watershed were calculated using daily discharge rates at the USGS Acme Station and calculating the percent of values (days) these flows were exceeded. This was done using the percentile calculation function in Microsoft Excel 2003.

Each flow duration curve was originally divided into five hydrologic flow regimes for associating flow patterns with water quality. As recommended by U.S. EPA (2007), these hydrologic flow regimes were identified as follows: very high flow (0%–10%), high flow (10%–40%), medium flow (40%–60%), low flow (60%–90%), and very low flow (90%–100%). However, because there were insufficient water quality data for all five of the original categories, final flow duration curves were grouped into three categories: high (0%–30%), medium (30%–70%), and low (70%–100%). The flow duration curves are provided in Appendix 2. These categories were used to calculate the pathogen TMDL for varying hydrologic flow regimes.

#### 4.3.2.2 RESULTS

The flow duration curves developed for the Goose Creek Watershed summarize flow values ranging from a maximum of 3,040 cfs to a minimum recorded flow of 3 cfs (Figure 4.4). The x-axis of the graph represents the duration, or ‘percent of time” flow is exceeded. The y-axis represents the flow values, and due to the large range of flow values the y-axis is logarithmic. The hydrologic flow regimes are also provided in the graphs. The flow values that define each hydrologic flow regime are summarized in Table 4.2. The hydrologic flow regimes are used in the water quality summary to associate water quality with flow in Chapter 5.

Flow values in the “very high” hydrologic flow regime of the flow duration curve account for only 10% of the recorded daily flows at the USGS Acme Station but represent over half of the total average annual flow in the Goose Creek Watershed. Alternatively, the two lowest hydrologic flow regimes (low and very low) represent 40% of the recorded daily flows at the USGS Acme Station but account for only 11% of the total flow out of the watershed (Figure 4.4). This pattern is accentuated for the summer recreation season flow duration curve but smoothed out during the winter recreation season (Figure 4.5). In other words, the summer season has a steeper flow duration curve and the winter season a flatter curve. This is because peak flows occur primarily in May and June (during the summer recreation season).

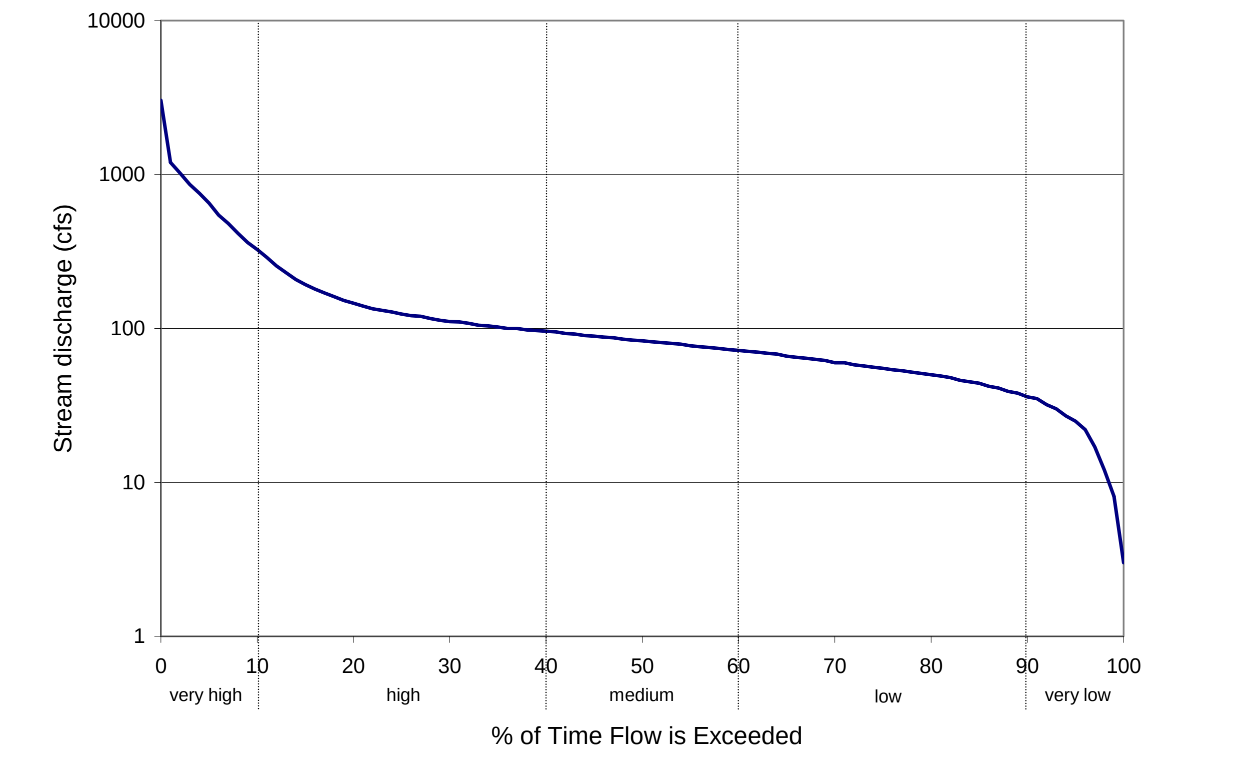


**Figure 4.4** Flow duration curve for the Goose Creek Watershed at the USGS Acme Station #06305700 (water years 1985–2007).

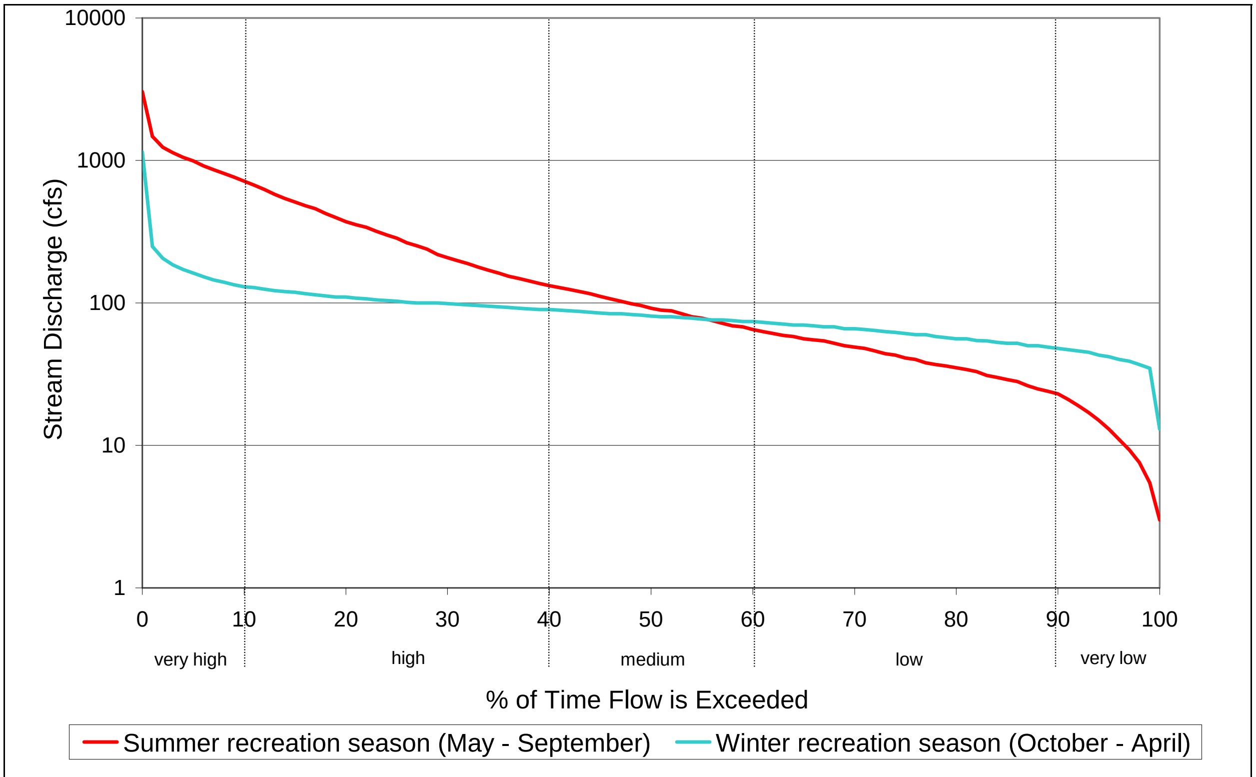


**Figure 4.5** Flow duration curve by Recreation Season for the Goose Creek Watershed at the USGS Acme Station #6305700 (water years 1985–2007).

**Table 4.2** Hydrologic Flow Regime Definition Based on Flow Duration Curves in the Goose Creek Watershed and Break Points for Flow Frequency Recommended by U.S. EPA

| Hydrologic Flow Regime | Flow Frequency of Exceedance | Flow Range for Total Season (cfs) | Flow Range for Summer Season (cfs) | Flow Range for Winter Season (cfs) |
|---|---|---|---|---|
| Very High | 10% | 326 | 714 | 130 |
| High | 40% | 96 | 132 | 90 |
| Medium | 60% | 72 | 65 | 74 |
| Low | 90% | 36 | 23 | 48 |
| Very Low | 100% | 3 | 3 | 13 |

## *4.3.3 Relationship between Climate and Hydrology*

Climate affects the hydrology of mountainous watersheds, such as the Goose Creek Watershed, through several different mechanisms. Snow pack during winter months is related to the total volume of flow observed during the spring melt period. The timing and length of the spring melt period is a function of the rate of temperature and precipitation changes in the mountains in the early spring. Spring melt periods that occur over a longer period allow for more percolation of snowmelt to groundwater, whereas a fast spring melt can lead to more overland flow and higher peak flows in watershed streams. Summer temperature patterns drive evapotranspiration rates in the lower segments of the watershed and affect the need for irrigation diversions from streams. The occurrence of large storms may also produce peak flows and may offset the need for diversion during some parts of the irrigation season.

The hydrology in the Goose Creek Watershed has been modified significantly over the past century. Modifications include five reservoirs that store spring melt water for use during the irrigation season and 16 major irrigation diversion canals and ditches. Additional diversions and hydrologic modifications are present. They supply water to watershed residents and provide flood control for streams in the City of Sheridan. Therefore, the natural relationships that occur between climate and hydrology may be affected by human modification of the system. Such relationships were explored to evaluate the relative importance of climate versus irrigation diversion on hydrologic patterns in the watershed.

Climate impacts to Goose Creek Watershed hydrology were assessed using statistical models exploring the relationship between key climate variables and streamflow. Climate variables explored included total precipitation, winter precipitation (assumed to be snowfall), snow pack (snow water equivalent) at the end of the snow season (assumed to be May 1), precipitation, and temperature. Streamflow variables included total annual flow, peak annual flow, and spring runoff flow (flow in May and June). Annual temperature, snowfall, and precipitation data were compiled for the period of 1985 to 2007 from two climate sites maintained by the WRCC: the Sheridan WSO AP (Station 488155) and the Sheridan Field Station (488160). The two sites were averaged for statistical analysis. Annual stream discharge data were taken from the USGS Acme Station for the same period. Streamflow data were consequently log-transformed to account for their non-linear nature. Snow pack data (measured as snow water equivalent) were taken from the NRCS Big Goose SNOTEL site for the entire period of data availability: 1999 to 2007.

Results from statistical analysis suggest that there is a moderate, positive linear relationship ($R^2$=0.42) between annual precipitation and annual stream discharge, and between winter precipitation (January–May) and annual stream discharge ($R^2$=0.39). This relationship is shown in Figure 4.6. A more positive, statistical, linear relationship exists between winter precipitation (January–May) and peak annual flow ($R^2$=0.62), and between winter precipitation (January–May) and average flow during the months of May and June, which represent most of the spring melt period (Figure 4.7). Snow pack (snow water equivalent) on May 1 of each year is positively related ($R^2$=0.54) to average flow during the spring melt period. Spring melt is defined as flow during the months of May and June (Figure 4.8). Other climatic and streamflow variables had weak relationships and were not explored further. Because the system is highly modified, it is not surprising that relationships between climatic variables and streamflow are not well correlated. The associated roles of irrigation diversions, reservoir releases, and climatic parameters in streamflow in the watershed are complex.

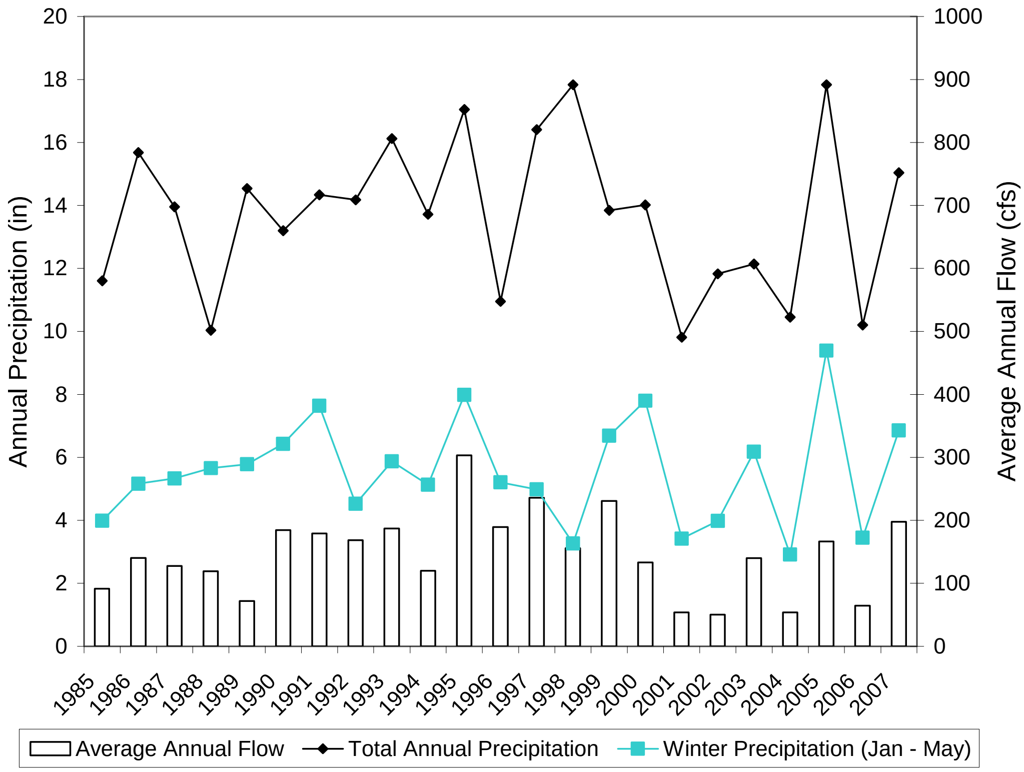


**Figure 4.6** Relationship between total annual and winter precipitation and average annual flow.

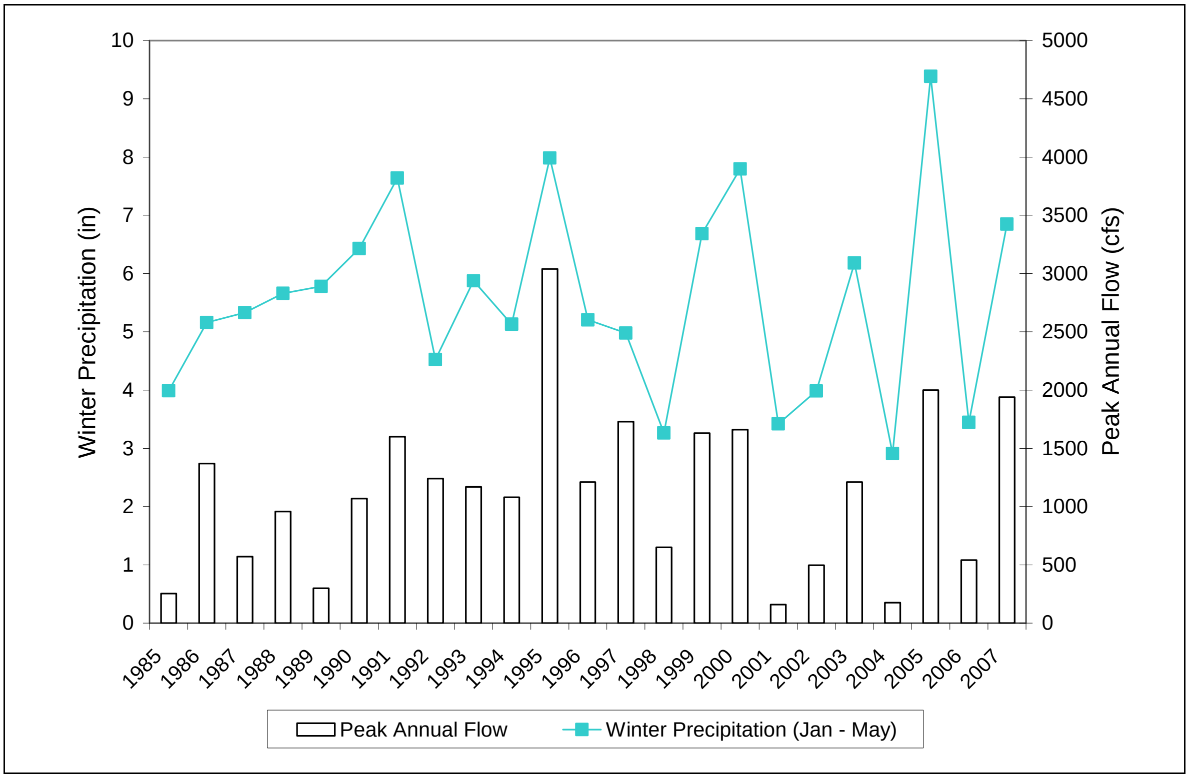


**Figure 4.7** Relationship between winter precipitation and peak annual flow.

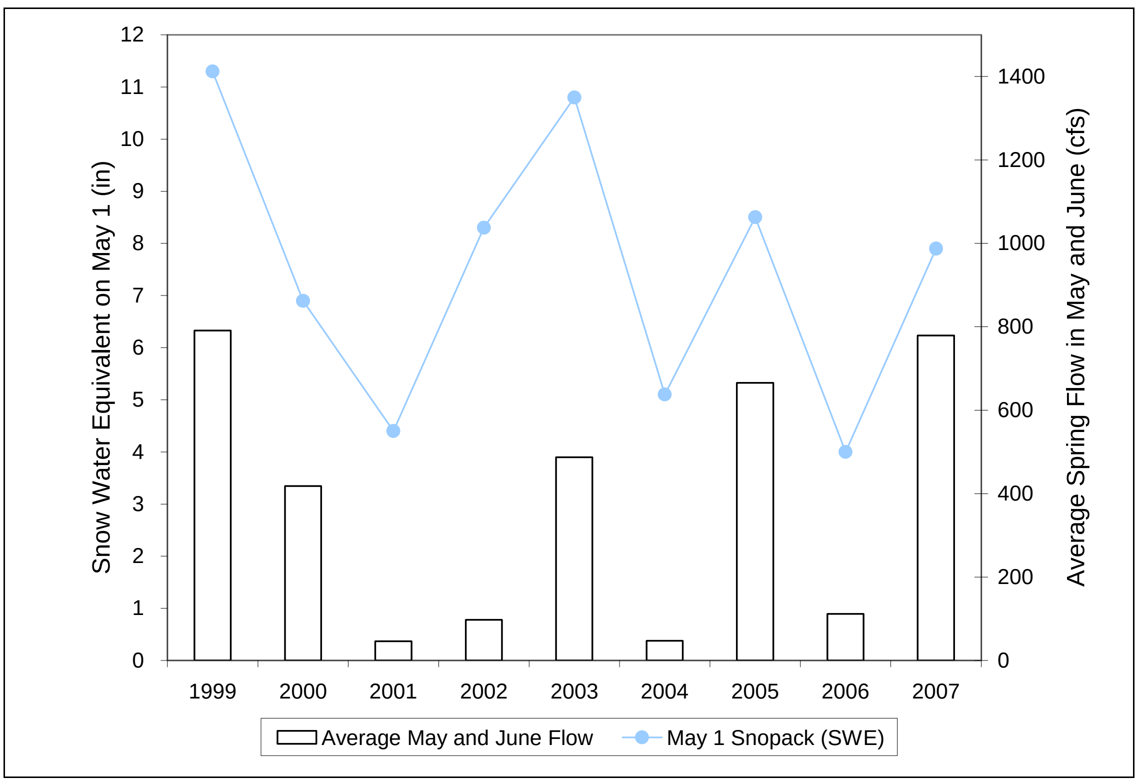


**Figure 4.8** Relationship between May 1 snowpack (snow water equivalent) and average spring flow.

Variability in streamflow may be explained through additional factors and model uncertainty. Irrigation practices in the Goose Creek Watershed and the timing and delivery of water throughout the system may influence stream volumes, as might climatic shifts from wet to dry years. Model uncertainty may also be increased through data errors from erroneous values or incomplete site coverage within the available data sources.

# 4.4 Tributary Flow

## 4.4.1 Summary of Flow Data in Impaired Streams

Flow data for impaired streams are summarized for the summer and winter recreation seasons in Tables 4.3 and 4.4, respectively. Across the entire watershed, tributary flows during the summer recreation season ranged from 0 to 735 cfs, with average flows from 0.2 to 96 cfs. Winter recreation season tributary flows ranged from 0 to 143 cfs, with average flows from 0.1 to 51 cfs.

**Table 4.3** Summer Recreation Season Streamflow Summary

| Impaired Segment | Subwatershed | SamplingSite[1] | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|---|
| Sackett Creek | Little Goose Creek | LG19 | 40 | 18.8 | 0.1 | 1.7 | 3.3 |
| Jackson Creek | Little Goose Creek | LG17 | 44 | 5.0 | 0.0 | 1.3 | 1.4 |
| Kruse Creek | Little Goose Creek | LG11 | 41 | 8.1 | 0.4 | 3.0 | 2.2 |
| McCormick Creek | Little Goose Creek | LG9 | 38 | 26.1 | – | 1.8 | 4.3 |
| Little Goose Creek | Little Goose Creek | LG1 | 29 | 125.7 | 0.3 | 12.5 | 23.8 |
| Rapid Creek | Big Goose Creek | BG16 | 42 | 11.6 | – | 2.0 | 2.4 |
| Park Creek | Big Goose Creek | BG13 | 12 | 1.1 | 0.0 | 0.2 | 0.3 |
| Beaver Creek | Big Goose Creek | BG9 | 42 | 19.1 | 0.9 | 4.5 | 4.7 |
| Big Goose Creek | Big Goose Creek | BG1 | 30 | 225.9 | 3.3 | 30.3 | 45.0 |
| Soldier Creek | Goose Creek | GC4 | 41 | 21.2 | – | 1.9 | 3.9 |
| Goose Creek | Goose Creek | GC1 | 47 | 735.0 | 5.1 | 96.1 | 168.3 |

[1] Sampling sites represent the lowermost site on each impaired stream.

**Table 4.4** Winter Recreation Season Tributary Flow Summary

| Impaired Segment | Subwatershed | Sampling Site[1] | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|---|
| Sackett Creek | Little Goose Creek | LG19 | 25 | 2.8 | 0.2 | 1.3 | 0.8 |
| Jackson Creek | Little Goose Creek | LG17 | 30 | 7.4 | 0.0 | 1.1 | 1.3 |
| Kruse Creek | Little Goose Creek | LG11 | 26 | 15.0 | 0.3 | 4.5 | 2.8 |
| McCormick Creek | Little Goose Creek | LG9 | 25 | 4.3 | 0.1 | 1.3 | 1.0 |
| Little Goose Creek | Little Goose Creek | LG1 | 22 | 45.9 | 3.3 | 21.1 | 10.9 |
| Rapid Creek | Big Goose Creek | BG16 | 27 | 5.5 | 0.2 | 2.6 | 1.6 |
| Park Creek | Big Goose Creek | BG13 | 20 | 0.1 | 0.0 | 0.1 | 0.0 |
| Beaver Creek | Big Goose Creek | BG9 | 28 | 7.6 | 0.8 | 2.9 | 1.7 |
| Big Goose Creek | Big Goose Creek | BG1 | 23 | 50.1 | 5.8 | 23.9 | 9.2 |
| Soldier Creek | Goose Creek | GC4 | 30 | 98.3 | 0.1 | 5.2 | 17.8 |
| Goose Creek | Goose Creek | GC1 | 32 | 143.2 | 6.5 | 51.3 | 26.6 |

[1] Sampling sites represent the lowermost site on each impaired stream

Goose Creek consistently had the largest maximum and average flows in both the Goose Creek subwatershed and across the entire watershed for both summer and winter recreation seasons. In the Big Goose Creek subwatershed, the lowermost sampling site (BG1) had the highest maximum and average flows for both the summer and winter recreation seasons (see Tables 4.3 and 4.4). Park Creek had the lowest minimum and average flows for both recreation seasons. In the Little Goose Creek subwatershed, the lowermost sampling site (LG1) had the highest maximum and average flows for both the summer and winter recreation seasons. The storm drain sampling location (LG3) had the lowest minimum and average flows for both recreation seasons.

The summary statistics presented in Tables 4.3 and 4.4 also indicate that flows are highly variable throughout the watershed. The large standard deviations for nine of 12 tributaries were larger than the average flow values. The lower average flows during the winter recreation period are expected, with maximum and average summer flows generally higher than winter flows due to spring snowmelt and summer precipitation patterns. However, the very large standard deviations for most sampling locations in all three subwatersheds (Table 4.3) indicate that flows are highly variable during the summer recreation period.

### 4.4.2 Flow Patterns on Main Stem Streams

Flow data for all SCCD sampling sites on main stem streams in the three subwatersheds are summarized for the summer and winter recreation seasons for the current period in Tables 4.5 and 4.6, respectively. Sampling sites are listed from upstream to downstream for each subwatershed. In general, maximum and average flows would be expected to steadily increase from upstream to downstream sampling sites, but this pattern does not occur in any of the three subwatersheds in either the summer or winter recreation season.

**Table 4.5** Summer Recreation Season Main Stem Upstream to Downstream Flow Summary

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|
| **Little Goose Creek** | | | | | | |
| LG22 | Little Goose Creek–upstream County Road 77 Bridge at Little Goose Ranch | 57 | 447.6 | 3.1 | 65.2 | 81.5 |
| LG21 | Little Goose Creek–upstream County Road 103 Bridge at Entrance to Bradford-Brinton Memorial | 31 | 30.6 | 1.6 | 13.8 | 6.6 |
| LG20 | Little Goose Creek–upstream County Road 103 Bridge S of Bighorn | 32 | 42.7 | 0.3 | 10.5 | 7.4 |
| LG18 | Little Goose Creek–downstream Sackett Creek Confluence | 30 | 98.6 | 3 | 13.7 | 16.6 |
| LG16 | Little Goose Creek–downstream Jackson Creek Confluence | 28 | 128.3 | 5.3 | 19.4 | 22.5 |
| LG14 | Little Goose Creek–upstream Clubhouse Road Bridge at Powderhorn Subdivision | 29 | 87 | 0 | 8.2 | 16.6 |
| LG13 | Little Goose Creek–upstream County Road 60 Bridge at Knode Ranch Subdivision | 39 | 75.6 | – | 6.6 | 12.5 |
| LG12 | Little Goose Creek–upstream Kruse Creek Confluence | 29 | 363.2 | 1.3 | 18.3 | 66.8 |
| LG10 | Little Goose Creek–downstream Kruse Creek, Upstream Highway 87 Bridge | 29 | 243.4 | 0 | 17.4 | 44.4 |
| LG8 | Little Goose Creek–downstream McCormick Creek Confluence | 47 | 164.8 | – | 16.4 | 24.1 |
| LG7 | Little Goose Creek–upstream Highway 87 Bridge Near Woodland Park | 32 | 166.6 | – | 12.2 | 30.5 |
| LG6 | Little Goose Creek–downstream County Road 66 Bridge | 32 | 120.2 | 2 | 12.1 | 21.5 |
| LG5 | Little Goose Creek–upstream Brundage Lane Bridge | 44 | 270.9 | –- | 19.3 | 42 |
| LG4 | Little Goose Creek–upstream Coffeen Avenue Bridge | 30 | 166.9 | 2.5 | 17.2 | 29.9 |
| LG2 | Little Goose Creek–upstream Concrete Lined Channel Entrance | 47 | 146.3 | – | 20.2 | 30.7 |
| LG1 | Little Goose Creek–near Big Goose Creek Confluence | 29 | 125.7 | 0.3 | 12.5 | 23.8 |

**Table 4.5** Summer Recreation Season Main Stem Upstream to Downstream Flow Summary

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|
| **Big Goose Creek** | | | | | | |
| BG18 | Big Goose Creek–upstream from Alliance Ditch Intake at USGS Station #06302000 | 62 | 256.5 | – | 37.3 | 47.9 |
| BG17 | Big Goose Creek–upstream from Ditch No. 9 Intake | 30 | 272.9 | 3.6 | 29.6 | 53.3 |
| BG15 | Big Goose Creek–downstream Rapid Creek Confluence | 30 | 468.4 | 2.2 | 33.9 | 89.8 |
| BG14 | Big Goose Creek–upstream Highway 331 Bridge Crossing, south of Beckton | 46 | 905.2 | 3.6 | 58.1 | 161.0 |
| BG12 | Big Goose Creek–downstream Park Creek Confluence | 32 | 152.0 | – | 16.5 | 34.6 |
| BG11 | Big Goose Creek–upstream County Road 81 Bridge | 34 | 286.3 | 3.8 | 32.1 | 55.8 |
| BG10 | Big Goose Creek–upstream County Road 87 Bridge | 40 | 216.4 | – | 24.1 | 39.6 |
| BG8 | Big Goose Creek–downstream Beaver Creek Confluence | 35 | 164.8 | 7.1 | 34.8 | 39 |
| BG7 | Big Goose Creek–west of Paulson Youth Camp | 33 | 171.1 | 2.7 | 27.9 | 38.5 |
| BG6 | Big Goose Creek–at Paulson Youth Camp | 47 | 386.9 | 0.8 | 50.0 | 80.9 |
| BG3 | Big Goose Creek–west end of Leopard Street | 34 | 465.5 | 2.8 | 34.2 | 84.8 |
| BG2 | Big Goose Creek–downstream footbridge at Works and Elk Streets | 46 | 348.5 | – | 30.5 | 61.9 |
| BG1 | Big Goose Creek–at footbridge in Kendrick Park | 30 | 225.9 | 3.3 | 30.3 | 45 |
| **Goose Creek** | | | | | | |
| GC6 | Goose Creek–upstream 5th Street Bridge | 31 | 217.6 | 3.9 | 40.1 | 51.7 |
| GC5 | Goose Creek–at footbridge in Thorne-Rider Park | 32 | 186.3 | 0 | 38.9 | 43.1 |
| GC3 | Goose Creek–upstream Fort Road Bridge | 33 | 286.8 | 5.2 | 50.1 | 61.7 |
| GC2 | Goose Creek–downstream Sheridan WWTP | 40 | 212.1 | – | 33.5 | 48.8 |
| GC1 | Goose Creek–downstream Highway 339 Bridge Crossing | 47 | 735.0 | 5.1 | 96.1 | 168.3 |

**Table 4.6** Winter Recreation Season Main Stem Upstream to Downstream Flow Summary

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|
| **Little Goose Creek** | | | | | | |
| LG22 | Little Goose Creek–upstream County Road 77 Bridge at Little Goose Ranch | 36 | 35.3 | 2.8 | 9.1 | 8 |
| LG21 | Little Goose Creek–upstream County Road 103 Bridge at Entrance to Bradford-Brinton Memorial | 21 | 23.7 | 1.7 | 8 | 6.2 |
| LG20 | Little Goose Creek–upstream County Road 103 Bridge south of Big Horn | 24 | 41.2 | 0.4 | 11.4 | 9.4 |
| LG18 | Little Goose Creek–downstream Sackett Creek Confluence | 23 | 39.7 | 3 | 12.9 | 8.6 |
| LG16 | Little Goose Creek–downstream Jackson Creek Confluence | 25 | 42 | 5.1 | 17.1 | 9.2 |
| LG14 | Little Goose Creek–upstream Clubhouse Road Bridge at Powderhorn Subdivision | 23 | 40.8 | 1.1 | 16.2 | 9.3 |
| LG13 | Little Goose Creek–upstream County Road 60 Bridge at Knode Ranch Subdivision | 21 | 51.3 | 1.5 | 18.9 | 12.2 |
| LG12 | Little Goose Creek–upstream Kruse Creek Confluence | 27 | 71.8 | 1.3 | 15.5 | 13.5 |
| LG10 | Little Goose Creek–downstream Kruse Creek, upstream Highway 87 Bridge | 23 | 55 | 4.9 | 19 | 11.1 |
| LG8 | Little Goose Creek–downstream McCormick Creek Confluence | 30 | 51.3 | 7 | 23.2 | 9.3 |
| LG7 | Little Goose Creek–upstream Highway 87 Bridge near Woodland Park | 24 | 98.3 | – | 24.9 | 29.2 |
| LG6 | Little Goose Creek–downstream County Road 66 Bridge | 25 | 58.8 | 3.5 | 24.4 | 9.9 |
| LG5 | Little Goose Creek–upstream Brundage Lane Bridge | 26 | 108.6 | 0.8 | 28.2 | 18.2 |
| LG4 | Little Goose Creek–upstream Coffeen Avenue Bridge | 26 | 63.4 | 6.4 | 29.2 | 13.6 |
| LG2 | Little Goose Creek–upstream concrete-lined channel entrance | 33 | 175.3 | 5 | 31.1 | 27.7 |
| LG1 | Little Goose Creek–near Big Goose Creek Confluence | 22 | 45.9 | 3.3 | 21.1 | 10.9 |
| **Big Goose Creek** | | | | | | |
| BG18 | Big Goose Creek–upstream from Alliance Ditch Intake, at USGS Station #06302000 | 40 | 36.8 | 5.3 | 13.4 | 6.2 |

**Table 4.6** Winter Recreation Season Main Stem Upstream to Downstream Flow Summary

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfs) | Minimum (cfs) | Average (cfs) | Standard Deviation (cfs) |
|---|---|---|---|---|---|---|
| BG17 | Big Goose Creek–upstream from Ditch No. 9 Intake | 24 | 24.2 | 2.4 | 12 | 7.9 |
| BG15 | Big Goose Creek–downstream Rapid Creek Confluence | 24 | 27.7 | 1.8 | 14.2 | 8.3 |
| BG14 | Big Goose Creek–upstream Highway 331 Bridge Crossing, south of Beckton | 30 | 40.1 | 3.4 | 16.7 | 9.3 |
| BG12 | Big Goose Creek–downstream Park Creek Confluence | 23 | 98.8 | – | 25.3 | 37.7 |
| BG11 | Big Goose Creek–upstream County Road 81 Bridge | 23 | 28.5 | 3.2 | 14.9 | 7.1 |
| BG10 | Big Goose Creek–upstream County Road 87 Bridge | 24 | 36.4 | 3.4 | 17.4 | 8 |
| BG8 | Big Goose Creek–downstream Beaver Creek Confluence | 24 | 44.3 | 3.1 | 26.7 | 9.6 |
| BG7 | Big Goose Creek–west of Paulson Youth Camp | 23 | 33.3 | 3.5 | 18.3 | 7.8 |
| BG6 | Big Goose Creek–at Paulson Youth Camp | 31 | 52.8 | 3 | 25.3 | 11.2 |
| BG3 | Big Goose Creek–west End of Leopard Street | 24 | 30.2 | 2.8 | 13.2 | 6.6 |
| BG2 | Big Goose Creek–downstream footbridge at Works and Elk Streets | 30 | 61.4 | 2.9 | 23.5 | 10.8 |
| BG1 | Big Goose Creek–at footbridge in Kendrick Park | 23 | 50.1 | 5.8 | 23.9 | 9.2 |
| **Goose Creek** | | | | | | |
| GC6 | Goose Creek–at footbridge in Thorne-Rider Park | 25 | 142.1 | 3.9 | 48.5 | 25.3 |
| GC5 | Goose Creek–upstream Fort Road Bridge | 24 | 149.3 | 13.7 | 51.7 | 29.7 |
| GC3 | Goose Creek–downstream Sheridan WWTP | 29 | 195.1 | 13.1 | 74.6 | 55 |
| GC2 | Goose Creek–downstream Highway 339 Bridge Crossing | 33 | 200.4 | – | 54.3 | 64.9 |
| GC1 | Goose Creek–upstream 5th Street Bridge | 32 | 143.2 | 6.5 | 51.3 | 26.6 |

#### 4.4.2.1 LITTLE GOOSE CREEK MAIN STEM FLOWS

In the summer recreation season, the average flows of Little Goose Creek's main stem ranged from 7 to 65 cfs, with maximum flows from 31 to 448 cfs. Minimum flows ranged from 0 to 5 cfs. Average, maximum, and minimum flows fluctuate from upstream to downstream, with the highest average and maximum flows occurring at the uppermost sampling site, and large decreases and increases in flow occurring at multiple locations along the creek. High variability in flows is supported by the consistently large standard deviation values for Little Goose Creek in the summer recreation season. These changes in flow are only partly explained by water diversions to the East Side Ditch and Burn Cleuch Ditch. These diversions occur in the upper segments of the creek and re-enter the creek in the lower segments. The remaining gains and losses in flow from upstream to downstream could be due to losses to or gains from groundwater and small-scale water diversions on the creek.

In the winter recreation season, main stem average flows ranged from approximately 8 to 31 cfs, with maximum flows from 24 to 175 cfs. Minimum flows ranged from 0 to 7 cfs. Average and maximum flows generally increase from upstream to downstream, with the highest average and maximum flows occurring at the second-most downstream sampling site and the lowest average and maximum flows occurring at the second-most downstream sampling site. The flow data suggest that Little Goose Creek is a gaining stream, with enough water flowing from groundwater to steadily increase flows from upstream to downstream.

#### 4.4.2.2 BIG GOOSE CREEK MAIN STEM FLOWS

In the summer recreation season, Big Goose Creek main stem average flows ranged from approximately 24 to 58 cfs, with maximum flows from 165 to 905 cfs. Minimum flows ranged from 0 to 7 cfs. Average, maximum, and minimum flows fluctuate from upstream to downstream, with the highest average and minimum flows occurring in the upper–middle segments. High variability in flows is supported by the consistently large standard deviation values for Big Goose Creek in the summer recreation season. Fluctuations in average flow are relatively small, but there are large decreases and increases in maximum and minimum flow along the creek. Fluctuations in flow are only partly explained by water entering Big Goose Creek from Park Creek and the Big Goose and Beaver Ditch mid-segment, and from the entry of the Colorado Colony Ditch in the lower portion of the creek. The remaining gains and losses in flow could be due to losses or gains from groundwater and small-scale water diversions on the creek.

In the winter recreation season, main stem average flows ranged from approximately 12 to 27 cfs, with maximum flows from 24 to 98 cfs. Minimum flows ranged from 2 to 6 cfs. Average, maximum, and minimum flows fluctuate from upstream to downstream, with the highest average and maximum flows occurring in the middle segments of the creek. Minimum flows fluctuate somewhat, but generally increase from upstream to downstream. The overall pattern of increasing average, maximum, and minimum flows from upstream to downstream during the winter recreation season suggests that Big Goose Creek may also be a gaining stream. The increase in flows from upstream to downstream cannot be explained by water diversions, which are minimal in Big Goose Creek from October through March.

#### 4.4.2.3 GOOSE CREEK MAIN STEM FLOWS

In the summer recreation season, average flows along the main stem of Goose Creek ranged from approximately 34 to 96 cfs, with maximum flows from 186 to 735 cfs. Minimum flows ranged from 0 to 5 cfs. Average, maximum, and minimum flows fluctuate from upstream to downstream, with the highest average and maximum flows occurring at the lowermost sampling site, and a large increase in the average, maximum, and minimum flows from the lowermost sampling sites. High variability in flows is supported by the consistently large standard deviation values for Goose Creek in the summer recreation season. The sharp increase in flows in the lower portions of the creek occurs downstream of the confluence of Goose Creek and Soldier Creek. Variability in main stem flows could be due to diversions to the Grinnell Livestock Company Ditch, which then re-enters lowermost portions the creek and appears to increase average, maximum, and minimum flows. Fluctuations in average flows are very large from upstream to downstream, and are at least in part due to water diversions to, and the re-entry of, the Grinnell Livestock Company Ditch. The remaining gains and losses in flow from upstream to downstream could be due to losses to or gains from groundwater and small-scale water diversions on the creek. Overall, Goose Creek appears to be a gaining stream during the summer season.

In the winter recreation season, main stem average flows ranged from approximately 49 to 75 cfs, with maximum flows from 142 to 200 cfs. Minimum flows ranged from 0 to 14 cfs. Average flows fluctuate from upstream to downstream, with the highest average and maximum flows occurring downstream from the confluence with Soldier Creek and generally declining downstream. This general decline in flows from upstream to downstream cannot be explained by water diversions, which do not occur from October through March. The flow data suggest that Goose Creek is a losing stream during the winter, with enough water flowing to groundwater to steadily reduce flows from upstream to downstream.

### 4.4.3 Relationship between Watershed Outlet and Upper Watershed Flow

To evaluate the relationship between flows recorded at the watershed outlet (USGS Acme Station) and flows measured in the upper watershed, a regression analysis was conducted. This evaluation consisted of pairing flow data from the USGS Acme Station with flow data from the upper watershed that had the same date. Examples of these paired datasets are shown in Figure 4.9.

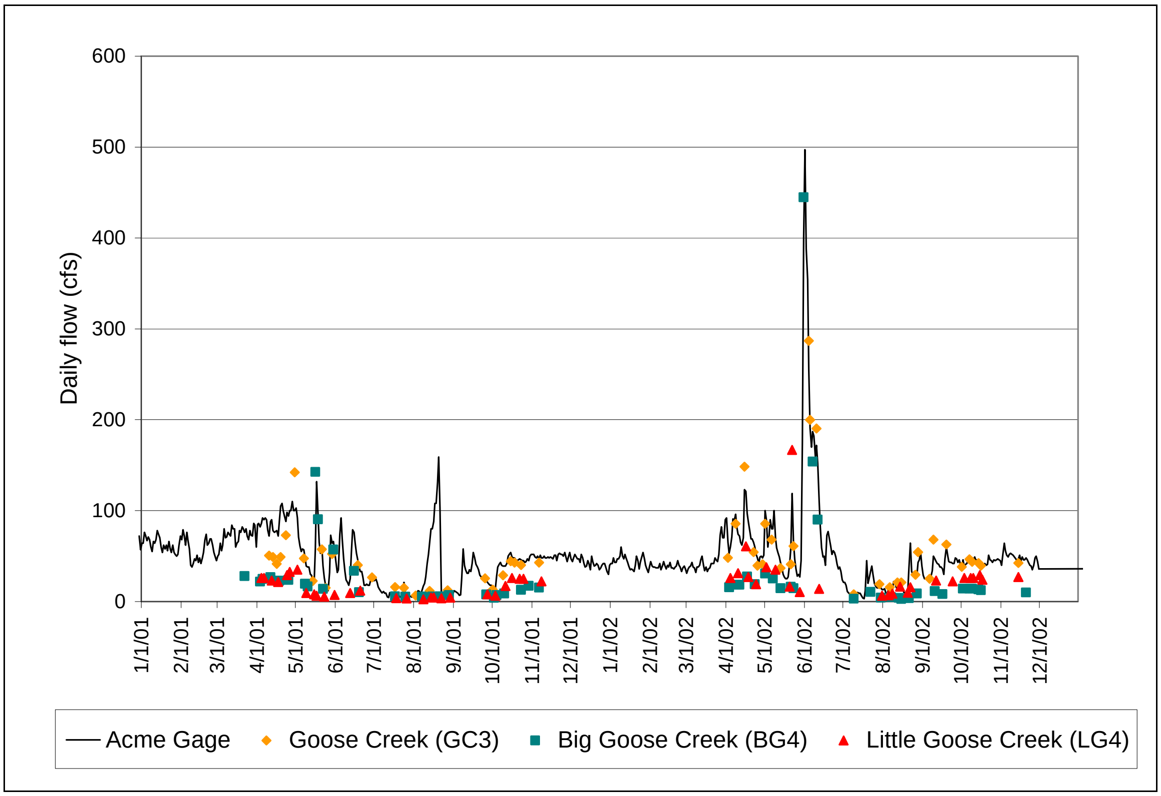


**Figure 4.9** Example of paired datasets for Goose Creek (GC3), Big Goose Creek (BG4), and Little Goose Creek (LG4) with daily flow at the USGS Acme Station.

To estimate the strength of the correlation between flows at the USGS Acme Station and flows in the upper watershed, a regression analysis was conducted and a coefficient of determination (R2) was calculated. Further, the regression analysis was conducted on the winter-flow and summer-flow data pairs to better understand the seasonal correlation of flows.

Regression of hydrologic data pairs resulting in a R2 greater than 0.7 was considered strong enough for data estimating. This methodology and threshold is used in calculating monthly wet, dry, and normal flow estimates in the Wyoming State Water Plan (2002).

All of the main stem streams in the watershed (Little Goose Creek, Big Goose Creek, and Goose Creek) have some sites with high correlation coefficients (Table 4.7). Correlation with other Goose Creek sites is generally very good, which is expected because these sites are the furthest downstream in the watershed. The correlation between flow in Little Goose Creek and the watershed outlet (USGS Acme Station) are very good in the winter and very poor in the summer. This reflects the importance of irrigation diversion and return flow in this system. Several Big Goose Creek sites also correlate well with the downstream USGS Acme Station. None of the tributaries to the three major streams had significant correlation coefficients. Most of the tributaries in the Goose Creek Watershed are dominated by non-natural flow conditions related to diversions and irrigation return flow (Wyoming State Water Plan 2002).

**Table 4.7** Correlations between Flow Readings from the USGS Acme Station and Upstream SCCD Spot Readings for Winter and Summer Recreation Periods

| Site Name | Sampling Site | Winter $R^2$ | Summer $R^2$ |
|---|---|---|---|
| **Main Stem Goose Creek** | | | |
| Goose Creek–upstream 5th Street Bridge | GC6 | 0.78* | 0.64 |
| Goose Creek–at footbridge in Thorne-Rider Park | GC5 | 0.68* | 0.38 |
| Goose Creek–upstream Fort Road Bridge | GC3 | 0.84* | 0.77* |
| Goose Creek–downstream Sheridan WWTP | GC2 | 0.52 | 0.00 |
| Goose Creek–downstream Highway 339 Bridge Crossing | GC1 | 0.67* | 0.98* |
| **Main Stem Little Goose Creek** | | | |
| Little Goose Creek–upstream County Road 77 Bridge at Little Goose Ranch | LG22 | 0.48 | 0.85* |
| Little Goose Creek–upstream County Road 103 Bridge at Entrance to Bradford-Brinton Memorial | LG21 | 0.79* | 0.01 |
| Little Goose Creek–upstream County Road 103 Bridge south of Big Horn | LG20 | 0.75* | 0.07 |
| Little Goose Creek–downstream Sackett Creek Confluence | LG18 | 0.80* | 0.15 |
| Little Goose Creek–downstream Jackson Creek Confluence | LG16 | 0.63 | 0.13 |
| Little Goose Creek–upstream Gerdle Ditch Intake | LG15 | 0.48 | 0.07 |
| Little Goose Creek–upstream Clubhouse Rd Bridge at Powderhorn Subdivision | LG14 | 0.72* | 0.17 |
| Little Goose Creek–upstream County Road 60 Bridge at Knode Ranch Subdivision | LG13 | 0.08 | 0.01 |
| Little Goose Creek–upstream Kruse Creek Confluence | LG12 | 0.67* | 0.15 |
| Little Goose Creek–downstream Kruse Creek, upstream Highway 87 Bridge | LG10 | 0.73* | 0.15 |
| Little Goose Creek–downstream McCormick Creek Confluence | LG8 | 0.79* | 0.02 |
| Little Goose Creek–upstream Highway 87 Bridge near Woodland Park | LG7 | 0.02 | 0.20 |
| Little Goose Creek–downstream County Road 66 Bridge | LG6 | 0.75* | 0.26 |
| Little Goose Creek–upstream Brundage Lane Bridge | LG5 | 0.36 | 0.00 |
| Little Goose Creek–upstream Coffeen Avenue Bridge | LG4 | 0.69* | 0.24 |
| Little Goose Creek–upstream Concrete Lined Channel Entrance | LG2 | 0.32 | 0.01 |
| Little Goose Creek–near Big Goose Creek Confluence | LG1 | 0.83* | 0.29 |
| **Main Stem Big Goose Creek** | | | |
| Big Goose Creek–upstream from Alliance Ditch Intake, at USGS Station #06302000 | BG18 | 0.35 | 0.00 |

**Table 4.7** Correlations between Flow Readings from the USGS Acme Station and Upstream SCCD Spot Readings for Winter and Summer Recreation Periods

| Site Name | Sampling Site | Winter $R^2$ | Summer $R^2$ |
|---|---|---|---|
| Big Goose Creek–upstream from Ditch No. 9 Intake | BG17 | 0.72* | 0.14 |
| Big Goose Creek–downstream Rapid Creek Confluence | BG15 | 0.80* | 0.12 |
| Big Goose Creek–upstream Highway 331 Bridge Crossing, south of Beckton | BG14 | 0.25 | 0.52 |
| Big Goose Creek–downstream Park Creek Confluence | BG12 | 0.02 | 0.66 |
| Big Goose Creek–upstream County Road 81 Bridge | BG11 | 0.87* | 0.25 |
| Big Goose Creek–upstream County Road 87 Bridge | BG10 | 0.75* | 0.21 |
| Big Goose Creek–downstream Beaver Creek Confluence | BG8 | 0.64 | 0.59 |
| Big Goose Creek–west of Paulson Youth Camp | BG7 | 0.88* | 0.60 |
| Big Goose Creek - at Paulson Youth Camp | BG6 | 0.59 | 0.85* |
| Big Goose Creek–upstream Brayton Lane Bridge at Normative Services | BG4 | 0.89* | 0.84* |
| Big Goose Creek–upstream Highway 331 Bridge four miles west of the City of Sheridan | BG5 | 0.46 | 0.58 |
| Big Goose Creek–west end of Leopard Street | BG3 | 0.48 | 0.86* |
| Big Goose Creek–downstream footbridge at Works and Elk streets | BG2 | 0.66 | 0.88* |
| Big Goose Creek–at footbridge in Kendrick Park | BG1 | 0.46 | 0.60 |
| **Impaired Tributaries** | | | |
| Sackett Creek–near Little Goose Creek Confluence | LG19 | 0.36 | 0.53 |
| Jackson Creek–near Little Goose Creek Confluence | LG17 | 0.12 | 0.07 |
| Kruse Creek–near Little Goose Creek Confluence | LG11 | 0.18 | 0.17 |
| McCormick Creek–near Little Goose Creek Confluence | LG9 | 0.00 | 0.01 |
| Rapid Creek–near Big Goose Creek Confluence | BG16 | 0.19 | 0.06 |
| Park Creek–downstream Highway 331 Crossing | BG13 | 0.03 | 0.49 |
| Beaver Creek–near Big Goose Creek Confluence | BG9 | 0.09 | 0.17 |
| Soldier Creek–downstream Dana Avenue Bridge | GC4 | 0.04 | 0.06 |

* $R^2$ values equal or greater than 0.7 are considered significant.

The flow duration curve methodology is applied in the load analysis section to estimate load by hydrologic flow regime at sites that correlate well with flow at the USGS Acme Station (Table 4.7). Water quality data for these sites are grouped by hydrologic flow regime. Load calculations at sites that do not correlate well with flow at the watershed outlet rely on alternative statistical methods to estimate seasonal flow. Flow data availability and correlation with flow data at the Goose Creek Watershed is one factor considered in the selection of compliance points in the load analysis portion of this TMDL study.

## 4.5 Groundwater

Groundwater in the Goose Creek Watershed occurs in shallow, unconfined, water table conditions. For this TMDL, shallow groundwater is of concern because it can be affected by surface land uses and affected near subsurface systems, such as septic systems and drainfields. Near-surface shallow groundwater decreases the travel distance pollutants take through unsaturated soils, and the contact time reduces the biological attenuating (breakdown) time.

Shallow aquifers in the watershed consist of unconsolidated Quaternary deposits of alluvium in and adjacent to streams in the watershed (see Map 7). The alluvium along the streams consists of fine sandy loam (see Map 8), and overlies bedrock composed of sedimentary siliciclastic rocks of the lower Tertiary Wasatch and/or Fort Union Formations (Bartos et al. 2008).

Recharge to the unconfined alluvial aquifers is from infiltration and percolation of precipitation, infiltration of diverted surface water from unlined irrigation canals and ditches, water applied to hayfields and gardens, and water from domestic septic systems (Bartos et al. 2008). Recharge to the shallow aquifers is expected to occur along losing stream segments. Similarly, discharge from the shallow aquifer is expected to occur along gaining segments of the streams. However, the locations of losing and gaining segments have not been identified in the Goose Creek Watershed.

In 2001 USGS installed 10 monitoring wells in the watershed (Bartos et al. 2008). Two of these wells are located in the Big Goose Creek subwatershed, and the remaining eight wells are located in the Little Goose Creek subwatershed (Map 10). The depths of the 10 USGS monitoring wells ranged from approximately 13 to 29 feet below land surface. In well RS-8, the full thickness of alluvium was penetrated because shallow bedrock was encountered at approximately 15 feet below land surface (Bartos et al. 2008). Another monitoring well (RS-2) could only be drilled to 2.5 feet until encountering the lower Tertiary-age Fort Union Formation. Sediments encountered during drilling consisted of unconsolidated deposits of silt, sand, and gravel.

Groundwater levels measured in the 10 USGS monitoring wells indicate that the water table was approximately 5 to 25 feet below land surface in the two wells installed along Big Goose Creek, and approximately 2 to 15 feet below land surface in the eight wells installed along Little Goose Creek (Bartos et al. 2008).

The most complete data for depth-to-groundwater in the Goose Creek Watershed were identified in the *Wyoming Ground Water Vulnerability Assessment Handbook Spatial Data and Visualization Report* (Hamerlinck and Ameson 1998). The Spatial Data and Visualization Center (SDVC) developed this groundwater sensitivity and vulnerability assessment to provide the public groundwater management agencies with a better understanding of the state’s groundwater resources and the vulnerability of important aquifers to contamination. The project was initiated in 1992 by WDEQ’s Water Quality Division, in cooperation with the University of Wyoming's Water Resources Center, the Wyoming State Geological Survey, and U.S. EPA (Hamerlinck and Ameson 1998).

As part of the SDVC study, a digital database was developed that compiles the “depth-to-initial-groundwater” in selected wells across the state and in the Goose Creek Watershed. The SDVC study developed a well location dataset using information from well drilling permits and completion reports cataloged by the Wyoming State Engineer’s Office. Compiled from the late 1800s through 1994, the permits include wells of varying use and status. These well permits represent data from different years and for various seasons. Therefore, each record is an individual snapshot of the groundwater levels and well characteristics at the time of completion. Thus the depth-to-groundwater is referred to by SDVC as the “depth-to-initial-groundwater.” The process used by SDVC to assemble the depth-to-initial-groundwater database is documented in the *Wyoming Ground Water Vulnerability Assessment Handbook Spatial Data and Visualization Report* (SDVC 1998).

Using the depth-to-initial-groundwater raster data for Sheridan County, available online from SDVC at the University of Wyoming, SWCA clipped the data to the Goose Creek Watershed. The data were further clipped, resulting in three datasets (one for each subwatershed). Table 4.8 summarizes the depth-to-initial groundwater for each subwatershed.

**Table 4.8** Depth-to-initial-groundwater for each Subwatershed

| Subwatershed | Minimum (feet) | Maximum (feet) | Average (feet) |
|---|---|---|---|
| Little Goose Creek | 0 | 60 | 18 |
| Big Goose Creek | 0 | 40 | 12 |
| Goose Creek | 0 | 44 | 20 |

As part of this TMDL, the SDVC depth-to-initial-groundwater raster data may be further manipulated and examined for specific buffer zones adjacent to Little Goose Creek, Big Goose Creek, and Goose Creek. This analysis may provide for a better understanding of the depth-to-initial-groundwater in critical areas of the Goose Creek Watershed.

In 2007 Tetra Tech conducted a groundwater investigation along North Main Street in the City of Sheridan (Tetra Tech 2008). As part of this study, pressure transducers were installed in eight monitoring wells, and groundwater level data were recorded for six months between March and October. During this study, groundwater levels rose to within 3 feet of the ground surface in April. The deepest groundwater levels were recorded at the end of September. Groundwater levels ranged from 12.0 feet below ground surface at the south end of Main Street to 2.7 feet below ground surface at the north end of Main Street. The maximum range of groundwater fluctuation along North Main Street was approximately 3.2 feet (Tetra Tech 2008).

No additional information could be identified that documents the fluctuation of groundwater levels in the watershed.

# CHAPTER 5 WATER QUALITY

## 5.1 Water Quality Period of Study and Seasons

The water quality period of study identified for the Goose Creek Watershed TMDLs is from 1998 to 2005. The period for water quality is shorter and more recent than the period for hydrology because the most robust water quality dataset available occurs during this period, and because it represents the most current status of water quality in the watershed. The period from 1998 to 2005 also represents a range in wet and dry years; therefore, it can represent average conditions across a multiyear period.

The recreation seasons defined for pathogens in the Wyoming water quality criteria are used to summarize seasonal patterns of pathogen bacteria. The summer season is defined as May to September and the winter recreation season is defined as October to April. Summary of pathogen data by season is appropriate because different water quality standards apply during these two seasons. Hydrologic flow regimes, defined by flow duration curves (see Section 4.32) provide another grouping mechanism for water quality data. Some water quality data are also summarized by month. Monthly summaries are also appropriate for pathogens because the water quality standard is based on a 30-day geometric mean of at least five samples.

## 5.2 Water Quality Data Sources and Coverage

Water quality data available during the period of study (1998–2005) were obtained from the USGS, SCCD, and WDEQ. These data were used to summarize current water quality across the watershed and are incorporated into the load analysis of the TMDL.

WDEQ collected water quality samples throughout the watershed in 1998 and 1999 at 28 sites in the Goose Creek Watershed, 18 of which overlap with SCCD water quality sampling sites. The USGS conducted a synoptic water quality study in June 2000 that included 24 stations in the Goose Creek Watershed. Of these 24 stations, 13 overlapped with SCCD water quality stations. Stations were considered to overlap if they were within 300 m of one another. The quality assurance and quality control procedures for the USGS and WDEQ sampling events were reviewed and found to be consistent with the SCCD methodology. Only the stations that overlapped with SCCD sites are used in the water quality summary in this section and load analysis for the TMDL. The stations that do not overlap with SCCD sites are noted in Table 5.1 but are not used in the water quality summary.

**Table 5.1** Summary of Water Quality Monitoring Points

| Impaired Segment | Organization | Sampling Site | Corresponding SCCD | Station Description | Dates |
|---|---|---|---|---|---|
| **Goose Creek Subwatershed** | | | | | |
| Goose Creek | SCCD | GC1 | GC1 | Goose Creek–downstream of Highway 339 Bridge crossing | 2001, 2002, 2005 |
| | WDEQ | Above KOA | NGPI50 | Goose Creek–above Big Horn Mountain KOA WWTP discharge | 1998 |
| | SCCD | GC2 | GC2 | Goose Creek–downstream of Sheridan WWTP | 2001, 2002, 2005 |
| | WDEQ | NGPI19 | GC2 | Goose Creek–below Sheridan WWTP discharge | 1998 |
| | SCCD | GC3 | GC3 | Goose Creek–upstream of Fort Road Bridge | 2001, 2002 |
| | WDEQ | Above Sheridan WWTP | GC3 | Goose Creek–above Sheridan WWTP discharge | 1998 |
| | SCCD | GC5 | GC5 | Goose Creek–at footbridge in Thorne-Rider Park | 2001, 2002 |
| | USGS | 44484810 6573701 | GC5 | Goose Creek–at 11th Street in the City of Sheridan | 2000 |
| | SCCD | GC6 | GC6 | Goose Creek–upstream of 5th Street Bridge | 2001, 2002 |
| Solider Creek | SCCD | GC4 | GC4 | Soldier Creek–downstream of Dana Avenue Bridge | 2001, 2002, 2005 |
| | USGS | 44491110 6574601 | GC4 | Soldier Creek–near mouth in the City of Sheridan | 2000 |
| **Big Goose Creek Subwatershed** | | | | | |
| Beaver Creek | SCCD | BG9 | BG9 | Beaver Creek–near Big Goose Creek confluence | 2001, 2002, 2005 |
| | WDEQ | Beaver Creek | BG9 | Near Big Goose Creek confluence | 1999 |
| Big Goose Creek | SCCD | BG1 | BG1 | Big Goose Creek–at footbridge in Kendrick Park | 2001, 2002 |
| | USGS | 44480310 6574701 | BG1 | Big Goose Creek at Kendrick Park in the City of Sheridan | 2000 |
| | WDEQ | BGH 1 | BG1 | Kendrick Park in the City of Sheridan | 1998, 1999 |
| | SCCD | BG2 | BG2 | Big Goose Creek–downstream of footbridge at Works and Elk Street intersection | 2001, 2002, 2005 |
| | SCCD | BG3 | BG3 | Big Goose Creek–west end of Leopard Street | 2001, 2002 |
| | SCCD | BG5 | BG5 | Big Goose Creek–upstream of Highway 331 Bridge crossing, 4 miles west of the City of Sheridan | 2001, 2002 |
| | SCCD | BG4 | BG4 | Big Goose Creek–upstream of Brayton Lane Bridge at Normative Services | 2001, 2002 |
| | WDEQ | BGH 2 | BG4 | Normative Services | 1998, 1999 |
| | | NGPI49 | BG4 | Normative Services | 1998 |
| | SCCD | BG6 | BG6 | Big Goose Creek–at Paulson Youth Camp | 2001, 2002, 2005 |
| | SCCD | BG7 | BG7 | Big Goose Creek–west of Paulson Youth Camp | 2001, 2002 |

**Table 5.1** Summary of Water Quality Monitoring Points

| Impaired Segment | Organization | Sampling Site | Corresponding SCCD | Station Description | Dates |
|---|---|---|---|---|---|
| | SCCD | BG8 | BG8 | Big Goose Creek–downstream of Beaver of Creek confluence | 2001, 2002 |
| | USGS | 44455010 7042601 | BG8 | Big Goose Creek–below Beaver Creek, near the City of Sheridan | 2000 |
| | WDEQ | Below Beaver Creek | BG8 | Big Goose Creek–below Beaver Creek confluence | 1999 |
| | SCCD | BG10 | BG10 | Big Goose Creek–upstream of County Road 87 Bridge | 2001, 2002, 2005 |
| | WDEQ | BGH 3 | BG10 | Bridge above Beaver Creek | 1998, 1999 |
| | SCCD | BG11 | BG11 | Big Goose Creek–upstream of County Road 81 Bridge | 2001, 2002 |
| | USGS | 44450310 7061601 | BG11 | Big Goose Creek–at County Road 81 near the City of Sheridan | 2000 |
| | WDEQ | County Highway 81 | BG11 | Big Goose Creek–at County Road 81 Bridge | 1999 |
| | SCCD | BG12 | BG12 | Big Goose Creek–downstream of Park Creek confluence | 2001, 2002 |
| | SCCD | BG14 | BG14 | Big Goose Creek–upstream of Highway 331 Bridge crossing, south of Beckton | 2001, 2002 |
| | USGS | 6302200 | BG14 | Big Goose Creek–above Park Creek, near the City of Sheridan | 1998, 1999 |
| | WDEQ | BGH 4 | BG14 | Bridge 1 mile below Beckton | 1998, 1999 |
| | SCCD | BG15 | BG15 | Big Goose Creek–downstream of Rapid Creek confluence | 2001, 2002 |
| | SCCD | BG17 | BG17 | Big Goose Creek–upstream from Ditch No. 9 Intake | 2001, 2002 |
| | USGS | 44431910 7085201 | BG17 | Big Goose Creek–below Kane Draw near the City of Sheridan | 2000 |
| | SCCD | BG18 | BG18 | Big Goose Creek–upstream from Alliance Ditch intake | 2001, 2002, 2005 |
| | WDEQ | BGH 5 | BG18 | Canyon–near Sheridan WWTP intake | 1998, 1999 |
| | USGS | 6301850 | (blank) | Big Goose Creek above PK ditch | 2002 |
| Park Creek | SCCD | BG13 | BG13 | Park Creek–downstream of Highway 331 crossing | 2001, 2002 |
| | WDEQ | Park Creek | BG13 | Near Big Goose Creek confluence | 1999 |
| Rapid Creek | SCCD | BG16 | BG16 | Rapid Creek–near Big Goose Creek confluence | 2001, 2002, 2005 |
| | WDEQ | Rapid Creek | BG16 | Near Big Goose Creek confluence | 1999 |
| **Little Goose Creek Subwatershed** | | | | | |
| Jackson Creek | SCCD | LG17 | LG17 | Jackson Creek–near Little Goose Creek confluence | 2001, 2002, 2005 |
| | WDEQ | Jackson Creek | LG17 | Jackson Creek irrigation ditch in Big Horn | 1999 |

**Table 5.1** Summary of Water Quality Monitoring Points

| Impaired Segment | Organization | Sampling Site | Corresponding SCCD | Station Description | Dates |
|---|---|---|---|---|---|
| Kruse Creek | SCCD | LG11 | LG11 | Kruse Creek–near Little Goose Creek confluence | 2001, 2002, 2005 |
| | WDEQ | Kruse Creek | LG11 | Near Little Goose Creek confluence | 1999 |
| Little Goose Creek | SCCD | LG1 | LG1 | Little Goose Creek–near Big Goose Creek confluence | 2001, 2002 |
| | USGS | 6304500 | (blank) | Little Goose Creek at the City of Sheridan | 1998, 1999, 2000, 2001, 2002, 2003, 2004 |
| | SCCD | LG2 | LG2 | Little Goose Creek–upstream of concrete-lined channel entrance | 2001, 2002, 2005 |
| | SCCD | LG4 | LG4 | Little Goose Creek–upstream of Coffeen Avenue Bridge | 2001, 2002 |
| | WDEQ | LGH 1 | LG4 | Coffeen Avenue Bridge | 1998, 1999 |
| | | NGPI36 | LG4 | Little Goose Creek–Coffeen | 1998 |
| | SCCD | LG5 | LG5 | Little Goose Creek–upstream of Brundage Lane Bridge | 2001, 2002, 2005 |
| | USGS | 44463410 6565401 | LG5 | Little Goose Creek below Brundage Lane Bridge in the City of Sheridan | 2000 |
| | WDEQ | LGH 2 | LG5 | Brundage Lane Bridge | 1998, 1999 |
| | SCCD | LG6 | LG6 | Little Goose Creek - downstream of County Road 66 Bridge | 2001, 2002 |
| | SCCD | LG7 | LG7 | Little Goose Creek–upstream of Highway 87 Bridge crossing near Woodland Park | 2001, 2002 |
| | USGS | 44441510 6565001 | LG7 | Little Goose Creek at Highway 87 Bridge below Woodland Park Village, north of the City of Sheridan | 2000 |
| | WDEQ | LGH 3 | LG7 | Woodland Park Bridge | 1998, 1999 |
| | SCCD | LG8 | LG8 | Little Goose Creek–downstream of McCormick Creek confluence | 2001, 2002, 2005 |
| | SCCD | LG12 | LG12 | Little Goose Creek–upstream of Kruse Creek confluence | 2001, 2002 |
| | SCCD | LG13 | LG13 | Little Goose Creek–upstream of County Road 60 Bridge crossing at Knode Ranch Subdivision | 2001, 2002, 2005 |
| | SCCD | LG14 | LG14 | Little Goose Creek–upstream of Clubhouse Road Bridge Crossing at Powderhorn Subdivision | 2001, 2002 |
| | SCCD | LG15 | LG15 | Little Goose Creek–upstream of Gerdle Ditch Intake | 2001, 2002 |
| | SCCD | LG16 | LG16 | Little Goose Creek–downstream of Jackson Creek confluence | 2001, 2002 |
| | SCCD | LG18 | LG18 | Little Goose Creek–downstream of Sackett Creek confluence | 2001, 2002 |
| | WDEQ | LGH 5 | LG18 | Bird Farm Road Bridge | 1998, 1999 |
| | SCCD | LG20 | LG20 | Little Goose Creek–upstream of County Road 103 Bridge south of Big Horn | 2001, 2002 |
| | USGS | 44401410 6593401 | LG20 | Little Goose Creek on County Road 103 near Big Horn | 2000 |

**Table 5.1** Summary of Water Quality Monitoring Points

| Impaired Segment | Organization | Sampling Site | Corresponding SCCD | Station Description | Dates |
|---|---|---|---|---|---|
| | WDEQ | South of Big Horn | LG20 | Little Goose Creek at County Road 103 Bridge | 1999 |
| | SCCD | LG21 | LG21 | Upstream of County Road 103 Bridge at entrance to Bradford-Brinton Memorial | 2001, 2002 |
| | USGS | 44390010 7002201 | LG21 | Little Goose Creek at Bradford Brinton Memorial near Big Horn | 2000 |
| | WDEQ | LGH 6 | LG21 | Bradford Brinton Bridge | 1998, 1999 |
| | SCCD | LG22 | LG22 | Little Goose Creek–upstream of County Road 77 Bridge at Little Goose Ranch | 2001, 2002, 2005 |
| | USGS | 6303700 | LG22 | Little Goose Creek above Davis Creek near Big Horn | 2000 |
| | WDEQ | LGH 7 | LG22 | County Road 77 Bridge, Little Goose Ranch | 1998, 1999 |
| | USGS | 6303500 | (blank) | Little Goose Creek in canyon near Big Horn | 2001, 2002 |
| | SCCD | LG10 | LG10 | Downstream of Kruse Creek confluence, upstream of Highway 87 Bridge crossing | 2001, 2002 |
| | WDEQ | LGH 4 | LG10 | Highway 87 Bridge | 1998, 1999 |
| McCormick Creek | SCCD | LG9 | LG9 | McCormick Creek–near Little Goose Creek confluence | 2001, 2002, 2005 |
| Sackett Creek | SCCD | LG19 | LG19 | Sackett Creek–near Little Goose Creek confluence | 2001, 2002, 2005 |
| | WDEQ | Sackett Creek | LG19 | Near Little Goose Creek confluence | 1999 |
| Storm Drain | SCCD | LG3 | LG3 | Storm drain effluent–downstream of Coffeen Avenue Bridge | 2001, 2002 |

## 5.3 Water Quality Parameters

Data used in this water quality characterization relate to the pathogen and sediment impairments in the Goose Creek Watershed. Parameters that relate directly to these impairments include fecal coliform, *E. coli*, TSS, and turbidity.

### *5.3.1 Pathogens*

Pathogenic organisms known to be waterborne include bacteria (e.g., dysentery), viruses (e.g., hepatitis), protists (e.g., *Giardia*), and parasites. Some pathogens and indicator bacteria can live in bottom sediments and can be re-suspended during high flows (Stephenson and Rychert 1982). Pathogenic organisms are costly and difficult to test for in natural waters due to their low concentrations and diversity.

Fecal coliforms are common bacteria found in the digestive tracts of warm-blooded animals, including humans, mammals (wildlife and livestock), and birds. Fecal coliforms are not harmful themselves but are a good indicator of fecal contamination of waters, which is a public health risk due to the possible presence of pathogenic organisms harmful to humans.

*E. coli* is one species of fecal coliform that can also be used as an indicator of fecal contamination. The majority of *E. coli* strains are not pathogenic to humans (Nataro and Kaper 1998). Some strains of *E. coli*, such as *E. coli* 157:H7, are responsible for hemorrhagic colitis (severe diarrhea) and hemolytic uremic syndrome (kidney failure) (Nataro and Kaper 1998). Both of these cause mild to extreme symptoms in humans and can be fatal if left untreated.

*E. coli* has become a more reliable indicator of pathogens originating from fecal matter than fecal coliforms. In 1986 the U.S. EPA recommended that *E. coli* or enterococci replace fecal-coliform bacteria in state water quality standards (U.S. EPA 1986). The recommendation resulted from a study that demonstrated a statistically significant relationship between swimming-related illness, *E. coli*, and enterococci concentrations in freshwater (Dufour 1984). The U.S. EPA's recommendation for *E. coli* as an indicator of fecal contamination in water and wastewater is based on the following: 1) *E. coli* occurs in human and warm-blooded animal feces in greater quantities than pathogens; 2) *E. coli* shows minimal growth in aquatic systems; 3) *E. coli* is easily detectable; and 4) *E. coli* is consistently present when pathogens are present (Elmund et al. 1999).

## 5.3.2 Sediment

Sediment is the most visible pollutant in freshwaters, leading to increased turbidity in water. Erosion of upland soils and streambanks is the primary causes of elevated sediment levels in rivers and reservoirs, both of which reflect land management practices in a watershed. Excessive sediment loading in receiving waters can lead to a) the alteration of aquatic habitat, b) reduced reservoir storage capacity due to sedimentation, and c) reduced aesthetic value of waters. Accumulation of sediments can directly harm fish and aquatic wildlife, or indirectly affect the functioning of aquatic systems by contributing to nutrient loading and eutrophication (algal overgrowth) (Novotny and Olem 1994). Sediments also readily adsorb other pollutants, such as persistent organochlorine compounds and polychlorinated biphenyls (PCBs), particularly from surface runoff, air pollution, and litter accumulation in urban areas (Novotny and Olem 1994).

Two methods that can be used to estimate sediment load in the water column include TSS and turbidity. TSS is measured in milligrams per liter (mg/L) and is usually well correlated to streamflow, making it highly variable across sampling periods. Turbidity is a measurement of the visible clarity of water. Turbidity can be caused by both inorganic particles (including minerals) and organic particles (including suspended algae). Turbidity is usually reported in nephelometric turbidity units (NTU), which represent the degree to which light is scattered in water. If a strong correlation exists between turbidity and TSS, the majority of turbidity can be assumed to be associated with suspended sediment.

The best estimates of sediment load in a stream are derived from both actual bed load samples and suspended load samples collected at various flows. TSS can be used as a surrogate for suspended or wash load. The lack of bed load data limits the predictability of sediment load for the TMDL. Actual measurements of bed load and suspended load would prove useful in the monitoring and implementation phase of the TMDL and in monitoring the TMDL progress.

## 5.3.3 Treatment of Nondetects

Many data points (7% of the pathogen and 42% of the TSS data points) in the Goose Creek Watershed dataset are concentration values identified as "below detection limits." In addition, three *E. coli* data points were reported as "greater than quantitation limits." For analyzing the data, a method must be developed to statistically interpret these values. This is generally accomplished by assigning a numeric value that is half the detection limit (in the case of concentrations identified as below detection limits) or a value that represents the quantitation limit (in the case of concentrations identified as greater than quantitation limits). Detection limits were reported for all of the nondetect data. These detection limits are summarized in Table 5.2.

**Table 5.2** Detection Limits for Nondetect Data

| Parameter | Organization | Units | Range of Detection Limit | Range of Quantitation Limit |
|---|---|---|---|---|
| *E. coli* | SCCD | cfu/100 mL | 1 | – |
| | USGS | cfu/100 mL | 1 | 300–800 |
| Fecal Coliform | SCCD | cfu/100 mL | 1–10 | – |
| | USSG | cfu/100 mL | 1 | – |
| Total Suspended Solids | SCCD | mg/L | 0–5 | – |
| | WDEQ | mg/L | 2–5 | – |

### *5.3.4 Correlation between* E. coli *and Fecal Coliforms*

The positive relationship between fecal coliform and *E. coli* concentrations has been demonstrated in the Goose Creek Watershed (Clark and Gamper 2003) and elsewhere (Elmund et al. 1999). A regression model specific to data in the Goose Creek Watershed was developed for existing fecal coliform and *E. coli* data. This model allows for the estimation of *E. coli* concentrations in portions of the watershed or during times when only fecal coliform data were collected. The model was based on a combined dataset of 354 *E. coli* (cfu/100 mL) and fecal coliform (cfu/100 mL) paired samples from the Goose Creek Watershed. Samples outside of the 95$^{th}$ percentile confidence interval were removed from the model and blank samples were not included. The samples were collected from 10 stations (27 samples) from the USGS study of fecal-indicator bacteria in the Goose Creek Watershed (Clark and Gamper 2003), and 26 stations (327 samples) from the SCCD *Goose Creek Watershed Assessment* (SCCD 2003). Only current (1998–2005) data were used to develop the regression. Fecal coliform concentrations ranged from 0.5 to 4,140 cfu/100 mL, and *E. coli* concentrations ranged from 0.5 to 4,700 cfu/100 mL. Twelve cases were removed from the regression dataset due to nondetection levels for fecal coliform (0.50 cfu/100 mL). In addition, 68 cases were removed where *E. coli* concentrations were greater than fecal coliform concentrations. Because *E. coli* is a subset of fecal coliform, the *E. coli* and/or fecal coliform concentrations were presumably erroneous in these cases. Finally, a 99.9% confidence interval was applied to the reduced dataset (278 cases), and four outlying cases were removed. The final regression dataset contained 274 cases (Table 5.3).

**Table 5.3** Fecal Coliform and *E. coli* Data Used in Regression Model Development

| Data Source | Cases | Nondetects | Errors | 99.9% CI Outliers | Total Cases Analyzed |
|---|---|---|---|---|---|
| SCCD | 327 | 12 | 63 | 4 | 252 |
| USGS | 27 | 0 | 5 | 0 | 22 |
| **Total** | **354** | **12** | **68** | **4** | **274** |

Additional explanatory variables, such as date or season of sample collection, water turbidity, or flow velocity, were not used to further refine the model because model-predicted *E. coli* concentrations will be used to examine fecal-indicator bacteria associations with these variables.

Analysis of the degree of correlation between fecal coliform and *E. coli* concentrations in the regression dataset was performed using Spearman's Rho, a non-parametric statistical technique. The resulting correlation value of 0.921 was highly significant ($p<0.0001$) and demonstrates a strong, positive relationship between the variables.

Linear regression was performed in SPSS 16.0.1, a statistical package developed by SPSS Inc. The results of the linear regression model resulted in the following equation to convert fecal coliform to *E. coli*:

$$E.\ coli = 0.8714 \times \text{fecal coliform} - 16.436$$

The fitted data had an $R^2$ value of 0.906 and the model parameters explain a significant proportion of variability in the data ($p<0.0001$) (Figure 5.1).

However, because the constant (16.436) is negative, the model predicts negative *E. coli* values at low concentrations of fecal coliform. Because the constant would cause an overall underestimation of *E. coli* concentrations, it was dropped from the equation, resulting in the following equation:

$$E.\ coli = 0.8714 \times \text{fecal coliform}$$

The resulting linear equation will slightly overestimate *E. coli* concentrations at low fecal coliform concentrations, as indicated by the scatter of points below the model in line on the left side of Figure 5.1. Similarly, the model may underestimate *E. coli* with increasing concentrations of fecal coliform.

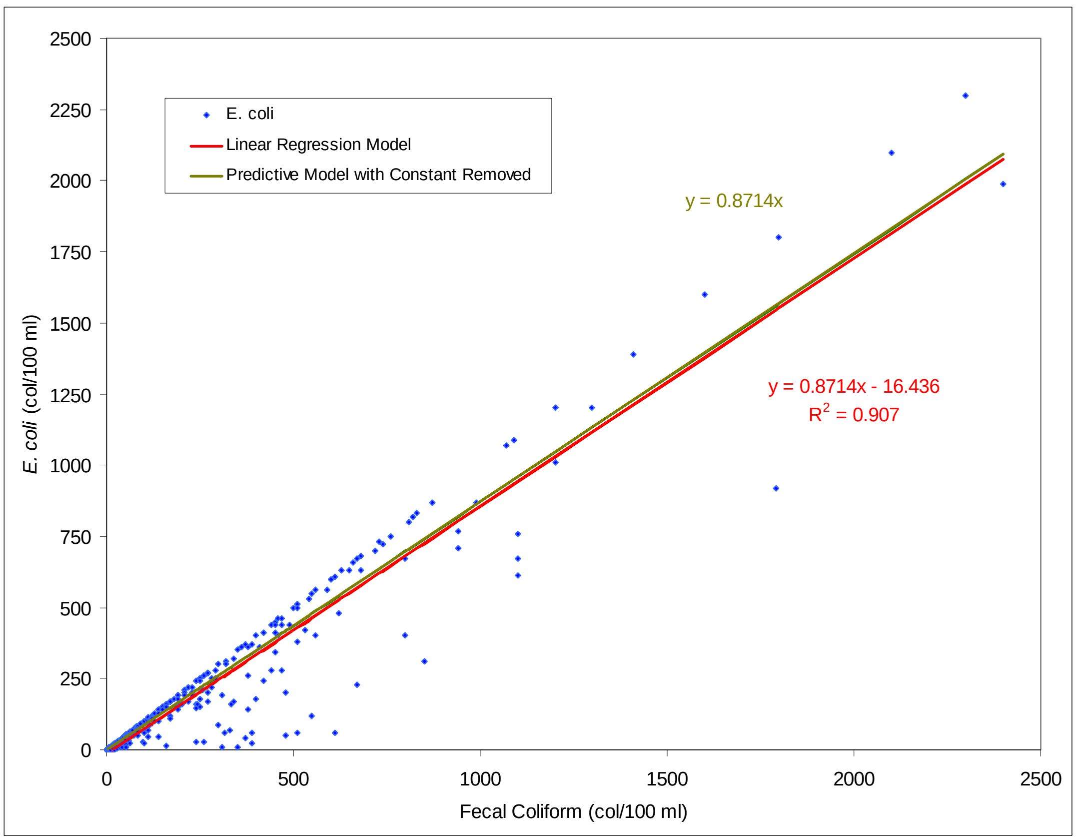


**Figure 5.1** Fecal coliform and *E. coli* concentrations (cfu/100 mL) regression model data scatter-plot with linear regression model and predictive model trend lines.

# 5.4 Water Quality Summary

## *5.4.1 Pathogens*

The regression model described in the previous section was used to estimate *E. coli* concentrations from fecal coliform concentrations, thereby providing more pathogen data for analysis. The original, combined dataset from WDEQ (STORET), USGS, and SCCD includes 354 fecal coliform and *E. coli* values (Table 5.3). Fecal coliform data that were excluded from the model dataset had their associated *E. coli* values estimated using the regression model. The combined *E. coli* dataset (original values and estimated values) of 2,288 values were used to characterize water quality throughout the watershed during two recreation seasons (summer and winter). In addition, pathogen data were summarized by month (Figures 5.2 and 5.3) and by the hydrologic flow regimes (Figure 5.4) developed using the flow duration curves. Data were summarized at the lowermost site in each of the impaired segments as well as at sites along the main stem streams. These data helped to evaluate trends from upstream to downstream.

### 5.4.1.1 *E. COLI* TRENDS BY MONTH

### Summary of *E. coli* Data at Mouth of Each Impaired Segment

The highest average *E. coli* concentrations in the Goose Creek Watershed, as measured at the lowermost point on each of the impaired segments, occur in Soldier Creek, Beaver Creek, and Park Creek. For Soldier Creek, the highest *E. coli* concentration occurs in August, whereas the highest average *E. coli* concentration for Beaver Creek and Rapid Creek occurs in July. High average *E. coli* concentrations are also observed in May on most of the streams in the watershed with the exception of Big Goose Creek, Rapid Creek, and Sackett Creek (Figure 5.2). There are very few instances of high *E. coli* values recorded outside the summer recreation season (May through September). None of the monthly average *E. coli* concentrations recorded during April and October (winter recreation season) exceed the winter *E. coli* standard of 630 cfu/100 mL.

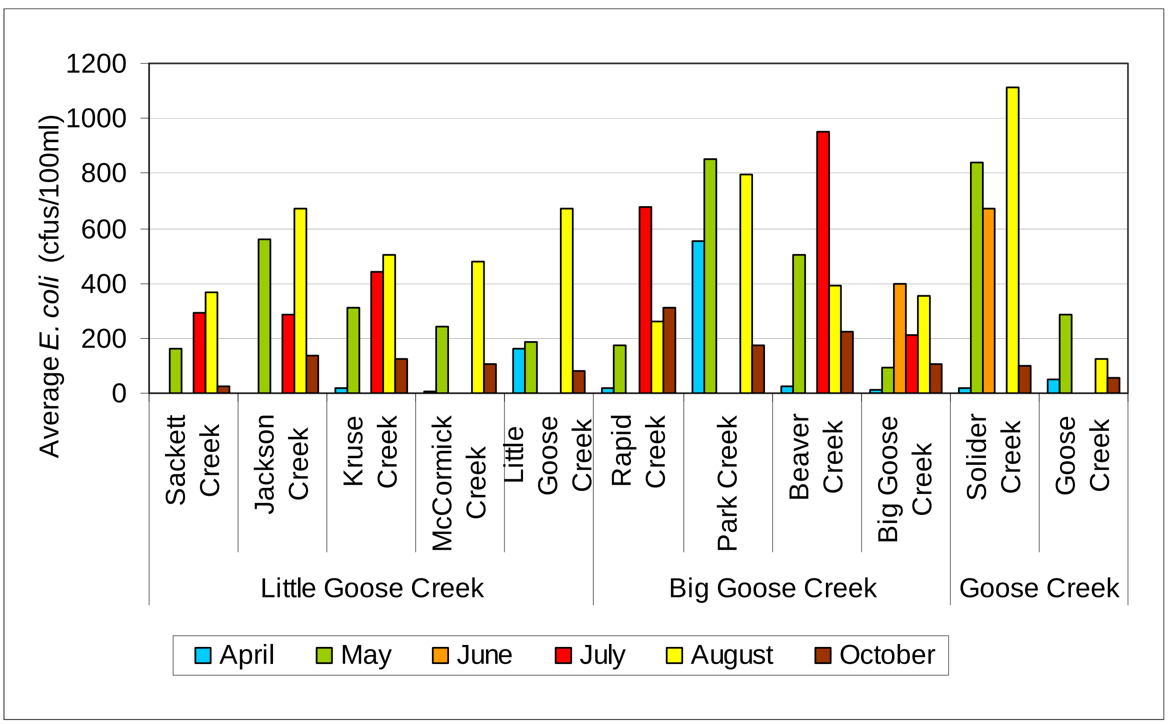


**Figure 5.2** Summary of average *E. coli* by month at the lowermost site of each of the impaired segments in the Goose Creek Watershed.

### Summary of *E. coli* Data along Big Goose Creek, Little Goose Creek, and Goose Creek

Along the main stems of Little Goose Creek, *E. coli* concentrations generally get much higher downstream of Site LG12 (River Mile 12) and peak below the confluence with McCormick Creek (River Mile 10). High values along Little Goose Creek occur primarily in July and August. *E. coli* concentrations in Big Goose Creek are highest in some of the middle–upper segments of the watershed (above River Mile 13, which corresponds to site BG8) with peaks occurring in June and July. The lower segments (from the mouth to River Mile 5) of Big Goose Creek have relatively high *E. coli* values, especially in August. *E. coli* trends in Goose Creek appear to be highly variable from upstream to downstream. In August, water quality improves slightly from upstream to downstream, whereas water quality is degraded downstream in May and October. The highest recorded *E. coli* average in Goose Creek is upstream of the confluence with Soldier Creek (Figure 5.3).

## 5.4.1.2 RELATIONSHIP TO HYDROLOGIC FLOW REGIMES

Although the hydrology of only some of the sites in the Goose Creek Watershed correlates significantly with the USGS Acme Station, it is helpful to examine patterns and trends in the *E. coli* data based on hydrologic flow regime, defined by the flow duration curve for the summer period at the watershed outlet (see Section 4.3.2). These hydrologic flow regimes reflect general trends associated with watershed processes, including overland flow, storms, and groundwater level that might affect water quality even when hydrologic correlations cannot be drawn.

Approximately half of the summer flow leaving the Goose Creek Watershed occurs during the “very high-flow” period defined as the top 10% of daily flow values observed at the USGS Acme Station. Another 37% of the total flow occurs during the high-flow period defined as the flow values occurring between 10% and 40% of the time.

### Summary of *E. coli* Data at Mouth of Each Impaired Segment

Figure 5.4 summarizes *E. coli* data for each of the five hydrologic flow regimes at the bottom of each impaired segment. The highest *E. coli* values are recorded during high-flow periods in some segments (Jackson Creek, Kruse Creek, Big Goose Creek, Little Goose Creek, Goose Creek, and Sackett Creek) and during both high-flow and low-flow periods in other segments (Soldier Creek, Beaver Creek, and Rapid Creek). The highest concentrations in Park Creek were recorded during the low-flow period. The medium-flow period generally represents the best water quality in terms of *E. coli* concentration, which could reflect a balance between dilution effects (the lack of dilution leads to high concentrations during low-flow periods) and transport of pathogens from watershed sources through overland flow and/or groundwater recharge of streams.

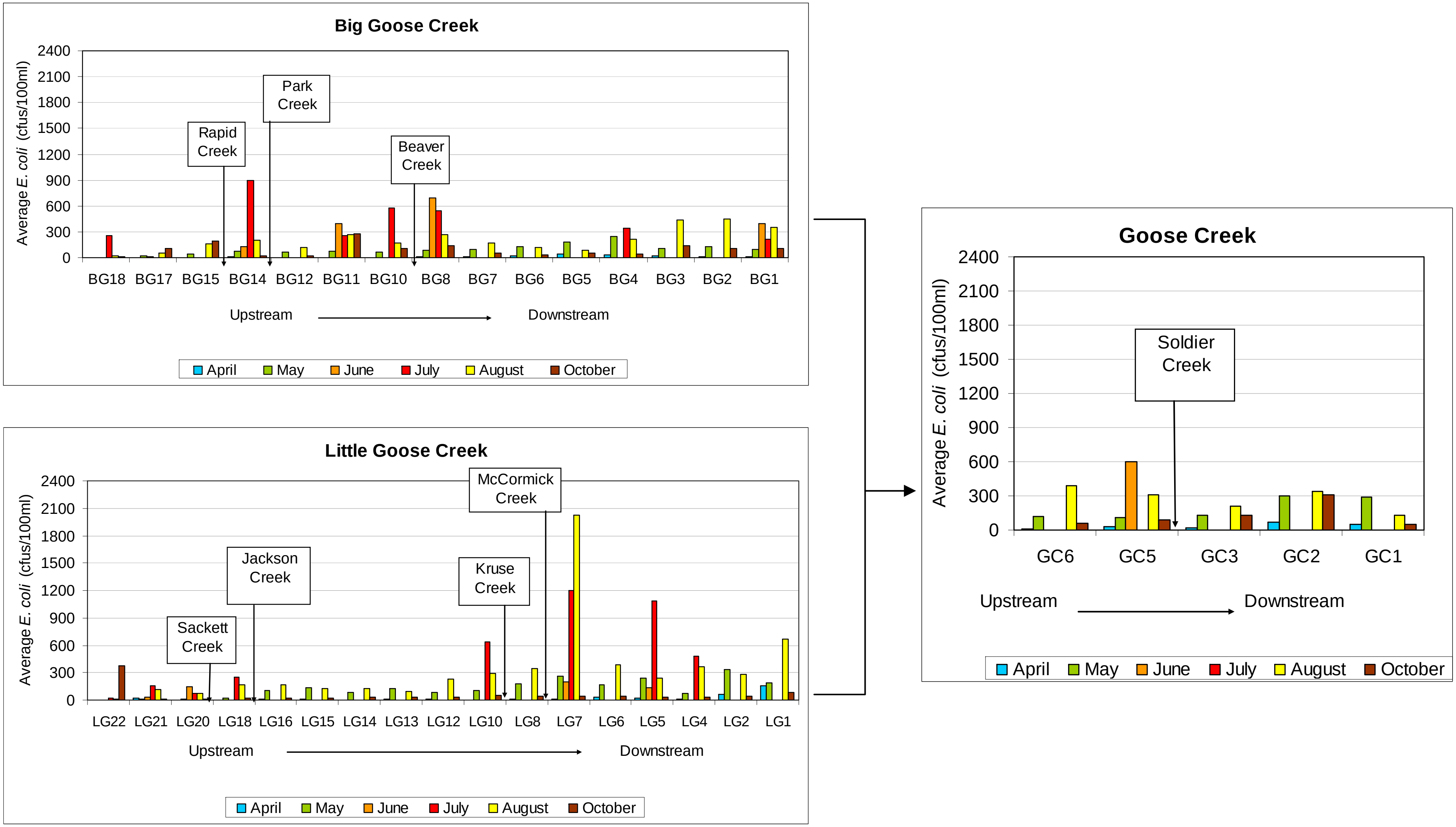


**Figure 5.3** Average summary of *E. coli* data in the Goose Creek Watershed by month.

**Table 5.4** Summary Statistics of *E. coli* Data (collected and estimated) for the Lowermost Site of Each Coliform-impaired Segment in the Goose Creek Watershed between 1998 and 2005

| Impaired Segment | Subwatershed | Site | Number of Samples | Maximum (cfu/100 mL) | Minimum | Average (cfu/100 mL) | Standard Deviation | Summer Samples Exceeding 126 cfu/100 mL | Winter Samples Exceeding 630 cfu/100 mL |
|---|---|---|---|---|---|---|---|---|---|
| Sackett Creek | Little Goose Creek | LG19 | 55 | 1,325 | Nondetect | 181 | 283 | 60.0% | 0.0% |
| Jackson Creek | Little Goose Creek | LG17 | 55 | 4,584 | Nondetect | 411 | 848 | 69.0% | 0.0% |
| Kruse Creek | Little Goose Creek | LG11 | 55 | 2,420 | Nondetect | 291 | 479 | 69.0% | 0.0% |
| McCormick Creek | Little Goose Creek | LG9 | 50 | 1,200 | Nondetect | 239 | 310 | 60.0% | 5.0% |
| Storm Drain | Little Goose Creek | LG3 | 40 | 2,396 | Nondetect | 273 | 446 | 60.0% | 5.0% |
| Little Goose Creek | Little Goose Creek | LG1 | 55 | 1,447 | Nondetect | 209 | 315 | 49.0% | 10.0% |
| Rapid Creek | Big Goose Creek | BG16 | 28 | 4,700 | Nondetect | 565 | 990 | 73.0% | 12.0% |
| Park Creek | Big Goose Creek | BG13 | 55 | 2,420 | Nondetect | 336 | 507 | 71.0% | 5.0% |
| Beaver Creek | Big Goose Creek | BG9 | 51 | 810 | Nondetect | 175 | 201 | 65.0% | 0.0% |
| Big Goose Creek | Big Goose Creek | BG1 | 48 | 6,361 | Nondetect | 579 | 1,082 | 93.0% | 0.0% |
| Soldier Creek | Goose Creek | GC4 | 50 | 1,990 | Nondetect | 145 | 291 | 47.0% | 0.0% |
| Goose Creek | Goose Creek | GC1 | 55 | 1,325 | Nondetect | 181 | 283 | 60.0% | 0.0% |

**Table 5.5** Summary Statistics of *E. coli* Data (collected and calculated) along the Main Stems of Little Goose Creek between 1998 and 2005

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfu/100 mL) | Minimum | Average (cfu/100 mL) | Standard Deviation | Summer Samples Exceeding 126 cfu/100 mL | Winter Samples Exceeding 630 cfu/100 mL |
|---|---|---|---|---|---|---|---|---|
| LG22 | Upstream of County Road 77 Bridge at Little Goose Ranch | 60 | 3,100 | Nondetect | 69 | 406 | 0.0% | 3.3% |
| LG21 | Upstream of County Road 103 Bridge at Entrance to Bradford-Brinton Memorial | 51 | 471 | Nondetect | 56 | 90 | 9.8% | 0.0% |
| LG20 | Upstream of County Road 103 Bridge South of Big Horn | 46 | 227 | Nondetect | 34 | 47 | 4.3% | 0.0% |
| LG18 | Downstream of Sackett Creek confluence | 50 | 375 | Nondetect | 79 | 114 | 33.0% | 0.0% |
| LG16 | Downstream of Jackson Creek confluence | 40 | 741 | Nondetect | 76 | 143 | 30.0% | 0.0% |
| LG15 | Little Goose Creek Upstream of Gerdle Ditch intake | 40 | 967 | Nondetect | 70 | 168 | 20.0% | 0.0% |
| LG14 | Upstream of Clubhouse Road Bridge at Powderhorn Subdivision | 40 | 619 | Nondetect | 60 | 119 | 25.0% | 0.0% |
| LG13 | Upstream of County Road 60 Bridge at Knode Ranch Subdivision | 50 | 980 | Nondetect | 72 | 148 | 27.0% | 0.0% |
| LG12 | Upstream of Kruse Creek confluence | 40 | 793 | Nondetect | 89 | 158 | 40.0% | 0.0% |
| LG10 | Downstream of Kruse Creek, upstream Highway 87 Bridge | 50 | 1,307 | Nondetect | 169 | 238 | 70.0% | 0.0% |
| LG8 | Downstream of McCormick Creek Confluence | 50 | 1,730 | Nondetect | 169 | 291 | 53.0% | 0.0% |
| LG7 | Upstream of Highway 87 Bridge Near Woodland Park | 51 | 16,382 | Nondetect | 810 | 2648 | 81.0% | 0.0% |
| LG6 | Downstream of County Road 66 Bridge | 40 | 870 | Nondetect | 158 | 208 | 65.0% | 0.0% |
| LG5 | Upstream of Brundage Lane Bridge | 61 | 2,876 | Nondetect | 208 | 446 | 59.0% | 0.0% |
| LG4 | Upstream of Coffeen Avenue Bridge | 52 | 1,656 | Nondetect | 171 | 299 | 53.0% | 0.0% |
| LG2 | Upstream of concrete-lined channel entrance | 50 | 2,420 | Nondetect | 207 | 408 | 50.0% | 0.0% |
| LG1 | Near Big Goose Creek Confluence | 40 | 2,396 | Nondetect | 273 | 446 | 60.0% | 5.0% |

**Table 5.6** Summary Statistics of *E. coli* Data (collected and calculated) along the Main Stems of Big Goose Creek between 1998 and 2005

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfu/100 mL) | Minimum | Average (cfu/100 mL) | Standard Deviation | Summer Samples Exceeding 126 cfu/100 mL | Winter Samples Exceeding 630 cfu/100 mL |
|---|---|---|---|---|---|---|---|---|
| BG18 | Upstream from Alliance Ditch intake at USGS Station #06302000 | 59 | 253 | Nondetect | 15 | 36 | 3.0% | 0.0% |
| BG17 | Upstream from Ditch No. 9 intake | 41 | 993 | Nondetect | 47 | 156 | 10.0% | 5.0% |
| BG15 | Downstream of Rapid Creek confluence | 40 | 1,481 | Nondetect | 98 | 266 | 15.0% | 5.0% |
| BG14 | Upstream of Highway 331 Bridge crossing, south of Beckton | 60 | 1,063 | Nondetect | 137 | 234 | 46.0% | 0.0% |
| BG12 | Downstream of Park Creek confluence | 40 | 340 | Nondetect | 52 | 82 | 25.0% | 0.0% |
| BG11 | Upstream of County Road 81 Bridge | 46 | 1,917 | Nondetect | 164 | 316 | 42.0% | 5.0% |
| BG10 | Upstream of County Road 87 Bridge | 60 | 976 | Nondetect | 121 | 191 | 45.0% | 5.0% |
| BG8 | Downstream of Beaver Creek confluence | 46 | 993 | Nondetect | 146 | 246 | 35.0% | 5.0% |
| BG7 | West of Paulson Youth Camp | 40 | 654 | Nondetect | 83 | 146 | 30.0% | 0.0% |
| BG6 | At Paulson Youth Camp | 50 | 697 | Nondetect | 82 | 126 | 27.0% | 0.0% |
| BG5 | Upstream of Highway 331 Bridge 4 Miles west of the City of Sheridan | 40 | 1,307 | Nondetect | 89 | 206 | 15.0% | 0.0% |
| BG4 | Upstream of Brayton Lane Bridge at Normative Services | 51 | 1,586 | Nondetect | 153 | 252 | 47.0% | 0.0% |
| BG3 | West End of Leopard Street | 40 | 1,725 | Nondetect | 174 | 305 | 60.0% | 0.0% |
| BG2 | Downstream of footbridge at Works and Elk streets | 50 | 1,600 | Nondetect | 198 | 301 | 63.0% | 0.0% |
| BG1 | At footbridge in Kendrick Park | 51 | 810 | Nondetect | 175 | 201 | 65.0% | 0.0% |

**Table 5.7** Summary Statistics of *E. coli* Data (collected and calculated) along the Main Stems of Goose Creek between 1998 and 2005

| Sampling Site | Sampling Site Description | Number of Samples | Maximum (cfu/100 mL) | Minimum | Average (cfu/100 mL) | Standard Deviation | Summer Samples Exceeding 126 cfu/100 mL | Winter Samples Exceeding 630 cfu/100 mL |
|---|---|---|---|---|---|---|---|---|
| GC6 | Upstream 5th Street Bridge | 40 | 920 | Nondetect | 145 | 205 | 65.0% | 0.0% |
| GC5 | At footbridge in Thorne-Rider Park | 41 | 802 | Nondetect | 146 | 180 | 57.0% | 0.0% |
| GC3 | Upstream Fort Road Bridge | 45 | 837 | Nondetect | 116 | 154 | 55.0% | 4.0% |
| GC2 | Downstream Sheridan WWTP | 55 | 2,420 | 8 | 271 | 373 | 67.0% | 12.0% |
| GC1 | Downstream Highway 339 Bridge Crossing | 50 | 1,990 | Nondetect | 145 | 291 | 47.0% | 0.0% |

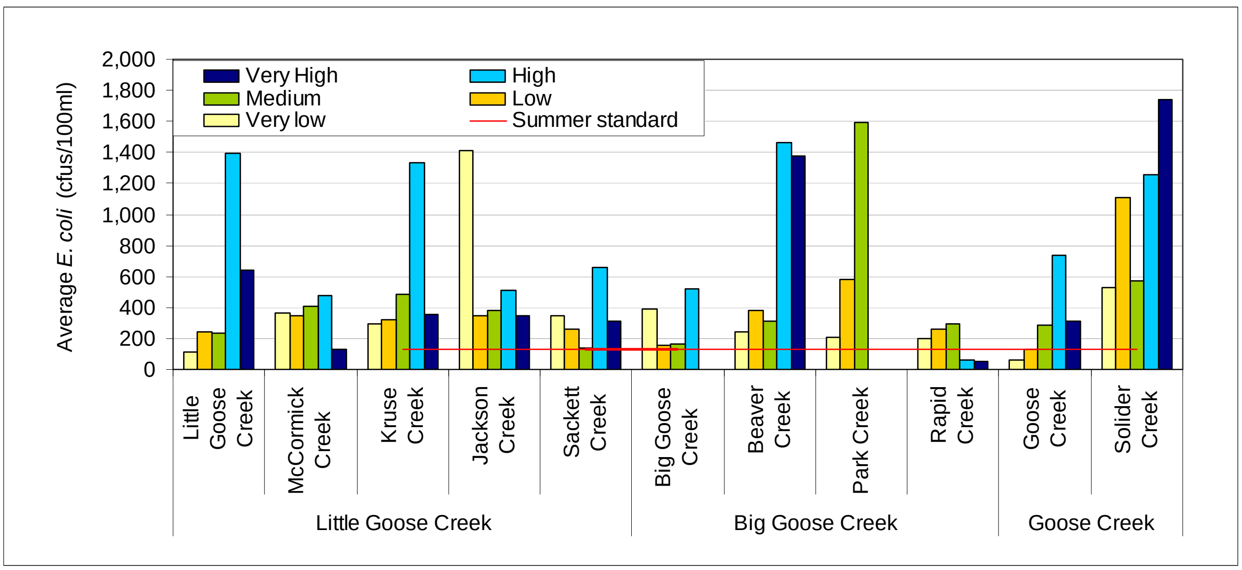


**Figure 5.4** Summary of average *E. coli* data by summer hydrologic flow regime (May–September) at the lowermost site of each impaired segment in the Goose Creek Watershed.

## Summary of *E. coli* Data along Big Goose Creek, Little Goose Creek, and Goose Creek

Trends along the main stem of Little Goose Creek indicate that the highest *E. coli* averages are recorded during the low-flow periods in the middle segments of the watershed, whereas high-flow periods in the lower parts of the creek represent the highest *E. coli* averages. This indicates that different processes could be driving the impairments observed in the lower, mid, and upper segments of Little Goose Creek. This will be an important consideration when establishing delineation points for the load analysis section of the TMDL. A similar pattern occurs in Goose Creek, with the lower segments exhibiting the highest *E. coli* averages especially during the high-flow periods. In Big Goose Creek, both low-flow and high-flow periods are associated with high *E. coli* values in the lower segments of the stream. Typically, the medium-flow condition is characterized by lower *E. coli* values that generally do not exceed the water quality standard (Figure 5.5). The water quality standard in the summer is routinely exceeded during the high-flow and low-flow periods, especially in the lower segments of the creeks.

### 5.4.2 Sediment

Summary statistics for TSS and turbidity were calculated for the sediment-impaired segments along Little Goose Creek and Goose Creek (Tables 5.8 and 5.9). The sediment-impaired segments identified on the 2008 Wyoming 303(d) list of impaired waters include Little Goose Creek from the confluence with Big Goose Creek upstream of the community of Big Horn, and Goose Creek from the confluence between Little Goose Creek and Big Goose Creek to an undetermined distance downstream. In consultation with WDEQ in 2009, the sediment-impaired segments for Little Goose Creek and Goose Creek are limited to in the City of Sheridan. Therefore, TSS data for available storm drains in the City of Sheridan are presented. Although the sediment impairments are attributed to stormwater, TSS data in the upper segments of the watershed were also explored to inform the source identification of the TMDL.

TSS and turbidity are correlated with instantaneous flow readings at some sites along the impaired segments of Goose Creek and Little Goose Creek. Sites with correlations coefficients ($R^2$) over 0.5 are shown in Figures 5.6 and 5.7. There may be several explanations for poor correlation between instantaneous discharge and sediment-related parameters. The turbidity and TSS correlations are based on a relatively small dataset (n=14 to 20). In addition, flow in the upper segments of Little Goose Creek during the summer season (the time when most of the sediment sampling was conducted) does not correlate well with discharge at the watershed outlet (see Section 4.3.2). This indicates that measured flow in the stream may not accurately represent watershed processes such as overland flow during storms or groundwater recharge, both of which are reflected in the hydrologic data at the watershed outlet. These processes may still be affecting sediment loading to the streams even if they are not reflected in discharge data, which could explain the patterns observed in TSS data when grouped by hydrologic flow regime (see Figures 5.8–5.11). The upper segments of the Little Goose Creek drainage exhibit relatively healthy geomorphic and stream corridor conditions. Relative erosion-potential subwatersheds in Little Goose Creek will be explored in the source identification portion of the TMDL. Ditches and tributaries also provide a dilution and concentration effect on sediment that could interfere with the natural relationship between sediment and flow. The relationship between hydrologic processes, flow, and sediment in streams is an important consideration in the application of the TMDL methodology in the load analysis portion of the TMDL (see Chapter 9).

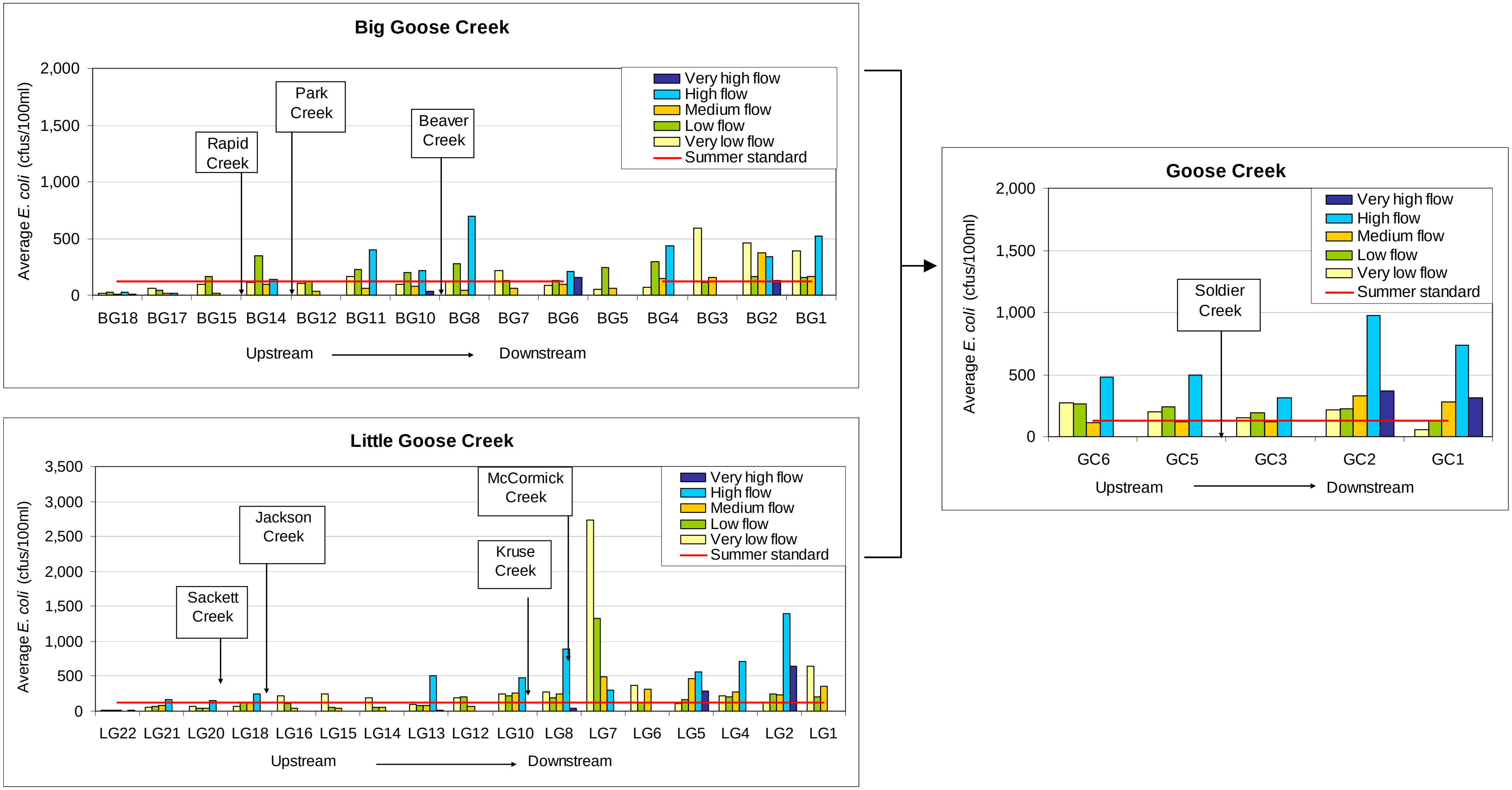


**Figure 5.5** Summary of average summer season (May–September) *E. coli* data by hydrologic flow regime defined by the summer flow duration curve.

**Table 5.8** Summary Statistics of TSS and Turbidity Data along the Sediment-impaired Sections of Little Goose Creek between 1998 and 2005

| Sampling Site | Sampling Site Description | Number of Samples | | Minimum | | Maximum | | Average | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Little Goose Creek** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** |
| LG18 | Downstream Sackett Creek confluence | 18 | 56 | 2 | 0.05 | 9 | 12.8 | 4.0 | 2.4 | 2.4 | 2.0 |
| LG16 | Downstream Jackson Creek confluence | 14 | 46 | 2.5 | 0.05 | 9 | 130 | 4.7 | 6.1 | 2.3 | 19.3 |
| LG15 | Little Goose Creek–Upstream of Gerdle Ditch intake | 14 | 46 | 2.5 | 0.05 | 12 | 76.6 | 5.9 | 4.2 | 2.7 | 11.1 |
| LG14 | Upstream Clubhouse Road Bridge at Powderhorn Subdivision | 14 | 46 | 2.5 | 0.05 | 19 | 57.7 | 4.2 | 4.4 | 4.4 | 8.9 |
| LG13 | Upstream of County Road 60 Bridge at Knode Ranch Subdivision | 14 | 56 | 2.5 | 0.05 | 17 | 55.3 | 4.9 | 4.2 | 4.2 | 8.3 |
| LG12 | Upstream of Kruse Creek confluence | 14 | 46 | 2.5 | 0.6 | 10 | 27.7 | 4.7 | 3.8 | 2.5 | 5.7 |
| LG10 | Downstream of Kruse Creek, Upstream of Highway 87 Bridge | 18 | 56 | 2.5 | 1.4 | 24 | 29.7 | 11.6 | 6.2 | 6.0 | 5.2 |
| LG8 | Downstream of McCormick Creek confluence | 14 | 56 | 2.5 | 1.7 | 22 | 52.4 | 8.0 | 8.1 | 6.1 | 8.5 |
| LG7 | Upstream of Highway 87 Bridge Near Woodland Park | 19 | 57 | 2.5 | 1.7 | 30 | 65.9 | 14.4 | 10.3 | 8.7 | 9.7 |
| LG6 | Downstream of County Road 66 Bridge | 14 | 46 | 2.5 | 2 | 24 | 82.6 | 12.0 | 10.9 | 6.7 | 13.3 |
| LG5 | Upstream of Brundage Lane Bridge | 19 | 67 | 2.5 | 2 | 83 | 94.3 | 13.5 | 9.4 | 19.1 | 12.4 |
| LG4 | Upstream of Coffeen Avenue Bridge | 20 | 58 | 2.5 | 1.3 | 84 | 104 | 12.1 | 9.1 | 18.2 | 14.6 |
| LG2 | Upstream of concrete lined channel entrance | 14 | 56 | 2.5 | 0.8 | 19 | 139 | 4.7 | 8.3 | 4.5 | 19.6 |
| LG1 | Near Big Goose Creek confluence | 14 | 46 | 2.5 | 0.5 | 20 | 147 | 5.7 | 7.3 | 5.2 | 21.4 |
| Overall Summary for Little Goose Creek | | 220 | 738 | 2 | 0.05 | 84 | 147 | 8.3 | 6.9 | 9.7 | 12.7 |

**Table 5.9** Summary Statistics of TSS and Turbidity Data along the Sediment-impaired Sections of Goose Creek between 1998 and 2005

| Sampling Site | Sampling Site Description | Number | | Minimum | | Maximum | | Average | | Standard Deviation | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Goose Creek** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** | **TSS (mg/L)** | **Turbidity (NTU)** |
| GC6 | Upstream of 5th Street Bridge | 14 | 46 | 2.5 | 1.5 | 42 | 34.9 | 9.9 | 6.7 | 10.2 | 7.1 |
| GC5 | At footbridge in Thorne-Rider Park | 15 | 47 | 2.5 | 1.3 | 38 | 33 | 10.9 | 6.6 | 10.0 | 7.2 |
| GC3 | Upstream of Fort Road Bridge | 19 | 51 | 2.0 | 1.0 | 34 | 38.6 | 9.7 | 5.7 | 9.5 | 6.8 |
| GC2 | Downstream of Sheridan WWTP | 19 | 61 | 2.5 | 1.0 | 36 | 50.5 | 9.9 | 7.1 | 10.0 | 8.6 |
| GC1 | Downstream of Highway 339 Bridge Crossing | 14 | 56 | 2.5 | 1.5 | 40 | 78.4 | 16.5 | 9.9 | 14.8 | 12.7 |
| Overall Summary for Goose Creek | | 81 | 261 | 2 | 1 | 42 | 78.4 | 11.2 | 7.3 | 10.9 | 8.9 |

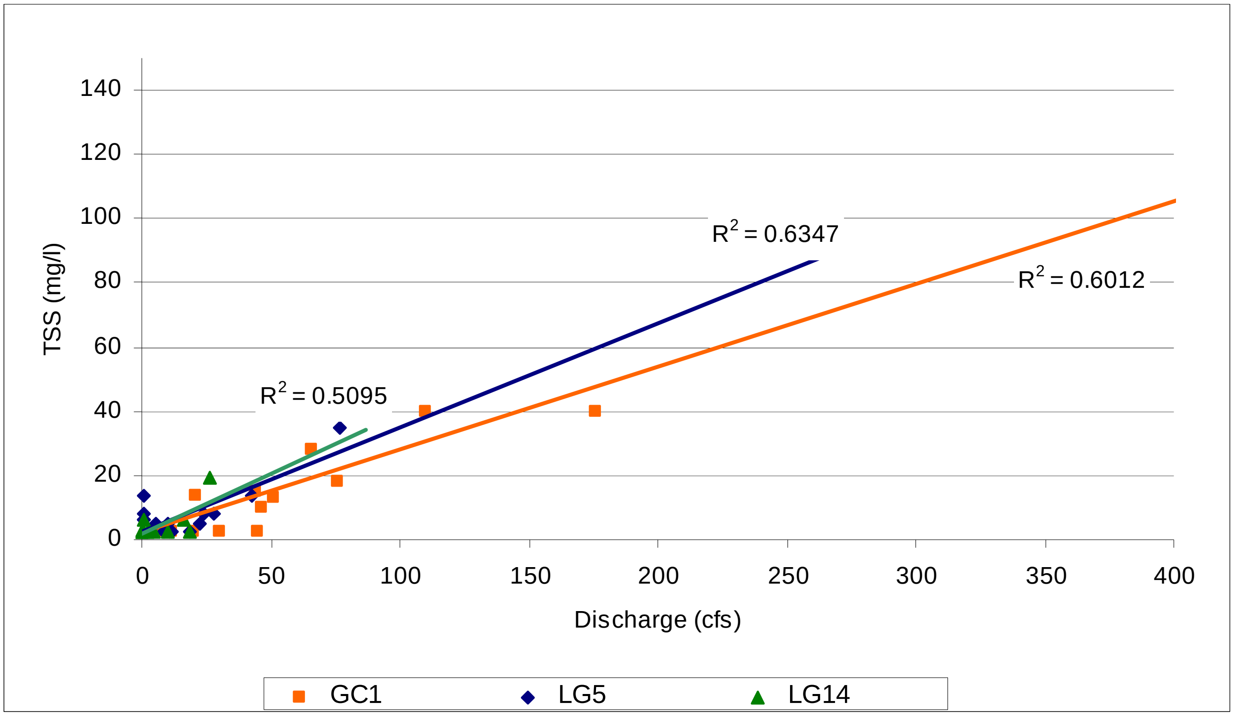


**Figure 5.6** Relationship between instantaneous discharge and TSS for three sites in the impaired segments of Goose Creek and Little Goose Creek. Correlation coefficients for all other sites were less than $R^2$=0.5.

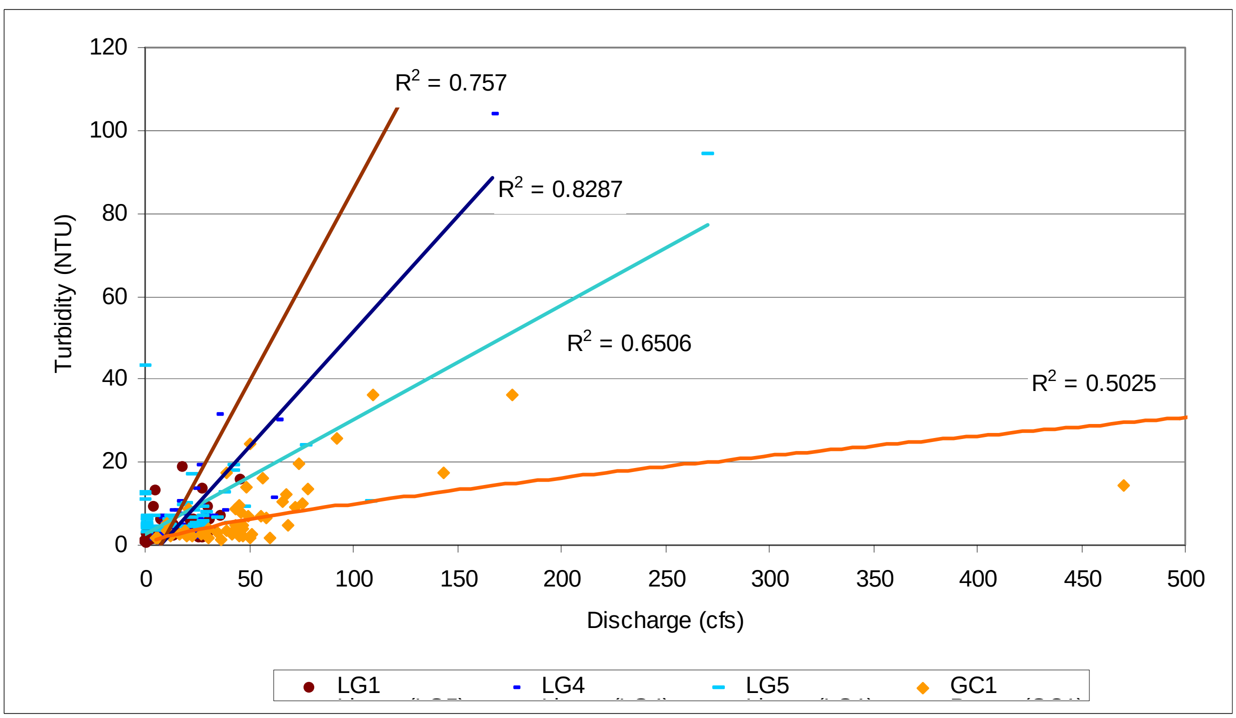


**Figure 5.7** Relationship between instantaneous discharge and turbidity for four sites in the impaired segments of Goose Creek and Little Goose Creek. Correlation coefficients for all other sites were less than $R^2$=0.5.

### 5.4.2.1 LITTLE GOOSE CREEK

In Little Goose Creek, the highest average TSS (Figure 5.8) and turbidity (Figure 5.9) values occur in the lower segments of the stream during the high-flow periods. No data are available for TSS during the very high-flow period, but peak turbidity recordings were obtained during very high flows. Turbidity and TSS values in Little Goose Creek between LG6 and LG10 are also relatively high during the low-flow periods. The medium-flow period represents the lowest turbidity and TSS values overall in the creek, which could indicate a balance between dilution effects and high-flow disturbance of stream sediments and bank erosion. The sediment-impaired portion of Little Goose Creek, identified on the 2008 Wyoming 303(d) list, includes Little Goose Creek sampling sites from LG1 to LG18 (just downstream of Big Horn). Based on the TSS and turbidity data available for the Little Goose Creek, the impairment appears to be most severe from LG10 (below Kruse Creek) downstream into the City of Sheridan (LG1). The maximum recorded TSS values in Little Goose Creek occur at LG4 and LG5 as the stream enters the City of Sheridan, with lower recorded values on segments in the city. However, the highest recorded turbidity values occur at LG1 and LG2 within the city boundaries.

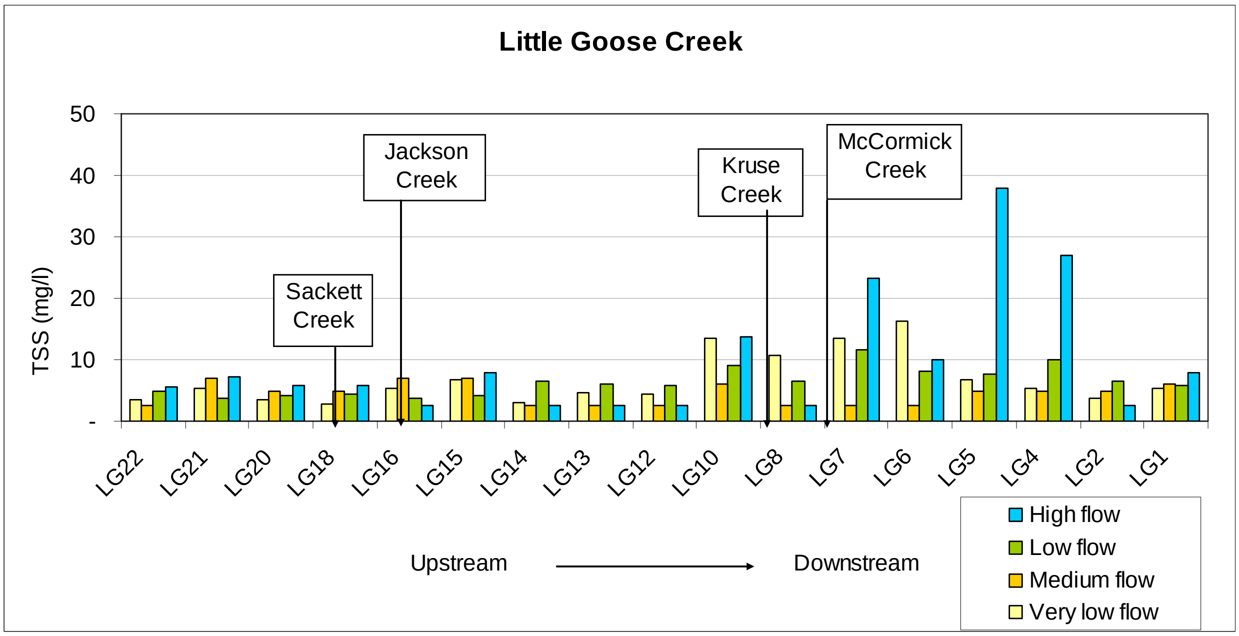


**Figure 5.8** Summary of TSS data along the main stem of Little Goose Creek. Sites LG1 through LG18 are in the sediment-impaired section of the creek.

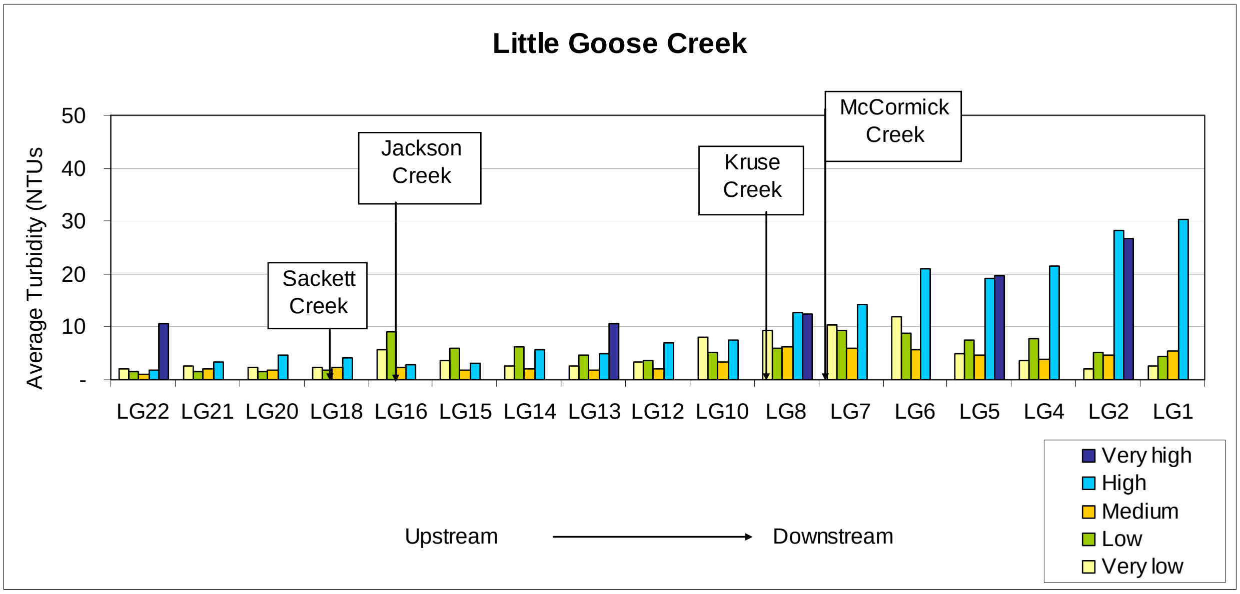


**Figure 5.9** Summary of turbidity data along the main stem of Little Goose Creek. Sites LG1 through LG18 are in the sediment-impaired section of the creek.

#### 5.4.2.2 GOOSE CREEK

In Goose Creek, the highest average TSS and turbidity values occur at GC1 (near the watershed outlet) during the high-flow periods. TSS values are substantially lower at sites in the City of Sheridan (GC2 and GC6). Sediment concentrations are expected to be the highest in the City of Sheridan during storm events and spring melt, which are not fully reflected in the averaged sediment data (Table 5.9). They are however, reflected in the maximum TSS (34 to 42 mg/L) and turbidity recordings (33 to 50 NTUs) in the city (GC2 to GC6). High average turbidity values are recorded during the very high-flow period at GC2, which is located on the stream as it leaves the City of Sheridan, below the WWTP.

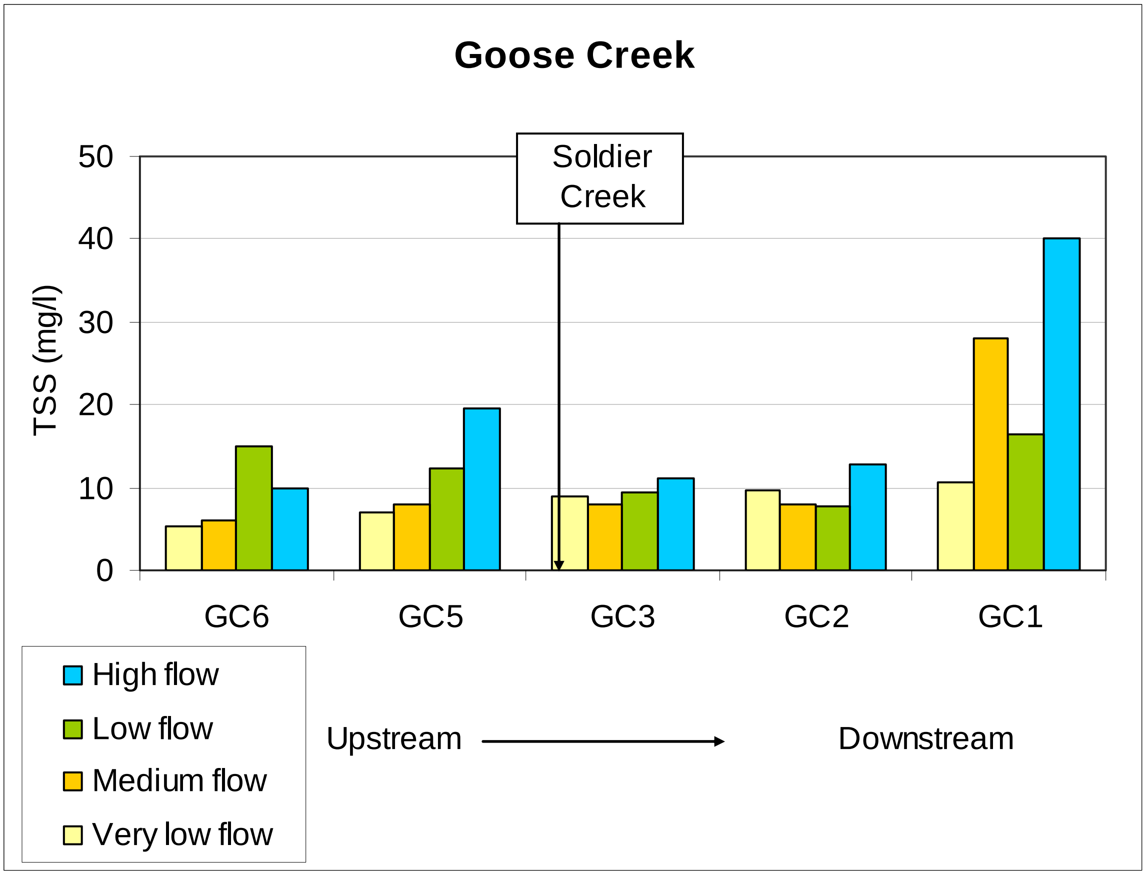


**Figure 5.10** Summary of TSS data along the main stem of Goose Creek.

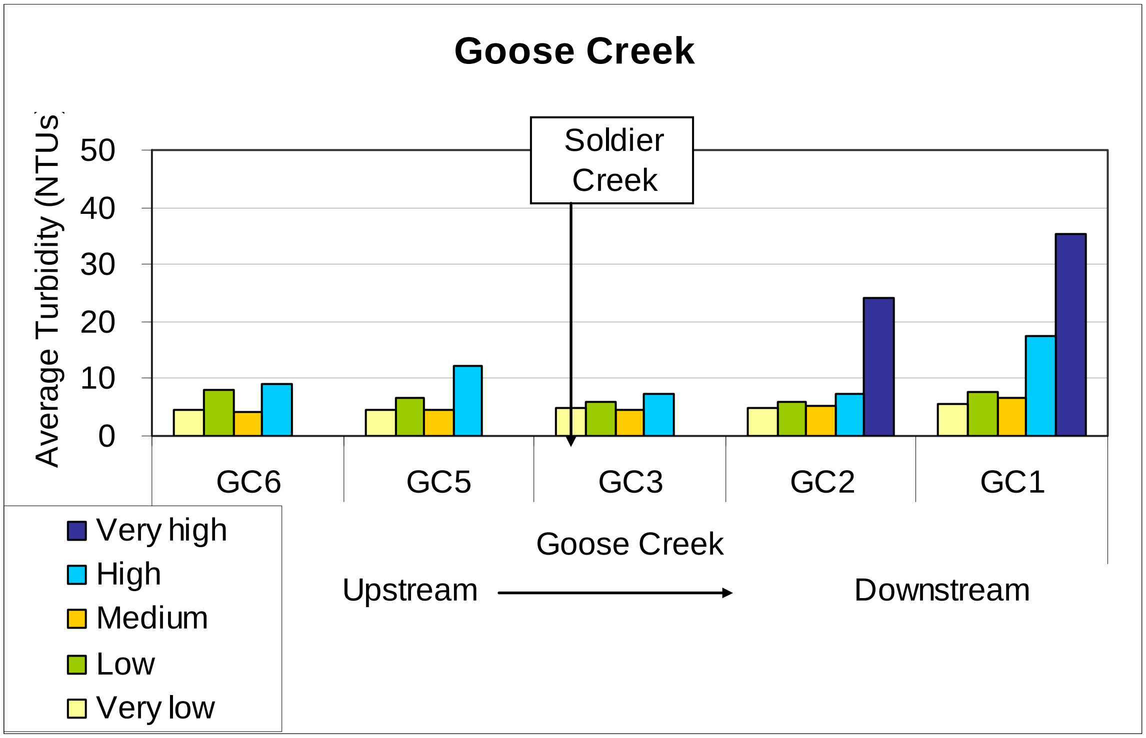


**Figure 5.11** Summary of turbidity data along the main stem of Goose Creek.

## 5.5 Pathogens in Stream Sediments

Fecal coliform and *E. coli* bacteria concentrations vary based on a variety of water quality factors. Several studies have documented elevated bacteria concentrations in bottom sediments, as compared with those in the overlying water column (see U.S. EPA 2001). Higher sediment-based pathogen concentrations are due to a combination of sedimentation, sorption, and extended survival times. Pathogens are removed from the water column as they settle at the sediment-surface interface. Sedimentation consequently protects pathogens from harmful factors such as sunlight and extreme temperatures, leading to increased survival times. Burton et al. (1987) reported enteric (intestinal) and pathogenic bacteria survival rates extending up to several months, whereas Sherer et al. (1992) documented fecal coliform and fecal streptococci bacteria half-lives of 11 to 30 days and nine to 17 days, respectively, when incubated with sediment (see U.S. EPA 2001).

Stream sediments represent a potential source of pathogens to the water column when disturbed due to their accumulation, survival, and potential re-suspension. Increased streamflow associated with storm events and spring melt periods disturbs and suspends sediment. It also disturbs and suspends associated pathogens, which had been previously deposited on the channel bottom (Yagow and Shanholtz 1998). This increases bacteria concentrations in the water column. Sherer et al. (1992) noted that the mean concentration of fecal coliform increased by a factor of 1.7 after the stream bottom was disturbed. Human recreational activity can also cause sediment disturbance (Burton et al. 1987), creating a potential health hazard from the possible ingestion of re-suspended pathogens.

### *5.5.1 Data Sources and Coverage*

SCCD conducted bed sediment sampling of fecal coliform during April and September 2002 at three sites: GC2 (downstream of the Sheridan WWTP), BG18 (site furthest upstream in Big Goose Creek), and LG8 (downstream of McCormick Creek). The sampling method involved raking streambed sediments and collecting downstream water column samples at 15-second intervals. GC2 on Goose Creek gives a good indication of pathogen survival and re-suspension potential for sites in the city.

BG18 on Big Goose Creek represents the most pristine of the three samples. This is because the site is upstream of the *E. coli* impairment on Big Goose Creek and water column *E. coli* data are relatively low at this site (see Table 5.6).Sampling site LG8 is located on an impaired segment of Little Goose Creek that is near rural and agricultural development. Samples collected during April give an indication of whether bacteria in bed sediments survive the cold stream temperatures during the winter months. Samples collected in September indicate peak concentrations of *E. coli* (while stream temperatures are still warm but the majority of sediment deposition prior to winter has already occurred).

Stream sampling methodology and detailed quality assurance and quality control of the samples are available in the *Goose Creek Watershed Assessment (*SCCD 2003). Stream velocity and turbidity were measured at the same time that fecal coliform samples were taken. This was done to determine if any relationship existed between bacteria concentrations and bed sediment.

### 5.5.2 Data Summary

Sediment bed disturbance at the Goose Creek site (GC2) led to the highest fecal coliform samples recorded during both the April and the September bed-sampling period. Following bed disturbance at this site, fecal coliform concentrations increased by a factor of 2 in April and by a factor of 3 in September. In both cases, peak concentrations are comparable to the grab sample collected within one week of the bed sampling and comparable to the overall average for the month represented by the sample (April and August; Table 5.10).

Sediment bed disturbance at the Little Goose Creek site (LG8) in April did not result in a spike in fecal coliform concentrations in the water column, indicating that bacteria may not survive in the sediment over the winter at this site. The same site however had a peak in fecal coliform concentrations (double the initial concentration) following bed disturbance in September. This suggests that fecal coliforms do accumulate in stream sediments over the summer and are available for re-suspension during summer and fall storms.

The Big Goose Creek site (BG18) is the most pristine of the three sampling sites in terms of water quality data, stream geomorphology, and upland land uses. Sediment bed disturbance at this site did not exhibit significant fecal coliform increases during either the April or September sampling times. This suggests that fecal coliforms are not present in significant quantities in the upper portions of the watershed, and that any existing (but nondetectable) fecal coliforms do not reside in stream sediments.

**Table 5.10** Summary of Bed Sediment Sampling in April 2002 and Comparison to Water Column Fecal Coliform Data at the Same Sites

| | Fecal Coliform (cfu/100 mL) | | | Turbidity (NTUs) | | |
|---|---|---|---|---|---|---|
| | GC2 | LG8 | BG18 | GC 2 | LG8 | BG18 |
| **Bed Sediment Sampling on 4/1/2002** | | | | | | |
| Time 0 Seconds | 58 | 1 | 1 | 17.7 | 8.1 | 0.3 |
| Time 15 Seconds | 37 | 1 | 1 | 17.3 | 8.8 | 10.3 |
| Time 30 Seconds | 89 | 2 | 1 | 17.5 | 8.2 | 12.5 |
| Time 45 Seconds | 118 | 1 | 1 | 17.1 | 8.2 | 10.8 |
| Time 60 Seconds | 62 | 4 | 1 | 16.9 | 13.4 | 1.9 |

**Table 5.10** Summary of Bed Sediment Sampling in April 2002 and Comparison to Water Column Fecal Coliform Data at the Same Sites

| | Fecal Coliform (cfu/100 mL) | | | Turbidity (NTUs) | | |
|---|---|---|---|---|---|---|
| | **GC2** | **LG8** | **BG18** | **GC 2** | **LG8** | **BG18** |
| **Week Following Sampling** | | | | | | |
| Date | 4/8/2002 | 4/4/2002 | 4/3/2002 | 4/8/2002 | 4/4/2002 | 4/3/2002 |
| Data Value | 110 | 1 | 1 | 8.6 | 0.5 | 1.3 |
| **Average for all April Samples (2001–2005)** | | | | | | |
| Number of Samples | 10 | 10 | 10 | 10 | 10 | 10 |
| Average | 89.3 | 10.2 | 0.55 | 5.6 | 3.9 | 0.78 |

Data: SCCD (2003)

**Table 5.11** Summary of Bed Sediment Sampling in September 2002 and Comparison to Water Column Fecal Coliform Data at the Same Sites

| | Fecal Coliform (cfu/100 mL) | | | Turbidity (NTUs) | | |
|---|---|---|---|---|---|---|
| | **GC 2** | **LG8** | **BG18** | **GC 2** | **LG8** | **BG18** |
| Water Column Data collected Prior to Bed Sediment Sampling | | | | | | |
| Date | 8/28/2002 | 8/22/2002 | 8/27/2002 | 8/28/2002 | 8/22/2002 | 8/27/2002 |
| Data Value | 470 | 830 | 2 | 5.6 | 12.3 | 1.2 |
| **Bed Sediment Sampling on 9/4/2002** | | | | | | |
| Time 0 Seconds | 130 | 140 | 5 | 2.1 | 3.4 | 1 |
| Time 15 Seconds | 160 | 160 | 4 | 2.3 | 3.2 | 6.7 |
| Time 30 Seconds | 400 | 270 | 5 | 2.7 | 11.5 | 6 |
| Time 45 Seconds | 150 | 220 | 5 | 3.1 | 16.9 | 4.5 |
| Time 60 Seconds | 180 | 230 | 6 | 3.7 | 8.9 | 8.8 |
| **Average for all August Samples (2001–2005)** | | | | | | |
| Number of Samples | 15 | 15 | 23 | 15 | 15 | 23 |
| Average | 363.8 | 385.4 | 21.5 | 4.5 | 10.3 | 1.2 |

Data: SCCD (2003).

## 5.6 Groundwater

The only groundwater quality data identified for the Big Goose Watershed are from the USGS sampling conducted in 2001 (Bartos et al. 2008). During this study, groundwater samples were collected from the 10 wells shown on Map 10 and submitted for a variety of analyses. Groundwater samples from nine of the 10 wells were analyzed for total coliform and *E. coli.* Total coliform bacteria were detected in water samples collected from wells RS-6 (estimated two colonies/100 milliliters (cfu/100 mL) and RS-10 (estimated 19 cfu/100). Both counts were larger than the U.S. EPA Maximum Contaminant Level Goal for drinking water (1 cfu/100 mL). Groundwater samples that contained detectable total coliform bacteria (RS-6 and RS-10) were also were analyzed for *E. coli*. Neither sample contained detectable *E. coli*. Therefore, USGS concluded that the bacteria detected in wells RS-6 and RS-10 was probably from soils, and not warm-blooded animals (Bartos et al. 2008).

# CHAPTER 6 PATHOGEN LOAD ANALYSIS AND SOURCE IDENTIFICATION

This section discusses priority catchment areas, critical conditions, and potential pollutant sources that contribute to the pathogen impairment of waters in the Goose Creek Watershed. Sources are identified specifically for the summer recreation season (May–September) and have been characterized using literature and local watershed information. Significant sources of nonpoint source pathogen loading in the Goose Creek Watershed include:

- wildlife (including birds and big game);
- grazing on public lands;
- pastured animals on private lands;
- animals in riparian areas and stream channels;
- functioning septic leach fields;
- failing septic systems;
- urban storm drains; and
- stream sediments.

## 6.1 Load Analysis by Catchment Area

### *6.1.1 Catchment Area Delineation*

Catchments were delineated for each impaired tributary and for intermediate delineation points along the main stems of Little Goose Creek, Big Goose Creek, and Goose Creek. Delineation points were selected from existing monitoring points in the watershed to guide source identification and identify the most problematic areas of the watershed in terms of pathogen load reduction required to meet the TMDL.

In the Goose Creek Watershed, two types of delineation points were selected: 1) points at the bottom of impaired tributaries, and 2) points along the main stems of the Big Goose Creek, Little Goose Creek, and Goose Creek. Impaired tributaries currently have only one water quality-monitoring site located at the bottom of each creek. These monitoring sites represent the delineation points for impaired tributaries. For the impaired main stems, five delineation points were selected along Little Goose Creek and Big Goose Creek, and four delineation points were selected on Goose Creek (Table 6.1). The catchment areas associated with each delineation point are shown on Map 11.

A greater City of Sheridan catchment was delineated by combining all the small catchments at the bottom of Little Goose Creek and Big Goose Creek with the upper segments of Goose Creek. This catchment was grouped together to characterize sources specific to the City of Sheridan, a distinct management entity in the watershed.

Factors that were considered in the selection of delineation points were 1) landscape characteristics, 2) data trends, 3) data availability, and 4) overall distance between delineation points.

- *Landscape characteristics*. Delineation points were established at the boundaries of different landscapes. Such differences may be associated with natural watershed characteristics (e.g., slope, soil type, or wildlife population) or human-related characteristics (e.g., land use, housing density, ownership, and local jurisdiction). For example, a delineation point was selected at LG6 because it is located just within the city limits of the City of Sheridan, where land use begins to change from pastureland and cropland to urban development.

- *Data trends.* Significant differences in water quality between two consecutive monitoring sites may indicate that both sites are suitable as delineation points. For example, there is a noticeable degradation in water quality between LG22 and LG20; therefore, both sites were chosen as delineation points.
- *Data availability*. Wherever possible, delineation points were selected at sampling locations where at least five samples were collected during drier than average years (2001 and 2002) and where at least five samples were collected during wetter than average years (1998, 1999, or 2005). This approach ensures that a broad set of hydrologic and climatic conditions is incorporated into current loading estimates, and accurate comparisons can be made between loading reductions at consecutive delineation points.
- *Distance between compliance points*. An effort was made to space delineation points along the main stems such that the areas delineated as subdrainages are similar in scale throughout the watershed. Existing monitoring sites located directly upstream of a confluence with a tributary were often selected as delineation points.

**Table 6.1** Delineation Points in the Goose Creek Watershed

| Catchment Name | Impaired Water(s) | Delineation Point Description | Catchment Area (acres)* |
|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | |
| LG22 | Little Goose Creek | Upstream County Road 77 Bridge at Little Goose Ranch | 34,728 |
| LG20 | Little Goose Creek | Upstream County Road 103 Bridge south of Big Horn | 13,284 |
| Sackett Creek (LG19) | Sackett Creek | Bottom of tributary | 2,186 |
| Jackson Creek (LG17) | Jackson Creek | Bottom of tributary | 6,082 |
| LG12 | Little Goose Creek | Upstream Kruse Creek confluence | 11,941 |
| Kruse Creek (LG11) | Kruse Creek | Bottom of tributary | 5,764 |
| McCormick Creek (LG9) | McCormick Creek | Bottom of tributary | 4,586 |
| LG6 | Little Goose Creek | Downstream County Road 66 Bridge | 8,895 |
| **Big Goose Creek Subwatershed** | | | |
| BG18 | Big Goose Creek | Upstream from Alliance Ditch Intake | 80,217 |
| Rapid Creek (BG16) | Rapid Creek | Bottom of tributary | 10,499 |
| BG14 | Big Goose Creek | Upstream of Highway 331 Bridge crossing, south of Beckton | 6,533 |
| Park Creek (BG13) | Park Creek | Bottom of tributary | 4,308 |
| BG11 | Big Goose Creek | Upstream of County Road 81 Bridge | 3,830 |
| Beaver Creek (BG9) | Beaver Creek | Bottom of tributary | 8,877 |
| BG4 | Big Goose Creek | Upstream of Brayton Lane Bridge at Normative Services | 12,471 |

**Table 6.1** Delineation Points in the Goose Creek Watershed

| Catchment Name | Impaired Water(s) | Delineation Point Description | Catchment Area (acres)* |
|---|---|---|---|
| **Goose Creek Subwatershed** | | | |
| City of Sheridan | Little Goose Creek, Big Goose Creek, and Goose Creek | In the 201 City Boundary | 19,536 |
| Soldier Creek (GC4) | Soldier Creek | Bottom of tributary | 20,529 |
| GC1 | Goose Creek | Downstream of Highway 339 Bridge crossing | 9,651 |
| Below GC1 | | | 2,935 |

Note: LG1, BG1, GC6, GC5, GC2 are included in the "City" catchment.

* The initial acreage delineation was compiled from USGS Water Resources Division - National Hydrography Dataset (NHD) and USDA NRCS Watershed Boundaries Dataset (WBD). The acreage delineation used in the remainder of this document was generated using the Hydrology Tool in ESRI's ArcGIS. As a result, the watershed boundary is not coincident with the boundary from NHD used in previous chapters. Therefore, some acreage estimates may differ by 0.06%.

The catchment areas associated with each delineation point are shown on Map 11. For the remainder of this document, tributary catchments are referred to by the tributary name (e.g., Sackett Creek) and mainstream catchments are referred to by the monitoring site identification (e.g., LG22).

### 6.1.2 Application of Duration Curve Methodology

Estimating the current pollutant loading in an impaired waterbody is an essential component of a TMDL analysis. In the Goose Creek Watershed, it is readily apparent that in-stream pollutant loads vary significantly with flow rate among catchments (SCCD 2003; SCCD 2006). Consequently, calculating daily loads requires accounting for variations in hydrologic flow conditions.

The selected method for calculating the Goose Creek TMDLs accounts for patterns of impairment across different hydrologic flow conditions. That is, TMDL calculations should 1) consider the hydrologic condition during which each load sample was collected, and 2) weigh each load sample in relation to the frequency of that hydrologic condition. Duration curves achieve these objectives and have been integrated into TMDL analyses by many states (Nevada Division of Environmental Protection 2003; Tennessee Department of Environment and Conservation 2005). This section describes the steps taken in this document to develop the duration curves, and explains their use in setting load reduction targets for impaired waters in the Goose Creek Watershed.

#### 6.1.2.1 FLOW DURATION CURVES

For the Goose Creek Watershed, we have applied the flow duration curve methodology as described by the U.S. EPA (2007). A flow duration curve is a hydrologic analysis that calculates the cumulative frequency of a given flow value (percent of time a flow value has been met or exceeded) over a historical period. Using this methodology, flow duration intervals are expressed as a percentage, with zero corresponding to the highest streamflow in the record and 100 to the lowest flow.

In the ideal case, a flow duration curve is generated from daily, mean flow data recorded at a continuous-record station, located at the point of interest or from extrapolated flows derived through regression analysis (Tennessee Department of Environment and Conservation 2005). However, in practice this is not always possible. Only one USGS continuous-record station exists in the Goose Creek Watershed, the USGS Acme Station #06305700. This station is located 7 miles downstream of the City of Sheridan, near

Acme, and many sampling sites are a considerable distance upstream. Moreover, a network of tributaries, draws, and irrigation diversions complicate flow patterns. As a result, a weak correlation ($R^2 << 0.7$) exists between the daily flows measured at the USGS Acme Station and the corresponding flow measurements recorded at the sampling sites upstream (see Chapter 4). Correlations are particularly weak during the summer months for sampling sites in the mid to upper parts of the watershed. To pursue the duration curve approach for calculating and analyzing loads across different hydrologic flow conditions in the Goose Creek Watershed, an alternative method was applied to develop flow duration curves.

It is worth noting the differences between the conventional method for developing flow duration curves and the method employed in this TMDL. First, a conventional flow duration curve typically depicts the frequency of flow rates during a full calendar year. By contrast, the flow duration curves developed for the Goose Creek Watershed depict flow patterns only during the summer recreation season (this is because none of the *E. coli* sampling results exceeds the water quality criterion for the winter recreation season). Second, the conventional flow duration curve is constructed from uniform time-series flow data over a long period of record. The method employed forms a flow duration curve from all available flow measurements recorded in 1998, 1999, 2001, 2002, and 2005 at a particular monitoring site of interest by fitting a percentile curve to the data. In other words, a flow duration curve was developed for each catchment delineation point using available flow data for that delineation point. We interpolated between known data points by calculating the k-th percentiles (in 0.001 intervals) of the available data. The resulting flow duration curve was used to classify the known flows (and associated concentration data, when available) into the high-flow, medium-flow, and low-flow regimes.

The flow duration curves developed for the Goose Creek Watershed show the percentage of time during the summer recreation season that a given flow rate is equaled or exceeded, based on available historical flow data. The rate of flow is plotted along the y-axis, and the flow duration interval (percent of days that rate is exceeded) are plotted on the x-axis. The y-axis is traditionally depicted in a logarithmic scale. As an example, the flow duration curve for the sampling site located on Beaver Creek (BG9) upstream from its confluence with Big Goose Creek is shown in Figure 6.1. Unique flow duration curve were developed for all impaired creeks in the Goose Creek Watershed and are provided in Appendix 2. Flow ranges associated with each hydrologic flow regime for each impaired segment are summarized in Table 6.2.

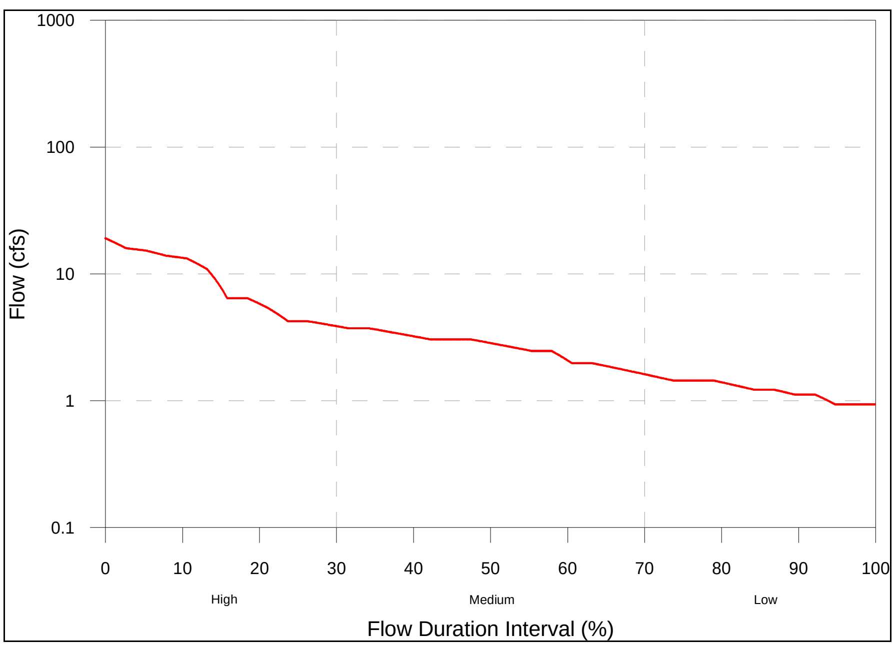


**Figure 6.1** Flow duration curve for Beaver Creek (BG9) showing the frequency of various flow rates during the summer recreation season.

**Table 6.2** Flow Range (cfs) for Hydrologic Regimes for the Goose Creek Watershed

| | Hydrologic Regime | Sackett Creek (LG 19) | Jackson Creek (LG 17) | Kruse Creek (LG 11) | McCormick Creek (LG9) | Little Goose Creek (LG1) | Rapid Creek (BG16) | Park Creek (BG13) | Beaver Creek (BG 9) | Big Goose (BG 1) | Soldier (GC 4) | Goose Creek (GC 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Flow Range (cfs)** | **High** | 1.1–18.8 | 1.1–5.0 | 4.0–8.1 | 2.1–26.1 | 10.0–125.8 | 1.4–11.6 | 0.1–0.3 | 3.8–19.1 | 25.8–225.9 | 1.6–21.2 | 53.5–1,170.0 |
| | **Medium** | 0.4–1.1 | 0.4–1.1 | 1.3–4.0 | 0.3–2.1 | 1.4–10.0 | 0.9–1.4 | 0.03–0.04 | 1.6–3.8 | 7.3–25.8 | 0.6–1.6 | 21.0–53.2 |
| | **Low** | 0.2–0.4 | 0.01–0.4 | 0.4–1.3 | 0.0–0.3 | 0.3–1.4 | 0.3-0.9 | 0.01–0.02 | 0.9–1.6 | 3.3–7.3 | 0.1–0.6 | 3.1–21.0 |

#### 6.1.2.2 LOAD DURATION CURVES

In general, a load duration curve is constructed by multiplying the flows from a flow duration curve by a numeric water quality target. In TMDL studies, the numeric water quality target for a pollutant of concern is used to determine the loading capacity for that pollutant. Therefore, a load duration curve is also referred to as a "load capacity curve." The U.S. EPA defines loading capacity as "the greatest amount of loading that a waterbody can receive without violating water quality standards" (U.S. EPA 2007). When instantaneous loads, calculated from ambient water quality and flow data, are plotted with the load capacity curve, load reductions can be visualized across a full range of flow conditions.

The flow duration curves described in the previous section serve as the foundation for development of load duration curves for impaired creeks in the Goose Creek Watershed. The numeric water quality target for *E. coli* was used to calculate the loading capacity data to form the load capacity curves. The numeric water quality target used for *E.* coli is the summer numeric criterion of 126 cfu/100 mL listed in Wyoming's water quality standards. An *E. coli* load capacity curve was developed for each impaired creek in the Goose Creek Watershed by multiplying the *E. coli* numeric criterion of 126 cfu/100 mL by the percentile flows used to generate the flow duration curve for that impaired creek. For convenience, load capacity was calculated in units of Giga ($10^9$) colony forming organisms per day. Each load capacity data point was calculated using the following equation:

*Load capacity [Giga-cfu/day] = flow rate [$ft^3$/sec] × 126 [cfu/100 mL] × conversion factor (0.024459)*

Next, instantaneous loads were calculated for each *E. coli* measurement by multiplying the sample concentration by the flow measured on the sample day. Instantaneous loads were calculated using the following equation:

*Load [Giga-cfu/day] = flow rate [$ft^3$/sec] × sample concentration [cfu/100 mL] × conversion factor (0.024459)*

Using the flow duration interval (%) from the flow duration curve that corresponds to the flow measured on the sample day, the calculated load was plotted on the load duration curve. Figure 6.2 is an example of an *E. coli* load duration curve for Beaver Creek developed from flow duration curve data for BG9 and multiplied by the *E. coli* numeric criteria to generate the load capacity curve, with the instantaneous loads from BG9 plotted. It is worth restating that the flow duration interval (%) assigned to each *E. coli* result reflects the discharge level on the day the sample was collected in relation to the overall distribution of discharge levels at that sampling location. The resulting load duration curve for Beaver Creek is shown in Figure 6.2.

Instantaneous loads that plot below the load capacity curve represent compliance with the water quality target, whereas loads that plot above indicate exceedances of the water quality target. The load duration curves developed for the Goose Creek Watershed also provide insight into the frequency of different hydrologic conditions and identification of critical conditions. *E. coli* load duration curves with instantaneous loads were developed for all impaired creeks in the Goose Creek Watershed and are provided in Appendix 2.

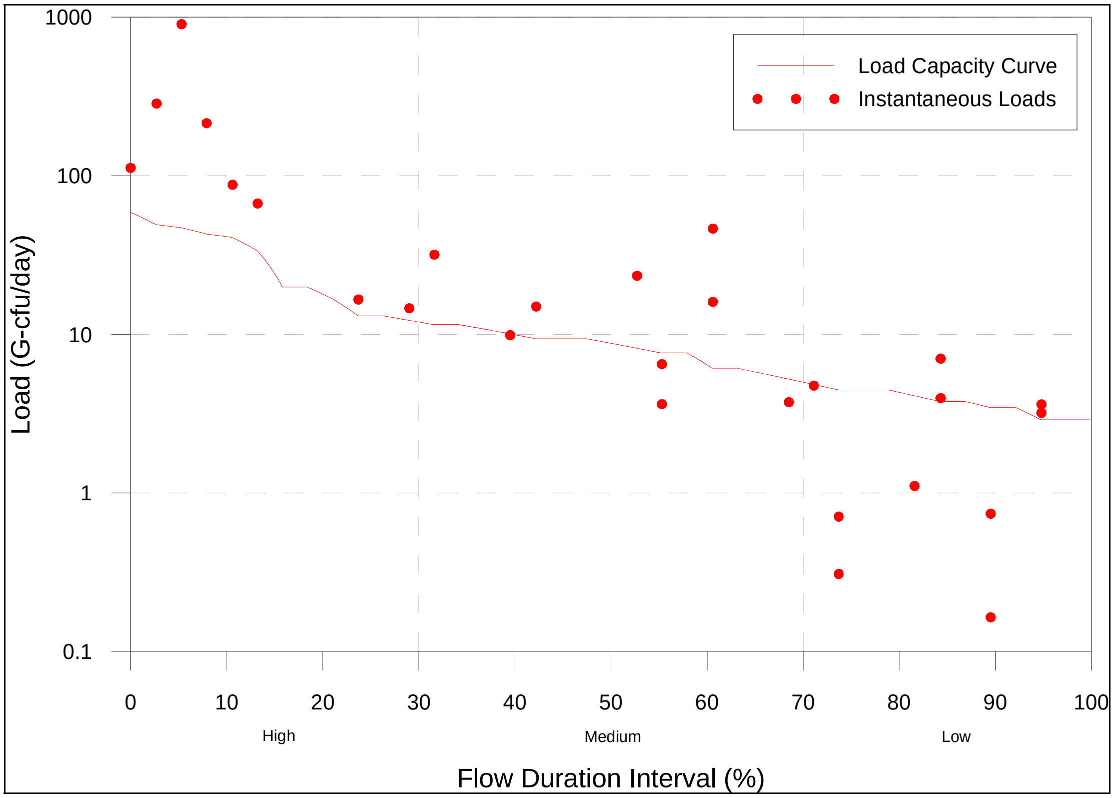


**Figure 6.2** Load duration curve and instantaneous water quality results for Beaver Creek (BG9).

Using the load duration curves, instantaneous loads were then assigned to a hydrologic regime based on the flow duration interval. Instantaneous loads were assigned to the three hydrologic flow regimes as follows: high (0% to 30% duration), medium (30% to 70% duration), and low (70% to 100% duration). In some cases, conclusions can be drawn regarding the hydrologic conditions most associated with impairment. For example, the load duration curve for Beaver Creek (Figure 6.2) indicates that *E. coli* loads are above the loading capacity curve during “high” and “medium” flow conditions. Furthermore, the samples that most exceed the loading capacity fall in the “high” category, which tends to capture the effects of storm events.

## 6.2 Critical Conditions

In the Goose Creek Watershed and its tributaries, *E. coli* violations are not exclusive to a single critical condition or time of year. Load exceedances occur frequently in early May and in October, but August is typically a month of concern because higher water temperatures are most conducive to bacterial growth, and overall flow volume is reduced relative to springtime levels. The Goose Creek Watershed TMDLs must encompass both the beginning and end of the summer recreation season, and address the possibility of *E. coli* entering the stream from multiple sources. Nonetheless, the role that storm events play in delivering bacteria to the creek deserves additional attention (SCCD 2003; SCCD 2006; Collyard 2005). The following sections discuss dry years and storm events, and how they relate to *E. coli* loads in the Goose Creek Watershed.

## *6.2.1 Seasonality*

### 6.2.1.1 DRY YEARS

The 2003 *Goose Creek Watershed Assessment* conducted by the SCCD was based on extensive water sampling efforts in 2001 and 2002. These data, taken from 46 sampling locations, reflect the most extensive watershed-wide monitoring effort to date. Data taken during this study period are particularly useful because the geometric mean of five sample measurements collected over a 30-day period—the basis of Wyoming's numeric criteria for *E. coli*—were collected in April, May, August, and October of 2001 and 2002. Historical sampling has not been collected in this manner and often does not provide a direct comparison with the *E. coli* geometric mean numeric criteria.

Despite the wealth of data collected by the SCCD in 2001 and 2002, it is important to note that annual precipitation levels in 2001 and 2002 were significantly below the historical average. Consequently, the samples collected in 2001 and 2002 do not represent the effects of storm events on water quality. Data collected in May and August of those years reflect a limited range of climatic and hydrologic conditions and may not illustrate mechanisms of contaminant loading during wetter years. For example, the total precipitation in August 2001 amounted to only 0.01 inch. At the other extreme, the total precipitation during August of 1998, a particularly wet month, was 2.47 inches. Average precipitation for August over the past 50 years is 0.82 inch.

### 6.2.1.2 WET YEARS

Further monitoring conducted in 2005 reflects wetter conditions. Sampling in May and August 2005 captured the impact to water quality from a number of summer storm events. Figure 6.3 shows the annual precipitation from 1950 to 2008, with the annual precipitation in 2001, 2002, and 2005 in historical context.

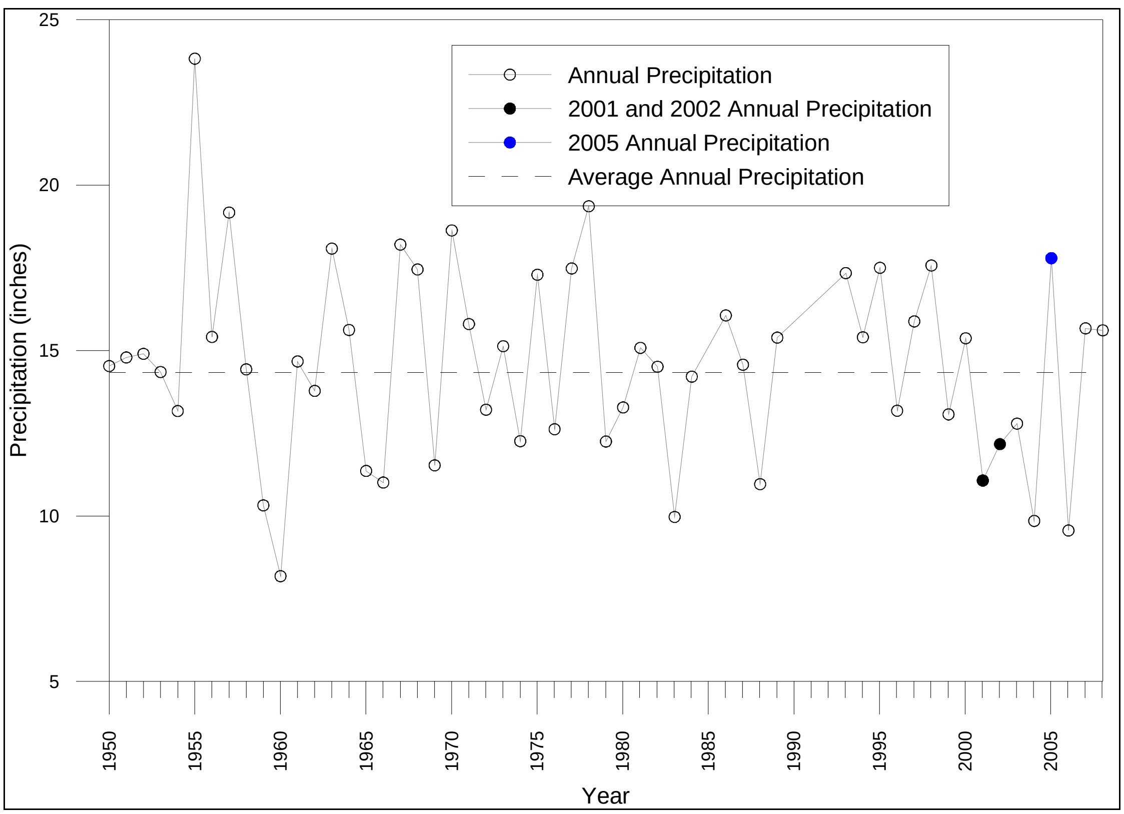


**Figure 6.3** Annual precipitation from 1950 to 2008; figure shows 2001, 2002, 2005 in historical context.

### 6.2.2 Major Spring Storm Events

A report from the SCCD (2003) offers compelling evidence that in-stream *E. coli* concentrations increase with intensifying land use along Big Goose Creek and Little Goose Creek. Mechanisms of contamination are less well characterized. Another SCCD report (2006) identifies the impact of a major precipitation event on water quality in May 2005. It further notes that rainfall increased bacteria concentrations throughout the watershed by: 1) transporting overland runoff into waterways and 2) scouring streambeds and suspending bacteria previously deposited in sediment.

May 2005 included a series of consecutive heavy-precipitation events that resulted in flooding. Pathogen sampling, however, did not coincide with the most intense day of precipitation (May 8, 2005). Water samples were collected on May 4 (prior to the precipitation event) and in the midst of a series of storms on May 9. A scheduled sampling on May 11 was postponed until the end of the month due to flooding. Nonetheless, the increase in bacteria levels is apparent. Figure 6.4 illustrates the increase in bacteria concentrations from May 4 to May 9 and the interceding precipitation event. Concentrations throughout the watershed remained elevated after the storm event and gradually decreased toward the end of the month as flows abated (SCCD 2006). Observations that can be made during the May 2005 sampling event include the following:

- The greatest increases in *E. coli* concentrations occur on Beaver Creek (BG9), Kruse Creek (LG11), and within the city limits of the City of Sheridan, at sampling sites LG2 and LG5, which capture a stretch of stream with storm drainages.
- Tributaries Sackett (LG19), Jackson (LG17), and McCormick (LG9) display noticeable increases in *E. coli* concentration.
- A noticeable increase in *E. coli* concentrations occurs on Soldier Creek (GC4), Beaver Creek (BG9) and, to a lesser extent, Kruse Creek (LG11), after a very small precipitation event on May 26. Soldier Creek, Beaver Creek, and Kruse Creek have the most cultivated and grazing land of the subwatersheds associated with impaired tributaries. The elevated *E. coli* concentrations on May 26 could be the result of upstream diversions and reduced dilution. They could also indicate susceptibility of these tributaries to minor precipitation events.

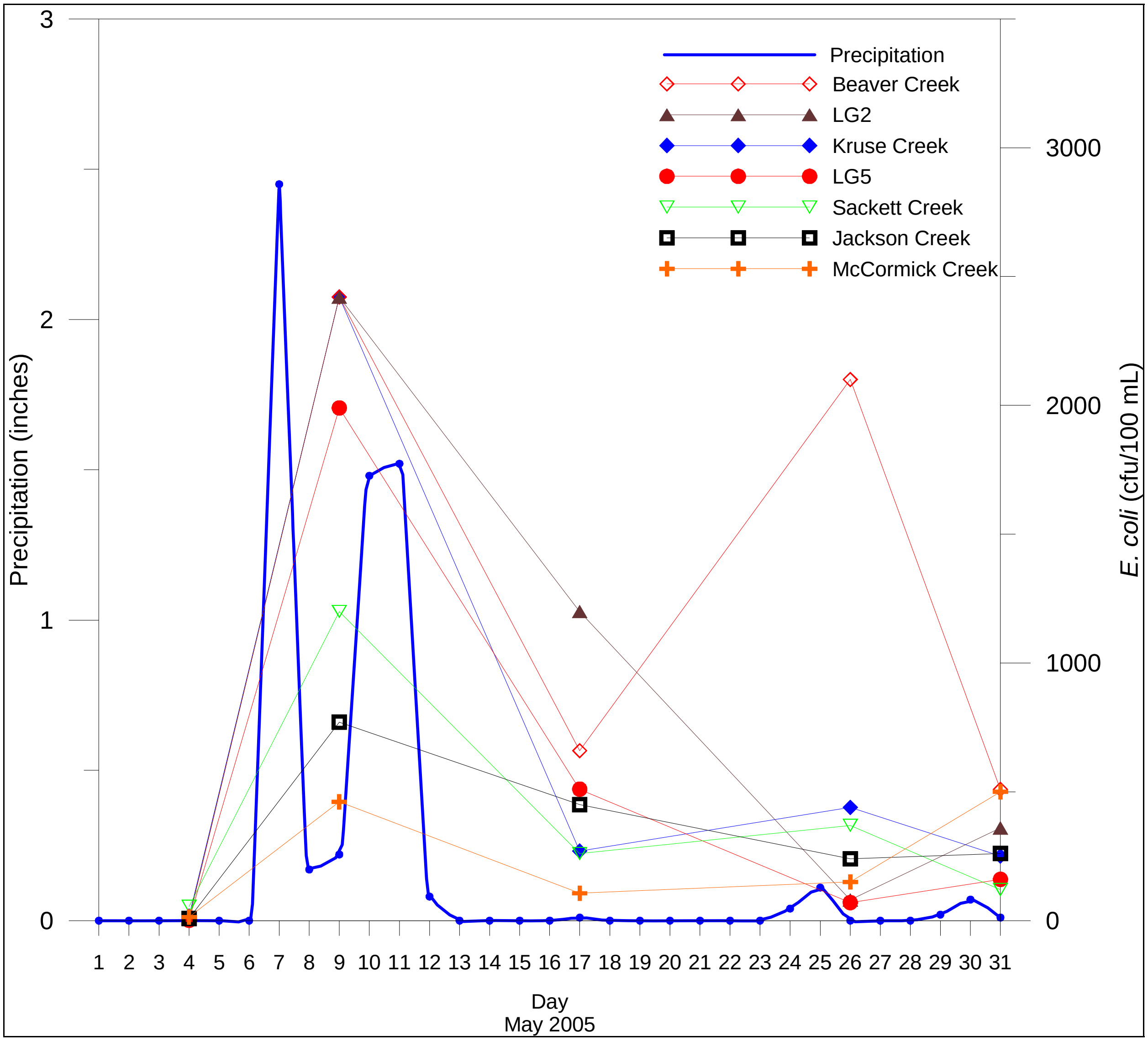


**Figure 6.4** May 2005 storm event and *E. coli* concentrations.

## 6.2.3 Isolated Storm Events

It is worthwhile to examine another case where sampling was conducted within 24 hours of intense precipitation that occurred on October 4, 2001. *E. coli* data are available for Big Goose Creek on October 4, 2001, when 0.84 inch of precipitation followed a two-week dry period. Data were not collected on Little Goose Creek until October 11, so the effect of the storm event is not as easy to discern there. Figure 6.5 shows the effect of this isolated storm event on *E. coli* concentrations along Big Goose Creek.

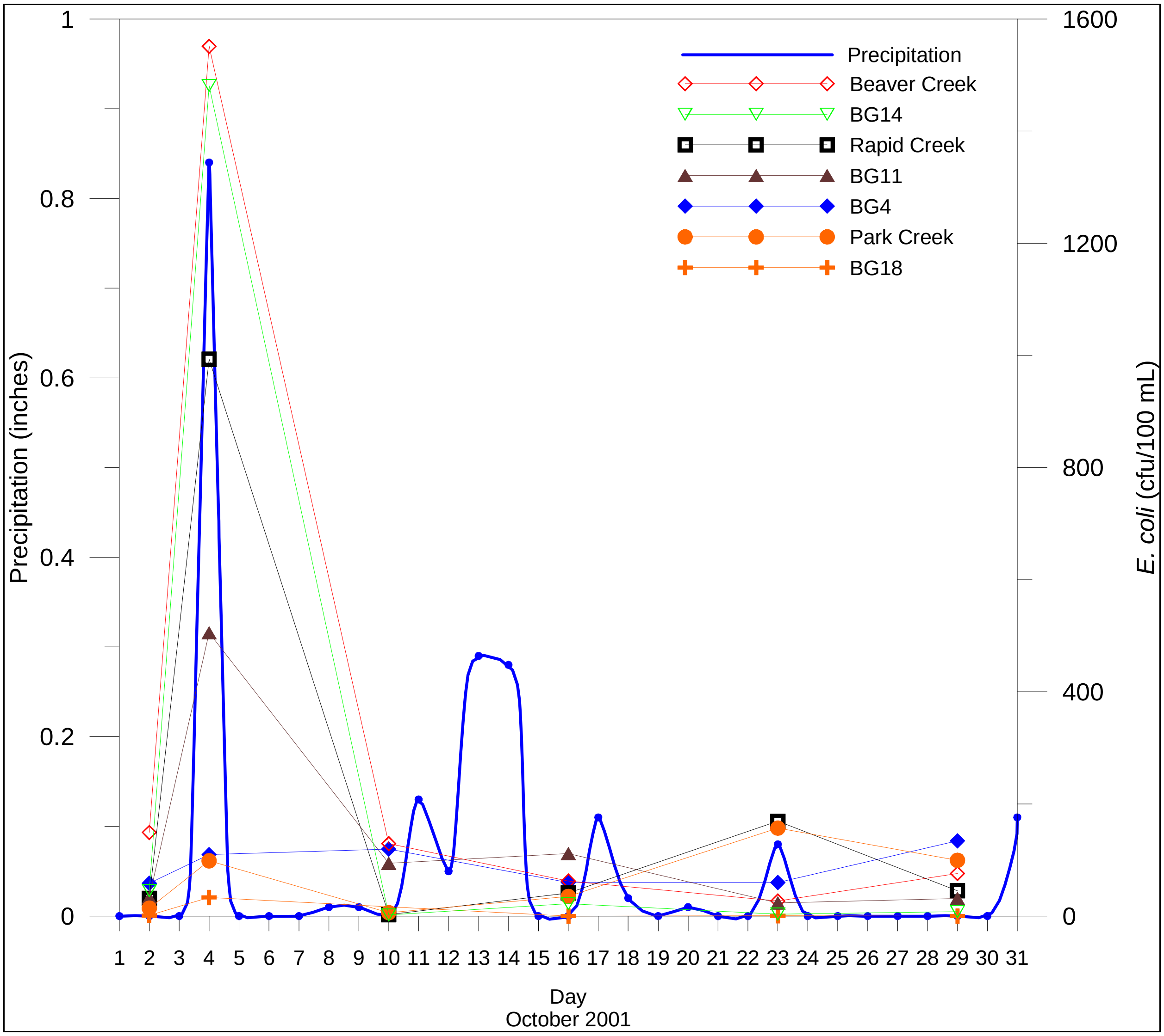


**Figure 6.5** Response of *E. coli* concentrations along Big Goose Creek due to an isolated storm event.

The significance of dry periods preceding a storm, soil saturation, and multiday periods of consecutive precipitation deserve further study. However, the dataset of water quality during major storm events is quite small. Collection of additional stormwater data is an important component of the future monitoring plan for the TMDL. In summary, the available *E. coli* data collected during storm events suggest that storm events represent critical periods when in-stream *E. coli* loads are expected to be high.

## 6.3 Point Sources

Point sources of pathogens and coliform bacteria affect year-round water quality in the Goose Creek Watershed at a constant rate. During periods of low flow, point sources represent a larger portion of the load to streams. Five regulated point sources in the watershed discharge pathogens under individual WYPDES permits. Seventeen urban drainage outfalls and 21 rural drainage outfalls are permitted under the Wyoming municipal separate storm sewer systems (MS4) general stormwater permit. The outfalls discharge pathogens and sediment, among other pollutants commonly found in stormwater. Point sources in the watershed that do not discharge pathogens include an additional seven WYPDES permits associated with coal-bed methane activities, and one permit associated with drinking water treatment for the City of Sheridan. These point sources are therefore not included in this analysis.

### *6.3.1 Wastewater Treatment*

The largest WWTP in the watershed is the City of Sheridan municipal treatment system. Two private communities in the watershed (Powder Horn Ranch and Royal Elk Properties) treat small flows of wastewater and discharge to Little Goose Creek upstream of the city. The Big Horn Mountain KOA WWTP also discharges small quantities of wastewater to Goose Creek below the city limits. The Sheridan County School District near Big Horn has a small WWTP that discharges to Jackson Creek upstream of its confluence with Little Goose Creek. The permits for each of these WWTPs are summarized in Table 6.3, and descriptions of each plant follow.

**Table 6.3** Summary of WYPDES Permits in the Goose Creek Watershed that Are Permitted to Discharge *E. coli* or Fecal Coliform

| Permit Number | Permit Holder | Use Type | Effective Until | Design Flow (cfs) | *E. coli* (cfu/100 mL) Monthly/Daily Summer | *E. coli* (cfu/100 mL) Monthly/Daily Winter | Fecal Coliform (cfu/100 mL) Monthly/Daily | Receiving water | Catchment |
|---|---|---|---|---|---|---|---|---|---|
| WY0020010 | City of Sheridan | Municipal wastewater | 5/31/2013 | 2.84 | 126/576 | 630/630 | – | Goose Creek | City |
| WY0026441 | Sheridan Big Horn Mountain KOA | Commercial wastewater | 5/31/2013 | 0.10 | 126/576 | 630/630 | – | Goose Creek | GC1 |
| WY0036251 | Powder Horn Ranch, LLC | Commercial wastewater | 4/30/2011 | – | – | – | 200/400 | Little Goose Creek | LG12 |
| WY0054399 | Royal Elk Properties, LLC | Commercial wastewater | 6/30/2011 | 0.027 | – | – | 200/400 | Little Goose Creek | LG6 |
| WY0056308 | Sheridan County School District | Wastewater | 4/30/2013 | 0.013 | 204/402 | 204/402 | – | Jackson Creek | Jackson |

#### 6.3.1.1 CITY OF SHERIDAN WWTP

The City of Sheridan provides wastewater service to 6,930 customers (15,939 people) inside city limits, and an additional 140 customers (322 people) outside city limits in the Downer Neighborhood Improvement and Service District. The WWTP uses a standard trickling filter design followed by an oxidation ditch, chlorination, and dechlorination. The WWTP discharges to Goose Creek and is designed to treat up to 4.4 million gallons of water per day (MGD). As part of newly revised Chapter 1 of the *Wyoming Water Quality Rules and Regulations* (WDEQ 2007), in-stream standards for fecal coliform are replaced by *E. coli* bacteria standards. The most recent permit (2008) replaces fecal coliform standards with *E. coli* bacteria standards, and designates a summer (April 1 through September 30), primary-contact, recreation, *E. coli* monthly average of 126 colonies/100 mL, with a 576 colonies/100 mL daily maximum. The latter standard is based on the "infrequently used full body contact standard," which is the default classification for most Wyoming waters. During the winter (October 1 through March 31), the *E. coli* monthly average and daily maximum for secondary contact recreation is 630 colonies/100 mL. This permit includes a 16-month interim effluent limit period to allow the facility to make adjustments as necessary to meet *E. coli* limits.

A summary of recent discharge monitoring report (DMR) data received from WDEQ for the WWTP indicates significant improvements in the treatment of *E. coli* and fecal coliform beginning in 2004. Daily *E. coli* loads have been reduced from 1,252 G-cfu/day in 2002 to 16 G-cfu/day in 2008 (Table 6.4). This *E. coli* load reduction is because year-round chlorination began at the WWTP in 2004.

**Table 6.4** Summary of Daily and Monthly Flow and Pathogen-related Data for the City of Sheridan WWTP

| Year | Monthly Average Fecal Coliform (cfu/100 mL) | Daily Average Fecal Coliform (cfu/100 mL) | Daily Average *E. coli* (cfu/100 mL) | Daily Average Discharge (MGD) | Daily *E. coli* Load (G-cfu/day) |
|---|---|---|---|---|---|
| 2001 | No data | No data | No data | 2.60 | No data |
| 2002 | 5,747 | 11,748 | 10,233 | 3.23 | 1,252.4 |
| 2003 | 2,192 | 4,727 | 4,117 | 3.56 | 554.8 |
| 2004 | 80 | 201 | 175 | 3.17 | 21.0 |
| 2005 | 72 | 159 | 139 | 3.68 | 19.3 |
| 2006 | 68 | 177 | 154 | No data | No data |
| 2007 | 44 | 172 | 150 | No data | No data |
| 2008 | 30 | 147 | 128 | 3.36 | 16.2 |
| **Average of All Available Data** | 1,036 | 2,064 | 1,798 | 3.33 | 226.8 |
| Source | DMR | DMR | Estimated from daily fecal coliform data | DMR | Calculated |

#### 6.3.1.2 BIG HORN MOUNTAIN KOA WWTP

The Big Horn Mountain KOA WWTP is designed to discharge 0.016 MGD, and consists of an extended aeration package plant with chlorination disinfection equipment. The facility is located approximately 1 mile north from the City of Sheridan WWTP and discharges near the city limit into Goose Creek. According to the Big Horn Mountain KOA WWTP permit (WYPDES 2008), "discharge from both plants must be considered to ensure that water quality standards are not being violated. Because Goose Creek is listed as impaired for fecal coliform, the effluent limits for *E. coli* are set equal to in-stream standards for both facilities." Consequently, the Big Horn Mountain KOA WWTP is subject to the same *E. coli* standards as the City of Sheridan WWTP (discussed above).

Daily, average, fecal coliform concentrations exceeded the state standard in 2002 and 2005, but they have been well below state standards since 2006. The estimated daily load of *E. coli* based on all the available flow and fecal coliform data is 37.7 G-cfu/day (Table 6.5).

**Table 6.5** Summary of Daily and Monthly Flow and Pathogen-related Data for the Big Horn Mountain KOA WWTP

| Year | Monthly Average Fecal Coliform (cfu/100 mL) | Daily Average Fecal Coliform (cfu/100 mL) | Daily Average *E. coli* (cfu/100 mL) | Daily Average Discharge (MGD) | Daily *E. coli* Load (G-cfu/day) |
|---|---|---|---|---|---|
| 2002 | 18 | 1,764 | 1,536 | 0.63 | 36.8 |
| 2003 | 15 | 15 | 13 | 2.51 | 1.2 |
| 2004 | 3 | 2 | 2 | No data | No data |
| 2005 | 4,535 | 5,099 | 4,441 | No data | No data |
| 2006 | 1 | 1 | 1 | No data | No data |
| 2007 | 5 | 16 | 14 | No data | No data |
| 2008 | 1 | 1 | 1 | No data | No data |
| **Average of All Available Data** | **1,139** | **1,591** | **1,386** | **0.72** | **37.7** |
| Source | DMR | DMR | Estimated from daily fecal coliform data | DMR | Calculated |

## 6.3.1.3 POWDER HORN RANCH, LLC WWTP

Powder Horn Ranch, LLC, is the developer of a development south of the City of Sheridan, upstream on Little Goose Creek. Wastewater treatment for this development is provided by an activated sludge package plant. Originally designed to treat 9,400 gallons of wastewater per day, the facility was recently upgraded and is now designed to treat 49,520 gallons of wastewater per day. The plant discharges to Powder Horn Pond No. 1 (Class 4 water), which has an overflow to Little Goose Creek. The permit establishes a fecal monthly average limit of 200 colonies/100 mL, and a daily maximum limit of 400 colonies/100 mL based on water quality standards that are developed by Chapter 1, *Wyoming Water Quality Rules and Regulations* for Class 4 water (WDEQ 2001b).

Daily, average, fecal coliform values exceeded the state standard in 2001, but no exceedances have occurred since. The estimated daily load of *E. coli* based on all available flow and fecal coliform data is 4 G-cfu/day (Table 6.6).

**Table 6.6** Summary of Daily and Monthly Flow and Pathogen-related Data for the Powder Horn Ranch LLC

| Year | Monthly Average Fecal Coliform (cfu/100 mL) | Daily Average Fecal Coliform (cfu/100 mL) | *E. coli* (cfu/100 mL) | Daily Average Discharge (MGD) | Daily *E. coli* Load (G-cfu/day) |
|---|---|---|---|---|---|
| 2001 | 192 | 764 | 665 | 0.02 | 13 |
| 2002 | 10 | 44 | 38 | 0.03 | 1 |
| 2003 | 44 | 162 | 141 | 0.03 | 3 |
| 2004 | 14 | 185 | 161 | 0.03 | 3 |
| 2005 | 31 | 664 | 579 | 0.03 | 11 |
| 2006 | 18 | 156 | 136 | | 3 |
| 2007 | 13 | 125 | 109 | | 2 |
| 2008 | 2 | 13 | 11 | | 0 |
| **Average of All Available Data** | **25** | **225** | **196** | **0.03** | **4** |
| Source | DMR | DMR | Estimated from daily fecal coliform data | DMR | Calculated |

#### 6.3.1.4 ROYAL ELK PROPERTIES, LLC

Royal Elk Properties, LLC, is the developer of the Woodland Mobile Home Park, which is supported by a package WWTP that includes the following modules: aeration in a 43,444-gallon chamber; flocculation and settling in a 11,200-gallon tank; clarification with baffle and weir troughs; and chlorine disinfection in a 6,000-gallon chamber. The plant's maximum discharge capacity is 42,000 gallons of wastewater per day. Effluent limits are based on Chapter 1, *Wyoming Water Quality Rules and Regulations* (WDEQ 2001b) and on low-flow conditions for Little Goose Canyon near Big Horn. Because the receiving stream is listed as impaired for fecal coliform, end-of-pipe effluent limits are set equal to in-stream standards: 200 colonies/100 mL monthly average and 400 colonies/100 mL daily maximum. No DMR data were available to characterize this wastewater source.

#### 6.3.1.5 SHERIDAN COUNTY SCHOOL DISTRICT

The WWTP for the Sheridan County School District uses a three-stage process: a septic tank for primary treatment; secondary treatment via a recirculating trickling filter that biodegrades organic matter and percolates effluent through filter media; and final ultraviolet disinfection. The treatment plant is designed to treat 20,000 gallons of wastewater per day and is subject to the newly revised Chapter 1, *Wyoming Water Quality Rules and Regulations* (WDEQ 2001b), which specifies these in-stream standards: a monthly *E. coli* average of 202 colonies/100 mL and a daily maximum of 402 colonies/100 mL for discharge to the receiving water (Jackson Creek). No DMR data were available to characterize this wastewater source.

### *6.3.2 Regulated Stormwater Flows*

Stormwater flows from urban areas consist of concentrated flows that accumulate from streets, parking areas, rooftops, and other impervious surfaces. Discharges from MS4s are permitted under the Wyoming

General MS4 Stormwater Permit for Small Dischargers under the WYPDES (WYR04-0000), renewed on December 1, 2008. Under the general permit, a municipality may discharge stormwater to a water of the State of Wyoming in accordance with a stormwater management plan (SWMP). Stormwater flow in the City of Sheridan is covered under the general MS4 permit.

The City of Sheridan is drained by 17 urban drainage areas that discharge directly to Little Goose Creek, Big Goose Creek, and Goose Creek (Map 12; Table 6.7). Collectively, the urban stormwater system drains 2,027 acres of the city, all within the City of Sheridan catchment. Additional acreage in the city is drained by 25 rural drainage basins, the majority of which is discharged directly to streams (Map 13; Table 6.8). The City of Sheridan's 1987 SWMP details the drainage network for stormwater in the city as well as recommended improvements to the stormwater system. Many of the large storm drains in the city used to be owned and maintained by the Wyoming Department of Transportation (WYDOT). All storms drains in the City of Sheridan are now managed by the city.

Limited data exist from stormwater drains in the city to characterize stormwater loads to surface waters. Data were collected in the summer of 1993 by the WDEQ at four of the 17 urban drainage outfalls. In addition, the SCCD sampled the S-line (SCCD site LG3) in the summer of 2001 and 2002. The WDEQ collected additional data in 2004 as part of a stormwater management report for the City of Sheridan. Sampling included one rain event (S-line), one snowmelt runoff event (Q-line), and two street cleaning events (P-line and N-line).

Runoff from the City of Sheridan was estimated using the rainfall-runoff curve number method developed by the USDA and described in the National Engineering Handbook (USDA 2004). Curve numbers are unitless representations of the portion of runoff expected for an area, based on unique soil/land-use combinations. Curve numbers range from a low of 30 to a high of 100. Higher curve numbers are indicative of a storm event with increased runoff and are influenced by slow draining soils and impervious cover. All soil types in the city were classified by their hydrologic class (A, B, C, or D), as defined in the NRCS Soil Survey Geographic (SSURGO) database. Class D soils are general poorly drained and shallow, whereas Class A soils are generally well drained and deep. Soil/land-use combinations were calculated for the City of Sheridan using geographical information systems (GIS), and each was assigned a representative curve number. Using this information, an area-weighted curve number (a unitless value used to estimate runoff from an area during a storm) for this area was found to be 80. The average annual precipitation during the summer season (May through September) is 7.45 inches (NCDC precipitation data). It was assumed that only storms with more than 0.15 inch of precipitation generate runoff in the city.

The SCCD and WDEQ recorded very high average concentrations (>10,000 cfu/100 mL) of *E. coli* in the outfalls from the D+E-line, the D-line, and the G-line in 1993, 2001, and 2002. Moderately high *E. coli* concentrations were also observed from the S-line. These high concentrations were not observed in 2004 on any of the lines during baseflow, rain events, snowmelt, or street cleaning; however, only four lines were sampled during that study.

**Table 6.7** Urban Drainage Areas in the City of Sheridan that Discharge Under the Wyoming General MS4 WYPDES Permit

| **Urban Drainage Basin** | **Description** | **Basin Acreage** | **Receiving Water** | **Estimated Flow (acre-feet per summer season)** | **WDEQ Stormwater Monitoring 2004 *E. coli* (cfu/100 mL)** | **WDEQ Stormwater Monitoring Base Flow 2004 *E. coli* (cfu/100 mL) 4/12/2004** | **SCCD and WDEQ Combined Data 1993–2002 *E. coli* (cfu/100 mL)** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | **Maximum** | **Minimum** | **Average** |
| A-line | – | 69 | Goose Creek | 29.39 | – | – | – | – | – |
| B-line | – | 41 | Goose Creek | 17.28 | – | – | – | – | – |
| D+E-line | – | 368 | Goose Creek | 156.75 | – | – | 52,284 | 52 | 20,002 |
| D-line | – | 140 | Goose Creek | 59.57 | – | – | 47,056 | 9 | 17,867 |
| F-line | – | 14 | Goose Creek | 5.75 | – | – | | | |
| G-line | Main and 1st Street | 16 | Little Goose Creek | 6.82 | – | 1 | 155,109 | 2,527 | 78,818 |
| H-line | – | | Little Goose Creek | - | – | 117.8 | – | – | – |
| I2-line | Near hockey rink | 146 | Little Goose Creek | 62.19 | – | 6.3 | – | – | – |
| I-line | Collage and Canby Streets | 83 | Little Goose Creek | 35.2 | – | 14.6 | – | – | – |
| J-line | – | 305 | Little Goose Creek | 129.91 | – | | – | – | – |
| K-line | – | 24 | Big Goose Creek | 10.25 | – | | – | – | – |
| N-line | Works and Candy Streets | 28 | Little Goose Creek | 11.96 | 1,732.9 during street washing | 12.1 | – | – | – |
| O-line | – | 24 | Little Goose Creek | 10.05 | – | | – | – | – |
| P-line | Discharge into LGC in Coffeen Park | 110 | Little Goose Creek | 46.94 | 50.4 during street washing | 6.3 | – | – | – |
| Q-line | Discharge into LGC near Emerson Park | 90 | Little Goose Creek | 38.51 | 14.8 during snow-melt event | 10.9 | – | – | – |
| RDA 19 | – | 109 | Little Goose Creek | 46.43 | – | | – | – | – |
| RDA 20 | – | 73 | Little Goose Creek | 31.09 | – | | – | – | – |
| RDA 7A | – | 218 | Big Goose Creek | 92.86 | – | | – | – | – |
| S-line | Near Coffeen Street | 170 | Little Goose Creek | 72.33 | 98.8 during rain | <1 | 8,278 | 2 | 962 |

**Table 6.8** Summary of Rural Drainage Areas in the City of Sheridan

| Basin Name | Acreage | Receiving Water or Drain | Land Use Description |
|---|---|---|---|
| Basin 1* | 71 | Soldier Creek Ditch and on to confluence of Soldier Creek and Big Goose Creek | Sparsely developed large lot residential area; land slopes 1%–30% |
| Basin 2* | 127 | Soldier Creek Ditch and on to confluence of Soldier Creek and Big Goose Creek | Medium-density development in southern area; sparsely situated large lot development in northern area |
| Basin 3* | 109 | Soldier Creek Ditch and on to confluence of Soldier Creek and Big Goose Creek | Moderately high-density mobile home park in upper areas; farm fields in lower areas; land slopes 1%–15% |
| Basin 4* | 116 | Soldier Creek | Undeveloped farmland; land slopes 1%–20% |
| Basin 5* | 76 | Big Goose Creek | Medium-density residential housing |
| Basin 6 | 949 | Holly and Hume Detention Ponds | Three sub-basins. Development centralized in lower portion of sub-basin 6-A (medium-density residential housing); land slopes 1%–10% |
| Basin 7* | 413 | Big Goose Creek | Two sub-basins; low-density residential development in the lower end of the basin; land slopes 1%–7% |
| Basin 8* | 333 | Big Goose Creek and reservoir near Loucks Street | Three sub-basins; land slopes 2%–16% |
| Basin 9* | 893 | Big Goose Creek and Stormwater Detention Reservoir | Two sub-basins; land slopes 2%–40% |
| Basin 10 | 324 | Cemetery Draw to open field; no discharge to surface waters | Medium-density residential areas, fields, cemetery; land slopes 1.5%–6%; southern part of basin near the airport |
| Basin 11* | 121 | Big Goose Creek | Three sub-basins; small residential/farm dwellings; small portion of cemetery; land slopes 3%–45% |
| Basin 12* | 365 | Big Goose Creek and reservoirs at upper end of Chapek Draw | County airport and unimproved rangeland; land slopes 1%–6% |
| Basin 13* | 262 | Stormwater ponds and reservoir and Big Goose Creek | Airport area, farmland, improved rangeland; land slopes 1%–20% |
| Basin 14* | 126 | Little Goose Creek and stormwater ponds | Medium density residential areas, fields, unimproved rangeland; land slopes 2%–8% |
| Basin 15* | 149 | Little Goose Creek | County airport, fields, unimproved rangeland; land slopes 2%–8% |
| Basin 16* | 375 | Soldier Creek | Fields, unimproved rangeland; land slopes 1%–10% |
| Basin 17* | 744 | Big Goose Creek | Three sub-basins, residential development |
| Basin 18* | 297 | Little Goose Creek | Open fields, unimproved rangeland, small areas of industrial development |
| Basin 19* | 109 | Little Goose Creek and I-90 stormwater reservoir/ponds | Lower portion of basin developed residential area, upper portion rangeland; land slopes 1%–17% |
| Basin 20* | 73 | Little Goose Creek | Residential development, fields, unimproved rangeland; land slopes 3%–17% |
| Basin 21* | 218 | Little Goose Creek and I-90 detention storage areas | Fields, rangelands, a few homes; land slopes 3%–18% |
| Basin 22 | 297 | Depression storage area on the east side of I-90 | Fields and rangeland with a few homes and commercial areas; land slopes 1%–18% |
| Basin 23 | 698 | Depression storage area | Fields, unimproved rangelands, some commercial areas, some low-density areas |
| Basin 24* | 502 | Little Goose Creek | Open rangeland, southern portion of airport runway |
| Basin 25* | 518 | Big Goose Creek | Veterans Administration hospital and open fields, lower portion of basin located within 100-year floodplain of Big Goose Creek |

*Basins assumed to be covered under the Wyoming MS4 general permit.

Fecal coliform in stormwater can be associated with old and leaky infrastructure associated with sewer lines, infrastructure that receives old and failing septic system influences, RV dumps, fairgrounds and recreational areas, domestic animals, waterfowl, pigeons nesting under bridges, and improper disposal of household garbage.

Waterfowl are found throughout the City of Sheridan, especially in parks that border the streams. Common waterfowl species in the Goose Creek Watershed include mallard, common goldeneye, wood duck, blue-winged teal, green-winged teal, common merganser, and Canada goose. These species are most common in the watershed's lower elevations. Pigeons are known to nest under bridges in the Goose Creek Watershed and may represent an additional direct load of fecal coliform and *E. coli* to streams (Collyard et al. 2005). Bacteria source tracking would be required to identify the proportion of fecal coliform and *E. coli* associated with avian sources. Bacteria source tracking was used in the mixed-use Guadalupe River watershed in Texas. In that study it was determined that approximately 16% of the *E. coli* in the watershed derived from wildlife, primarily pigeons and other birds (Texas Commission on Environmental Quality 2007). Typical concentrations of fecal coliform excreted by each of these species are summarized in Table 6.9.

**Table 6.9** Fecal Coliform Excreted by Domestic Animals and Waterfowl in the City of Sheridan

| Species | Fecal Coliform Excreted per Animal | Data Source |
|---|---|---|
| Cat | $5 \times 10^9$ organisms/day | Horsley and Whitten 1996; in U.S. EPA 2001 |
| Dog | $5 \times 10^9$ organisms/day | Horsley and Whitten 1996; in U.S. EPA 2001 |
| Duck | $2.5 \times 10^9$ organisms/day | ASAE 1998; in U.S. EPA 2001 |
| Goose | $4.9 \times 10^{10}$ organisms/day | LIRPB 1978; in U.S. EPA 2001 |
| Pigeon | $1.8 \times 10^8$ organisms per gram | Oshiro and Fujioka 1995; in U.S. EPA 2001 |

## 6.4 Nonpoint Sources

Nonpoint sources of pollution are generally considered to be diffuse across the landscape, originating from numerous small sources and aggregating in the streams. However, there could be isolated cases of intensive pollution loading from some nonpoint sources in the Goose Creek Watershed. For example, direct discharge of human waste from one household through a straight pipe to a creek could account for 5 G-cfu/day of *E. coli* load to the creek (assuming a household size in the City of Sheridan of 2.7 people). Similarly, manure from a small herd of five cattle standing in a stream could account for up to 8 G-cfu/day of *E. coli* load to the creek. These values are within the same order of magnitude of current *E. coli* loads to the steams in the Goose Creek Watershed (see Table 7.3 for comparison).

### *6.4.1 Big-game Wildlife*

Big-game species in the Goose Creek Watershed include mule deer, white-tailed deer, elk, moose, and pronghorn antelope. Mountain lions and black bears are also known to occur in the area. All warm-blooded animals have the potential to contribute pathogens to waterways through direct excretion into waterways or runoff of excrement from riparian and upland areas. Both the density of wildlife and species composition affects how much wildlife waste is transported to streams. Most wildlife habitat in the Goose Creek Watershed occurs in the higher elevations of the watershed; although mule deer, pronghorn, and white-tailed deer habitat extends into the valleys, especially during winter months (see Maps 9a, 9b, 9c).

Elk use a variety of habitats throughout the year. In the absence of natural predators, expanding elk populations in some parts of Wyoming have browsed on riparian seedlings to the extent that development of a riparian zone has been substantially reduced, and the integrity of riparian corridors is jeopardized. In Yellowstone National Park, wolf reintroductions have led to cottonwood and aspen recovery based on reductions in elk populations (Ripple and Beschta 2003; Ripple and Larsen 2000). In 2008 elk were reported to be the source of an *E. coli* (strain O157:H7) outbreak in children in Johnson County, Colorado, according to the Colorado Department of Public Health and the Johnson County Department of Health (Colorado Department of Public Health 2008).

Moose spend significant amounts of time near rivers and streams, and tend to avoid nonvegetated open terrain. Moose tend to prefer riparian habitats that typically have young willows, an important food for moose (Maier et al. 2005). Moose are also often found near ponds, lakes, and small water holes. Elk or moose habitat covers more than 75% of the following catchments: BG18 and BG14; Park Creek; and Rapid Creek in the Big Goose subwatershed as well as catchments LG22 and LG20 in the Little Goose subwatershed (Table 6.10). The upper portions of Beaver Creek, Jackson Creek, Sackett Creek, and Kruse Creek catchments also include elk and moose habitat.

White-tailed deer and mule deer also use riparian corridors for travel. They will also fawn within a relatively close distance to a water source (Olson 1992a; Olson 1992b). Deer obtain most of their water needs from food sources (including riparian vegetation) but do not spend very much time directly in streams. However, in late summer (when vegetation begins to dry up), deer rely directly on streams and springs for their daily water needs. White-tailed deer densities are estimated to be between 15 and 30 deer per square mile in the Goose Creek Watershed, among the highest density estimates in Wyoming according to the Quality Deer Management Association (I-Maps 2010*)*. Deer populations have been associated with pathogenic *E. coli*, although at relatively low rates. In a study of deer populations in Nebraska, 0.25% of deer fecal samples tested positive for pathogenic *E. coli* (O157:H7) (Renter et al. 2001). Deer habitat is found throughout the Goose Creek Watershed with few exceptions. They also tend to congregate in irrigated hayfields adjacent to riparian areas, although deer spend most of their time during summer months at higher elevations in the BHNF (Table 6.10).

Pronghorn evolved in open dry habitat. They distribute themselves relatively evenly across the landscape and do not typically congregating near water. Although water is critical to their movement patterns, they do not spend time in riparian habitat (Utah Division of Wildlife Resources 2009). Pronghorn habitat extends throughout the Soldier catchment and along the eastern edge of all Little Goose Creek catchments (see Map 9a).

In summary, considering the time spent in riparian habitat and recent recorded incidents of pathogenic *E. coli* associated with these species, moose and elk present the greatest risk of *E. coli* contamination to waters in the higher elevations of the watershed. However, deer present the most likely wildlife contributors of *E. coli* and fecal coliform throughout the watershed, given their extensive range and high population densities. *E. coli* measured in water quality monitoring is not differentiated between pathogenic and non-pathogenic strains.

**Table 6.10** Big-game Habitat–Percent of Catchment Areas

| Catchment | Acreage | Elk Habitat | Moose Habitat | White-tailed Deer Habitat | Mule Deer Habitat | Pronghorn Habitat |
|---|---|---|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | | | | |
| LG22 | 34,728 | 96% | 79% | 5% | 100% | 0% |
| LG20 | 13,284 | 36% | 83% | 81% | 100% | 0% |
| Sackett Creek | 2,186 | 20% | 23% | 95% | 98% | 0% |
| Jackson Creek | 6,082 | 23% | 52% | 62% | 100% | 2% |
| LG12 | 11,941 | 2% | 24% | 82% | 92% | 16% |
| Kruse Creek | 5,764 | 27% | 14% | 95% | 100% | 0% |
| McCormick Creek | 4,586 | 0% | 0% | 94% | 98% | 43% |
| LG6 | 8,895 | 0% | 0% | 72% | 90% | 46% |
| **Big Goose Creek Subwatershed** | | | | | | |
| BG18 | 80,217 | 97% | 75% | 0% | 89% | 0% |
| Rapid Creek | 10,499 | 86% | 94% | 20% | 100% | 16% |
| BG14 | 6,533 | 29% | 87% | 55% | 100% | 22% |
| Park Creek | 4,308 | 41% | 80% | 33% | 100% | 25% |
| BG11 | 3,830 | 20% | 0% | 84% | 100% | 25% |
| Beaver Creek | 8,877 | 27% | 23% | 66% | 100% | 1% |
| BG4 | 12,471 | 0% | 0% | 50% | 100% | 43% |
| **Goose Creek Subwatershed** | | | | | | |
| City of Sheridan | 19,536 | 0% | 0% | 40% | 79% | 20% |
| Soldier Creek | 20,529 | 21% | 25% | 41% | 100% | 75% |
| GC1 | 9,651 | 0% | 0% | 32% | 100% | 70% |
| Below GC1 | 2,935 | 0% | 0% | 100% | 100% | 10% |
| **Total** | 267,646 | 52% | 49% | 32% | 93% | 17% |

*Note:* Big-game habitat acreages may overlap.

## 6.4.2 Pastured Animals on Private Land

Rangeland and pasturelands in the watershed are typically located adjacent to local streams and support a diversity of livestock, including horses, sheep, cattle, and other grazing animals. Improper management of these lands can result in an increase in hoof action and animal weight, with compresses the soil profile and results in a dense layer of low permeability 12 to 15 inches below the upper soil horizon. During storm events and spring melt, water cannot penetrate this compacted layer, and the volume and velocity of overland flow increases, as well as the total sediment and pathogen load. Vegetation in overused rangeland or pastureland is also commonly insufficient to retain sediment during overland flows, leading to the increased likelihood of deposited manure movement directly into nearby stream and irrigation channels.

The agricultural census for Sheridan County was used to estimate the number of animal units on private pastureland and rangeland in the watershed (Table 6.11). Most private land in the Goose Creek Watershed is in Sheridan County. The Goose Creek Watershed makes up 14% of the area of Sheridan County, and includes 41% of the hay and pastureland in the county, 8% of the grassland in the county, and 9% of the shrub and scrub lands in the county. The Goose Creek Watershed makes up 10% of the combined pastureland and rangeland (grassland and shrub/scrub) in Sheridan County. Therefore, an estimated 10% to 41% of the animals found in Sheridan County are likely to occur in the Goose Creek Watershed (Table 6.11). Cattle dominate the livestock in the county, with between 7,000 and 29,000 cattle in the Goose Creek Watershed. This includes more than 10,000 head of cattle and approximately 1,000 horses and sheep (Table 6.11).

The excretion rates of fecal coliform from various livestock species are summarized in Table 6.11 and range from $9.5 \times 10^7$ for poultry to $1.0 \times 10^{11}$ for cattle. Cattle spend approximately 11% of their time in streams and 54% of their time in riparian areas when given the opportunity (Gary et al. 1983).

Coliform bacteria and pathogens die quickly outside of an animal's intestine. During extended periods of low precipitation and hot temperatures, *E. coli* and fecal coliform in manure deposited on livestock-associated pasturelands and rangelands die off before reaching a waterway. One study found that no *E. coli* or fecal coliform survived after 35 days at a temperature of 41°C (Wang et al. 2004). However, at moderate temperatures (27°C), coliform bacterial populations remained viable for more than three months. Therefore, during periods of rain or spring melt, the likelihood of manure transport from a field to a stream increases. Fecal streptococci are the most resilient of the fecal bacteria tested (Wang et al. 2004).

The catchments with the largest percentage of hay and pastureland are BG11 (20%), Beaver Creek (20%), followed by LG6 (16%), LG12 (15%), Park Creek (14%), and Kruse Creek (13%). Livestock pasturing likely plays an important role in the impairments identified in these catchments (Table 6.12).

The catchments with large percentages (more than 85%) of all rangeland and pastureland uses are GC1 (89%), BG4 (88%), BG11 (86%), GC1 (86%), and McCormick Creek (86%).

**Table 6.11** Estimated Livestock on Private Lands in the Goose Creek Watershed

| Livestock Type | Number in Sheridan County | Estimated Number in the Goose Creek Watershed | | Fecal Coliform Excreted per Animal (organisms per day) | Source of Concentration Data |
|---|---|---|---|---|---|
| | | Minimum (10% of Sheridan County Animals) | Maximum (41% of Sheridan County Animals) | | |
| Cattle and calves | 71,560 | 7,156 | 29,340 | $1.0 \times 10^{11}$ | ASAE 1998; U.S. EPA guidance |
| Total hogs and pigs | 70 | 7 | 29 | $1.1 \times 10^{10}$ | ASAE 1998; U.S. EPA guidance |
| Layers (chickens) | 684 | 68 | 280 | $1.4 \times 10^{8}$ | ASAE 1998; U.S. EPA guidance |
| Ducks | 51 | 5 | 21 | $2.50 \times 10^{9}$ | ASAE 1998; U.S. EPA guidance |
| Geese | 33 | 3 | 14 | $4.9 \times 10^{10}$ | LIRPB 1978 |
| Other poultry | 133 | 13 | 55 | $9.5 \times 10^{7}$ | ASAE 1998; U.S. EPA guidance |
| Horses and ponies | 4,608 | 461 | 1,889 | $4.2 \times 10^{8}$ | ASAE 1998; U.S. EPA guidance |
| Sheep and lambs | 4,287 | 29 | 1,758 | $5.0 \times 10^{9}$ | ASAE 1998; U.S. EPA guidance |
| Goats | 162 | 16 | 66 | — | – |
| Alpacas | 106 | 11 | 43 | — | – |
| Bison | 54 | 5 | 22 | — | – |
| Llamas | 64 | 6 | 26 | — | – |
| Mules, Burros, and Donkeys | 57 | 6 | 23 | — | – |
| Rabbits | 50 | – | 21 | — | – |

**Table 6.12** Acres of Pasture and Rangeland in Goose Creek Watershed Catchments

| Catchment | Total Acres | Percent Grassland | Percent Pasture/Hay | Percent Shrub/Scrub | Percent all Pastureland and Rangeland |
|---|---|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | | | |
| LG22 | 34,728 | 10% | 0% | 11% | 20% |
| LG20 | 13,284 | 23% | 7% | 24% | 54% |
| Sackett Creek | 2,186 | 26% | 11% | 37% | 74% |
| Jackson Creek | 6,082 | 29% | 10% | 23% | 62% |
| LG12 | 11,941 | 34% | 15% | 18% | 66% |
| Kruse Creek | 5,764 | 27% | 13% | 28% | 67% |
| McCormick Creek | 4,586 | 40% | 9% | 37% | 86% |
| LG6 | 8,895 | 36% | 16% | 18% | 71% |
| **Big Goose Creek Subwatershed** | | | | | |
| BG18 | 80,217 | 13% | 0% | 13% | 26% |
| Rapid Creek | 10,499 | 18% | 3% | 18% | 38% |
| BG14 | 6,533 | 32% | 11% | 35% | 79% |
| Park Creek | 4,308 | 29% | 14% | 30% | 73% |
| BG11 | 3,830 | 43% | 20% | 22% | 86% |
| Beaver Creek | 8,877 | 27% | 20% | 29% | 76% |
| BG4 | 12,471 | 50% | 9% | 30% | 88% |
| **Goose Creek Subwatershed** | | | | | |
| City of Sheridan | 19,536 | 20% | 9% | 20% | 48% |
| Soldier Creek | 20,529 | 44% | 11% | 26% | 81% |
| GC1 | 9,651 | 42% | 5% | 39% | 86% |
| Below GC1 | 2,935 | 45% | 0% | 44% | 89% |

### 6.4.3 Grazing on Public Lands

Cattle grazing on public lands contributes a small amount of coliform bacteria and pathogens to waters in the upper segments of the Goose Creek Watershed. None of the stream segments in the USFS-owned and managed lands is impaired. However, grazing on USFS lands could contribute to impairments downstream below the USFS boundary. Most grazing on USFS lands in the watershed occurs from June through September. Grazing on public forest lands contributes pathogens to streams through manure deposition and wash-off. Grazing allotments in the Goose Creek Watershed are summarized in Table 6.13 and Map 14.

Six USFS grazing allotments are found in the Goose Creek Watershed (see Map 14). Grazing intensity and duration information, provided by the BHNF, are presented in Table 6.14. It is important to note that a) allotments do not coincide with subwatershed boundaries and may only be partially contained in a watershed, and b) cattle are not dispersed evenly across the landscape. Cattle graze on USFS land primarily during July, August, and September, although some grazing occurs as early as June and as late as October. Generally, cattle that graze on public lands are pastured on private lands in the valley during the rest of the year.

**Table 6.13** Identified Grazing Permits on USFS Lands in the Goose Creek Watershed

| Allotment Name | Allotment Area in Watershed (acres) | Typical Dates | Average Days in Allotment During Season | Average Animal Units | Catchments Intersected |
|---|---|---|---|---|---|
| Big Goose C&H | 11,504 | July–Sept | 76 | 129 | BG18, LG22, Rapid Creek |
| Little Goose C&H | 27,915 | July–Sept | 63 | 123 | BG18 and LG22 |
| Little Goose Canyon C&H | 1,152 | July–early Oct | 62 | 10 | LG20 and LG22 |
| Little Goose Canyon C&H lower unit pasture | | Late June–Sept | 88 | 77 | |
| Rapid Creek C&H | 14,398 | Late June–Sept | 85 | 283 | Beaver, BG14, BG18, Jackson, LG12, LG20, LG22, Rapid Creek |
| Walker Prairie C&H | 17,880 | July–Oct | 81 | 123 | BG18, Soldier Creek |

The area of each catchment covered by allotments with current grazing herds in the BHNF is provided in Table 6.14. Other allotments in the watershed are not currently grazed and therefore are not included in the analysis. Two catchments are predominately (more than 50%) covered by grazing allotments with cattle: LG22 in the Little Goose Creek subwatershed, and BG18 and Rapid Creek in the Big Goose Creek subwatershed.

**Table 6.14** Percent of Catchments Covered by Grazing Allotments with Cattle on USFS Lands

| Catchment | Total Acres | Percent of Catchment Covered by Grazing Allotments with Cattle | Percent of Catchments Covered by All Grazing Allotments |
|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | |
| LG22 | 34,728 | 84% | 85% |
| LG20 | 13,284 | 1% | 1% |
| Sackett Creek | 2,186 | 0% | 0% |
| Jackson Creek | 6,082 | 13% | 13% |
| LG12 | 11,941 | 4% | 4% |
| Kruse Creek | 5,764 | 0% | 0% |
| McCormick Creek | 4,586 | 0% | 0% |
| LG6 | 8,895 | 0% | 0% |

**Table 6.14** Percent of Catchments Covered by Grazing Allotments with Cattle on USFS Lands

| Catchment | Total Acres | Percent of Catchment Covered by Grazing Allotments with Cattle | Percent of Catchments Covered by All Grazing Allotments |
|---|---|---|---|
| **Big Goose Creek Subwatershed** | | | |
| BG18 | 80,217 | 44% | 93% |
| Rapid Creek | 10,499 | 55% | 55% |
| BG14 | 6,533 | 1% | 1% |
| Park Creek | 4,308 | 0% | 0% |
| BG11 | 3,830 | 0% | 0% |
| Beaver Creek | 8,877 | 7% | 7% |
| BG4 | 12,471 | 0% | 0% |
| **Goose Creek Subwatershed** | | | |
| City of Sheridan | 19,536 | 0% | 0% |
| Soldier Creek | 20,529 | 2% | 2% |
| GC1 | 9,651 | 0% | 0% |
| Below GC1 | 2,935 | 0% | 0% |
| **Total** | **267,646** | **27%** | **42%** |

## 6.4.4 On-site Wastewater Treatment (septic systems)

Septic systems have the potential to deliver pathogen loads to surface waters due to improper design, malfunctions, failures, direct pipe discharges, or improperly located systems in close proximity to surface waters and groundwater.

A properly operating septic system treats wastewater and disposes of the water through an underground leach field. Soils beneath the leach field remove most pathogens by filtering, adsorption, and biological processes. However, where soils or groundwater conditions are marginally suitable, or where septic densities are too high, conventional septic systems fail and are not adequate for removing most pathogens. A septic system can affect surface waters when soils below the leach field become clogged or flooded and when effluent reaches the surface where it can be washed off into a stream. An associated problem occurs when a septic system is flooded by groundwater or the depth-to-groundwater is near the base of the leach field and effluent is released to groundwater, which moves along flow lines and discharges into nearby streams.

In areas where groundwater is shallow and aquifer materials are permeable (as is typical in valley bottoms near creeks in the Goose Creek Watershed), discharge to groundwater from septic systems can be relatively rapid. In these areas, the transport of pathogens from septic systems to streams by groundwater can be significant if the travel time is less than the pathogen survival rate. The septic system density in the Goose Creek Watershed is described below, followed by an assessment of the number of septic systems in each catchment area where a high potential exists for pathogens to affect creeks by groundwater transport.

Sheridan County began permitting septic systems in 1977. In 2009 Sheridan County reported that there are 1,546 permitted septic systems in the Goose Creek Watershed. This number does not include septic systems installed prior to 1977. Some of the septic systems in the Goose Creek Watershed can be reasonably assumed to be affecting surface waters. Therefore, pathogen loading to creeks in the Goose Creek Watershed can be partly attributed to septic systems. Table 6.15 lists the number and density of permitted septic systems in each catchment area. The highest septic densities are located in the LG6 and LG12 catchment areas. Conversely, the lowest septic densities are located in the BG18 and LG22 catchment areas. No septic systems are reported in the BG13 catchment (Park Creek).

**Table 6.15** Number and Density of Septic Systems by Catchment Area

| Catchment | Acres | Permitted Septic Systems | Septic System Density (number per acre) |
|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | |
| LG22 | 34,728 | 25 | 0.001 |
| LG20 | 13,284 | 43 | 0.003 |
| Sackett Creek | 2,186 | 24 | 0.011 |
| Jackson Creek | 6,082 | 58 | 0.010 |
| LG12 | 11,941 | 253 | 0.021 |
| Kruse | 5,764 | 78 | 0.014 |
| McCormick Creek | 4,586 | 62 | 0.014 |
| LG6 | 8,895 | 344 | 0.039 |
| **Big Goose Creek Subwatershed** | | | |
| BG18 | 80,217 | 7 | 0.000 |
| Rapid Creek | 10,499 | 8 | 0.001 |
| BG14 | 6,533 | 5 | 0.001 |
| Park Creek | 4,308 | 0 | 0 |
| BG11 | 3,830 | 24 | 0.006 |
| Beaver Creek | 8,877 | 43 | 0.005 |
| BG4 | 12,471 | 151 | 0.012 |
| **Goose Creek Subwatershed** | | | |
| GC1 | 9,651 | 21 | 0.002 |
| Soldier Creek | 20,529 | 26 | 0.001 |
| City of Sheridan | 19,536 | 374 | 0.019 |
| Below GC1 | 2,935 | | 0 |
| **Total** | | 1,546 | |

Note: LG1, BG1, GC6, GC5, GC2 are included in the City of Sheridan catchment.

Several factors were considered in the identification of septic systems that have a high potential to affect creeks by groundwater transport of pathogens. First, areas in the Goose Creek Watershed were identified where the potential for groundwater impact is high. Second, the pathogen survival rate was investigated from published literature. Third, a critical distance was estimated from hydrogeologic parameters and pathogen survival rates.

Identification of the areas in the watershed where the potential for groundwater impact is high is beneficial to understanding the potential linkage of septic system pathogen sources to surface water contamination. Information provided in the *Septic System Impact Study* for the Goose Creek Watershed (HKM Engineering Inc. [HKM] 2006) includes GIS layers that delineate areas of high groundwater sensitivity. These data were originally collected by the WDEQ's Water Quality Division for assessing groundwater sensitivity in preparation of a groundwater vulnerability assessment (WDEQ 1998). Aquifer sensitivity is defined as the relative ease with which a contaminant applied on or near the land surface can migrate to the aquifer of interest (WDEQ 1998). Using the groundwater sensitivity data, septic systems located in areas mapped as "high aquifer sensitivity" were identified.

Although many septic systems in the Goose Creek Watershed are located in areas defined as "high aquifer sensitivity," the groundwater transport distance is large enough that pathogens could die off before reaching the creek. Therefore, a critical transport distance was estimated. Estimates of critical distances require some assumption about pathogen survival rates. The survival rate is influenced by the environmental conditions, the physical and chemical properties of water and soil in the system, as well as the identity and physiological state of the organisms (Teutsch 1991; Abu-Ashour 1994).

The survival of pathogens in groundwater is generally thought to be limited; a 90% reduction may be expected at 20ºC within approximately 10 days, although a few may persist for 200 days or more as a result of the absence of ultraviolet light, lower temperature, and less competition for nutrients (Morris 2001). Laboratory viral studies on groundwater samples have demonstrated persistence of both poliovirus and echovirus for up to 28 days at 12ºC before a 10-fold reduction was achieved (Yates et al, 1985). The lifecycle of some protozoan parasites, such as *Cryptosporidium* and *Giardia*, includes an environmentally hardy cyst stage. Viability in the subsurface of the protozoan *Cryptosporidium* has not been extensively studied, but as oocysts (similar to eggs) they are reported to survive dormant for months in moist soil or up to a year in clean water. Other studies have shown that pathogens can survive in groundwater for up to six months (Conboy and Goss 2001).

Considering the pathogen survival estimates above, a 50% pathogen survival rate over three months was assumed. Using Darcy's flow equation to estimate the average groundwater linear velocity, a critical distance was calculated for the three-month travel time. The Darcy average linear flow equation and input variables used are described as follows:

Darcy average linear velocity:

$$v = Ki/n$$

where

v = average linear velocity
K = hydraulic conductivity
i = hydraulic gradient
n = porosity

The input value for hydraulic conductivity was obtained from the aquifer vulnerability study for high sensitivity aquifers, and reported to be $1 \times 10^3$ gallons/day/square feet for a mixed silt, sand, and gravel aquifer. The hydraulic gradient was also obtained from the aquifer vulnerability study by assuming that the hydraulic gradient was equal to the land slope for high sensitivity aquifers (10%). A porosity of 30% was obtained from Freeze and Cherry (1979) for a silt, sand, and gravel mixture. Using these inputs, the average linear groundwater velocity is $1.35 \times 10^{-5}$ meters per second, and the critical distance for a three-month travel time is approximately 100 m.

The 100-m critical distance was mapped on each side of the impaired waters in the Goose Creek Watershed. Septic systems located in high aquifer sensitivity areas and within the 100-m critical distance were mapped and counted for each catchment basin in the watershed. The results of this assessment are summarized in Table 6.16. The largest number of septic systems found in high sensitivity zones were in catchments LG12 (35), LG6 (23), and the City of Sheridan (20).

**Table 6.16** Number of Septic Systems by Catchment Area Located in High Aquifer Sensitivity Areas and within Critical Distances of a Surface Water

| Catchment | Number of Septic Systems Located in High Aquifer Sensitivity Areas and within 100 m of a Creek |
|---|---|
| **Little Goose Creek Subwatershed** | |
| LG22 | 0 |
| LG20 | 6 |
| Sackett Creek | 7 |
| Jackson Creek | 16 |
| LG12 | 35 |
| Kruse Creek | 3 |
| McCormick Creek | 9 |
| LG6 | 23 |
| **Big Goose Creek Subwatershed** | |
| BG18 | 0 |
| Rapid Creek | 1 |
| BG14 | 1 |
| Park Creek | 0 |
| BG11 | 0 |
| Beaver Creek | 0 |
| BG4 | 18 |
| **Goose Creek Subwatershed** | |
| GC1 | 2 |
| Soldier Creek | 3 |
| City of Sheridan | 20 |
| Below GC1 | 0 |

### 6.4.5 Stormwater Runoff from Developed Areas Outside of the City of Sheridan

In addition to the regulated stormwater sources identified in the City of Sheridan, small developed areas of medium-density and low-density residential land uses are found in several other parts of the watershed. Runoff from these landscapes also has the potential to carry pathogens associated with domestic animals and waterfowl. Table 6.17 gives a summary of developed land uses throughout the Goose Creek Watershed.

**Table 6.17** Acres of Developed Land Uses in Goose Creek Watershed Catchments

| Catchment | Total Acres | High Density Development | Medium Density Development | Low Density Development and Open Space | Total Developed |
|---|---|---|---|---|---|
| **Little Goose Creek Subwatershed** | | | | | |
| LG22 | 34,728 | 0% | 0% | 0% | 0% |
| LG20 | 11,941 | 0% | 0% | 0% | 0% |
| Sackett | 2,186 | 0% | 0% | 0% | 0% |
| Jackson | 6,082 | 0% | 0% | 2% | 2% |
| LG12 | 13,284 | 0% | 0% | 4% | 4% |
| Kruse | 5,764 | 0% | 0% | 0% | 0% |
| McCormick | 4,586 | 0% | 0% | 3% | 3% |
| LG6 | 8,895 | 0% | 0% | 5% | 5% |
| **Big Goose Creek Subwatershed** | | | | | |
| BG18 | 80,217 | 0% | 0% | 0% | 0% |
| Rapid | 10,499 | 0% | 0% | 0% | 0% |
| BG14 | 6,533 | 0% | 0% | 0% | 0% |
| Park | 4,308 | 0% | 0% | 0% | 0% |
| BG11 | 3,830 | 0% | 0% | 0% | 0% |
| Beaver | 8,877 | 0% | 0% | 0% | 0% |
| BG4 | 12,471 | 0% | 0% | 0% | 0% |
| **Goose Creek Subwatershed** | | | | | |
| City of Sheridan | 19,536 | 2% | 6% | 31% | 39% |
| GC1 | 9,651 | 0% | 0% | 3% | 3% |
| Soldier | 20,529 | 0% | 0% | 0% | 0% |
| Below GC1 | 2,935 | 0% | 0% | 2% | 3% |

## 6.4.6 Stream Sediments

Many studies have shown that there are often much higher concentrations of pathogens in sediments than in overlying waters due to a combination of sedimentation, sorption, and extended pathogen survival times (U.S. EPA 2001). After discharge to a waterbody, pathogens are removed from the water column as they settle at the sediment/surface interface. Once settled, sedimentation provides protection from harmful factors such as sunlight and temperature. Due to this increased longevity, sediment pathogens represent a potential long-term source of pathogens to watersheds, particularly because pathogens are subsequently reintroduced into the water column through stream sediment disturbance and re-suspension events, such as increased streamflow associated with storm events and spring-melt periods, or through human recreation activities (U.S. EPA 2001).

To evaluate the relative impact of stream sediments as a significant source of pathogen concentrations in the Goose Creek Watershed, the SCCD conducted bed sediment sampling of fecal coliform during April and September 2002 at three sites: GC2 (downstream of the City of Sheridan WWTP), BG18 (the site furthest upstream in Big Goose Creek), and LG8 (downstream of McCormick Creek). Results indicate that high concentrations of bacteria were unlikely to survive winter stream conditions, thereby limiting the potential for pathogen accumulation and later release into the water column—particularly in the upper segments of the watershed (SCCD 2003). Based on these data, stream sediments are not anticipated to be a significant source of pathogens in the Goose Creek Watershed.

## 6.5 Summary of Sources and Linkage

Establishing the relationship between the in-stream, water quality targets and sources is an important component of TMDL development. This linkage allows for the evaluation of management options that will achieve the desired source load reductions (Section 7.5; Map 15). Table 6.18 provides a summary of the potential pathogen sources identified for the Goose Creek Watershed by catchment.

In the Little Goose Creek subwatershed, Jackson Creek and McCormick Creek have very high percent load reductions needed to meet the TMDL. Kruse Creek and Sacket Creek follow with high percent reductions needed. Main stem catchments along Little Goose Creek have a low percent reduction required to meet the TMDL. Largely, the impairment in Little Goose Creek could be improved through implementation in the impaired tributaries. The number of septic systems in these tributary catchments is relatively high and is a likely source of pathogens to impaired waters. Pasturing of animals on private land in these tributary catchments is also a likely source of pathogens.

In the Big Goose Creek subwatershed, Beaver Creek has a very high percent load reduction needed to meet the TMDL. Park Creek has a high load reduction required, followed by medium load reductions needed in the BG4 and BG11 catchments. The remaining catchments in the Big Goose Creek subwatershed (Rapid, BG14, and BG18) have a low percent load reduction needed to meet the TMDL.

The most likely sources of *E. coli* in Beaver Creek are from pastureland and rangeland on private properties and from some contribution from septic systems. In the Park Creek catchment, wildlife and pastureland and rangeland on private properties are the most likely *E. coli* sources. Septic systems are of greater concern in the BG4 catchment, which has a relatively high density (0.012/acre) and the largest number of septic systems (151) of all catchments in the Big Goose Creek subwatershed; 18 of these are located in critical areas. In BG11 the most likely sources of *E. coli* are from wildlife and from pastureland and rangeland on private properties. There are no septic systems located in critical areas of BG11, and there are only 24 permitted septic systems in the catchment.

The catchment associated with the City of Sheridan has a high percent load reduction need to meet the TMDL. The most likely contributor of pathogens in this catchment is stormwater runoff. Historically, the wastewater load of *E. coli* has also been significant in this catchment. In addition, there is a relatively large number of septic systems in critical areas in or near the City of Sheridan. The very high percent reduction needed in Soldier Creek is most likely the result of both septic and grazing sources.

**Table 6.18** Surface of Sources and Linkages for Catchment in the Goose Creek Watershed

| Catchment | Total Acres | Pathogen Load Reduction Needed for TMDL | Pathogen Load Reduction Qualifier | Percent Elk or Moose Habitat | Percent Deer Habitat | Percent Pasture and Range | Percent Public Grazing Land | Percent Developed | Number of Septic Systems Located in Critical Areas | Permitted Septic Systems |
|---|---|---|---|---|---|---|---|---|---|---|
| LG22 | 34,728 | 0% | Low | 96% | 100% | 20% | 84% | 0% | 0 | 25 |
| LG20 | 13,284 | 0% | Low | 83% | 100% | 54% | 1% | 0% | 6 | 43 |
| Sackett Creek (LG19) | 2,186 | 68% | High | 23% | 98% | 74% | 0% | 0% | 7 | 24 |
| Jackson Creek (LG17) | 6,082 | 84% | Very High | 52% | 100% | 62% | 13% | 2% | 16 | 58 |
| LG12 | 11,941 | 0% | Low | 24% | 92% | 66% | 4% | 4% | 35 | 253 |
| Kruse Creek (LG11) | 5,764 | 73% | High | 27% | 100% | 67% | 0% | 0% | 3 | 78 |
| McCormick Creek (LG9) | 4,586 | 78% | Very High | 0% | 98% | 86% | 0% | 3% | 9 | 62 |
| LG6 | 8,895 | 0% | Low | 0% | 90% | 71% | 0% | 5% | 23 | 344 |
| BG18 | 80,217 | 0% | Low | 97% | 89% | 26% | 44% | 0% | 0 | 7 |
| Rapid Creek (BG16) | 10,499 | 17% | Low | 94% | 100% | 38% | 55% | 0% | 1 | 8 |
| BG14 | 6,533 | 0% | Low | 87% | 100% | 79% | 1% | 0% | 1 | 5 |
| Park Creek (BG13) | 4,308 | 74% | High | 80% | 100% | 73% | 0% | 0% | 0 | 0 |
| BG11 | 3,830 | 54% | Medium | 20% | 100% | 86% | 0% | 0% | 0 | 24 |
| Beaver Creek (BG9) | 8,877 | 82% | Very High | 27% | 100% | 76% | 7% | 0% | 0 | 43 |
| BG4 | 12,471 | 45% | Medium | 0% | 100% | 88% | 0% | 0% | 18 | 151 |
| City of Sheridan | 19,536 | 69% | High | 0% | 79% | 48% | 0% | 39% | 20 | 374 |
| Soldier Creek (GC4) | 20,529 | 81% | Very High | 25% | 100% | 81% | 2% | 0% | 3 | 26 |
| GC1 | 9,651 | 0% | Low | 0% | 100% | 86% | 0% | 3% | 2 | 21 |
| Below GC1 | 2,935 | No data. | - | 0% | 0% | 89% | 0% | 3% | 0 | 0 |

# CHAPTER 7 PATHOGEN TMDL

## 7.1 Water Quality Targets

The water quality target for the summer recreation season (May 1 through September 30) is 126 organisms per 100 mL, measured as a geometric mean of five samples obtained during separate 24-hour periods within a 30-day time span. This water quality target is derived directly from the water quality standards for bacteria established by the State of Wyoming (Table 7.1). *E. coli* is the bacteria parameter with a numeric water quality standard for Wyoming waters. In 1986 the U.S. EPA recommended that *E. coli* replace fecal coliform bacteria in state water quality standards (U.S. EPA 1986). This recommendation is reflected in current Wyoming water quality standards and in the water quality targets identified for this TMDL.

**Table 7.1** Wyoming Numeric Surface Water Quality Standard for *E. coli* Bacteria

| Parameter | Water Quality Standard Reference | Standard/Description |
|---|---|---|
| *E. coli* bacteria[1] | Section 27 | Standard during the summer recreation season (May 1 through September 30): geometric mean of five samples obtained during separate 24-hour periods within a 30-day time span shall not exceed 126 organisms per 100 mL. |

Source: WDEQ (2007).

[1] Original impairments were based on the old fecal coliform standard: geometric mean of 5 samples obtained during separate 24-hour periods within a 30-day time span shall not exceed 200 organisms per 100 mL.

## 7.2 TMDL Load, Capacity, and Reduction Calculations

The *E. coli* load for each impaired waterbody during each hydrologic flow regime was determined by using the load duration curve methodology introduced in Section 6.1.2. For each hydrologic regime, the average *E. coli* instantaneous loads were calculated for each impaired water. These loads were then multiplied by the weighted frequency of each hydrologic flow regime category. In other words, the average load for “high” flows was multiplied by 30%; the average load for “medium” flows was multiplied by 40%, and the average load for “low” flows was multiplied by 30%. These average-weighted loads were summed to develop the summer recreation season weighted load.

Consistent with the load duration approach, load capacity (TMDL) was calculated for each impaired water during each hydrologic flow regime. These weighted load capacities were summed to develop the summer recreation season weighted load capacity.

Load reduction was determined by simple arithmetic calculation of the current load and the TMDL for each hydrologic flow regime as follows:

$$\text{Load Reduction (\%)} = \frac{\text{Current Load} - \text{TMDL}}{\text{Current Load}} \times 100$$

A summary of the current load, load capacity, and load reduction for Beaver Creek is provided in Table 7.2. The same methodology for calculating current loads, load capacities, and load reduction were applied to all other impaired creeks in the Goose Creek Watershed.

**Table 7.2** Current Load, Load Capacity, and Load Reduction Summary for Beaver Creek

| | Hydrologic Flow Regime | Beaver Creek (BG9) |
|---|---|---|
| **Current Load(G-cfu/100 mL)** | High | 212.6 |
| | Medium | 17.4 |
| | Low | 2.6 |
| | Weighted load | 71.5 |
| **Load Capacity (G-cfu/100 mL)** | High | 29.1 |
| | Medium | 8.4 |
| | Low | 3.8 |
| | Weighted-load capacity | 13.2 |
| **Load Reduction (percent)** | High | 86% |
| | Medium | 52% |
| | Low | 0% |
| | Weighted-load reduction | 47% |

## 7.3 Seasonality and Critical Periods

The TMDLs for waters impaired due to pathogen (*E. coli*) exceedances in the Goose Creek Watershed were developed for the summer recreation season. This represents the critical season in terms of water quality exceedances in the watershed. No exceedances of the *E. coli* water quality standards have been observed during the winter season. Furthermore, *E. coli* have been documented to die off over the winter season, as observed in previous studies (SCCD 2005a). This reduces or eliminates the need to account for *E. coli* survival between seasons.

Using the load duration curve methodology developed for the Goose Creek Watershed, current loads and load capacities were calculated for three hydrologic flow regimes: high (0% to 30% duration), medium (30% to 70% duration), and low (70% to 100% duration). The results of this analysis indicate that the most critical periods for load exceedances occur during high flows on most tributaries, and during high and low flows on the main stems of Little Goose Creek, Big Goose Creek, Goose Creek, and Soldier Creek. In terms of critical months, early May and October are of greatest concern, followed by August. Load exceedances during these critical periods are intensified by storm events, including major spring storms and isolated summer storms. As an example, during one spring storm event in May 2005, increases in *E. coli* concentrations were present throughout the watershed. During this storm event, the greatest increase in *E. coli* load occurred in Beaver Creek and Kruse Creek and within the city limits of the City of Sheridan (the increased load within the city limits occurred at sampling sites LG2 and LG5, which capture a stretch of stream with stormwater flows). Another example of the effect storms have on the increase in *E. coli* loads was observed during an isolated storm event in October 2001. This storm event was preceded by a relatively dry period and also resulted in elevated *E. coli* concentrations in the watershed.

## 7.4 Current Loads

Current loads in the Goose Creek Watershed for each hydrologic flow regime are provided in Table 7.3. The weighted load, calculated by the duration of each flow regime, is also listed.

As expected, loads accumulate downstream such that the highest loads are recorded at the bottom of Goose Creek (GC1) with a weighted load of 750 G-cfu/day. The two largest subwatersheds, Big Goose Creek and Little Goose Creek, also represent high loads in the watershed. The sharp rise in load at Goose Creek, compared to the load in the subwatersheds of Little Goose Creek and Big Goose Creek, represents the relatively large loads contributed to the city creeks from stormwater and historically from wastewater. The highest loads from tributaries are found in Beaver Creek (71 G-cfu/day) followed by Soldier Creek (36 G-cfu/day) and Kruse Creek (33 G-cfu/day). The lowest loads (less than 10 G-cfu/day) in the watershed are in the Park and Rapid tributaries. For all impaired waters in the watershed, loads are the highest during high-flow conditions.

**Table 7.3** TMDL Load Summary Table for Goose Creek Watershed Pathogen TMDLs Summarized by Hydrologic Regime (G-cfu/day)

| | Hydrologic Flow Regime | Sackett Creek | Jackson Creek | Kruse Creek | McCormick Creek | Little Goose Creek (LG1) | Rapid Creek | Park Creek | Beaver Creek | Big Goose (BG 1) | Soldier Creek (GC 4) | Goose Creek (GC 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Current Load** | High | 44.2 | 69.4 | 85.6 | 81.4 | 149.4 | 10.4 | 0.6 | 212.6 | 258.9 | 103.3 | 2,270.2 |
| | Medium | 2 | 6.5 | 15.9 | 9.7 | 32.2 | 8.3 | 1.3 | 17.4 | 32.3 | 5.8 | 121.8 |
| | Low | 1.3 | 0.2 | 3.9 | 1.1 | 18.1 | 3 | 0.02 | 2.6 | 41.5 | 9.3 | 68.0 |
| | Weighted load | 14.4 | 23.5 | 33.2 | 28.6 | 63.1 | 7.4 | 0.7 | 71.5 | 103.0 | 36.1 | 750.2 |
| **Load Capacity (TMDL)** | High | 12.1 | 9.1 | 17.2 | 15.4 | 81.3 | 13.9 | 0.5 | 29.1 | 198.0 | 17.2 | 469.3 |
| | Medium | 1.9 | 2.4 | 7.9 | 3.7 | 18.6 | 3.4 | 0.1 | 8.4 | 48.1 | 3.2 | 109.2 |
| | Low | 0.8 | 0.5 | 2.5 | 0.5 | 3.5 | 1.9 | 0.1 | 3.8 | 16.0 | 1.1 | 33.4 |
| | Weighted load | 4.6 | 3.9 | 9.0 | 6.2 | 32.8 | 6.1 | 0.2 | 13.2 | 83.5 | 6.8 | 192.9 |
| **Required Percent Reduction** | High | 73% | 87% | 80% | 81% | 46% | 0% | 27% | 86% | 24% | 83% | 79% |
| | Medium | 1% | 63% | 50% | 62% | 42% | 59% | 93% | 52% | 0% | 45% | 10% |
| | Low | 38% | 0% | 36% | 57% | 81% | 36% | 0% | 0% | 61% | 88% | 51% |
| | Area-weighted Percent Reduction | 68% | 84% | 73% | 78% | – | 17% | 74% | 82% | – | 81% | 0% |

## 7.5 Loading Capacity and Percent Reductions

Loading capacity was assessed for each impaired segment in the Goose Creek Watershed for each hydrologic regime identified using the load duration curve methodology. Load capacities were calculated by multiplying the average flow during each hydrologic flow regime by 126 organisms per 100 mL. The use of average flows rather than geometric means is appropriate because hydrologic regimes represent flows that do not occur in consecutive 30-day periods, and represent a conservative assumption more protective of water quality because geometric means eliminate data outliers.

The maximum *E. coli* load (i.e., load capacity or TMDL) that will attain the *E. coli* water quality target for Goose Creek is 469 G-cfu/day during high flows, 109 G-cfu/day during medium flows, and 33 G-cfu/day during low flows, for an average weighted load of 195 G-cfu/day (see Table 7.3). For Big Goose Creek, Beaver Creek, and Little Goose Creek, the *E. coli* TMDLs are 84, 13, and 33 G-cfu/day, respectively. For all other impaired waters, the TMDL for *E. coli* is less than 10 G-cfu/day (Table 7.3). These TMDLs represent an overall *E. coli* reduction (other than zero) ranging from a low of 17% for Rapid Creek to a high of 84% for Jackson Creek. Most load reductions occur during high-flow periods; however, the main subwatersheds—Little Goose Creek, Big Goose Creek, and Soldier Creek—have the highest reductions needed during low-flow conditions.

## 7.6 Allocations and Reductions

To achieve the *E. coli* load reductions discussed in the previous section, waste load allocations (WLA) have been identified for regulated point sources in the watershed, and load allocations (LA) have been applied to nonpoint sources by catchment area. Allocations of load are shown graphically in Figure 7.1 for each impaired waterbody in the watershed and are listed in Table 7.4.

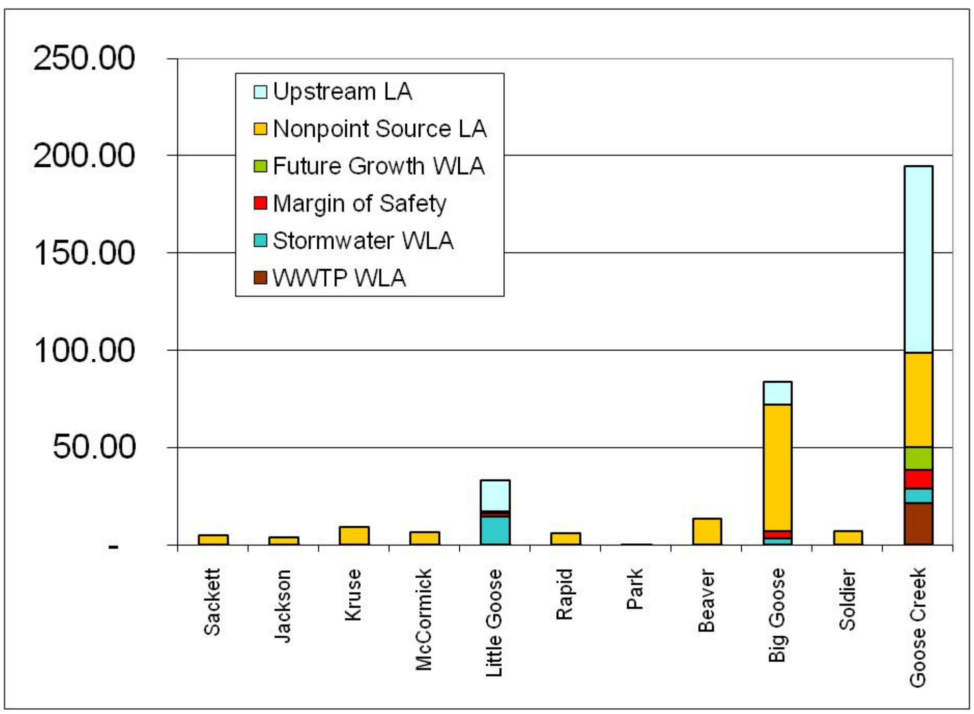


**Figure 7.1** WLAs and LAs for impaired waters in the Goose Creek Watershed.

**Table 7.4** Goose Creek Watershed Allocation of Loads (G-cfu/day)

| | Hydrologic Flow Regime | Sackett Creek | Jackson Creek | Kruse Creek | McCormick Creek | Little Goose Creek (LG1) | Rapid Creek | Park Creek | Beaver Creek | Big Goose (BG 1) | Soldier (GC 4) | Goose Creek (GC 1) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **WWTP WLA** | High | – | 0.1 | – | – | 0.4 | – | – | – | – | – | 21.1 |
| | Medium | – | 0.1 | – | – | 0.4 | – | – | – | – | – | 21.1 |
| | Low | – | 0.1 | – | – | 0.4 | – | – | – | – | – | 21.1 |
| | Weighted load | – | 0.1 | – | – | 0.4 | – | – | – | – | – | 21.1 |
| **Stormwater WLA** | High | – | – | – | – | 14.1 | – | – | – | 3.0 | – | 7.7 |
| | Medium | – | – | – | – | – | – | – | – | – | – | – |
| | Low | – | – | – | – | – | – | – | – | – | – | – |
| | Weighted load | – | – | – | – | 14.1 | – | – | – | 3.0 | – | 7.7 |
| **Upstream LA** | High | – | – | – | – | 35.7 | – | – | – | 25.0 | – | 231.6 |
| | Medium | – | – | – | – | 10.7 | – | – | – | 6.9 | – | 54.6 |
| | Low | – | – | – | – | 2.9 | – | – | – | 3.3 | – | 10.7 |
| | Weighted load | – | – | – | – | 15.9 | – | – | – | 11.3 | – | 94.5 |
| **Nonpoint Source LA** | High | 11.5 | 8.5 | 16.3 | 14.7 | 27.0 | 13.2 | 0.4 | 27.6 | 160.2 | 16.3 | 174.1 |
| | Medium | 1.8 | 2.2 | 7.5 | 3.5 | 6.5 | 3.2 | 0.1 | 8.0 | 38.8 | 3.1 | 16.6 |
| | Low | 0.8 | 0.4 | 2.4 | 0.5 | - | 1.8 | 0.1 | 3.6 | 11.9 | 1.1 | 0.0 |
| | Weighted load | 4.4 | 3.6 | 8.6 | 5.9 | 0.8 | 5.8 | 0.2 | 12.6 | 65.1 | 6.4 | 48.5 |
| **Future Growth WLA** | High | – | – | – | – | – | – | – | – | – | – | 11.5 |
| | Medium | – | – | – | – | – | – | – | – | – | – | 11.5 |
| | Low | – | – | – | – | – | – | – | – | – | – | - |
| | Weighted load | – | – | – | – | – | – | – | – | – | – | 11.5 |
| **Margin of Safety** | High | 0.6 | 0.5 | 0.9 | 0.8 | 4.1 | 0.7 | - | 1.5 | 9.9 | 0.9 | 23.5 |
| | Medium | 0.1 | 0.1 | 0.4 | 0.2 | 0.9 | 0.2 | - | 0.4 | 2.4 | 0.2 | 5.5 |
| | Low | - | - | 0.1 | - | 0.2 | 0.1 | - | 0.2 | 0.8 | 0.1 | 1.7 |
| | Weighted load | 0.2 | 0.2 | 0.5 | 0.3 | 1.6 | 0.3 | - | 0.7 | 4.2 | 0.3 | 9.7 |
| **TMDL (load capacity)** | High | 12.1 | 9.1 | 17.2 | 15.4 | 81.3 | 13.9 | 0.5 | 29.1 | 198.0 | 17.2 | 469.3 |
| | Medium | 1.9 | 2.4 | 7.9 | 3.7 | 18.6 | 3.4 | 0.1 | 8.4 | 48.1 | 3.2 | 109.2 |
| | Low | 0.8 | 0.5 | 2.5 | 0.5 | 3.5 | 1.9 | 0.1 | 3.8 | 16.0 | 1.1 | 33.4 |
| | Weighted load | 4.6 | 3.9 | 9.0 | 6.2 | 32.8 | 6.1 | 0.2 | 13.2 | 83.5 | 6.8 | 192.9 |

### 7.6.1 Waste Load Allocations

WLAs for point sources in the Goose Creek Watershed include allocations for WWTPs in the watershed, as well as stormwater flows from the City of Sheridan that are regulated under the general Wyoming MS4 permit (Collyard et al. 2005).

WLAs were assigned to five WWTPs in the watershed: the City of Sheridan WWTP; Big Horn Mountain KOA WWTP; Powder Horn Ranch WWTP; Royal Elk Properties WWTP; and the Sheridan County School District WWTP. WLAs for WWTPs are based on the maximum discharge allowed in the current permit and an *E. coli* concentration of 126 cfu/100 mL. However, some of the WWTPs are permitted at higher daily average *E. coli* concentrations (e.g., the City of Sheridan WWTP and Big Horn Mountain KOA WWTP are permitted to discharge 576 cfu/100 mL as a maximum daily average). Therefore, the WLAs identified in this TMDL may necessitate permit revisions.

The City of Sheridan WWTP and the Big Horn Mountain KOA WWTP (a minor load contributor) account for the WLAs to Goose Creek. On Little Goose Creek, the WLAs are evenly split between the Powder Horn and Royal Elk WWTPs. In Jackson Creek, the WLAs are associated with the Sheridan School District WWTP. The assigned WLAs for the WWTPs are the same under all hydrologic flow regimes.

The total WLA for stormwater sources in the watershed is estimated to be 24.8 G-cfu/day, and is allocated across the following three creeks during the high-flow regime: 14.1 G-cfu/day for Little Goose Creek, 3.0 G-cfu/day for Big Goose Creek, and 7.7 G-cfu/day for Goose Creek (Table 7.5).

These WLAs are based on currently permitted flows by the WDEQ and state *E. coli* limits. Additionally, the WLA for the City of Sheridan WWTP is reduced during low-flow conditions to meet water quality standards, thereby increasing the load reduction required for Goose Creek during that period. The calculated WLAs should be applied throughout the year.

**Table 7.5** Summary of WLAs in the Goose Creek Watershed

| Permit No. | Permit Holder | Use Type | Flow Capacity (gallons/day) | WLA (high flow) | WLA (medium flow) | WLA (low flow) | Weighted WLA | Receiving water | Catchment |
|---|---|---|---|---|---|---|---|---|---|
| WY0020010 | City of Sheridan | Municipal wastewater | 4,400,000 | 21.1 | 21.1 | 21.1 | 21.1 | Goose Creek | City of Sheridan |
| WY0026441 | Sheridan Big Horn Mountain KOA | Commercial wastewater | 16,000 | 0.1 | 0.1 | 0.1 | 0.1 | Goose Creek | GC1 |
| WY0036251 | Powder Horn Ranch, LLC | Commercial wastewater | 49,520 | 0.2 | 0.2 | 0.2 | 0.2 | Little Goose Creek | LG12 |
| WY0054399 | Royal Elk Properties, LLC | Commercial wastewater | 42,000 | 0.2 | 0.2 | 0.2 | 0.2 | Little Goose Creek | LG6 |
| WY0056308 | Sheridan County School District | Wastewater | 20,000 | 0.1 | 0.1 | 0.1 | 0.1 | Jackson Creek | Jackson |
| WYR04-0000 | City of Sheridan MS4 discharge to Little Goose Creek | MS4 stormwater | 2,953,225 | 14.1 | 0 | 0 | 14.1 | Little Goose Creek | City of Sheridan |
| WYR04-0000 | City of Sheridan MS4 discharge to Big Goose Creek | MS4 stormwater | 619,600 | 3.0 | 0 | 0 | 3.0 | Big Goose Creek | City of Sheridan |
| WYR04-0000 | City of Sheridan MS4 discharge to Goose Creek | MS4 stormwater | 1,615,016 | 7.7 | 0 | 0 | 7.7 | Goose Creek | City of Sheridan |

### *7.6.2 Load Allocations*

LAs are identified for each impaired water in the Goose Creek Watershed. Subwatershed main stems include an LA for upstream sources to account for TMDLs on contributing tributaries. In addition, upstream LAs incorporate estimates of *E. coli* die-off rates. Bacteria die-off rates were calculated using the standard decay function for bacteria (U.S. EPA 2001):

$$e^{-Kc*t}$$

"Kc" is a decay coefficient (assumed to be 0.54 for the Goose Creek TMDL based on U.S. EPA 2007; Bowie et al. 1985) and "t" is travel time in days calculated using average stream velocity and distance between points.

Upstream LAs were also calculated for the subwatersheds in the watershed to account for *E. coli* die-off associated with travel time. Upstream LAs for Goose Creek, Big Goose Creek, and Little Goose Creek were calculated as 96 G-cfu/day, 11 G-cfu/day, and 16 G-cfu/day, respectively. For example, Beaver Creek is 7.34 miles upstream of the Big Goose Creek sampling site BG4. The stream velocity in this section is 1 foot/second or 16.4 miles/day. Using these inputs, there is an estimated 45% die-off of bacteria between the Beaver Creek outlet and BG4 (65% survival rate).

For most impaired waters in the watershed, nonpoint sources make up the primary source of total LAs. Nonpoint source LAs represent the remaining load capacity after upstream LAs, WLAs, margin of safety (MOS), and future growth have been accounted. Nonpoint source LAs varied from a low of 1 G-cfu/day for Little Goose Creek to a high of 65 G-cfu/day for Big Goose Creek, although most segments were in the 4 to 13 G-cfu/day range.

### *7.6.3 Margin of Safety*

The CWA requires that the load capacity calculated in TMDLs must also include a MOS. The MOS accounts for uncertainty in the loading calculations. It does not have to be the same for different waterbodies, because differences exist in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs with the use of conservative assumptions in the load calculation, or be specified explicitly as a proportion of the total load. This TMDL uses an MOS of 5%.

The explicit 5% MOS incorporated into the LAs for the Goose Creek Watershed was estimated by allocating 5% of the TMDL to the MOS (see Table 7.3). For the Goose Creek Watershed, this corresponds to roughly 10 G-cfu/day for Goose Creek, 4 G-cfu/day for Big Goose Creek, and 2 G-cfu/day for Little Goose Creek. The MOS for smaller tributaries, such as Jackson Creek, Rapid Creek, and Park Creek, range from negligible to 0.7 G-cfu/day.

### *7.6.4 Future Growth*

Future growth is incorporated into the Goose Creek TMDLs through projected peak flow estimates for the City of Sheridan WWTP in 2025 (6.8 cfs), as described in the *City of Sheridan Wastewater Collection System Assessment* (HKM 2008). Assuming that the Wyoming water quality standard for *E. coli* will remain consistent, and assuming an increase in plant treatment discharge, a future WLA was calculated and compared to current WWTP WLAs. The difference in WLAs was identified as the potential future growth WLA.

Based on this approach, approximately 11 G-cfu/day of *E. coli* was incorporated into the TMDL allocated load for Goose Creek. This estimate does not incorporate low-flow conditions into the allocation calculation. However, because the allocation is based on peak flows (instead of average flows), this assumption should address low-flow periods.

# CHAPTER 8 SEDIMENT TMDL

Wyoming's 2006 305(b) Report and 303(d) List (WDEQ 2006) listed Little Goose Creek and Goose Creek in the City of Sheridan as impaired for sediment. More recently, Wyoming's 2008 305(b) Integrated Report and 303(d) List (WDEQ 2008) lists Little Goose Creek as impaired for sediment from the City of Sheridan upstream to above Big Horn; and Goose Creek as impaired for sediment from the confluence of Big Goose Creek and Little Goose Creek to an undetermined distance downstream. However, in 2009 WDEQ changed the 2008 listings for Little Goose Creek and Goose Creek back to the description provided in the Wyoming's 2006 305(b) Report and 303(d) List (WDEQ 2006). Therefore, this sediment TMDL addresses Little Goose Creek and Goose Creek in the City of Sheridan.

Impairments of the aquatic life uses on Little Goose Creek and Goose Creek are determined primarily based on macroinvertebrate data and quantitative measures of stream morphology. Chemical, physical, and other ancillary data and information supplemented these metrics in a weight-of-evidence approach for making the determination. The biological health of the creeks was determined by comparing the biological potential of the stream to observed biological communities in the stream. This analysis was based on a regionally calibrated macroinvertebrate index called the WSII and a statewide macroinvertebrate-based predictive model called RIVPACS. In the case of the Little Goose Creek and Big Goose Creek impairments, both sediment and habitat are listed as causes of biological criteria exceedances (WDEQ 2008). This TMDL only addresses the sediment-related portion of the impairment. Additional work to restore the physical habitat of the stream may be warranted to attain full support status.

## 8.1 Sources

The City of Sheridan is drained by 17 urban drainage areas that flow directly to Little Goose Creek, Big Goose Creek, and Goose Creek (see Map 12; Table 6.8). WDEQ sampled stormwater from stormwater lines (outfalls) in 1993 and 1994 and completed a study of stormwater runoff in 2004 (WDEQ 2005). SCCD also collected stormwater samples in 2001 and 2002 from one outfall. WDEQ conducted an assessment of these data and concluded that stormwater flows are contributing excessive fine sediment that is causing physical degradation of Little Goose Creek and Goose Creek in the City of Sheridan, and is keeping these segments from supporting their aquatic life and fisheries uses (WDEQ 2008). Therefore, stormwater is the primary source considered for calculation of the sediment TMDL.

Besides stormwater flows, other sources of sediment include upstream sources associated with overland erosion and in-stream erosion. The City of Sheridan municipal WWTP and the City of Sheridan Big Horn Mountain KOA WWTP also contribute minor sediment to the creeks. Upstream sources on Little Goose Creek and Big Goose Creek are minor contributors of sediment to Little Goose and Goose Creek reaches within the City of Sheridan. Upstream load includes nonpoint sources, natural stream erosion, and the discharge from three small wastewater treatment plants on Little Goose Creek and Jackson Creek (a tributary to Little Goose Creek).

## 8.2 Water Quality Sediment Targets

Many western states' water quality standards for sediment, including Wyoming, are currently defined by narrative criteria to prevent sediment from exceeding quantities that would impair designated uses. This approach allows for flexibility in management of sediment TMDLs, but also requires interpretation on a site-specific basis to identify appropriate targets. To facilitate this effort, the Idaho Department of Environmental Quality (IDEQ) has applied a numerical sediment target for use in many state sediment TMDLs. Although a range of measures are available, TSS is a commonly used proxy for sediment concentrations. The TSS sediment target is typically set at less than or equal to 80 mg/L for acute events lasting no more than 14 days, and less than or equal to 50 mg/L as a monthly average.

As stated in the *Snake River-Hells Canyon TMDL* (2004), "It is the professional opinion of IDEQ and ODEQ [Oregon Department of Environmental Quality] that these targets will be protective of both aquatic life (EIFAC 1964; NAS/NAE 1973; IDEQ 1991; CH2MHill 1998; Newcombe and Jensen 1996) and water quality, and will meet the requirements of the CWA. It is the professional opinion of IDEQ and ODEQ that attainment of these targets represents a valid interpretation of narrative standards and will result in support of the designated uses within the system." IDEQ has previously used the seasonal target of 50 mg/L and 80 mg/L for TSS in several subbasins, including the Boise River (IDEQ 1999), Portneuf River (IDEQ 2001a), Goose Creek (IDEQ 2003), and Blackfoot River (IDEQ 2001b).

This target concentration is in line with other state standards and targets. Nevada has state standards for suspended solids in rivers and creeks that range from 25 to 80 mg/L (Nevada Administrative Code 445A.119-445.A.225). Sediment in the Yakima River in Washington was assessed using a TSS target of 56 mg/L (Joy and Patterson 1997). For Utah's Bear River, TSS targets were set at 35 mg/L for smaller streams and 90 mg/L for larger streams (Utah Department of Environmental Quality 1995), whereas the same river in Idaho had a TSS target of 60 to 80 mg/L during lower and upper basin runoff and 35 to 60 mg/L during summer and winter base flow (IDEQ 2006).

The target also falls within the range, 25 to 80 mg/L, of suspended solids recommended by the European Inland Fisheries Advisory Commission for maintaining good to moderate fisheries. Newcombe and Jensen's (1996) review of 80 published reports on suspended sediment in streams and estuaries found that lethal effects in rainbow trout began at observed concentrations of 50 to 100 mg/L, when those concentrations were maintained for 14 to 60 days.

A sediment water quality target of 50 mg/L TSS is used for the Little Goose Creek and Goose Creek sediment TMDLs. This standard was applied to stormwater generated from a design storm (24-hour, two-year storm) to calculate the TMDL. The standard applies to all storms of this size and should be applied throughout the year. Other sources of sediment are already well below the 50 mg/L limit, as are the current TSS concentration in the streams.

## 8.3 Current Load Summary

### *8.3.1 Stormwater*

Collectively, the urban stormwater system drains 2,027 acres of the city, all in the City of Sheridan. Additional acreage in the city is drained by 25 rural drainage basins, the majority of which also discharge directly to streams (see Map 13; Table 6.8). The City of Sheridan's SWMP from 1987 details the drainage network for stormwater in the city as well as recommended improvements to the stormwater system. Historically, many of the large storm drains in the City of Sheridan were owned and maintained by WYDOT. Currently all storms drains in the City of Sheridan are managed by the city.

Stormwater flows from urban areas consist of concentrated flows that accumulate from streets, parking areas, rooftops, and other impervious surfaces. Discharges from MS4s will be permitted under the Wyoming General MS4 Stormwater Permit for Small Dischargers under the WYPDES (WYR04-0000), renewed on December 1, 2008. Under the general permit, a municipality may discharge stormwater to a water of the State of Wyoming in accordance with the SWMP. Stormwater flow in the City of Sheridan is covered under the general MS4 permit.

#### 8.3.1.1 SEDIMENT DATA

Limited data exist from stormwater drains in the city to characterize stormwater loads to surface waters. Data were collected in 1993 and 1994 by the WDEQ at four of the 17 urban drainage outfalls. In addition, the SCCD sampled the S-line (SCCD site LG3) in the summer of 2001 and 2002. The WDEQ collected additional data in 2004 as part of a stormwater management report for the City of Sheridan (WDEQ 2005). Sampling included one rain event (S-line), one snowmelt runoff event (Q-line), and two street cleaning events (P-line and N-line). From these sampling events there are 56 TSS results for stormwater.

SCCD developed a regression for TSS and turbidity; however, that correlation was conducted on river samples and does not apply to stormwater. Further, the number of TSS and turbidity data pairs is not sufficient to allow for a correlation and conversion of stormwater turbidity data to develop a stormwater specific regression for the City of Sheridan.

Stormwater samples collected by WDEQ in 1993 and 1994 are identified as SW1, SW2, SW3 and SW4. These samples were collected from storm drain lines identified as the S-line (SW1), the G-line (SW2), the D-line (SW3), and the D+E-line (SW4). In 2001 and 2002 SCCD also collected stormwater samples from the S-line (SCCD ID - LG3) for TSS analysis. In 2004 WDEQ collected samples from the N-line, P-line, Q-line and S-line; however, only one sample (from the S-line) was analyzed for TSS. The stormwater drains that discharge into the 303(d)-listed creeks—Little Goose Creek and Goose Creek—are summarized as follows:

- Twelve stormwater drains discharge to Little Goose Creek: G-line, H-line, I2-line, I-line, J-line, N-line, O-line, P-line, Q-line, RDA 19, RDA 20, and S-line.
- Five stormwater drains discharge to Goose Creek: A-line, B-line, D+E-line, D-line, and F-line
- Two stormwater drains discharge to Big Goose Creek, a tributary to Goose Creek: K-line and RDA-7A

Statistical analysis of the available stormwater TSS sampling results for these drains was conducted for each impaired creek. The minimum TSS concentration was below laboratory detection limits (2 to 5 mg/L) for all samples. The maximum stormwater TSS concentration delivered to Little Goose Creek was 1,796 mg/L and the average was 213 mg/L. For stormwater flows to Goose Creek, the maximum TSS concentration was 777 mg/L and the average was 196 mg/L. For stormwater flows to Big Goose Creek, the average TSS concentration was 2,107 mg/L. Average TSS concentrations were used, in conjunction with modeled stormwater flows, to calculate stormwater sediment loading to these impaired creeks.

#### 8.3.1.2 STORMWATER FLOW MODELING

Runoff from the City of Sheridan was estimated using the rainfall-runoff curve number method developed by the USDA and described in the National Engineering Handbook (USDA-NRCS 2004). Curve numbers are unitless representations of the portion of runoff expected for an area based on unique soil and land-use combinations. Curve numbers range from a low of 30 to a high of 100. Higher curve numbers indicate more runoff during a storm event and are influenced by slow draining soils and impervious cover. All soil types in the city were classified by their hydrologic class (A, B, C, or D) as defined in the SSURGO database. The soils of interest are Class D and Class A soils. Class D soils are general poorly drained and shallow, whereas Class A soils are generally well drained and deep. Soil and land-use combinations were calculated for the City of Sheridan using GIS, and each was assigned a representative curve number using tables provided in Win-TR55 (Table 8.1). Using this information, an area-weighted curve number (a unitless value used to estimate runoff from an area during a storm) for this area was found to be 80.

**Table 8.1** Summary of Curve Numbers for Land Use and Soil Hydrologic Groups Found in the City of Sheridan

| Land Use | Soil Hydrologic Group | Curve Number | Acres |
|---|---|---|---|
| Cultivated Crops | B | 78 | 19.3 |
| Cultivated Crops | C | 85 | 26.0 |
| Deciduous Forest | B | 58 | 1.3 |
| Deciduous Forest | D | 79 | 0.2 |
| Developed, High Intensity | B | 92 | 6.6 |
| Developed, High Intensity | C | 94 | 48.6 |
| Developed, High Intensity | D | 95 | 0.8 |
| Developed, High Intensity | Unknown | 92 | 168.1 |
| Developed, Low Intensity | A | 77 | 0.4 |
| Developed, Low Intensity | B | 85 | 130.6 |
| Developed, Low Intensity | C | 90 | 1,045.2 |
| Developed, Low Intensity | D | 92 | 9.2 |
| Developed, Low Intensity | Unknown | 85 | 492.4 |
| Developed, Medium Intensity | B | 72 | 43.3 |
| Developed, Medium Intensity | C | 81 | 418.8 |
| Developed, Medium Intensity | D | 86 | 7.0 |
| Developed, Medium Intensity | Unknown | 81 | 292.0 |
| Developed, Open Space | A | 49 | 1.3 |
| Developed, Open Space | B | 69 | 239.3 |
| Developed, Open Space | C | 79 | 565.5 |
| Developed, Open Space | D | 84 | 86.0 |
| Developed, Open Space | Unknown | 69 | 256.4 |
| Emergent Herbaceous Wetlands | B | 0 | 10.8 |
| Emergent Herbaceous Wetlands | C | 0 | 10.3 |
| Evergreen Forest | B | 55 | 3.3 |
| Grassland/Herbaceous | A | 35 | 0.7 |
| Grassland/Herbaceous | B | 56 | 64.7 |
| Grassland/Herbaceous | C | 70 | 51.9 |
| Grassland/Herbaceous | D | 77 | 3.1 |
| Pasture/Hay | B | 69 | 84.4 |
| Pasture/Hay | C | 79 | 118.8 |
| Shrub/Scrub | A | 35 | 1.4 |
| Shrub/Scrub | B | 56 | 63.4 |
| Shrub/Scrub | C | 70 | 71.2 |
| Shrub/Scrub | D | 77 | 15.9 |

**Table 8.1** Summary of Curve Numbers for Land Use and Soil Hydrologic Groups Found in the City of Sheridan

| Land Use | Soil Hydrologic Group | Curve Number | Acres |
|---|---|---|---|
| Shrub/Scrub | Unknown | 56 | 0.2 |
| Woody Wetlands | B | 0 | 16.2 |
| Woody Wetlands | C | 0 | 30.1 |
| **Area-weighted average Curve Number** | | **80.05** | |

Runoff was calculating using the curve number method according to the following equations:

$$Q = (P- 0.2\,S^2)/(P + 0.8S)$$

$$S = (1000/CN) - 10$$

"Q" is discharge (inches), "CN" is the curve number, and "P" is precipitation in inches. To obtain the volume of runoff during the storm in units of acre-feet, Q is multiplied by acres and divided by 12 inches per foot.

The two-year, 24-hour design storm precipitation, estimated from precipitation frequency maps obtained from the WRCC (NOAA 1973) was estimated at 1.7 inches per day for Sheridan and used to calculate stormwater runoff to the sediment-impaired streams. Therefore, the Little Goose Creek and Goose Creek sediment TMDLs are calculated directly as daily loads.

### 8.3.1.3 STORMWATER LOAD SUMMARY

The current stormwater sediment load to Little Goose Creek and Goose Creek was determined using the modeled flows for each stormwater drain (see Section 8.3.1.2) and the average TSS concentration from stormwater sampling (see Section 8.3.1.1). The loads are summarized in Table 8.2 for Little Goose Creek and cumulatively for Goose Creek in Table 8.3.

**Table 8.2** Little Goose Creek Stormwater: Modeled Flow and Estimated Current Load Summary for Sediment

| Stormwater Flow Drain | Flow ($m^3$/day) | Current Load (kg/day) |
|---|---|---|
| G-line | 643 | 137 |
| H-line | – | – |
| I2-line | 5,867 | 1,250 |
| I-line | 3,321 | 707 |
| J-line | 12,257 | 2,611 |
| N-line | 1,129 | 240 |
| O-line | 948 | 202 |
| P-line | 4,428 | 943 |

**Table 8.2** Little Goose Creek Stormwater: Modeled Flow and Estimated Current Load Summary for Sediment

| Stormwater Flow Drain | Flow ($m^3$/day) | Current Load (kg/day) |
|---|---|---|
| Q-line | 3,634 | 774 |
| RDA 19 | 4,380 | 933 |
| RDA 20 | 2,934 | 625 |
| S-line | 6,824 | 1,453 |
| **Total** | **46,364** | **9,875** |

**Table 8.3** Goose Creek Stormwater (including Big Goose Creek, a tributary to Goose Creek): Modeled Flow and Estimated Current Load Summary for Sediment

| Stormwater Flow Drain | Flow ($m^3$/day) | Current Load (kg/day) |
|---|---|---|
| **Big Goose Creek** | | |
| K-line | 967 | 200 |
| RDA 7A | 8,760 | 1,814 |
| ***Subtotal Big Goose Creek*** | ***9,727*** | ***2,014*** |
| **Little Goose Creek** | | |
| ***Subtotal Little Goose Creek**** | ***46,364*** | ***9,875*** |
| **Goose Creek** | | |
| A-line | 2,773 | 543 |
| B-line | 1,631 | 320 |
| D+E-line | 14,788 | 2,899 |
| D-line | 5,620 | 1,102 |
| F-line | 543 | 106 |
| ***Subtotal Goose Creek*** | ***25,355*** | ***4,970*** |
| **Cumulative Total Stormwater to Goose Creek** | **81,446** | **16,859** |

*(see Table 8.2 for details)

### 8.3.2 Wastewater Treatment Plants

There are two WWTPs that discharge sediment to the impaired section of Goose Creek in the City of Sheridan: the City of Sheridan WWTP and the Big Horn Mountain KOA WWTP. The permits for these plants are summarized in Table 8.4, and descriptions of each treatment plant follow. Both plants have an existing TSS effluent target of 30 mg/L, which is protective of the 50 mg/L water quality target identified for point sources to the stream in Section 8.2.

In addition, there are three WWTPs that are permitted to discharge sediment upstream of the City of Sheridan: Powder Horn Ranch and Royal Elk Properties, which discharge to Little Goose Creek, and Sheridan County School District, which discharges to Jackson Creek, a tributary to Little Goose Creek. These other small WWTPs discharge small quantities of sediment to streams above the city limits and are not described in detail in this section. There is limited data on current TSS discharges, and it was assumed that current loads are the permitted load. These plants also have an existing TSS effluent target of 30 mg/L, which is protective of the 50 mg/L water quality target identified for point sources to the stream.

**Table 8.4** Summary of WYPDES Permits in the Goose Creek Watershed that are Permitted to Discharge Sediment

| Permit Number | Permit Holder | Use Type | Effective Until | Discharge Flow Limit (MGD) | TSS limit (mg/L) | Permitted Load (kg/day) |
|---|---|---|---|---|---|---|
| WY0020010 | City of Sheridan | Municipal wastewater | 5/31/2013 | 4.4 | 30 | 499.7 |
| WY0026441 | Sheridan Big Horn Mountain KOA | Commercial wastewater | 5/31/2013 | 0.016 | 30 | 1.82 |
| WY0036251 | Powder Horn Ranch, LLC | Commercial wastewater | 4/30/2011 | 0.050 | 30 | 5.62 |
| WY0054399 | Royal Elk Properties, LLC | Commercial wastewater | 6/30/2011 | 0.042 | 30 | 4.77 |
| WY0056308 | Sheridan County School District | Wastewater | 4/30/2013 | 0.020 | 30 | 2.27 |

#### 8.3.2.1 CITY OF SHERIDAN MUNICIPAL WASTEWATER TREATMENT

The City of Sheridan currently provides wastewater service to 6,930 customers (15,939 people) inside city limits, and an additional 140 customers (322 people) outside city limits in the Downer Neighborhood Improvement and Service District. The WWTP uses a standard trickling filter design followed by an oxidation ditch, chlorination, and dechlorination. The WWTP discharges to Goose Creek and is designed to treat up to 4.4 MGD. The permitted TSS concentration for the plant is 30 mg/L. The plant is currently discharging TSS values well below the permitted concentration (Table 8.5).

**Table 8.5** Summary of Daily and Monthly Flow and Total Suspended Solids Data for the City of Sheridan WWTP

| Year | Monthly Average *TSS* (mg/L) | Daily Maximum *TSS* (mg/L) | Daily Average Discharge (MGD) | Daily Sediment Load (kg/day) |
|---|---|---|---|---|
| 2001 | 5.00 | 7.00 | 2.60 | – |
| 2002 | 5.50 | 8.08 | 3.23 | – |
| 2003 | 3.40 | 4.80 | 3.56 | – |
| 2004 | 3.43 | 5.43 | 3.17 | – |
| 2005 | 3.08 | 4.42 | 3.68 | – |
| 2006 | 3.75 | 6.17 | No data | – |
| 2007 | 4.63 | 6.92 | No data | – |
| 2008 | 3.75 | 5.53 | 3.36 | – |
| **Average** | **4.03** | **6.06** | **3.33** | **67.12** |
| Source | DMR | DMR | DMR | Calculated |

#### 8.3.2.2 BIG HORN MOUNTAIN KOA WWTP

The Big Horn Mountain KOA WWTP is designed to discharge 0.016 MGD, and consists of an extended aeration package plant with chlorination disinfection equipment. The facility is located approximately 1 mile north from the City of Sheridan WWTP and discharges near the city limit into Goose Creek. The permitted TSS concentration for the plant is 30 mg/L. The plant is currently discharging TSS values well below the permitted concentration (see Table 8.6).

**Table 8.6** Summary of Daily and Monthly Flow and Total Suspended Solids Data for the Big Horn Mountain KOA WWTP

| Year | Monthly Average TSS (mg/L) | Daily Average *TSS* (mg/L) | Daily Average Discharge (MGD) | Daily TSS Load (kg/day) |
|---|---|---|---|---|
| 2002 | 9.38 | 11.73 | 0.63 | – |
| 2003 | 7.60 | 7.60 | 2.51 | – |
| 2004 | 11.82 | 9.14 | – | – |
| 2005 | 21.00 | 22.22 | – | – |
| 2006 | 14.33 | 15.14 | – | – |
| 2007 | 14.29 | 13.33 | – | – |
| 2008 | 20.00 | 20.00 | – | – |
| **Average** | **13.52** | **11.73** | **0.72** | **0.82** |
| Source | DMR | DMR | DMR | Calculated |

### *8.3.3 Upstream Nonpoint Source Sediment Load*

Little Goose Creek and Big Goose Creek carry some sediment from the upper and middle segments of the Goose Creek Watershed into the City of Sheridan. The current upstream load of sediment, during high flows, was estimated by multiplying the average high flow (defined by the flow duration curve for each sampling site as the high hydrologic flow regimes) recorded in Little Goose Creek and Big Goose Creek by the average TSS concentration in the creeks. Data from LG6 and BG4, the sampling sites just above the City of Sheridan on Little Goose Creek and Big Goose Creek, were used in the calculations.

The average flow during the high hydrologic flow regime at LG6 on Little Goose Creek is 23.9 cfs, which equates to 58,375 $m^3$/day. The average TSS concentration at LG6 during high flow is 10 mg/L, returning an average water column sediment load during high-flow periods of 584 kg/day. Compared to the stormwater sediment load, the upstream water column load represents 6% of the load delivered to the impaired section of Little Goose Creek in the City of Sheridan. The point source permitted loads of 14 kg/day were subtracted from the total, leaving a remaining 570 kg/day of sediment from upstream nonpoint sources.

The average flow during the high hydrologic flow regime at BG4 on Big Goose Creek is 89.6 cfs, which equates to 219,140 $m^3$/day. The average TSS concentration at BG4 during high flow is 2.2 mg/L returning an average water column sediment load during high-flow periods of 482 kg/day.

The best estimates of total sediment load in a stream are derived from both actual bed and suspended load samples collected at various flows. The upstream load calculated using the method described above includes both water column and bed loads of sediment. Although no sediment bed load data were available to use directly in the calculation, the sediment TMDL is calculated for high flow events, when bed load is resuspended into the water column. Any additional bed load is considered to be negligible and well within the MOS identified for the TMDL. Compared to the stormwater and wastewater sediment loads, the upstream water column load from Big Goose Creek and Little Goose Creek together represents 6% of the load delivered to the impaired section of Goose Creek in the City of Sheridan. This is a very low contribution to the impairment, considering the calculations represent high flow conditions when bed load has been resuspended into the water column. Upstream flow represents 74% of the flow in the creeks during high flow periods, compared to 24% from stormwater sources and 4% from the other point sources.

### 8.3.4 Current Load Summary

A summary of current sediment load to the impaired sections of Little Goose Creek and Goose Creek are provided in Tables 8.7 and 8.8. In both creeks, the dominant source of sediment to the creek is from stormwater. The water column load from upstream nonpoint sources accounts for only 6% of the total load to the creeks during high-flow periods. These load calculations do not include bed load from upstream sources. However, there is currently no sediment impairment identified for Little Goose Creek and Big Goose Creek upstream of the City of Sheridan. This indicates that both the bed load and the water column sediment load are currently protective of designated uses in the watershed, even if they cannot be quantified.

**Table 8.7** Summary of Current Sediment Loads (kg/day) to the impaired Section of Little Goose Creek Sediment TMDL

| Source | Load (kg/day) | Percent of Total |
|---|---|---|
| Stormwater (MS4) | 9,875 | 94% |
| Wastewater | 14 | 0% |
| Little Goose Creek Upstream Nonpoint Sources | 570 | 6% |
| **Total** | **10,459** | **100%** |

**Table 8.8** Summary of Current Sediment Loads (kg/day) to the Impaired Section of Goose Creek

| Source | Load (kg/day) | Percent of Total |
|---|---|---|
| **Stormwater** | | |
| Little Goose Creek Stormwater | *9,875* | *54.9%* |
| Big Goose Creek Stormwater | *2,014* | *11.2%* |
| Goose Creek Stormwater | *4,970* | *27.6%* |
| ***Stormwater Subtotal*** | ***16,859*** | ***93.7%*** |
| **Wastewater** | | |
| City of Sheridan WWTP | *67* | <1% |
| Big Horn Mountain KOA WWTP | *1* | <0.1% |
| Little Goose Creek WWTPs | *14* | <1% |
| ***Wastewater Subtotal*** | ***82*** | ***<1%*** |
| Big Goose Creek Upstream Nonpoint Sources | 482 | 2.7% |
| Little Goose Creek Upstream Nonpoint Sources | 570 | 3.2% |
| **Total** | **17,992** | **100%** |

# 8.4 Loading Capacity and Allocation of TMDL

The loading capacity of sediment to Little Goose Creek and Goose Creek includes stormwater loads, wastewater loads, and upstream nonpoint source loads. The major source of sediment to streams in the City of Sheridan, as identified by WDEQ (WDEQ 2008), is stormwater. Therefore, the TMDL focuses on load reductions from stormwater sources in the city.

To achieve necessary sediment load reductions, WLAs have been identified for regulated point sources in the watershed, and LAs have been applied to nonpoint sources on upstream segments of the impaired streams. The following sections describe the methods used to calculate the allocations, and the results are summarized below in Tables 8.9 and 8.10 for Little Goose Creek and Goose Creek, respectively.

LAs for stormwater in the city are based on the current stormwater flow estimated for each storm drain in the city and a stormwater target of 50 mg/L of TSS. WLAs for the WWTPs in the watershed are the current permitted load of TSS from these plants. Both of the plants in the City of Sheridan are well below the current permitted TSS concentrations of 30 mg/L. Finally, the LAs assigned to upstream nonpoint sources are the current estimates of water column sediment loads from Little Goose Creek and Big Goose Creek. The current loads were used as the allocated load because concentrations of water column TSS in these creeks are well below the 50 mg/L water quality target. The upstream load portion of the TMDL could be improved with bed load data in the future.

**Table 8.9** Summary of Allocated Loads for the Little Goose Creek Sediment TMDL

| Source | Allocated Load (kg/day) |
|---|---|
| **Wastewater WLAs** | |
| Powder Horn Ranch, LLC (WY0036251) | 6 |
| Royal Elk Properties, LLC (WY0054399) | 5 |
| Sheridan County School District (WY0056308) | 3 |
| ***Wastewater WLAs Subtotal*** | **14** |
| Stormwater WLAs | 2,086 |
| Little Goose Creek Upstream LA | 570 |
| Margin of Safety | 232 |
| Future Growth | 0 |
| **Total** | **2,902** |

**Table 8.10** Summary of Allocated Loads for the Goose Creek Sediment TMDL

| Source | Allocated Load (kg/day) |
|---|---|
| **Stormwater WLAs** | |
| Little Goose Creek Stormwater WLA | 2,086 |
| Big Goose Creek Stormwater WLA | 438 |
| Goose Creek Stormwater WLA | 1,141 |
| ***Stormwater WLAs Subtotal*** | ***3,665*** |
| **Wastewater WLAs** | |
| City of Sheridan WWTP (WY0020010) | *500* |
| Big Horn Mountain KOA WWTP (WY0026441) | *2* |
| WLAs for Little Goose Creek | *14* |
| ***Wastewater WLAs Subtotal*** | ***516*** |
| **Upstream Nonpoint Source LAs** | |
| Big Goose Creek Upstream LA | 482 |
| Little Goose Creek Upstream LA | 570 |
| ***Upstream LAs Subtotal*** | ***1,052*** |
| **Other Allocations** | |
| Margin of Safety | 407 |
| Future Growth | 273 |
| ***Other Allocations Subtotal*** | **680** |
| **Total** | **5,913** |

## 8.4.1 Waste Load Allocations

### 8.4.1.1 LITTLE GOOSE CREEK

WLAs for point sources and stormwater flows from the City of Sheridan will be regulated under the general Wyoming MS4 permit (Collyard et al. 2005).

No point sources, other than stormwater flows, are known to exist along Little Goose Creek in the City of Sheridan. WLAs totaling 14 kg/day were assigned to three point sources upstream of the City of Sheridan, two of which discharge to Little Goose Creek, and the third one discharging to Jackson Creek, a tributary to Little Goose Creek.

The TMDL for sediment to Little Goose Creek from stormwater, after accounting for a 10% MOS (232 kg/day), is 2,086 kg/day, which requires a load reduction of sediment from stormwater to the creek of 7,589 kg/day, or 79%. The stormwater load allocations are distributed across the 12 stormwater drains listed in Table 8.11. The sediment load capacity or TMDL was calculated for each stormwater drain using the TSS water quality target of 50 mg/L. A summary of the modeled flow, current load, and load capacity (TMDL) for stormwater sediment discharged to Little Goose Creek is provided in Table 8.11.

**Table 8.11** Little Goose Creek Stormwater: Modeled Flow, Current Load, and TMDL Load (including a 10% MOS) Summary for Sediment

| Stormwater Flow Drain | Flow ($m^3$/day) | Current Load (kg/day) | TMDL (kg/day) |
|---|---|---|---|
| G-line | 643 | 137 | 29 |
| H-line | – | | - |
| I2-line | 5,867 | 1,250 | 264 |
| I-line | 3,321 | 707 | 149 |
| J-line | 12,257 | 2,611 | 552 |
| N-line | 1,129 | 240 | 51 |
| O-line | 948 | 202 | 43 |
| P-line | 4,428 | 943 | 199 |
| Q-line | 3,634 | 774 | 164 |
| RDA 19 | 4,380 | 933 | 197 |
| RDA 20 | 2,934 | 625 | 132 |
| S-line | 6,824 | 1,453 | 307 |
| **Total** | **46,364** | **9,875** | **2,086** |

The TMDL also includes a load allocation of 570 kg/day for upstream nonpoint sources on Little Goose Creek. The cumulative sediment TMDL for Little Goose Creek is 2,902 kg/day.

### 8.4.1.2 GOOSE CREEK

WLAs were assigned to two WWTPs that discharge to Goose Creek: the City of Sheridan WWTP and the Big Horn Mountain KOA WWTP. WLAs for WWTPs are based on the maximum discharge and maximum TSS concentration (30 mg/L) allowed in the current permit and total 502 kg/day. In addition, wastewater WLAs for point sources along Little Goose Creek (14 kg/day) were also carried downstream to Goose Creek.

Stormwater WLAs for Little Goose Creek (2,086 kg/day) were also carried downstream to Goose Creek. The total WLA allocated to stormwater sources along Big Goose Creek is 438 kg/day. The total WLA allocated load for stormwater sources along Goose Creek is 1,141 kg/day, allocated across the five stormwater drains listed in Table 8.12.

The modeled flow, current load, and load capacity (TMDL) for stormwater sediment discharged to Goose Creek is provided in Table 8.12. The cumulative TMDL for sediment to Goose Creek is 5,913 kg/day, which includes upstream stormwater loads from Little Goose Creek and Big Goose Creek (584 kg/day and 482 kg/day, respectively). The cumulative TMDL for Goose Creek requires a load reduction from stormwater to the creeks of 13,194 kg/day, or 78%.

**Table 8.12** Goose Creek Stormwater (including Big Goose Creek, a tributary to Goose Creek): Modeled Flow, Current Load, and TMDL Load Summary for Sediment

| Stormwater Flow Drain | Flow ($m^3$/day) | Current Load (kg/day) | TMDL (kg/day) |
|---|---|---|---|
| **Big Goose Creek** | | | |
| K-line | 967 | 200 | 44 |
| RDA 7A | 8,760 | 1,814 | 394 |
| ***Subtotal Big Goose Creek*** | ***9,727*** | ***2,014*** | ***438*** |
| **Little Goose Creek** | | | |
| ***Subtotal Little Goose Creek**** | ***46,364*** | ***9,875*** | ***2,086*** |
| **Goose Creek** | | | |
| A-line | 2,773 | 543 | 125 |
| B-line | 1,631 | 320 | 73 |
| D+E-line | 14,788 | 2,899 | 665 |
| D-line | 5,620 | 1,102 | 253 |
| F-line | 543 | 106 | 24 |
| ***Subtotal Goose Creek*** | ***25,355*** | ***4,970*** | ***1,141*** |
| **Cumulative Total Stormwater To Goose Creek** | **81,446** | **16,859** | **3,665** |

* See Table 8.11 for details.

## 8.4.2 Upstream Nonpoint Source Load Allocations

LAs are identified for nonpoint sources upstream of the City of Sheridan for Little Goose Creek and Big Goose Creek. The Little Goose Creek upstream LAs are included in the Little Goose Creek TMDL, whereas both the Little Goose Creek and Big Goose Creek upstream LAs are included in the Goose Creek TMDL because it is the lowermost sediment-impaired segment in the watershed. In both cases, the current water column load during high-flow periods is used as the LA.

The upstream nonpoint source LA for Little Goose Creek is 570 kg/day, and the upstream LA for Big Goose Creek is 482 kg/day.

### 8.4.3 Margin of Safety

The CWA requires that TMDLs must also include a MOS. The MOS accounts for uncertainty in the loading calculations. It does not have to be the same for different waterbodies, because differences exist in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs with the use of conservative assumptions in the load calculation, or be specified explicitly as a proportion of the total load. The Little Goose Creek and Goose Creek sediment TMDLs use an explicit MOS of 10%. This MOS is higher than the MOS used for the pathogen TMDLs due to the higher level of uncertainty associated with the relationship between sediment load to the creek and macroinvertebrates and other biological criteria.

The explicit 10% MOS was incorporated into the WLAs for stormwater flowing to Little Goose Creek and Goose Creek and corresponds to 232 kg/day and 407 kg/day, respectively.

In addition to the explicit MOS, the Goose Creek sediment TMDLs also incorporate conservative assumptions to meet the MOS requirement, including the following:

1. Selection of a water quality target (50 mg/L) for stormwater WLAs. This target is typically applied as an in-stream value. Therefore, the dilution of stormwater in the creek was not accounted for in the TMDL, thereby providing assurance that if the WLAs for stormwater are attained the sediment impairment in the creek will be achieved.
2. There will be significant dilution of stormwater discharge from upstream flows. Upstream flows account for 74% of the flow during storm events, compared to 24% from stormwater outfalls. Therefore, the stormwater loads will be further diluted from 50 mg/L down to less than 30 mg/L instream based on this dilution factor.
3. The TSS sediment target for acute events is typically 80 mg/L in other states, and less than or equal to 50 mg/L as a monthly average. This TMDL uses 50 mg/L for acute events.
4. Existing point sources in the City of Sheridan have an existing TSS effluent target of 30 mg/L, which is protective of the 50 mg/L water quality target identified for point sources to the stream.
5. No impairments on stream segments upstream of the City of Sheridan have been identified, providing confidence that addressing the stormwater load in the city will result in attainment of water quality standards.

### 8.4.4 Future Growth

Future growth is incorporated into the Goose Creek TMDLs through projected peak flow estimates for the City of Sheridan WWTP in 2025 (6.8 cfs), as described in the *City of Sheridan Wastewater Assessment* (HKM 2008). Assuming a TSS water quality target of 30 mg/L, and assuming an increase in plant treatment discharge, a future WLA was calculated and compared to current WWTP WLAs. The difference in WLAs was identified as the potential future growth WLA and totals 273 kg/day TSS. The Big Horn Mountain KOA WWTP is well below its currently permitted flow and TSS concentration, and there are no plans for expansion of this treatment plant. Therefore the WLA for the KOA WWTP accounts for any future growth and does not need to be explicitly incorporated into the future growth calculations. Furthermore, because no point sources are known along Little Goose Creek, no future growth was considered for this creek.

## 8.5 Seasonality

The TMDL for sediment was developed around a two-year, 24-hour design storm because the primary source of sediment to the impaired sections of Little Goose Creek and Goose Creek is stormwater. Stormwater BMPs designed to attain the TMDL under a two-year, 24-hour design storm will also meet water quality standards for smaller storms. The TMDL applies to storms throughout the year. The critical periods for addressing sediment load to the creeks are the first storm following the beginning of the spring melt, when sediment build-up over the winter is at greatest risk for washing into the creek. During this time vegetation might not be established enough to prevent erosion or reduce sediment runoff from urban areas. Other critical periods are summer storms that occur following a long, dry period when sediment may have built up on streets and other impervious surfaces. The calculated WLAs should be applied throughout the year.

# CHAPTER 9 GOOSE CREEK WATERSHED-BASED IMPLEMENTATION PLAN

The Goose Creek Watershed-based implementation plan outlines a strategy for reducing pathogens and sediment to attain water quality standards in the watershed's impaired creeks and tributaries. When combined with existing implementation planning, management measures, and pathogen and sediment reduction efforts, completion of the proposed implementation plan will result in a cleaner and healthier Goose Creek Watershed for current and future generations.

This implementation plan, in conjunction with portions of the TMDL, includes the nine key elements identified by the U.S. EPA that are considered critical for achieving improvements in water quality (U.S. EPA 2008). The U.S. EPA requires that these nine elements be addressed in watershed plans funded with incremental CWA Section 319 funds, and strongly recommends that they be included in all watershed plans intended to address water quality impairments. Although there is no formal requirement for the U.S. EPA to approve watershed plans, the plans must address the nine elements discussed below if they are developed in support of Section 319-funded projects (U.S. EPA 2008). This implementation plan provides reasonable assurance that the load reductions identified in the TMDL can be attained through implementation of BMPs throughout the watershed in addition to stormwater treatment in the City of Sheridan. The project implementation plan identifies land use-specific BMPs, priorities for implementation, a period for implementation, a coordination plan, a monitoring plan, and unit costs associated with recommended structural BMPs.

The U.S. EPA's nine elements are listed below in the order they appear in the guidelines; however, it should be noted that although they are listed as *a* through *i*, they do not necessarily need to be completed sequentially.

- a Identify and quantify causes and sources of the impairment(s).
- b Estimate load reductions needed to meet water quality standards.
- c Identify BMPs needed to achieve load reductions and critical areas where these management measures will be implemented.
- d Estimate needed technical and financial resources.
- e Provide an information, education, and public participation component.
- f Include a schedule for implementing nonpoint source management measures.
- g Identify/describe interim measurable milestones for implementation.
- h Establish criteria to determine if load reductions/targets are being achieved.
- i Provide a monitoring component to evaluate effectiveness of the implementation over time for criteria in h.

For the purposes of this implementation plan, BMPs refer to any action or measure implemented or maintained in the watershed to control nonpoint sources of pathogens or sediment to waters in the Goose Creek Watershed. These include traditional structural and nonstructural BMPs, as defined by the NRCS, the USFS, and in stormwater management plans, as well as actions and measures related to planning, education of landowners, and enforcement of stormwater ordinances. Recommendations for nonpoint source reductions consider all sources and are based on management measures that consider BMPs, effectiveness, attainability, cost, and the goal of distributing the responsibility for water quality improvement among all users in the watershed. BMPs should be implemented year-round even though the pathogen TMDL is developed to attain summer water quality standards.

The implementation strategy for reducing pathogens is an iterative process where data are gathered on an ongoing basis, sources are identified and eliminated if possible, and control measures including BMPs are implemented, assessed, and modified as needed. Measures to abate probable sources of waterborne pathogens include everything from public education and improved stormwater management to reducing the influence from inadequate and/or failing sanitary sewer infrastructure. Implementation of a suite of BMPs, as described in this and other plans, provides reasonable assurance that load reductions will be achieved and designated uses will be restored.

For the purposes of watershed planning, the Goose Creek Watershed was divided into three main jurisdictions or areas represented by different management authorities and characterized by different types of pathogen sources:

- Forested catchments managed by the USFS
- Mixed-use catchments in Sheridan County
- The City of Sheridan

These three areas are described further in Section 9.2 in terms of management authorities, catchments, pathogen sources, and loads.

The Goose Creek Watershed implementation plan has been developed based on a 72% reduction in pathogen loads for rural catchments in Sheridan County and a 78% reduction of *E. coli* loads in the City of Sheridan. There are currently no impairments in the portion of the watershed managed by the USFS. The plan is also designed to achieve sediment reduction targets of 72% for Little Goose Creek and 74% for Goose Creek, respectively. These source reductions have been determined to be sufficient to achieve water quality criteria established for creeks in the watershed (see Chapters 8 and 9).

## 9.1 Identification of Pathogen and Sediment Sources in the Watershed

The Goose Creek Watershed drains 415 square miles and encompasses the City of Sheridan; the communities of Acme, Beckton, and Big Horn; the BHNF; several rural subdivisions; and several ranches. The BHNF makes up 43% of the watershed's drainage area (115,000 acres) and is managed as a multiple-use area for recreation, seasonal cattle grazing, logging, and wildlife. Half of the watershed (136,700 acres) is owned by private land holders, the majority of which own and operate small and large ranches. These ranches have some irrigated hay and crop lands, as well as pastureland for cattle grazing and corrals for feeding. Habitat found on private lands also supports big game, waterfowl, and other wildlife species. The City of Sheridan is the largest and most developed urban area in the watershed (6,399 acres). Subdivisions converted from rural areas along Little Goose Creek and Big Goose Creek are becoming more common, especially near Sheridan. Pollutant sources are described generally in the remainder of this section and discussed in detail for each of the three main areas (the USFS, Sheridan County, and the City of Sheridan) in Section 9.2.

### *9.1.1 Point Sources*

Point sources in the watershed include wastewater treatment in the City of Sheridan and in smaller treatment plants in Sheridan County, and regulated stormwater flows in the City of Sheridan. These point sources are described in detail in Sections 6.3 and 8.1, and are summarized below.

#### 9.1.1.1 WASTEWATER TREATMENT

There are five point sources in the watershed that operate under individual WYPDES permits. These permit holders treat wastewater and discharge pathogens and sediment to creeks in the watershed. These pathogen point sources for each area of the watershed are described in Section 9.2.

#### 9.1.1.2 REGULATED STORMWATER FLOWS

Stormwater flows from areas in the City of Sheridan consist of concentrated flows that accumulate from streets, parking areas, rooftops, and other impervious surfaces. Discharges from MS4s are permitted under the Wyoming General MS4 Stormwater Permit for Small Dischargers under the WYPDES (WYR04-0000), renewed on December 1, 2008. Under the general permit, a municipality may discharge stormwater to a water of the State of Wyoming in accordance with a SWMP. Stormwater flow in the City of Sheridan is covered under the general MS4 permit.

The City of Sheridan is drained by 17 urban drainage areas that discharge pathogens and sediment directly to Little Goose Creek, Big Goose Creek, and Goose Creek (see Sections 6.3.2 and 8.1). The City of Sheridan's 1987 SWMP details the drainage network for stormwater in the city as well as recommended improvements to the stormwater system. Most of the large storm drains in the city are owned and maintained by WYDOT.

Stormwater in the City of Sheridan represents a source of pathogens to the creeks. *E. coli* in stormwater is associated with domestic animals, waterfowl, pigeons nesting under bridges, and improper disposal of household garbage. Waterfowl are found throughout the City of Sheridan, especially in parks that border the streams. Common waterfowl species in the Goose Creek Watershed include mallard, common goldeneye, wood duck, blue-winged teal, green-winged teal, common merganser, and Canada goose. These species are most common in the watershed's lower elevations. Pigeons are known to nest under bridges in the Goose Creek Watershed and may represent an additional direct load of fecal coliform and *E. coli* to streams (Collyard et al. 2005).

In addition to pathogen sources, stormwater in the City of Sheridan also represents the primary source of sediment to the creeks. Based on a study of stormwater runoff in the City of Sheridan and on a sampling of storm drains along Little Goose Creek and Goose Creek, the identified source of sediment to Goose Creek was determined to be stormwater (WDEQ 2008a).

### *9.1.2 Nonpoint Sources*

Nonpoint sources in the Goose Creek Watershed are mostly located in Sheridan County and include on-site wastewater treatment (septic systems); grazing on public lands; pastured animals on private lands; and wildlife, waterfowl, and domestic animals. Stream sediments containing pathogens are recognized as a nonpoint source, but are considered accumulations from the above sources.

#### 9.1.2.1 ON-SITE WASTEWATER TREATMENT (SEPTIC SYSTEMS)

Septic systems have the potential to deliver pathogen loads to surface waters due to improper design, malfunctions, failures, direct pipe discharges, or improperly located systems in close proximity to surface waters, groundwater, or both. A properly operating septic system treats wastewater and disposes of the water through an underground drainfield. Soils beneath the drainfield remove most pathogens by filtering, adsorption, and biological processes. However, where soils or groundwater conditions are marginally suitable, or where septic densities are too high, conventional septic systems fail and are not adequate for removing most pathogens. A septic system can affect surface waters when soils below the drainfield become clogged or flooded and effluent reaches the surface where it can be washed off into a stream. An associated problem occurs when a septic system is flooded by groundwater or the depth-to-groundwater is near the base of the drainfield and effluent is released to groundwater, which moves along flow lines and discharges into nearby streams.

Sheridan County began permitting septic systems in 1977. In 2009 Sheridan County reported 1,546 permitted septic systems in the Goose Creek Watershed. This number does not include septic systems installed prior to 1977; therefore, not all septic systems have been accounted for or inventoried. Some of the septic systems in the Goose Creek Watershed can be reasonably assumed to be affecting surface waters. Therefore, pathogen loading to creeks in the Goose Creek Watershed can be partly attributed to septic systems. Septic system sources are described at the catchment scale in Section 6.4.4.

#### 9.1.2.2 GRAZING ON PUBLIC LANDS

Grazing on public lands contributes pathogens to streams through deposition of cattle manure and wash-off. Cattle grazing on public lands occurs mostly from June through September on lands owned and managed by the USFS in the upper segments of the Goose Creek Watershed. None of the streams in the upper segments of the watershed is impaired by pathogens. However, cattle grazing on USFS lands could contribute to pathogen loads downstream. Grazing allotments in the Goose Creek Watershed are summarized in Table 6.14 and Map 14.

#### 9.1.2.3 PASTURED ANIMALS ON PRIVATE LAND

Rangeland and pastureland in the watershed are frequently located adjacent to local streams, and support a diversity of livestock, including horses, sheep, cattle, and other grazing animals. Improper management of these rangelands and pasturelands can result in subsurface compaction of soil, thereby increasing overland flow and runoff as well as the sediment and pathogen load. Vegetation in overused rangelands and pasturelands is also commonly insufficient to retain sediment during overland flows, leading to the increased likelihood of deposited manure directly into nearby streams and irrigation canals.

The agricultural census for Sheridan County was used to estimate the number of animal units on private pastureland and rangeland in the watershed (Table 6.11). Cattle dominate the livestock in the county, with between 7,000 and 29,000 cattle in the Goose Creek Watershed. This includes more than 10,000 head of cattle and approximately 1,000 horses and sheep (Table 6.11).

During extended periods of low precipitation and hot temperatures, *E. coli* and fecal coliform in livestock manure deposited on pasturelands and rangelands die off before reaching a waterway. However, during periods of increased precipitation or spring melt, the likelihood of manure transport from a pastureland or rangeland to a stream increases. To estimate the pathogen load from livestock manure, the excretion rates of fecal coliform from various livestock types and the estimated number of livestock in the Goose Creek Watershed were used.

#### 9.1.2.4 BIG-GAME WILDLIFE, WATERFOWL, AND DOMESTIC ANIMALS

Big-game species in the Goose Creek Watershed include mule deer, white-tailed deer, elk, moose, and pronghorn antelope. Mountain lions and black bears are also known to occur in the area. All warm-blooded animals have the potential to contribute pathogens to waterways through direct excretion into waterways or runoff of excrement from riparian and upland areas. Both the density and species of wildlife affect how much excreted waste is available for transport to streams. Most wildlife habitat in the Goose Creek Watershed occurs in the higher elevations of the watershed; although mule deer, pronghorn, and white-tailed deer habitat extends into the valleys, especially during winter months. Mule deer and white-tailed deer vary in terms of distribution and densities. Deer density for both species varies seasonally, more so for mule deer than white-tailed deer. Mule deer are more evenly distributed in the watershed whereas white-tailed deer tend to be more limited in their distribution. There are an estimated 18 to 20 white-tailed deer per square mile and 7 to 8 mule deer per square mile in the Goose Creek Watershed (personal communication between Tim Thomas, Wyoming Game and Fish and John Christensen, SWCA, on June 29, 2010).

Deer are the most likely wildlife contributors of *E. coli* and fecal coliform in the watershed given their extensive range and high population densities in the watershed.

Waste excretions from big game, waterfowl, and domestic animals in the Goose Creek Watershed have the potential to runoff the landscape during storm events and deliver pathogens to creeks in unregulated stormwaters. In addition to the regulated stormwater sources identified in the City of Sheridan, small developed areas of medium-density and low-density residential land uses are found in Sheridan County where these landscapes also have the potential to carry stormwater pathogens associated with waterfowl and domestic animals.

## 9.2 Identification of Current Loads by Source and Jurisdiction

To identify the relative contributions of nonpoint pathogen sources in the Goose Creek Watershed, the Bacteria Source Load Calculator (BSLC) was used. This calculator is available from the Center for TMDL and Watershed Studies at Virginia Tech. The BSLC was developed using Visual Basic for Applications in Microsoft Excel and designed to organize and process bacteria inputs needed to develop a TMDL for bacteria impairments. For the purposes of this implementation plan, and modeling nonpoint sources, the Goose Creek Watershed was divided into three jurisdictional areas that cross hydrologic boundaries but are the most relevant for watershed management measures and implementation. These jurisdictional areas include the City of Sheridan Catchment, USFS-managed forest catchments, and rural catchments in Sheridan County. The BSLC tool was used to estimate the relative contributions of pathogens during the summer recreation season for the following sources: wildlife (white-tailed deer, mule deer, and elk), waterfowl (ducks and geese), septic systems, domestic animals such as dogs and cats, and livestock (cattle, horses, goats, and sheep) (Appendix 3).

The results of this model were integrated with the current loads calculated in each of the jurisdictional areas using the load duration curve methodology discussed in previous sections of the TMDL. Input data to the model included the following:

- Estimated numbers of livestock, including beef cattle, layers, turkeys, horses, sheep, and goats; estimates were scaled based on the Wyoming Agricultural Census
- Estimated wildlife and waterfowl populations, including white-tailed deer, mule deer, geese, ducks, and elk; estimates for deer were obtained from the Wyoming Game and Fish Department; estimates for geese and ducks were based on typical seasonal densities provided as a default in the BSLC
- Estimated land-use acreages for forests, cropland, and pastureland
- Estimated unsewered and sewered homes that are in each of three age categories: old (pre-1966), mid-age, and new; these were obtained from population estimates in the City of Sheridan and the HKM septic study
- Estimated straight pipes to the creek; these were based on national averages per permitted septic systems
- Management coefficients and assumptions for animal size, fecal coliform excretion/animal/day, agricultural management (manure spreading, cattle near and in streams, proportion of time animals are confined by month)

## *9.2.1 USFS Catchments*

Forested catchments managed by the USFS in the higher elevations of the watershed are composed of catchments BG18 and LG22 in the detailed source identification section of the TMDL (Chapter 7). There are no point sources of pathogens in the USFS catchments. The primary nonpoint pathogen sources in these catchments are grazing on public lands and wildlife (Table 9.1).

**Table 9.1** Summary of Point and Nonpoint Pathogen Sources and Daily Average *E. coli* Loads in USFS Catchments

| Pathogen Sources | | Daily Average Load (G-cfu/day) | Percent of Daily Average Load in USFS Catchments |
|---|---|---|---|
| **Point Sources** | **Nonpoint Sources** | | |
| Wastewater Treatment | – | 0 | 0% |
| Regulated Stormwater Flows | – | 0 | 0% |
| – | On-site Wastewater Treatment (septic systems) | 1 | 5% |
| – | Grazing on Public Lands | 11 | 59% |
| – | Pastured Animals on Private Land | 0 | 0% |
| – | Wildlife and Waterfowl | 7 | 36% |
| – | Domestic Animals | <1 | <1% |
| Total Point Sources | – | 0 | 0% |
| Total Nonpoint Sources | – | 19 | 100% |
| Total Point and Nonpoint Sources | – | 19 | 100% |

## *9.2.2 Sheridan County Rural Catchments*

Rural catchments in Sheridan County include catchments along Little Goose Creek, Big Goose Creek, Soldier Creek, and tributaries to these creeks. These catchments and tributaries are summarized as follows:

- Little Goose Creek main stem catchments:
    - LG20, LG12, and LG6
- Little Goose Creek tributaries:
    - Sackett Creek (LG19)
    - Jackson Creek (LG17)
    - Kruse Creek (LG11)
    - McCormick Creek (LG9)
- Big Goose Creek main stem catchments:
    - BG14, BG11, BG4
- Big Goose Creek tributaries:
    - Rapid Creek (BG16), Park Creek (BG13), Beaver (BG9)

- o Soldier Creek (GC4)
- o Goose Creek (GC1)

Pathogen point sources in Sheridan County catchments include two private communities that treat small flows of wastewater (Powder Horn Ranch and Royal Elk Properties) and discharge to Little Goose Creek upstream of the city. The Sheridan County School District near Big Horn has a small WWTP that discharges to Jackson Creek upstream of its confluence with Little Goose Creek. The Big Horn Mountain KOA WWTP also discharges small quantities of wastewater to Goose Creek below the city limits. The permit holders and *E. coli* loads for each of these point sources are summarized in Table 9.2.

**Table 9.2** Summary of WYPDES Permit Holders and Estimated *E. coli* Loads in Sheridan County

| Permit Holder | Receiving Water | Catchment | Average Annual *E. coli* Load (G-cfu/year) |
|---|---|---|---|
| Powder Horn Ranch, LLC | Little Goose Creek | LG12 | 1,353 |
| Royal Elk Properties, LLC | Little Goose Creek | LG6 | – |
| Sheridan County School District | Jackson Creek | Jackson | – |
| Big Horn Mountain KOA | Goose Creek | GC1 | 13,777 |

The primary nonpoint pathogen sources in Sheridan County are pastured animals on private lands, septic systems, and big-game wildlife (Table 9.3).

**Table 9.3** Summary of Point and Nonpoint Pathogen Sources and Daily Average *E. coli* Loads in Sheridan County

| Pathogen Sources | | Daily Average Load (G-cfu/day) | Percent of Daily Average Load in Sheridan County Rural Catchments |
|---|---|---|---|
| Point Sources | Nonpoint Sources | | |
| Wastewater Treatment | – | 1.0 | 0% |
| Regulated Stormwater Flows | – | 0 | 0% |
| – | On-site Wastewater Treatment (septic systems) | 111 | 24% |
| – | Grazing on Public Lands | 0 | 0% |
| – | Pastured Animals on Private Land | 305 | 65% |
| – | Wildlife and Waterfowl | 34 | 7% |
| – | Domestic Animals | 9.2 | 2% |
| Total Point Sources | – | 1 | 0% |
| Total Nonpoint Sources | – | 459 | 97% |
| Total Upstream Sources | – | 12 | 3% |
| Total Point and Nonpoint Sources | – | 472 | 100% |

### 9.2.3 City of Sheridan Catchment

The City of Sheridan, managed by the municipality of the city, is designated its own catchment. The sampling site used to characterize pathogen loads in the city is GC2.

Pathogen point sources in the City of Sheridan catchment include the City of Sheridan WWTP and regulated stormwater flows. *E. coli* loads for the City of Sheridan WWTP averaged 227 G-cfu/day from 2001 through 2008. However, since 2004 the load from the plant has been substantially reduced to an average of 16 G-cfu/day. In addition to the municipal treatment plant, the City of Sheridan is drained by 17 urban drainage areas that discharge directly to Little Goose Creek, Big Goose Creek, and Goose Creek (see Map 12; Table 7.8). Collectively, the urban stormwater system drains 2,027 acres of the city, all within the City of Sheridan catchment. Additional acreage in the city is drained by 25 rural drainage basins, most of which also discharge directly to streams (see Map 13; Table 6.8). The City of Sheridan's SWMP from 1987 details the city's stormwater drainage network as well as recommended improvements to the network. Most of the large storm drains in the city are owned and maintained by WYDOT.

The primary pathogen sources in these catchments are regulated stormwater, septic systems, and wastewater treatment (Table 9.4.)

**Table 9.4** Summary of Point and Nonpoint Pathogen Sources and Daily Average *E. coli* Loads in the City of Sheridan Catchment

| Pathogen Sources | | Daily Average Load (G-cfu/day) | Percent of Daily Average Load in City of Sheridan Catchment |
|---|---|---|---|
| **Point Sources** | **Nonpoint Sources** | | |
| Wastewater Treatment | – | 227 | 21% |
| Regulated Stormwater Flows (includes domestic animals and wildlife) | – | 303 | 27% |
| – | On-site Wastewater Treatment (septic systems) | 221 | 20% |
| – | Grazing on Public Lands | 0 | 0% |
| – | Pastured Animals on Private Land | 0 | 0% |
| – | Waterfowl | 17 | 2% |
| Total Point Sources | – | 529 | 48% |
| Total Nonpoint Sources | – | 237 | 21% |
| Total Upstream Sources | – | 338 | 31% |
| Total Load | – | 1,105 | 100% |

### 9.2.4 Summary of Pathogen Loads

Average daily current pathogen loads are estimated in Table 9.5 for the three jurisdictional areas that comprise the Goose Creek Watershed. The largest loads, as expected, are recorded furthest downstream of the watershed in the City of Sheridan. Of the 1,105 G-cfu/day of *E. coli* load to the streams in the City of Sheridan, 31% is from upstream sources, 48% is from point sources (including stormwater), and 21% is from other nonpoint sources. Most of the pathogen load in Sheridan County comes from pastured livestock (65%) and septic systems (24%). To simplify the load calculations described elsewhere for watershed management, the values in this section represent average daily loads (weighted for the three flow conditions described elsewhere in the TMDL); however, it is important to note that some sources dominate during different flow conditions. During low-flow periods, for example, septic systems are the most likely contributor to impairments. However, stormwater loads, one of the largest pathogen sources in the watershed, only occur during storm events and spring runoff, a relatively small portion of the summer season. A more complete description of pathogen loading during different flow conditions is described in Chapter 8 for each of the impaired segments for which this TMDL applies.

**Table 9.5** Summary of Point and Nonpoint Pathogen Sources and Daily Average *E. coli* Loads in the Goose Creek Watershed

| Pathogen Sources | | Area | Daily Average Load (G-cfu/day) | Percent of Daily Average Load by Area |
|---|---|---|---|---|
| **Point Sources** | **Nonpoint Sources** | | | |
| Wastewater Treatment | – | USFS | 0 | 0% |
| | | Sheridan County | 1 | 0% |
| | | City of Sheridan | 227 | 21% |
| Regulated Stormwater Flows (includes domestic animals) | – | USFS | 0 | 0% |
| | | Sheridan County | 0 | 0% |
| | | City of Sheridan | 303 | 27% |
| – | On-site Wastewater Treatment (septic systems) | USFS | 1 | 5% |
| | | Sheridan County | 111 | 24% |
| | | City of Sheridan | 221 | 20% |
| – | Grazing on Public Lands | USFS | 11 | 59% |
| | | Sheridan County | 0 | 0% |
| | | City of Sheridan | 0 | 0% |
| – | Pastured Animals on Private Land | USFS | 0 | 0% |
| | | Sheridan County | 305 | 65% |
| | | City of Sheridan | 0 | 0% |
| – | Wildlife and Waterfowl | USFS | 7 | 36% |
| | | Sheridan County | 34 | 7% |
| | | City of Sheridan | 17 | 2% |
| – | Domestic Animals | USFS | <1 | 1% |
| | | Sheridan County | 9.2 | 2% |
| | | City of Sheridan | Captured in point source stormwater | |
| Total Point Sources | | USFS | 0 | 0% |
| | | Sheridan County | 1 | <1% |
| | | City of Sheridan | 529 | 48% |
| Total Nonpoint Sources | | USFS | 19 | 100% |
| | | Sheridan County | 459 | 97% |
| | | City of Sheridan | 237 | 21% |
| Total Upstream Sources | | USFS | 0 | 0% |
| | | Sheridan County | 12 | 2.5% |

**Table 9.5** Summary of Point and Nonpoint Pathogen Sources and Daily Average *E. coli* Loads in the Goose Creek Watershed

| Pathogen Sources | | Area | Daily Average Load (G-cfu/day) | Percent of Daily Average Load by Area |
|---|---|---|---|---|
| **Point Sources** | **Nonpoint Sources** | | | |
| | | City of Sheridan | 338 | 31% |
| Total Load | | USFS | 19 | 100% |
| | | Sheridan County | 472 | 100% |
| | | City of Sheridan | 1,105 | 100% |

# 9.3 Pathogen and Sediment Load Reductions Needed to Meet Water Quality Standards

## *9.3.1 Point Sources*

Load reductions described in Table 9.6 are based on the load reductions required for the receiving segment. The methodologies associated with segment-specific LAs are described in Sections 7.2 and 7.4. Point source LAs for each impaired segment are summarized in Table 7.4 and are consistent with the loads described in Table 9.6. It is important to note that data from 2001 through 2008 were used to characterize current loads from point sources in the watershed to be comparable with the in-stream water quality data that were used to calculate in-stream loads. These data were collected in 2001, 2002, and 2005. A summary of recent DMR data received from the WDEQ for the WWTP indicates significant improvements in the treatment of *E. coli* and fecal coliform beginning in 2004. Daily *E. coli* loads have been reduced from 1,252 G-cfu/day in 2002 to 16 G-cfu/day in 2008 (see Table 6.4). Therefore, although Table 9.6 identifies that a more than 90% reduction is required for the City of Sheridan WWTP, this reduction has already been attained due to the improvements described above. In addition, a future growth allocation of 11 G-cfu/day has been identified for the City of Sheridan to accommodate additional population growth and additional sewer connections in the future (see Section 7.6.4). The most significant point source requiring attention from the perspective of both pathogen (92% reduction required) and sediment (76% reduction required) loads is MS4 stormwater outfalls in the City of Sheridan. *E. coli* sources in stormwater include domestic animals, wildlife in the city (not along the creeks), and irrigation ditches that discharge into storm drains.

**Table 9.6** Summary of Load Reductions Required from Point Sources to Attain TMDL and Water Quality Standards

| **Descriptions** | | | | **Pathogens** | | | | | **Sediment** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Permit No. | Permit Holder | Discharge Type | Impaired Segment | Waste Load Allocation (G-cfu/day) | Current Permitted Load (G-cfu/day) | Current Load (G-cfu/day) | Required Reduction from Current Permit | Required Reduction from Current Load | Current Load (kg/day) | Permitted Load (kg/day) | TMDL Load (kg/day) | Required Reduction from Current Load | Required Reduction from Current Permit |
| **USFS** | | | | | | | | | | | | | |
| No point sources in the USFS-managed areas of the watershed | | | | | | | | | | | | | |
| **Sheridan County** | | | | | | | | | | | | | |
| WY0036251 | Powder Horn Ranch, LLC | Commercial wastewater | Little Goose Creek | 0.24 | 0.33 | 3.7 | 28% | 93.6% | 14.63 | 5.62 | 6 | 0% | 0% |
| WY0054399 | Royal Elk Properties, LLC | Commercial wastewater | Little Goose Creek | 0.20 | 0.28 | Unknown | 28% | Unknown | unknow n | 4.77 | 5 | 0% | 0% |
| WY0056308 | Sheridan County School District | Wastewater | Jackson Creek | 0.10 | 0.15 | Unknown | 38% | Unknown | unknow n | 2.27 | 3 | 0% | 0% |
| **City of Sheridan** | | | | | | | | | | | | | |
| WY0020010 | City of Sheridan | Municipal wastewater | Goose Creek | 20.99 | 20.99 | 226.8 | 0% | 90.7% | 96.8 | 500 | 500 | 0% | 0% |
| WY0026441 | Sheridan Big Horn Mountain KOA | Commercial wastewater | Goose Creek | 0.08 | 0.08 | 37.7 | 0% | 99.8% | 0.82 | 2 | 2 | 0% | 0% |
| – | City of Sheridan | Stormwater | Big Goose Creek, Little Goose Creek, and Goose Creek | 24.74 | – | 302.6 | – | 92% | 16,859 | – | 4,072 | 76% | – |

## *9.3.2 Nonpoint Sources*

For purposes of identifying watershed-wide priority sources of reduction, the expected load reductions for pathogens have been grouped into the three jurisdictional areas defined for the Goose Creek Watershed: USFS, Sheridan County, and the City of Sheridan. Required percent reduction values and expected load reductions are summarized in Table 9.7. Load reductions for the Goose Creek Watershed implementation plan rely heavily on nonpoint source reductions to achieve water quality standards, especially in Sheridan County where a 75% reduction of nonpoint sources of pathogens is required to attain water quality standards throughout the watershed. The majority of the load in the City of Sheridan comes from point sources of wastewater and stormwater; however, nonpoint sources also require a 67% reduction in the city. Specific percent reduction values for individual impaired segments are summarized in Table 7.3. There are no impaired segments in the USFS area of the watershed; therefore no load reductions are required.

**Table 9.7** Summary of Load Reductions Required from Nonpoint Sources to Attain Pathogen TMDL and Water Quality Standards

| **Pathogen Sources**<br>**Nonpoint Sources** | **Area** | **Daily Average Load of *E. coli* (G-cfu/day)** | **Load Allocation of *E. coli* (G-cfu/day)** | **Expected Load Reduction Required to Attain TMDL** |
|---|---|---|---|---|
| On-site Wastewater Treatment (septic systems) | USFS | 1.0 | 1.0 | 0% |
| | Sheridan County | 110.6 | 27.7 | 75% |
| | City of Sheridan | 220.9 | 72.9 | 67% |
| Grazing on Public Lands | USFS | 11.2 | 11.2 | 0% |
| | Sheridan County | 0 | 0 | 0% |
| | City of Sheridan | 0 | 0 | 0% |
| Pastured Animals on Private Land | USFS | 0 | 0 | 0% |
| | Sheridan County | 305.3 | 76.3 | 75% |
| | City of Sheridan | – | – | 0% |
| Wildlife and waterfowl | USFS | 6.8 | 6.8 | 0% |
| | Sheridan County | 33.9 | 8.5 | 75% |
| | City of Sheridan | 16.7 | 5.5 | 67% |
| Domestic Animals | USFS | 0.1 | 0.1 | 0% |
| | Sheridan County | 9.2 | 2.3 | 75% |
| | City of Sheridan | – | – | 0% |
| Total Nonpoint Sources | USFS | 19.0 | 19.0 | 0% |
| | Sheridan County | 459.0 | 114.8 | 75% |
| | City of Sheridan | 237.6 | 78.4 | 67% |

In addition to the point source reductions required for sediment in the City of Sheridan (described in the previous section), a nonpoint source sediment reduction of 76% is required for sources upstream of the city that drain to Little Goose Creek and Big Goose Creek (Table 9.8).

**Table 9.8** Summary of Load Reductions Required from Nonpoint Sources to Attain Sediment TMDL

| | Daily Average Load (kg TSS/day) | Load Allocation (kg TSS/day) | Expected Load Reduction |
|---|---|---|---|
| Little Goose Creek Upstream Nonpoint Sources | 3,225 | 756.9 | 77% |
| Big Goose Creek Upstream Nonpoint Sources | 7,856 | 1,897.6 | 75% |
| **Total** | **11,081** | **2,654.5** | **76%** |

## 9.4 Recommended Management and Implementation Measures for the USFS

The *Bighorn National Forest Revised Land and Resource Management Plan* (BHNF 2005) outlines the goals and objectives in detail for the Bighorn National Forest. The main goals of this plan are to 1) ensure sustainable ecosystems, 2) provide multiple benefits to people, 3) provide scientific and technical assistance, and 4) provide effective public service. The BHNF encourages the management of healthy ecosystems throughout public land, and plans to maintain Wyoming water quality standards for designated uses through the management of healthy riparian, aquatic, and wetland ecosystems. In areas that are affected by groundwater and surface water flows, the BHNF will only allow those actions that maintain or improve long-term stream health and riparian ecosystem condition. These areas include the aquatic ecosystem (i.e., the riparian ecosystem), which is characterized by distinct vegetation and associated valley bottom, wetlands, and ecosystems that remain within approximately 100 feet horizontally from both edges of all perennial and intermittent streams, and from the shores of lakes and other still waterbodies. It also includes areas adjacent to unstable and highly erodible soils (BHNF 2005). The BHNF is also committed to actively participating in planning with other federal, state, and local agencies, when these plans could affect the designated uses of water on BHNF lands (BHNF 2005). Although no load reductions are required for the forest lands, the BHNF's efforts will help protect the source waters of these watersheds and will ideally represent natural conditions that other basins in the watershed can work toward.

### *9.4.1 Point Source Management Measures*

There are no point sources of pathogens or sediment in USFS-managed lands.

### *9.4.2 Nonpoint Source Management Measures*

#### 9.4.2.1 ON-SITE WASTEWATER TREATMENT PLANTS (SEPTIC SYSTEMS)

Any existing on-site WWTP located on USFS land should be inventoried and maintained on a regular basis. Priority areas for septic system inventories and maintenance would be USFS work centers, campgrounds, and picnic areas that have on-site bathroom facilities. Generally these areas are located near river systems; however, greater priority would be given to those with the closest proximity to a water source. Other priorities would be permanent structures and facilities that have been built on public lands. These would include USFS facilities, livestock camps, hunting camps, or private recreation cabins. Again, priority for implementation would be areas that are in closest proximity to water sources, or sites that are believed to have septic tank failure.

### 9.4.2.2 GRAZING ON PUBLIC LANDS

Livestock management activities on public lands in the USFS area of the watershed are currently being designed and implemented to protect and manage the watershed. Forage levels are established to ensure adequate vegetation levels, which prevent sediment loss to rivers by creating areas of accelerated erosion. Grazing on public lands is managed to prevent grazing on an individual unit throughout the entire grazing period, and is managed to prevent units from being grazed during the same growing season throughout successive years. When the USFS prepares allotment management plans, desired plant communities are first identified during site-specific analyses. Grazing can then be managed to allow for successional progress toward these desired plant communities or vegetative conditions. These implementations enforced by the USFS help to attain the goal of reduced sediment transport and reduced contamination of fecal coliforms (BHNF 2005).

To maintain grazing management objectives, the USFS has established guidelines to influence the design and operations of future public land activities. For future public land use, the USFS encourages the use of portable livestock handling facilities. These facilities provide for localized impacts while giving managers the option of relocating such facilities if impacts become too great. The USFS also encourages the creation of off-channel watering facilities, which can reduce the pressure of grazing animals on sensitive areas. Off-channel watering facilities can alleviate pressure on riparian areas, springs, and aspen groves, while also providing a maintainable water source for grazing animals and wildlife.

In the Goose Creek Watershed, springs and riparian areas on public lands form the headwaters of the streams that later flow through the county and city. Because of this, the water quality and quantity are directly related to the health of these sensitive areas. The continual monitoring and updating of grazing management strategies for these areas is a main priority on public lands. Other areas of high priority on public lands include areas that have been designated as pristine or natural. These areas include wild and scenic river segments, pristine wilderness areas, and research natural areas. These are areas that have been designated as having unique features or values that need to be preserved for a number of economic, recreational, and educational needs. The protection of these areas is also valuable to serve as reference conditions for any future restoration activities.

### 9.4.2.3 BIG-GAME WILDLIFE

Wildlife are a valuable element in a healthy ecosystem; however, if events cause forest resources to become limited, high concentrations of wildlife can occur in areas of sensitive habitat. These sensitive areas tend to be near the source waters of streams and in riparian areas. Proper management of big-game habitat on public land can aid in sustaining a variety of habitats that allows for suitable dispersal of wildlife. To meet these goals, the BHNF is currently implementing plans that protect winter habitat for wildlife, managing forage for wildlife needs, and regulating USFS use to minimize impacts to wildlife. In areas used by wildlife for winter habitat, the BHNF manages for a habitat mosaic of various types, age classes, and structural stages throughout the area. In addition, the BHNF manages shrub conditions in wintering areas, which will provide a key food source for wildlife.

To continually manage adequate big-game habitat on public land, the BHNF has established guidelines to accomplish specific goals. For the improvement of winter range habitats, the design of grazing practices will enhance forage palatability, availability, and nutritional quality for wildlife uses. This will include monitoring programs to identify areas where combined livestock and wildlife grazing are exceeding forage utilization standards. Spring sites will be developed or reconstructed in a manner that will maintain the function of the dependant riparian and wetland resources, while also allowing for continued wildlife use.

In addition, wildlife need to be provided with sufficient wintering areas. Ample winter habitat will reduce the effect of wildlife on sediment and of fecal deposition into stream systems. During the winter, wildlife have limited options for habitat, and these options can be further limited if winter habitats are not properly managed. Providing well-managed wintering habitat can disperse wildlife, reducing the impacts of a large herd at a single site. Other areas of high priority are springs, riparian areas of headwaters, and other sensitive habitats. Protecting these areas by fencing or by alternative off-channel watering facilities will ensure the headwater tributaries are supplying clean water to the larger systems.

# 9.5 Recommended Management and Implementation Measures for Sheridan County

## *9.5.1 Point Source Management Measures*

Pathogen and sediment point sources in Sheridan County catchments include discharges from three small WWTPs. Two private communities in the watershed (Powder Horn Ranch and Royal Elk properties) treat small flows of wastewater and discharge to Little Goose Creek upstream of the city. The Sheridan County School District near Big Horn has a small WWTP that discharges to Jackson Creek upstream of its confluence with Little Goose Creek. The flows from these plants are generally quite low, resulting in a minimal load to the creeks. However, additional reductions of *E. coli* could be accomplished through installing improved disinfection systems on each plant (chlorination, ozonation, or ultraviolet light).

## *9.5.2 Nonpoint Source Management Measures*

Pathogen and sediment nonpoint sources in Sheridan County catchments include septic systems, pastured animals on private lands, and waterfowl, domestic animals, and big-game wildlife. Management measures for these nonpoint sources are described below.

### 9.5.2.1 ON-SITE WASTEWATER TREATMENT PLANTS (SEPTIC SYSTEMS)

On-site WWTPs make up 24% of the total pathogen load to creeks in the Sheridan County rural catchments. This load is associated with failing septic systems, straight pipe systems that do not include a functioning drainfield, and septic systems that are in close proximity to creeks and shallow groundwater.

#### Existing Implementation Measures in Watershed

In response to specific action items listed in the *Goose Creek Watershed Management Plan* (SCCD 2004), the GCWPC Partnership, SCCD, Sheridan County, and the City of Sheridan contracted HKM to assess the impact of septic systems in the Goose Creek Watershed. This project was funded by a $54,000 grant secured by the City of Sheridan. The grant was from the CWA Section 319 program, administered by the WDEQ. A $36,000 in-kind match was also provided by the City of Sheridan, Sheridan County, and SCCD.

The resulting *Septic System Impact Study* (HKM 2006) addresses three of the action items regarding Issue 4.1.1 of the *Goose Creek Watershed Management Plan*, specifically “Rural and urban septic systems are likely contributors of bacteria to local streams” (SCCD 2004). The action items addressed by the *Septic System Impact Study* (HKM 2006) include the following:

1. The GCWPC will consider sponsoring a feasibility study to evaluate potential sewage treatment options and/or the need for expanding central sewer lines to rural areas.
2. The City of Sheridan and Sheridan County will identify and map septic systems in or near riparian areas, and within city limits, as feasible.
3. The GCWPC will evaluate alternative, individual sanitation system technologies and systems for the treatment of wastewater from multiple dwellings.

The study area for the *Septic System Impact Study* includes all of the Goose Creek Watershed (excluding public lands administered by the USFS). The study area also includes all contributing areas to Little Goose Creek, Big Goose Creek, and Goose Creek. The impact study is divided into two phases. Phase I involves an inventory and mapping of existing septic systems. The outcome of Phase I was the identification of zones of high risk for impacts to groundwater. Phase II was developed to identify options to mitigate impacts from conventional septic systems. The outcome of Phase II was the identification of appropriate alternative technologies and methods that could be applied to the Sheridan County septic permitting process.

Ultimately, the purpose of the *Septic System Impact Study* was to develop a recommended mechanism by which septic system installation and replacement could be evaluated for appropriate use of alternative technologies in areas of high risk for impacts to groundwater. The impact study recommends strategies for implementing alternative septic system technologies and suggests that it would require minor amendment to the current Sheridan County septic system permitting program. Further, the impact study indicates that implementation of the program should include review and updates, if determined appropriate, to the 201 Intergovernmental Agreement between the city and the county and the Delegation Agreement between the WDEQ and the county. In addition, detailed evaluation criteria and design guidelines should be developed. A commitment of appropriately trained staff to implement and administer the program is also deemed necessary. Input from the public, agency staff, and policy boards were crucial for completion of this study. The questions and comments provided during public meetings held on October 5, 2006 and December 7, 2006 helped formulate the conclusions and recommendations of this study. The implementation measures described in these documents are listed below:

- Septic system operation and maintenance
- Septic tank with a mounded absorption field
- Septic tank with a gravel-less absorption field
- Septic tank with a constructed wetland
- Septic tank with an evapotranspiration system
- Septic tank with a sand filter system
- Aerobic unit or aerated tank
- Vacuum sewer collection systems
- Alternating drainfields
- Dosed drainfields

Additional implementation measures that are also presented and discussed include the following:

- Expansion of the City of Sheridan sewer system
- Regional central sewer system, including cluster systems
- Regional central sewer system in Little Goose Creek Valley
- Alternative collection systems (for a central sewer system)

Management recommendations listed in the *Septic System Impact Study* (HKM 2006) include the following:

- Programs outlined in the *Goose Creek Watershed Management Plan* should be continued.
- Sheridan County should consider updating the current septic permitting program.

- Sheridan County should consider establishing a licensing program for septic system installers and pumpers.
- Sheridan County should select an appropriate management program ranging from "homeowner awareness" to "responsible management entity ownership."
- A regional sewer master plan for the Little Goose Drainage should be initiated.
- The City of Sheridan should continue wastewater collection and treatment master planning and plan implementation.

From 2005 to 2009 the SCCD and NRCS completed 10 septic system improvement projects in the Goose Creek Watershed, consisting of seven septic system improvements in the Little Goose Creek subwatershed and three in the Big Goose Creek subwatershed. These septic system improvement projects consisted of mounding the septic drainfield to provide vertical separation that is otherwise not available due to a high water table, a restrictive soil layer, or shallow rock. In mounded septic systems, the wastewater flows from the septic tank to a storage tank. The liquid is then pumped from the tank to perforated plastic pipes buried in a mound of sand built on the original soil surface. The sand mound provides a layer of suitable soil thick enough to ensure adequate time and distance for proper treatment of the wastewater.

In addition, the SCCD and NRCS have established a local working group to develop criteria for the septic system program, and to guide the program into the future. SCCD and NRCS have developed local water resource-related projects that include water quality assessments, watershed planning efforts, and watershed improvement programs that include improvements to AFOs and septic systems, stock water development projects, riparian buffer projects, and stream channel restoration projects. The SCCD maintains self-assessment forms on their web site to assist homeowners in assessing their AFOs and septic systems. In addition, the SCCD provides a *Septic System Information Packet*. This information packet describes measures for installing, replacing, and maintaining a septic system, in addition to providing alternatives for locations where a conventional system will not protect human health and the environment (SCCD 2005b). Further, the information packet contains additional sources of information and resources, authorities and applicable regulations, design and installation considerations, and septic system operation and maintenance.

In 2008, Sheridan County, with funding from WDEQ, contracted with EnTech, Inc. to assess the feasibility of installing a sewer line and providing wastewater treatment to homes in the Little Goose Creek Valley. The findings from this study, the *Little Goose Wastewater Treatment Feasibility Study*, indicates the recommended alternative for wastewater service to the Little Goose wastewater service area to be 1) The construction of a centralized gravity collection system, 2) Connection to the City's South Side Interceptor (SSI), 3) Relaying of two SSI pipeline segments to provide for the 25-year design flows. The 2009 total project cost including plant investment fees is $12,678,000 (EnTech 2009).

The SCCD web site also provides funding criteria for septic system improvements and AFO improvements for cost-share assistance to homeowners and landowners in implementing water quality improvement projects.

### Recommended Implementation Measures for Future

Reducing the pathogen load from septic systems will require several different types of implementation measures that apply to specific situations and septic systems in the watershed. Many (if not all) of the appropriate and applicable implementation measures have been identified and discussed in detail in the *Septic System Information Packet* (SCCD 2005b) and the *Septic System Impact Study* (HKM 2006), both available on the SCCD web site.

#### *Regional Central Sewer in Little Goose Creek Valley*

As recommended in the *Septic System Impact Study* (HKM 2006) and found to be feasible in the *Little Goose Creek Wastewater Treatment Feasibility Study* (EnTech 2009), a central sewer in Little Goose Creek Valley would provide the most comprehensive solution to the potential impact of septic systems on pathogen impairments in the Little Goose Creek and its tributaries. The study identifies a threshold of 1,000 homes to make this suggestion viable. There are currently 862 permitted septic systems in the Little Goose Creek portion of the watershed. There are known to be additional homes with septic systems that are not permitted.

#### *Cluster Systems in High Density Developments*

If the regional sewer system is not found to be feasible, cluster systems (small WWTPs) are recommended for rural areas with relatively high densities of septic systems, including the community of Big Horn and developments such as McNaly, Meadowlark Meadows, Knode Ranch, and Big Horn Ranch. The Powder Horn development already operates a small extended-aeration WWTPs.

#### *Inventory, Inspect, Upgrade, and Maintain Septic Systems throughout Watershed*

A systematic approach for developing a septic system inventory, inspection, and upgrade program is outlined below for Sheridan County and summarized in Figure 9.1.

Step 1–Conduct a Septic Inventory

A septic system inventory should be conducted. As noted above in the *Septic System Impact Study* (HKM 2006), an inventory of septic systems in the Goose Creek Watershed was conducted. However, as noted in that report, there were data limitations, as follows:

- Many parcels had more than one septic permit tied to them. The reason for this may be that the septic system was initially permitted and was re-permitted due to repair or replacement of the system. The original permits were not removed from the dataset, resulting in the duplicate permits.
- The inventory only included those septic systems that are properly permitted with Sheridan County. There are undoubtedly septic systems in existence that were either installed prior to the county's permitting program (1979) or were installed without permits (HKM 2006).

The initial septic system update could be accomplished several ways. First, residences and businesses that have water-only utility bills could be correlated with the existing septic database to evaluate situations where occupancy and water supply are present, but where a septic system is not identified. Second, aerial imagery, combined with a GIS layer of known septic systems, could be used to identify developed parcels not included in the inventory.

A septic tank inventory list would provide managers the information necessary to identify high priority areas to focus project efforts and to maximize implementation effectiveness.

Step 2–Update Database and Spatial Query to Identify Additional Priority Septic Systems

The septic system priority list should be updated following Step 1. The intersection of several GIS layers has been queried to identify the number and location of septic systems in priority areas. These layers include the existing septic system inventory layer, the aquifer sensitivity layer provided by HKM (2006), and a created layer for a 100-m buffer adjacent to the creeks.

After the inventory has been completed in Step 1, this query should be updated to identify priority septic systems.

Step 3–Mail Septic System Self-assessment Form and Conduct a Field Follow-up

The SCCD has developed a Septic System Self-assessment Form that should be mailed to land owners identified in Step 2. Initially, these mailings should focus on septic systems located in critical areas that combine the three attributes (priority 1 septic systems): 1) within 100 m of the creek, 2) in aquifer sensitivity areas, and 3) in irrigated areas. If the landowner does not complete and return the form, field visits will be necessary to assist the landowner in filling out the form.

Subsequent mailings should be sent to landowners that have septic systems that are located in the next critical areas (priority 2 septic systems): 1) within 100 m of the creek, 2) in aquifer sensitivity areas, or 3) in irrigated areas. Following these mailings would be mailings to landowners that have septic systems located within 100 m of the creek (priority 3 septic systems). Finally, mailings would be sent to all remaining landowners with septic systems.

Step 4–Determine Triggers for Inspection

A septic system inspection program should be initiated. Management is an important issue for the successful performance of any on-site septic system. Part of that management is having septic tanks inspected and pumped on a regular basis. The frequency of required maintenance will vary due to the capacity of the septic tank and water usage. Periodic inspections can determine the current conditions of the tank and whether maintenance is required to obtain proper functioning.

Inspection triggers would be determined from information gathered on the Septic System Self-assessment Forms. Information that would trigger septic system inspections include, but are not limited to the following:

- The location of septic tank is unknown.
- The location of drainfield is unknown.
- The depth to season high groundwater is less than 4 feet.
- The septic tank is undersized for the size of the household.
- The septic system is older than 25 years.
- There is an impermeable surface such as concrete, asphalt, or brick located over the drainfield.
- Septic odors are present.
- Ponding or wastewater breakout is present.
- Burnt-out grass or ground staining is present over the drainfield.
- Patches of lush green grass are present over the drainfield.
- Pipes are exposed at or near the ground surface.
- Cracks or signs of leakage are present in risers and lids.
- There is an apparent cave-in or exposed component identified.
- The septic system was pumped/inspected over three years ago.
- The septic system is not permitted by Sheridan County.

Step 5–Inspect Septic System

This step includes a series of decision points used to evaluate the condition of the septic system. Using the information from Step 4, certain septic systems should be inspected. The first step in Step 5 is to determine if the seasonal high groundwater level has been determined. If not, a borehole, trench, or monitoring well (small 1-inch pipe, or piezometers) is needed. If the seasonal high groundwater level is less than 4 feet beneath the drainfield, an alternative drainfield should be designed and constructed. Alternative drainfields and septic system management measures are identified in the *Septic System Information Packet* (SCCD 2005b) and the *Septic System Impact Study* (HKM 2006). In addition to the alternative collection systems described in those references, water separation systems should be considered. One way to reduce septic system discharge is to reduce the volume of water passing through the system. This can be achieved by separating reusable water (e.g., showers, hand washing, sump pumps, and laundry) from highly contaminated water such as sewage. This reusable water is known as gray water, which can be used in Wyoming as subirrigation for trees and gardens. The use of gray water in Wyoming requires a permit from the Water and Wastewater group.

The next step is determining whether or not the septic tank has been pumped. The final step is determining a maintenance schedule for the septic system.

A successful and effective septic system management plan requires that the septic tank (or tanks) must be located on each property. This is particularly important for septic tanks located in priority areas, as described above (e.g., within 100 m of the creek, in aquifer sensitivity areas, in irrigated areas). If the location of the septic tank (or tanks) is not known, a maintenance plan cannot be implemented.

There are several methods available to locate a septic tank. The building permit for the home or the original septic system permit may show the location of the septic tank. If the septic tank is not shown on any permits, probes may be used to locate the tank. A probe (such as a metal rod) can be used to trace the pipeline from the house or by listening to the noise a plumber's snake makes when it contacts the tank inlet. Care must be used during probing to prevent damaging the inlet tees or piping. Another probing method used to locate septic tanks involves using a small diameter 0.5-inch galvanized pipe approximately 6 feet long and threaded to a garden hose. With the water turned on, the pipe is used to “jet” a hole into the ground and sound for the tank. If these methods fail, small radio transmitters can be used to locate the septic tank. The transmitters are flushed down the toilet, and a receiver is used to locate the transmitter inside of the tank. Once the tank is uncovered and opened, the transmitter can be retrieved.

Locating septic tanks can alert managers of improperly functioning systems or even illegal systems such as straight pipes. Creating an inventory and inspection, and developing a maintenance schedule of septic systems, can reduce pathogen loads without construction of new treatment facilities.

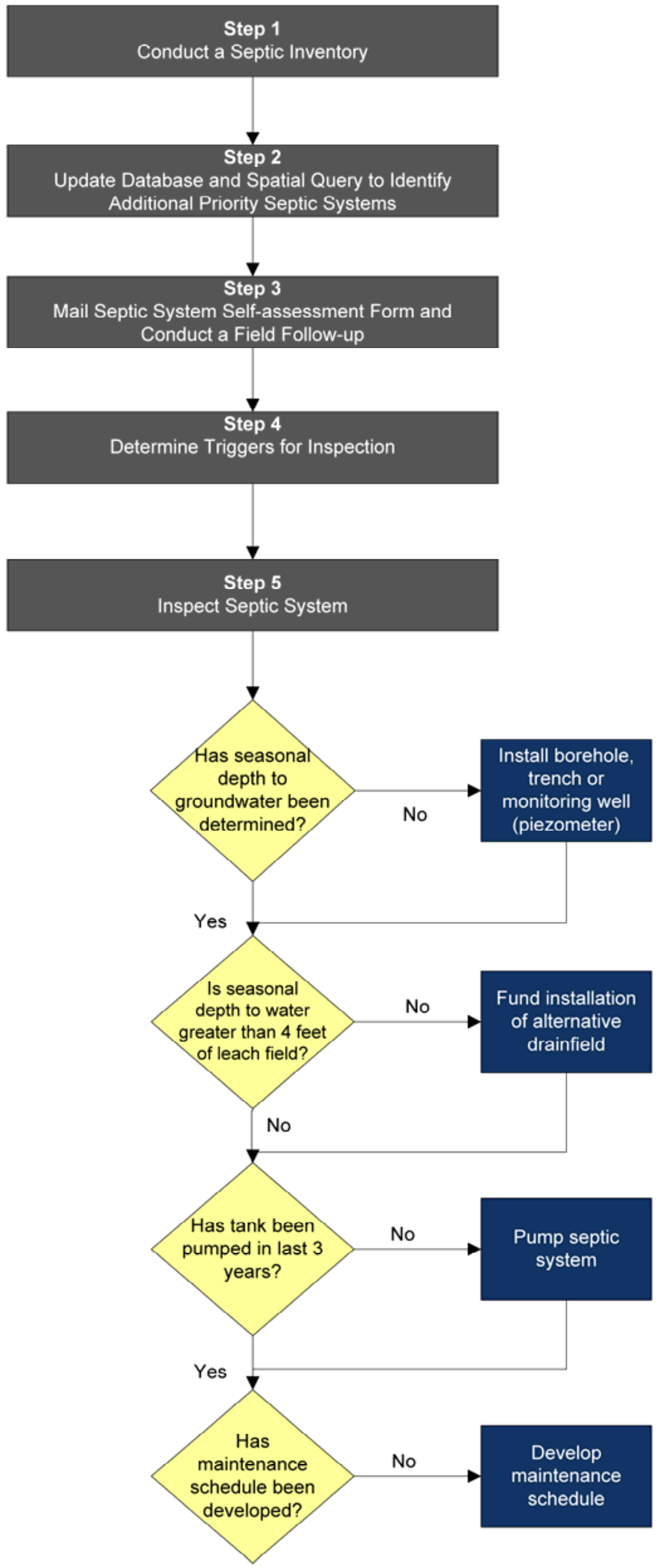


**Figure 9.1** A systematic approach for developing a septic system inventory and inspection program.

### Priority Areas for Implementation

To attain the TMDL target reductions of 75% from nonpoint sources in the Sheridan County area of the watershed, at least 862 septic systems (of the 1,149 septic systems in the county) need to be addressed through sewering or inspection and upgrades on an as-needed basis. The improvements would be spread among all of the impaired segments in the watershed; therefore, although sewering the Little Goose Creek Valley would result in improvement to impairments in that subwatershed, there would still be a need to address septic systems in the Big Goose Creek, Goose Creek, and Soldier Creek areas of the watershed. Specific quantities of septic systems requiring inventory, inspection, and possibly upgrades are described in Section 9.5.2.1.3. Using the information gathered from Step 4, septic system inspections and determination of potential project implementations are prioritized as follows:

**Priority 1 Septic Systems:** These septic systems are located in areas with a very high potential for delivering pathogen loads to creeks. These areas meet the following three criteria: 1) within 100 m of the creek, 2) in high aquifer sensitivity areas, and 3) in irrigated areas. There are 62 Priority 1 septic systems in Sheridan County.

**Priority 2 Septic Systems:** These septic systems are located in areas with a high potential for delivering pathogen loads to creeks. These areas meet the following two criteria: 1) within 100 m of the creek, and 2) in high aquifer sensitivity areas *or* in irrigated areas. There are 71 Priority 2 septic systems in Sheridan County.

**Priority 3 Septic Systems:** Septic systems located in these areas have the potential to deliver pathogen loads to creeks. These areas are located within 100 m of a creek. There are 11 Priority 3 septic systems in Sheridan County.

**Priority 4 Septic Systems:** Includes all other septic systems in Sheridan County. There are 996 Priority 4 septic systems in Sheridan County.

The locations of known septic systems within Priority 1 areas are shown on maps specific to each impaired segment (Maps 16 through 26).

Although a septic system may be considered a priority system under this implementation plan, Section 319 funds have more stringent eligibility criteria in Wyoming that limit which septics system projects can be funded. These include the following:

- Single family dwellings
- Septic systems installed prior to July 1, 1973
- Septic systems that surface within 500 feet from a focus water or a tributary to an impaired water (same HUC-8)
- Septic systems within 50 feet of a focus water with drainfields within seasonal groundwater saturation zone
- *Potentially eligible*: Systems with leach field within seasonal groundwater saturation zone but greater than 50 feet from focus waters (DEQ discretion)

## 9.5.2.2 PASTURED ANIMALS ON PRIVATE LANDS

### Existing Implementation Measures in Watershed

Twelve livestock facility improvements were implemented by SCCD and NRCS from 2004 to 2009. These consisted of seven projects in the Little Goose Creek Watershed, three projects in the Big Goose

Creek Watershed, and two projects in the Goose Creek Watershed. The SCCD and NRCS are currently funding and administering the local AFO program, including education and assistance for landowners with winter feeding grounds that potentially affect water quality. In addition, SCCD and NRCS have developed local water resource-related projects that include water quality assessments, watershed planning efforts, and watershed improvement programs that include improvements to AFOs, stock water development projects, riparian buffer projects, and stream channel restoration projects. The SCCD maintains self-assessment forms on their web site to assist homeowners in assessing their AFO. The SCCD web site also provides funding criteria for AFO improvements for cost-share assistance to homeowners and landowners in implementing water quality improvement projects.

## Recommended Implementation Measures for Future

It is recommended that the SCCD and NRCS continue to move forward with the AFO program and continue to make improvements to livestock feeding operations (Table 9.9). The first step in this effort should be documenting all of the existing projects (especially prescribed grazing plans) that have been completed for livestock in the watershed. Continuing the outreach and educational programs for rural livestock owners will also help raise awareness about the potential impacts of excessive grazing. The SCCD and NRCS should continue to provide landowners with education about riparian buffer technologies, as well as cost-share assistance through the USDA to landowners willing to improve properties.

**Table 9.9** Recommended Implementations for Pastured Animals on Private Lands

| AFO Implementation Measures | Strategy |
|---|---|
| Relocate Feeding Grounds | Move AFOs to upland areas away from streams. |
| Vegetative Buffer Strips | Construct vegetated filter strips between AFO and stream. |
| Stormwater Management | Redirect runoff flows that have a direct path to the stream. |
| Catch Basin | Create catchment areas for runoff flows. |
| Manure Stockpiling | Regularly remove manure from site and store away from AFO. |
| Stream Fencing | Fence animals out of stream. |
| Livestock Grazing Management Plan | Rotate livestock to maximize utilization of pastures and minimize impacts to water quality |
| Monitor Grazing | Regularly monitor vegetation to prevent overgrazing. |
| Riparian Buffer Strips | Protect a natural riparian buffer along streambank. |
| Stream Fencing | Fence animals out of stream. |
| Supplemental Feed Away from Stream | Feed animals as far as possible away from stream. |
| Delay Grazing until Upland Plants are Established | Allow time for seasonal succession of vegetation. |

## Priority Areas for Implementation

Approximately 6,400 cattle are in the rural catchments of the Goose Creek Watershed during the summer. To attain TMDL targets, implementation of AFOs and livestock grazing BMPs should be implemented for at least 4,800 cattle (approximately 75% of the total) to attain the required 75% reduction identified in the TMDL. The catchments that require the most load reduction of pastured animals are below the City of Sheridan (below GC1), BG4, McCormick Creek, BG11, Soldier Creek (GC4), Beaver Creek (BG9), Sackett Creek (LG19), and Park Creek (BG13). The first step in this effort is to document all of the prescribed grazing plans that have already been developed by SCCD and NRCS and the number of animals included in the plans. Once this has been completed SCCD will be able to determine how many additional plans and projects will be necessary to meet the target of addressing grazing management for 4,800 cattle.

The highest priority areas would be livestock operations that currently do not maintain any vegetative cover throughout the year, and that are in direct contact with the streambank. Focus should also be on areas that have high densities or high numbers of animals and for operations that facilitate animals year-round with no rest period.

### 9.5.2.3 BIG-GAME WILDLIFE, WATERFOWL, AND DOMESTIC ANIMALS

Waterfowl, domestic animals, and big-game wildlife in Sheridan County represent pathogen sources to rural stormwater and runoff to the creeks. Wildlife (mammals and birds) contribute a low level of fecal coliform to surface waters. Wildlife wastes are carried into nearby streams by runoff during rainfall or by direct deposit. White-tailed deer are the largest and most prominent wild animals in this area.

Urbanized or developed land typically generates an increased loading for pollutants, relative to forest and other undeveloped land uses. Dogs, cats, and other pets are the primary source of fecal coliform deposited on the urban landscape. Impervious surfaces increase the amount of runoff relative to predevelopment. The increased runoff from storms washes more of this fecal material into streams directly or through the storm sewers.

#### Existing Implementation Measures in Watershed

In 2003 a 27-acre riparian buffer project was completed on Jackson Creek. In 2009 a stream restoration project on Big Goose Creek was completed (SCCD 2004).

The SCCD is currently working with local agencies to improve or install stormwater BMPs to the extent that they are feasible. These BMPs include storm drain stenciling, settling basins, street snow management, street sweeper management, and oil/grease traps. The SCCD is working with contractors to minimize the potential stormwater impacts during development and construction periods (SCCD 2004) throughout Sheridan County. The SCCD aims to do the following:

- Encourage local municipalities, Sheridan County, and/or WYDOT to improve and/or install stormwater BMPs to the extent feasible (storm drain stenciling, settling basins, street snow management, street sweeper management, oil/grease traps, etc.).
- Continue to use the EnviroScape Model as an educational tool concerning stormwater (SCCD 2004).
- Work with stakeholders in the private sector to improve BMP implementation to minimize potential stormwater impacts during development and construction periods.
- Work with volunteer and nonprofit entities to improve the awareness of watershed condition and protection. Examples may include a river rakers program, watershed signage, and poster development (similar to the Goose Creek Watershed poster) for storm sewers.

#### Recommended Implementation Measures for Future

The SCCD should continue to provide public education concerning the potential wildlife impacts to water quality and the impacts of feeding wildlife near riparian areas, which artificially concentrates wildlife near sensitive riparian areas (see Section 9.8.1.11 for details). The SCCD should also provide education to dog owners with regard to pet waste management (see Section 9.8.12). The SCCD should also continue providing information on the impact of feeding wildlife near surface water through local backyard conservation organizations. In addition, measures for herd management may need to be taken to control herd sizes and distribution. Herd management may include the relocation of some herd members or simply the creation of alternate off-channel watering facilities away from streams.

### Priority Areas for Implementation

Priority areas for wildlife implementations would be in high-density wildlife populations near or in riparian areas. Priority would also be placed along streams that have unstable banks or poor riparian vegetation.

Areas of concern for contaminated stormwater would be dump sites located next to the river, and land where little or no riparian buffer exists to slow and filter stormwater flows. Other areas of high priority may be where recreational use along the river has left the streambanks unstable or has compacted the soil (not allowing for riparian vegetation to emerge).

# 9.6 Recommended Management and Implementation Measures for the City of Sheridan

## *9.6.1 Point Source Management Measures*

### 9.6.1.1 WASTEWATER TREATMENT

### City of Sheridan WWTP

A summary of recent DMR data received from WDEQ for the City of Sheridan WWTP indicates significant improvements in the treatment of *E. coli* and fecal coliform beginning in 2004. Daily *E. coli* loads have been reduced from 1,252 G-cfu/day in 2002 to 16 G-cfu/day in 2008 (see Table 6.4). Therefore, although Table 9.6 identifies a 90% reduction required for the City of Sheridan WWTP, this reduction has already been attained due to the improvements described above. In addition, a future growth allocation of 11 G-cfu/day has been identified for the City of Sheridan to accommodate additional population growth and sewer connections in the future (see Section 7.6.4).

Similarly, the City of Sheridan WWTP is currently discharging very low concentrations of sediment that are well below the permitted concentration of 30 mg/L and well below the LA for sediment of 500 kg/day.

No upgrades to the City of Sheridan WWTP are necessary to comply with this TMDL.

### Big Horn Mountain KOA WWTP

The TMDL calls for a 99.8% reduction in *E. coli* load from the current load for the Big Horn Mountain KOA WWTP. This load is consistent with the current permitted load for the facility. Although data used in the TMDL from 2002 through 2008 indicate significant exceedances of the KOA WWTP permit in 2002 and 2005, the treatment plant has been within its permit and therefore within the WLA for the TMDL since 2006. Therefore, continued operation of the WWTP, including chlorine disinfection, is necessary to meet the targets identified in this TMDL.

The Big Horn Mountain KOA WWTP is currently discharging very low concentrations of sediment that are well below the permitted concentration of 30 mg/L and well below the LA for sediment of 2 kg/day.

### 9.6.1.2 STORMWATER TREATMENT

The most significant point sources for the City of Sheridan requiring reduction of both pathogen (92% reduction required) and sediment (76% reduction required) loads are MS4 stormwater outfalls in the City of Sheridan.

## Existing Implementation Measures in Watershed

The *City of Sheridan Stormwater Management Plan* (HDR 1987) identifies the need to protect water quality by removing and collecting sediment and debris from stormwater. The plan indicates that sediment and debris must be taken into account by using detention storage and other means. The plan recognizes that detention and retention reservoirs provide an opportunity to improve the quality of the stormwater before it reaches streams in the watershed. The plan indicates that existing ponds and detention storage should be maintained as part of the stormwater facilities.

The plan also identifies the need for permanent or temporary erosion and sediment control. The need for sediment and erosion control facilities, either permanent or temporary, shall be determined according to the standards for sediment and erosion control in developing areas. A temporary erosion and sediment control plan is required unless otherwise approved by the city engineer. The temporary erosion and sedimentation control facility shall be constructed prior to any grading or extensive land clearing, in accordance with the above plan. These facilities must be satisfactorily maintained until construction and landscaping are completed and the potential for on-site erosion has passed.

In the past five years, the City of Sheridan has retrofitted six of the city's outfalls with Stormceptor technology, a type of sediment trap that provides a means to capture sediment prior to discharge to the receiving waterbody. Each Stormceptor cost approximately $60,000. The city is also currently installing 2 additional sediment traps, "downstream defenders," in conjunction with the North Main project with a cost of $56,000 (personal communication between Lane Thompson, City Engineer, City of Sheridan and Erica Gaddis, SWCA on July 29, 2010). The sediment traps are vacuumed out periodically on a regular basis. The City of Sheridan is also working to complete stormwater inlet marking and is conducting a public outreach campaign to educate the public on the potential impacts to water quality from storm runoff. The City of Sheridan is also working to enhance the city's stormwater system maintenance program. This includes identifying timelines for routine maintenance and identifying potential improvements that will reduce suspended solid impacts. Work is also being done to identify storm sewer improvements that will reduce levels of suspended solids. These improvements will be integrated into the city's five-year capital improvement plan. The SCCD and the City of Sheridan are working with stakeholders to improve BMPs to reduce sediment loads that could result from development and construction projects.

In addition, the city has made design criteria available to private developers. These design criteria are for detention points for new developments to reduce sediment and other pollutant transport to streams. The criteria are available at the City of Sheridan's web site. Developers are asked to design detention ponds for the first flush event (0.5 inch of rainfall depth) and to include a sediment forebay prior to discharging to the pond (City of Sheridan 2006).

The SCCD and the City of Sheridan are working with contractors to minimize the potential stormwater impacts during development and construction periods (SCCD 2004). Other efforts currently underway include the following:

- Complete stormwater inlet marking and conduct a public education and outreach campaign related to the City of Sheridan's stormwater system and to potential impacts to the watershed.
- Develop a GIS layer showing City of Sheridan stormwater components with appropriate attribute data.
- Enhance the City of Sheridan's stormwater system maintenance program by identifying timelines for routine maintenance and establishing record-keeping criteria. Review the City of Sheridan routine street maintenance protocols and identify potential improvements that will reduce suspended solids impacts.

- Evaluate options for identifying undesirable connections to the City of Sheridan storm drain system (i.e., sanitary sewer service line connections), particularly in those segments of storm sewer that have shown elevated levels of fecal coliform and/or *E. coli* in sample results.
- In the City of Sheridan, identify physical storm sewer improvements that will reduce levels of suspended solids entering the watershed. These improvements should be included in the *City of Sheridan–Capital Improvement Plan*, as funding will allow.

## Recommended Implementation Measures for Future

### *Stormwater Treatment*

We recommend that the city continue to implement sediment traps for all outfalls around the city. Additional stormwater treatment measures are also required to reduce the pathogen load from storm drains. The most effective measures for pathogen reduction are infiltration basins and trenches as well as measures to reduce stormwater flow and increase infiltration (e.g., bioretention in the form of rain gardens and green roofs or porous pavement). Wetland basins are also very effective at removing pathogens, but they would need to be designed such that they do not attract additional waterfowl. A combination of surface and subsurface flow wetlands would be recommended for this reason. A description of each of these measures is available at the U.S. EPA-sponsored BMP database and is summarized below (U.S. EPA et al. 2010).

**Infiltration basins and trenches:** Infiltration basins and trenches are designed to infiltrate stormwater into the soil with high pollutant-removal efficiency. Other benefits to the practice are recharging groundwater, increasing baseflow in stream systems, and slowing stormwater runoff and in-stream erosion associated with peak flows. Infiltration basins are generally shallow impoundments, whereas infiltration trenches are rock-filled trenches with no outlets. They have been found to remove 90% of bacteria in stormwater (U.S. EPA 2006a). Infiltration basins can be designed as constructed wetlands by incorporating wetland plants into the shallow impoundment. This offers both aesthetic value as well as improved pollution reduction.

**Green roofs, rain gardens, and porous pavement:** Green roofs are roofs that are composed of soil and planted with vegetation. Rain gardens are landscaping features in small pockets of residential land uses that provide for on-site infiltration of groundwater. Porous pavement is pervious concrete that allows water to drain through it. They are generally planted with water tolerant plants. The primary mechanism by which these systems reduce pathogens is through reducing the total volume of stormwater that runs off the landscape. In addition, pathogens tend to die quickly when infiltrated through soil into groundwater. Green roofs and rain gardens effectively capture, infiltrate, and absorb stormwater. These systems should be dispersed around the city on individual roofs and residential and commercial properties (U.S. EPA 2006b, 2008, 2009).

## Priority Areas for Implementation

The *City of Sheridan Stormwater Management Plan* includes a drainage plan that would move stormwater out of the city more efficiently. The report identifies 13 locations where stormwater was backing up and several pipelines that needed to be updated. In addition to improving drainage in the city, stormwater drains with the highest recorded fecal coliform and *E. coli* concentrations should be the priority for stormwater treatment to improve water quality. Based on the available data from storm drains in the City of Sheridan (see Table 6.8) the priority outfalls and lines, in this order, are as follows:

- Priority 1: G-line
- Priority 2: D+E-line and D-line
- Priority 3: S-line and N-line

Areas of concern in the drainage of each of these would include locations of large areas of impervious surfaces, such as large commercial or municipal buildings. Any large impervious surface would quickly transport snowmelt and stormwater into the water system along with any contaminants found on those surfaces. Areas of high usage of domestic pets would also be of concern. These areas could include dog parks or large open spaces that are frequented by pet owners.

## 9.6.2 Nonpoint Source Management Measures

### 9.6.2.1 ON-SITE WASTEWATER TREATMENT PLANTS (SEPTIC SYSTEMS)

On-site WWTPs make up 20% of the total pathogen load to creeks in the Sheridan County rural catchments. This load is associated with failing septic systems, straight pipe systems that do not include a functioning drainfield, and septic systems that are close to shallow groundwater.

#### Existing Implementation Measures in Watershed

The City of Sheridan is continuing to identify and map the septic systems within the city limits. The City of Sheridan is also investigating the condition of sanitary sewer creek crossings and identifying those in need of repair. The HKM study evaluates alternative funding sources for public sewer development and the formation of sewer improvement districts. The HKM septic study also evaluates alternative, individual sanitation systems technologies for the treatment of on-site septic systems (HKM 2006).

Several septic permits exist in the City of Sheridan where sanitary sewer service is currently available. Any septic systems in these areas were likely abandoned and the residence connected to the city sewer. The septic dataset does not reflect permitted systems that were abandoned due to connection to the city sewer, however, as demonstrated in the Downer Neighborhood area where sanitary sewer is now available.

#### Recommended Implementation Measures for Future

As noted above in the *Septic System Impact Study* (HKM 2006), an inventory of septic systems in the Goose Creek Watershed was conducted. However, as also noted in that study, several septic permits exist in the City of Sheridan where sanitary sewer service is currently available. Any septic systems in these areas should have been abandoned and the residence connected to the city sewer. The septic dataset does not reflect permitted systems that were abandoned due to connection to the city sewer, however, as demonstrated in the Downer Neighborhood area where sanitary sewer is now available.

The overall recommendation for the city septic systems is to ensure that all septic systems within the city limits are connected to the city sewer.

### 9.6.2.2 BIG-GAME WILDLIFE, WATERFOWL, AND DOMESTIC ANIMALS

The majority of the load from domestic animals and some waterfowl is captured in the point stormwater loads described in Section 9.2.3.

#### Existing Implementation Measures in Watershed

The SCCD provides information to the public about the impacts of high concentrations of wildlife near riparian areas, which are usually caused by the feeding the wildlife.

#### Recommended Implementation Measures for Future

To reduce the fecal coliform load from city wildlife, the feeding of wildlife should be discourage by signage at local city parks. In addition, efforts could be made to educate homeowners along the river corridor about the potential water quality effects that could occur if they were to feed wildlife on their property. Educational programs could be initiated to educate the public about the negative effects of releasing domesticated waterfowl into the environment. In addition, swales or other infiltration mechanisms should be considered in city parks adjacent to creeks to reduce washoff of waterfowl excrement.

### Priority Areas for Implementation

Priority areas are city parks that are known to have a large duck and goose population that is sustained largely by public feeding. Another priority would be identifying or locating homeowners that may feed wildlife on their property, especially if the feeding is taking place during winter months.

## 9.7 Summary of Implementation Measures for Impaired Waters

To gain further perspective on the implementations required to meet water quality standards, efforts were made to summarize the suggested measures to improve water quality on each of the impaired segments in the Goose Creek Watershed. The total watershed area is included in each table, and the total area for differing land uses and habitat is included. It is important to note that land uses overlap with habitat (e.g., wildlife habitat and pasture), therefore they do not sum to the total acreage in the watershed. In the following tables, the percent reduction required was classified into hydrologic flow regimes, and priority actions were designated for each impaired segment.

**Table 9.10** A Summary of Implementation Measures for McCormick Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 4,586 acres | |
| **Current Average Daily Load** | | 28.6 G-cfu/day | |
| **Current Average Daily Capacity** | | 6.2 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 28.6 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 78% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 81% | Livestock, wildlife, domestic animals |
| | **Medium** | 62% | All |
| | **Low** | 57% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 62 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 9 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 11 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 0 | |
| | Priority 4: Number of all other septic systems | 42 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 3,943.9 | |
| | Public grazing land | 0 | |
| | Developed | 137.6 | |
| | Deer habitat | 4,494.3 | |
| | Irrigated land | 412.7 | |
| **Priority Actions** | | 1. Conduct a septic inventory<br>2. Address at least nine septic systems that are within 100 m of the creek and in high aquifer sensitivity and in irrigated lands.<br>3. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis. | |

**Table 9.11** A Summary of Implementation Measures for Sackett Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 2,186 acres | |
| **Current Average Daily Load** | | 14.4 G-cfu/day | |
| **Current Average Daily Capacity** | | 4.6 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 14.4 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 68% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 73% | Livestock, wildlife, domestic animals |
| | **Medium** | 1% | All |
| | **Low** | 38% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High Flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 24 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 4 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 3 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 3 | |
| | Priority 4: Number of all other septic systems | 14 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 1,617.6 | |
| | Public grazing land | 0 | |
| | Developed | 0 | |
| | Deer habitat | 2,142.3 | |
| | Irrigated land | 371.6 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock/wildlife.<br>4. Develop prescribed grazing plans for all livestock in watershed.<br>2. Conduct a septic inventory.<br>3. Address at least four septic systems that are within 100 m of creek and in high aquifer sensitivity and in irrigated lands.<br>4. Improve AFOs and manage pasture on a voluntary basis. | |

**Table 9.12** A Summary of Implementation Measures for Jackson Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 6,082 acres | |
| **Current Average Daily Load** | | 23.5 G-cfu/day | |
| **Current Average Daily Capacity** | | 3.8 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 23.5 G-cfu/day | |
| | **Point Sources** | *N/A | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 84% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 87% | Livestock, wildlife, domestic animals |
| | **Medium** | 63% | All |
| | **Low** | 0% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High Flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 58 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 6 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 9 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 0 | |
| | Priority 4: Number of all other septic systems | 43 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 3,770.8 | |
| | Public grazing land | 790.7 | |
| | Developed | 121.6 | |
| | Deer habitat | 6,082 | |
| | Irrigated land | 1,033.9 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock and wildlife.<br>2. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis.<br>3. Conduct a septic inventory.<br>4. Address at least six septic systems that are within 100 m of creek and in high aquifer sensitivity and in irrigated lands. | |

**Table 9.13** A Summary of Implementation Measures for Little Goose Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 96,572 acres | |
| **Current Average Daily Load** | | 63.1 G-cfu/day | |
| **Current Average Daily Capacity** | | 32.8 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 20% | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 80% (impaired tributaries Sackett, Jackson, Kruse, and McCormick creeks) | |
| **Overall Percent Reduction Required** | | 48% (attainable through improvements on tributaries) | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 46% | Livestock, wildlife, domestic animals |
| | **Medium** | 42% | All |
| | **Low** | 81% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | Low flow | |
| **Diversions to and from Impaired Segment** | | Colorado Colony Ditch to Big Goose Creek (Stream mile 21.1)<br>Peralta Ditch | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 665 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 24 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 9 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 2 | |
| | Priority 4: Number of all other septic systems | 630 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 46,354.6 | |
| | Public grazing land | 29,937.3 | |
| | Developed | 4,828.6 | |
| | Deer habitat | 48,286 | |
| | Irrigated land | 14,485.8 | |
| **Priority Actions** | | 1. Conduct a septic inventory.<br>2. Conduct septic tank improvements that are warranted by inspection or on a voluntary basis.<br>3. Support improvements in tributary catchments. | |

**Table 9.14** A Summary of Implementation Measures for Kruse Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 5,764 acres | |
| **Current Average Daily Load** | | 33.2 G-cfu/day | |
| **Current Average Daily Capacity** | | 9.0 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 33.2 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 73% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 80% | Livestock, wildlife, domestic animals |
| | **Medium** | 50% | All |
| | **Low** | 36% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High Flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 78 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 3 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 1 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 1 | |
| | Priority 4: Number of all other septic systems | 73 | |
| **Land use and Habitat Distribution (acres** | Pasture and range | 3,861.9 | |
| | Public grazing land | 0 | |
| | Developed | 0 | |
| | Deer habitat | 5,764 | |
| | Irrigated land | 1,786.8 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock and wildlife.<br>2. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis.<br>3. Conduct a septic inventory.<br>4. Address at least three septic systems that are within 100 m of creek and in high aquifer sensitivity and in irrigated lands. | |

**Table 9.15** A Summary of Implementation Measures for Rapid Creek

<table>
<tr><td colspan="2">Watershed Area</td><td colspan="2">10,499 acres</td></tr>
<tr><td colspan="2">Current Average Daily Load</td><td colspan="2">7.4 G-cfu/day</td></tr>
<tr><td colspan="2">Current Average Daily Capacity</td><td colspan="2">6.1 G-cfu/day</td></tr>
<tr><td rowspan="3">Distribution of Current Average Daily Load</td><td>Nonpoint Sources</td><td colspan="2">7.4 G-cfu/day</td></tr>
<tr><td>Point Sources</td><td colspan="2">0 G-cfu/day</td></tr>
<tr><td>Upstream Sources</td><td colspan="2">0 G-cfu/day</td></tr>
<tr><td colspan="2">Overall Percent Reduction Required</td><td colspan="2">18%</td></tr>
<tr><td rowspan="4">Flow Regime Reduction Required and Probable Sources</td><td></td><td>Percent Reduction Required</td><td>Probable Sources</td></tr>
<tr><td>High</td><td>0%</td><td>Livestock, wildlife, domestic animals</td></tr>
<tr><td>Medium</td><td>59%</td><td>All</td></tr>
<tr><td>Low</td><td>36%</td><td>Septic systems</td></tr>
<tr><td colspan="2">Critical Flow Regime(s) for Exceedances</td><td colspan="2">Medium Flow</td></tr>
<tr><td colspan="2">Diversions to and from Impaired Segment</td><td colspan="2">None</td></tr>
<tr><td colspan="4">Potential Nonpoint Sources:</td></tr>
<tr><td rowspan="5">Septic Statistics</td><td>Total number of septic systems</td><td colspan="2">8</td></tr>
<tr><td>Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands</td><td colspan="2">0</td></tr>
<tr><td>Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands]</td><td colspan="2">3</td></tr>
<tr><td>Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands</td><td colspan="2">3</td></tr>
<tr><td>Priority 4: Number of all other septic systems</td><td colspan="2">2</td></tr>
<tr><td rowspan="5">Land Use and Habitat Distribution<br>(acres)</td><td>Pasture and range</td><td colspan="2">3,989.6</td></tr>
<tr><td>Public grazing land</td><td colspan="2">5,774.5</td></tr>
<tr><td>Developed</td><td colspan="2">0</td></tr>
<tr><td>Deer habitat</td><td colspan="2">10,499</td></tr>
<tr><td>Irrigated land</td><td colspan="2">524.9</td></tr>
<tr><td colspan="2">Priority Actions</td><td colspan="2">1. Conduct a septic inventory<br>2. Address at least three septic systems that are within 100 m of creek and in high aquifer sensitivity or in irrigated lands.<br>3. Install upland off-channel watering troughs for livestock/wildlife.<br>4. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis.</td></tr>
</table>

**Table 9.16** A Summary of Implementation Measures for Park Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 4,308 acres | |
| **Current Average Daily Load** | | 0.7 G-cfu/day | |
| **Current Average Daily Capacity** | | 0.2 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 0.7 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 71% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 27% | Livestock, wildlife, domestic animals |
| | **Medium** | 93% | All |
| | **Low** | 0% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | Medium Flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 0 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 0 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 0 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 0 | |
| | Priority 4: Number of all other septic systems | 0 | |
| **Land Use and Habitat Distribution** **(acres)** | Pasture and range | 3,144.8 | |
| | Public grazing land | 0 | |
| | Developed | 0 | |
| | Deer habitat | 4,308 | |
| | Irrigated land | 818.5 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock/wildlife.<br>2. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis. | |

**Table 9.17** A Summary of Implementation Measures for Beaver Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 8,877 acres | |
| **Current Average Daily Load** | | 71.5 G-cfu/day | |
| **Current Average Daily Capacity** | | 13.2 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 71.5 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 82% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 86% | Livestock, wildlife, domestic animals |
| | **Medium** | 52% | All |
| | **Low** | 0% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High Flow | |
| **Diversions to and from Impaired Segment** | | None | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 43 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 0 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 4 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 0 | |
| | Priority 4: Number of all other septic systems | 39 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 6,746.5 | |
| | Public grazing land | 621.4 | |
| | Developed | 0 | |
| | Deer habitat | 8,877 | |
| | Irrigated land | 3,373.3 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock and wildlife.<br>2. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis.<br>3. Conduct a septic inventory<br>4. Address at least four septic systems that are within 100 m of creek and in high aquifer sensitivity or in irrigated lands. | |

**Table 9.18** A Summary of Implementation Measures for Big Goose Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 130,192 acres | |
| **Current Average Daily Load** | | 103 G-cfu/day | |
| **Current Average Daily Capacity** | | 83.5 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 51% | |
| | **Point Sources** | 0% | |
| | **Upstream Sources** | 49% | |
| **Overall Percent Reduction Required** | | 19% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 24% | Livestock, wildlife, domestic animals |
| | **Medium** | 0 | All |
| | **Low** | 61% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | Low. | |
| **Diversions to and from Impaired Segment** | | PK Ditch and Alliance Lateral Ditch to Soldier Creek Subwatershed<br>Colorado Colony ditch from Little Goose Creek | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 187 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 15 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 26 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 1 | |
| | Priority 4: Number of all other septic systems | 145 | |
| **Land Use and Habitat Distribution**<br>**(acres)** | Pasture and range | 55,982.6 | |
| | Public grazing land | 41,661.4 | |
| | Developed | 1,301.9 | |
| | Deer habitat | 70,303.7 | |
| | Irrigated land | 10,415.4 | |
| **Priority Actions** | | 1. Conduct a septic inventory.<br>4. Conduct septic tank improvements that are warranted by inspection or on a voluntary basis.<br>2. Support improvements in tributary catchments. | |

**Table 9.19** A Summary of Implementation Measures for Soldier Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 20,529 acres | |
| **Current Average Daily Load** | | 36.1 G-cfu/day | |
| **Current Average Daily Capacity** | | 6.8 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 36.1 G-cfu/day | |
| | **Point Sources** | 0 G-cfu/day | |
| | **Upstream Sources** | 0 G-cfu/day | |
| **Overall Percent Reduction Required** | | 81% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 83% | Livestock, wildlife, domestic animals |
| | **Medium** | 45% | All |
| | **Low** | 88% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | High & Low Flow | |
| **Diversions to and from Impaired Segment** | | PK Ditch and Alliance ditch from Big Goose Creek. | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 26 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 0 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 0 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 0 | |
| | Priority 4: Number of all other septic systems | 26 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 16,628.5 | |
| | Public grazing land | 410.6 | |
| | Developed | 0 | |
| | Deer habitat | 20,529 | |
| | Irrigated land | 4,311.1 | |
| **Priority Actions** | | 1. Install upland off-channel watering troughs for livestock/wildlife.<br>2. Develop prescribed grazing plans for all livestock in watershed. Improve AFOs and manage pasture on a voluntary basis.<br>3. Conduct a septic inventory.<br>5. Conduct septic tank improvements that are warranted by inspection or on a voluntary basis. | |

**Table 9.20** A Summary of Implementation Measures for Goose Creek

| | | | |
|---|---|---|---|
| **Watershed Area** | | 39,822 acres | |
| **Current Average Daily Load** | | 750.2 G-cfu/day | |
| **Current Average Daily Capacity** | | 192.9 G-cfu/day | |
| **Distribution of Current Average Daily Load** | **Nonpoint Sources** | 7% | |
| | **Point Sources** | 70% | |
| | **Upstream Sources** | 22% | |
| **Overall Percent Reduction Required** | | 43% | |
| **Flow Regime Reduction Required and Probable Sources** | | **Percent Reduction Required** | **Probable Sources** |
| | **High** | 79% | Stormwater |
| | **Medium** | 10% | All sources |
| | **Low** | 51% | Septic systems |
| **Critical Flow Regime(s) for Exceedances** | | | |
| **Diversions to and from Impaired Segment** | | | |
| **Potential Nonpoint Sources:** | | | |
| **Septic Statistics** | Total number of septic systems | 395 | |
| | Priority 1: Number of septic systems within 100 m of creek AND in high aquifer sensitivity areas AND in irrigated lands | 13 | |
| | Priority 2: Number of septic systems within 100 m of creek AND [in high aquifer sensitivity areas OR in irrigated lands] | 16 | |
| | Priority 3: Number of septic systems within 100 m of creek not in high aquifer sensitivity areas not in irrigated lands | 18 | |
| | Priority 4: Number of all other septic systems | 348 | |
| **Land Use and Habitat Distribution (acres)** | Pasture and range | 30,264.7 | |
| | Public grazing land | 398.2 | |
| | Developed | 1,194.7 | |
| | Deer habitat | 13,141.3 | |
| | Irrigated land | 7,566.2 | |
| **Priority Actions** | | 1. Improve stormwater treatment in the City of Sheridan.<br>2. Connect septic systems within the City of Sheridan to WWTP.<br>3. Install upland off-channel watering troughs for livestock/wildlife (area below City of Sheridan).<br>4. Develop prescribed grazing plans for all livestock in watershed (area below City of Sheridan).<br>5. Improve AFOs and manage pasture on a voluntary basis (area below City of Sheridan). | |

# 9.8 Information and Education

The information and education plan (I/E plan) described in this section is partially adapted from the plans outlined in the 2004 *Goose Creek Watershed Management Plan*. Further watershed improvement actions and recommendations can be found in the management plan. The goals and objectives of the I/E plan include outreach, training, information, and assistance to specific demographics throughout the Goose Creek Watershed.

## *9.8.1 Define the Driving Forces, Goals, and Objectives*

The driving force of the I/E plan is to attain water quality standards through implementation of TMDL target sediment and pathogen load reductions and to eliminate the impairments to the recreational uses and cold-water fishery. The goals of the I/E plan are described in the following sections per target audience.

### 9.8.1.1 RESIDENTIAL OUTREACH

The target audience for the residential outreach goal consists of residents who are responsible for managing lands on either streambank or the stream channel itself, and whose actions or inactions have a direct impact to the water quality of the stream. The objective of this goal is to educate this portion of the public whose activities have a direct relationship to pollutant loading into the stream channel.

To accomplish this objective, the SCCD, the Wyoming Department of Health, and WDEQ have already posted signs to warn residents of the potential pathogens in highly used areas. The SCCD, City of Sheridan, and Sheridan County participate in the Sheridan County Household Hazardous Waste Collection Day. The SCCD and NRCS provide a) information and assistance to landowners for fish-friendly irrigation structures, b) information concerning inter-relationships among water quality parameters, and c) technical and financial assistance to landowners for watershed improvement projects. In addition to these measures, the SCCD should initiate a volunteer-based biennial stormwater inlet marking campaign, which would include educating landowners on the proper mitigation and potential fates of excess sediment during storm events.

### 9.8.1.2 WATERSHED OUTREACH

The target audience for the watershed outreach goal consists of any citizen or organization in the region seeking information or regulations specific to the Goose Creek Watershed. The objective of this goal is to create a central database housing all watershed information and links that individuals can be referred to for a variety of inquiries.

To accomplish this objective, an online database will be maintained where watershed residents can access information about Goose Creek Watershed projects, water laws, water conservation, volunteer opportunities, and poster contests. In addition to maintaining a data storage site, public meetings, such as the one held at Sheridan College in 2003, will also be held.

### 9.8.1.3 LANDOWNERS

The target audience for this goal consists of individuals who own land directly adjacent to the stream and who use the land for grazing or agricultural purposes. The objective of this goal is to educate agricultural managers on proper land stewardship and on the potential harm caused by poor land-use practices.

To accomplish this objective, an educational booth could be operated annually at the local county fair, educating small-acreage landowners on the proper management of riparian vegetation and stream diversion structures. Wildlife resource agents could join this effort and help educate landowners on ways to increase fishing opportunities on their property by establishing quality aquatic habitats.

### 9.8.1.4 ANIMAL FEED OPERATIONS OPERATORS

The target audience for the AFO goal consists of businesses or individuals that maintain and operate AFOs in the watershed. These AFOs result in land that does not produce any type of vegetation cover throughout the majority of the year. The objective of this goal is to provide voluntary, locally directed, financial and technical assistance to producers wishing to minimize the impact of a livestock operation on adjacent waterways.

The SCCD and NRCS currently administer an AFO improvement program aimed at providing financial and technical assistance to local livestock owners who desire to improve impacts caused by livestock operations. The program provides incentives to landowners for the rearrangement or relocation of corrals and feeding areas that have potential to negatively affect water quality. Funding for this program is provided by a combination of federal and state grants and landowner contributions, which are administered by the SCCD. Information about this program can be accessed through the SCCD web site. In addition, public workshops to discuss AFO with local landowners have been held in January 2001, February 2002, and April 2003.

### 9.8.1.5 AFFILIATES OF THE AGRICULTURAL INDUSTRY

The target audience for this goal consists of individuals that have contact or relationships with the agricultural community in the watershed (extension agents, veterinarians, Future Farmers of America, county commissioners). The objective of this goal is to maintain working relationships with representatives of the agricultural community who can expand outreach to the communities in which they already have established relationships.

Regional agricultural affiliates should be included on planning and outreach committees to broaden the networking of education and outreach to agricultural operators. The SCCD currently has plans to deliver an education program to affiliates of the agricultural industry concerning the potential impacts animal waste may have on local water quality.

### 9.8.1.6 CONTRACTORS AND BUILDERS

The target audience for this goal consists of individuals responsible for the day-to-day operation of construction sites or other building projects in the watershed. The objective of this goal is to educate contractors and builders about BMPs that minimize the potential stormwater impacts during development and construction.

The City of Sheridan and the SCCD currently work with stakeholders in the private sector to improve BMP implementation to minimize potential stormwater impacts during development and construction periods. In addition, a hands-on seminar hosted by vendors should be organized on a regular basis to demonstrate proper selection, installation, and maintenance of stormwater control methods for local contractors and builders.

### 9.8.1.7 LOCAL SCHOOL EDUCATION PROGRAM

The target audience for this goal consists of local school districts in the watershed. The objective of this goal is to get future Goose Creek Watershed residents informed and involved about watershed health.

During January 2005, in coordination with a sixth grade after-school program, a contest was initiated for developing a logo to represent the watershed project. Contests such as these should be continued to expand community involvement and awareness of current watershed projects. In addition to contests, local grade school teachers should be provided with classroom curriculum for using the EnviroScape Model as an educational tool. A materials checkout program should be created, which would allow for school districts to borrow models owned by extension offices, or from the SCCD.

#### 9.8.1.8 SEPTIC TANK OWNERS

The target audience for this goal consists of individuals in the watershed who own or use septic tank systems. The objective of this goal is to continue SCCD and NRCS's outreach campaign to improve residential septic tank systems.

The SCCD-NRCS Septic System Improvement program is a local program that provides voluntary, locally directed, financial and technical assistance for repair or replacement of existing septic systems that likely impact water quality. Funding for this program is provided by a combination of federal and state grants, landowner contributions, and is administered by the SCCD. Septic system information packets, homeowner self-assessment forms, criteria for funding, and a HKM 2006 *Septic System Impact Study* are all available on the SCCD web site. In addition, a septic system and pathogen workshop was hosted by SCCD and the Soil and Water Conservation Society in January 2005. A second septic system workshop was hosted by SCCD in February 2006.

#### 9.8.1.9 TOURS OF SUCCESSFUL RESTORATION AND ENHANCEMENT PROJECTS

The target audience for this goal consists of citizens of the watershed who may be interested in volunteering time or property for future restoration projects. The objective of this goal is to increase awareness and benefits of stream restoration projects.

To accomplish this objective, virtual tours of restoration projects should be featured on the SCCD's web site. Tours could include before and after pictures taken at reference points, including pre- and post-monitoring summaries as they are conducted. A similar demonstration project was completed by the SCCD, where a mounded drainfield was constructed for a landowner, and video of the project is available through the SCCD office and the Sheridan County Engineer's Office.

#### 9.8.1.10 MUNICIPAL EMPLOYEE TRAINING

The target audience for this goal consists of Sheridan County and City of Sheridan employees involved in plan reviews and inspections. The objective of this goal is to train municipal employees to enforce rules and regulations related to pathogen and sediment management when reviewing plans and permits for buildings and developments.

To accomplish this objective, annual training sessions should be conducted for municipal personnel involved in building permit issuance, inspections, or stormwater compliance.

#### 9.8.1.11 HUMAN WILDLIFE INTERACTIONS

The target audience for this goal consists of residents or visitors to the watershed who feed wildlife, thereby artificially concentrating wildlife near sensitive riparian areas. The objective of this goal is to discontinue the feeding of wildlife, especially waterfowl in city parks, to reduce pathogen loading from artificially high density populations.

The SCCD currently provides public education concerning the potential wildlife impacts to water quality, and the impacts of feeding and thereby artificially concentrating wildlife near sensitive riparian areas. The SCCD also provides information on the impact of feeding wildlife near surface waters through local backyard conservation organizations. In addition to the programs the SCCD has established, the City of Sheridan should post informational signage at city parks providing information about potential pathogen loading from overcrowded wildlife densities.

#### 9.8.1.12 PET WASTE MANAGEMENT

The target audience for this goal consists of homeowners and city park managers located in the watershed. The objective of this goal is to increase public awareness of the bacteria, viruses, and parasites that can be transported by improperly disposed of pet waste. Furthermore, education should be provided to illustrate the link between pet waste and unhealthy drinking and recreation waters.

City ordinances should be passed to implement pet waste management at local parks. Park signage should be used to designate where dogs are prohibited, where waste must be recovered, or where dogs can roam freely. In areas where dog waste must be recovered, clean up stations should be provided for park visitors.

### *9.8.2 Identify and Analyze the Target Audiences*

The target audience for the I/E plan consists of residential homeowners, agricultural operation managers, contractors and builders, and municipal employees in the watershed.

### *9.8.3 Create the Message*

Specific messages will be developed for each I/E plan effort as implementation proceeds. However, the following are the primary messages that will be communicated in all I/E plan efforts:

- Excess sediment deposition to the water contributes to impairments observed throughout the Goose Creek Watershed.
- The majority of pathogen and sediment load reductions rely on nonpoint source management measures.
- Likely contributors to pathogen and sediment loading in the Goose Creek Watershed may be a result of wild and domestic animal loading in the upper watershed and as a result of human activities lower in the watershed.
- Residents must work together and become good stewards of the land to overcome sediment and pathogen issues.
- Information concerning all watershed activities should be published and made accessible in a centralized online database collection.
- Those entrusted with oversight and regulation authority will be trained to provide accurate land-use and watershed information to the public.

Specific appropriate messages for the identified target audiences will be developed for each I/E plan effort as implementation proceeds. The survey work will assess current levels of knowledge regarding water quality impairments. The information obtained from this survey will be used to develop the messages.

### *9.8.4 Package and Distribute the Message*

Each I/E plan component will require a different means to package and distribute the message. Successful I/E plan efforts already undertaken in the watershed relied primarily on workshops, trainings, and short informational materials.

## 9.9 Technical and Financial Needs

This section identifies the types of technical and financial assistance needed to implement the plan and the agencies, resources, and authorities that may be relied on for implementation. Funding and technical assistance are critical factors for implementing the plan, long-term operation and maintenance of management measures, information and education activities, and monitoring.

Implementation of the management measures and BMPs necessary to meet the water quality goals outlined in the TMDL will require a significant allocation of financial and technical resources from multiple sources. Cost-benefit studies are recommended as a tool for identifying the most cost-effective strategies to prioritize throughout the watershed. The implementation plan and costs outlined here are a general guide and are not intended to be a comprehensive list of costs associated with all potential BMPs or required resources. Final decisions on project implementation will be made by land managers and owners based on their intricate knowledge of specific areas of the watershed.

## 9.9.1 Plan Sponsors and Resources

The GCWPC will be the lead project sponsor for nonpoint source improvements. The committee is a coalition of public and private individuals who have a vested interest in restoring the watershed to a healthy state. The committee has several working groups including education, monitoring, and stream restoration. In addition, the committee maintains a link on the SCCD web site as a public service to educate and inform those interested in the issues surrounding the Goose Creek Watershed. Stakeholders that will be involved in technical assistance and execution of the implementation plan include the following:

- Sheridan County Conservation District
- Natural Resources Conservation Service
- Sheridan County
- Sheridan County Planning and Zoning Commission
- City of Sheridan
- Wyoming Department of Environmental Quality
- Private land owners
- Watershed residents

Historically, members of the GCWPC met on a quarterly basis to implement various projects in the watershed. Watershed improvement projects continue to be implemented, with much more activity planned for the near future.

## 9.9.2 Point Source Management Measures and BMP Implementation

### 9.9.2.1 POINT SOURCES IN CITY OF SHERIDAN

To address point sources in the City of Sheridan, the SCCD is currently working with local agencies to improve or install stormwater BMPs in the city to the extent that they are feasible. These BMPs include storm drain stenciling, settling basins, street snow management, street sweeper management, and oil/grease traps. The SCCD and the City of Sheridan are working with contractors to minimize the potential stormwater impacts during development and construction periods (SCCD 2004).

Additional technical and financial support is needed to accomplish the following:

- Install stormwater treatment BMPs throughout the city, including infiltration trenches and detention basins. Assuming a cost of $2/cubic foot of stormwater treated and a design storm of 0.5 inch, the estimated cost to install infiltration trenches throughout the city is $545,500.

- Install sediment traps in remaining lines for the entire City of Sheridan (several have already been installed). Sediment traps cost approximately $56,000 each. Assuming the City of Sheridan has already installed Stormceptors for seven lines in the city, the cost for the remaining 12 lines would cost approximately $720,000.
- Improve stormwater through educational efforts, including the following:
  - Continue to use the EnviroScape Model as an educational tool concerning stormwater.
  - Complete stormwater inlet marking and conduct a public education and outreach campaign related to the City of Sheridan's stormwater system and potential impacts to the watershed.
  - Work with construction contractors to improve BMP implementation to minimize potential stormwater impacts during development and construction periods.
  - Work with volunteer and nonprofit entities to improve the awareness of watershed condition and protection. Examples may include a river rakers program, watershed signage, and poster development (similar to the Goose Creek Watershed poster) for storm sewers.
  - Develop a public education program for feeding wildlife in city parks. Install signs reminding people not to feed waterfowl or wildlife.
  - Continue public education program for pet waste management. Install signs and bag dispensers to control pet waste in city parks
  - Evaluate options for identifying undesirable connections to the City of Sheridan storm drain system (e.g., sanitary sewer service line connections) particularly in those segments of storm sewer that have shown elevated levels of fecal coliform and/or *E. coli* in sample results.

### *9.9.3 Nonpoint Source Management Measures and BMP Implementation*

The Goose Creek Watershed requires implementation of a number of nonpoint management measures and BMPs to achieve water quality goals. As such, a significant allocation of technical and financial resources from multiple sources is required. These management strategies, resources, and estimated costs are summarized below and in Table 9.21.

#### 9.9.3.1 SEPTIC SYSTEMS IN SHERIDAN COUNTY

Management measures and BMPs to address pathogen loads from septic systems in Sheridan County include the following:

- Construct a regional central sewer system for Little Goose Creek
- Expand the Powder Horn WWTP
- Install cluster sewer systems in high density rural developments.
- Develop a septic system inventory.
- Upgrade failing septic systems.

### Regional Central Sewer System for Little Goose Creek

As outlined in the *Septic System Impact Study* (HKM 2006) and the *Little Goose Wastewater Treatment Feasibility Study* connection of homes in Little Goose Creek Valley to the City of Sheridan WWTP. The system would need to be owned and operated as a public system and administered by a public entity such as Sheridan County, a joint powers board, or an established sewer district. The 2009 total project cost including plant investment fees is $12,678,000 (EnTech 2009). Advantages and concerns for such a system are described in the *Septic System Impact Study* (HKM 2006).

As indicted in the *Septic System Impact Study* (HKM 2006), the Powder Horn WWTP currently provides a central sewer system and has its own extended aeration package treatment plant. This plant serves the approximately 150 homes in this development, but is expandable to serve a much larger number. This plant seems to provide satisfactory treatment and has been complying with its discharge permit. Having this system, the Powder Horn understands the operational requirements, responsibilities, and costs associated with having a central sewer system and package treatment plant. Although they can continue as they are for many years to come, they are interested in studying the idea of a regional or area-wide sewer system (such as the Little Goose Creek Valley south of the City of Sheridan's service area), and possibly participating in such a system. Costs to expand the Powder Horn WWTP have not been estimated.

### Cluster Systems

Cluster systems consisting of a small central collection system and a single treatment unit could be used to serve adjoining homes or developments. However, as noted in the *Septic System Impact Study* (HKM 2006), these small package treatment plants do not have a good history of providing a high level of treatment because loadings tend to vary and operation is typically not at the level required to fully manage the treatment process. Furthermore, costs for operation, maintenance, and management of the system are often disproportionately high because of the relatively small number of users. Smaller package treatment plants can result in higher unit costs due to lack of economy of scale. Notwithstanding these disadvantages, the feasibility of cluster systems should be included in an evaluation of alternatives. Costs for cluster systems have not been estimated.

### Update Sheridan County Septic System Inventory and Conduct Inspections

As discussed in the recommended implementation measures for Sheridan County (Section 9.5), the Sheridan County inventory of septic systems should be updated. Resources required to update this inventory include personnel to review water-only utility bills and compare this information to the locations of permitted septic systems. GIS personnel are also required to review aerial imagery and develop a GIS database of residences without a septic system permit. These inputs need to be combined with GIS priority layers (aquifer sensitivity, 100-m stream buffer, irrigated lands) to develop a mailing list for the Septic System Self-assessment form. The form should first be sent to landowners in priority septic systems in categories 1 through 4. Additional resources will be needed to follow-up with landowners who do not complete and return the form (i.e., personnel trained in door-to-door interviews to assist landowners in completing their forms). An inspector will then be needed to review the forms and determine which landowners require an on-site inspection and to make recommendations for septic system improvements or upgrades.

## 9.9.3.2 UPGRADE FAILING SEPTIC SYSTEMS

Based on the results of the septic system inventory and site inspections, some septic systems will be determined to be failing and will require upgrades or improvements. If failure is due to inadequate vertical separation between the bottom of the drainfield and some restrictive or limiting layer (e.g., water table, bedrock, hardpan, unacceptable fine textured soils, or excessively permeable material), drainfield mounding will be required. U.S. EPA (1999) estimates the cost for a mounded drainfield, with dosing chamber would cost $8,750.

The U.S. Bureau of the Census has indicated that at least 10% of on-site systems have stopped working, and some communities report failure rates as high as 70%. Studies reviewed by U.S. EPA cite septic system failure rates ranging from 10% to 20% (U.S. EPA 2000). Using the lower end of this failure rate (10% to 20%), and assuming these failures are due to inadequate vertical separation to protect groundwater or lack of unsaturated soil for proper treatment, mounding of 86 to 172 of the 862 known drainfields in the Little Goose Creek Valley would be required. This equates to $862,000 to $1,724,000 for mounding projects in the Little Goose Creek Valley.

#### 9.9.3.3 PASTURED ANIMALS ON PRIVATE LANDS IN SHERIDAN COUNTY

Management measures and BMPs to address pathogen loads from pastured animals on private lands in Sheridan County include the following:

- Continue the SCCD-NRCS AFO program and continue to make improvements to livestock feeding operations listed in Table 9.9
- Continue the outreach and educational programs for rural livestock owners. This will also help raise awareness about the potential impacts of excessive grazing.
- The SCCD and NRCS should continue to educate landowners about riparian buffer technologies, as well as cost-share assistance through the USDA to landowners willing to improve properties.

The resources and financial needs to continue these management measures are well understood by SCCD. Grants to support these activities should be continually pursued.

#### 9.9.3.4 PATHOGEN INPUTS FROM WATERFOWL, DOMESTIC ANIMALS, AND BIG-GAME WILDLIFE TO STORMWATER AND RUNOFF IN SHERIDAN COUNTY

Management measures and BMPs to address pathogen loads from waterfowl, domestic animals, and big-game wildlife to stormwater and runoff to creeks include the following:

- The SCCD should continue to provide public education concerning the potential wildlife impacts to water quality and the impacts of feeding wildlife, which artificially concentrates wildlife near sensitive riparian areas.
- The SCCD should also provide education to dog owners with regard to pet waste management.
- The SCCD should also continue providing information on the impact of feeding wildlife near surface water through local backyard conservation organizations.
- In addition, measures for herd management may need to be taken to control herd sizes and distribution. Herd management may include the relocation of some herd members or simply the creation of alternate off-channel watering facilities away from streams.

The resources and financial needs to continue these management measures are well understood by SCCD. Grants to support these activities should be continually pursued.

**Table 9.21** Summary of Financial and Technical Needs to Implement the Goose Creek Watershed TMDLs

| Implementation Goal | Measure | Responsible Party | Financial Vehicle | Resources Needed | Expected Cost |
|---|---|---|---|---|---|
| Reduce Pathogen Contributions to Impaired Waters From Septic Systems | Construct a central sewer in Little Goose Creek Valley. | Sheridan County | CWA State Revolving Fund | – | Approximately $9 to $12 million |
| | Install cluster systems in high density rural developments. | Sheridan County | CWA State Revolving Fund | Designs must comply with DEQ, county or city requirements | Not Estimated |
| | Conduct a septic inventory. | Sheridan County, SCCD-NRCS | Grants from U.S. EPA through WDEQ under Section 319 and 205(j) of the CWA | Administrative and technical | $75,000 |
| | Upgrade failing septic systems (assume assumes failure is due to inadequate vertical separation and drainfield mounding is required). | SCCD | Grants from U.S. EPA through WDEQ under Section 319 of the CWA.<br>State Grants from Wyoming Dept. Agriculture and Wyoming Association of Conservation Districts<br>Combined federal and state grants.<br>CWA State Revolving Fund<br>USDA Rural Utilities Service, Water and Waste Disposal Loans and Grants<br>USDA Rural Development grants<br>Public-private partnerships including nonprofit organizations | – | $8,750 per mounding project. $862,000 to $1,724,000 for mounding projects in the Little Goose Creek Valley |
| Reduce Pathogen Contributions to Impaired Waters from Pastured Animals on Private Lands in Sheridan County | Implement AFO improvement projects and grazing management planning. | SCCD | Grants from U.S. EPA through WDEQ under Section 319 of the CWA.<br>NRCS Farm Bill funds (e.g., EQIP program)<br>Wyoming Wildlife Natural Resource Trust Funds<br>Public-private partnerships including nonprofit organizations | – | Not Estimated |

**Table 9.21** Summary of Financial and Technical Needs to Implement the Goose Creek Watershed TMDLs

| Implementation Goal | Measure | Responsible Party | Financial Vehicle | Resources Needed | Expected Cost |
|---|---|---|---|---|---|
| Improve Stormwater Treatment of Pathogens and Sediment in City of Sheridan | Install infiltration trenches and detention basins throughout the City of Sheridan. | City of Sheridan<br>WYDOT | – | Administrative and technical | $545,500 |
| | Install sediment traps in all remaining stormwater lines in the City of Sheridan. | City of Sheridan<br>WYDOT | – | Administrative and technical | $720,000 |
| Reduce Pathogen Contributions to Impaired Waters from Wildlife, Waterfowl, and Domestic animals in Sheridan County and City of Sheridan | Education activities to reduce pet waste and waterfowl waste to streams | SCCD | Grants from U.S. EPA through WDEQ under Section 319 of the CWA.<br>Public-private partnerships including nonprofit organizations | – | $20,000/year |
| | Require new developments to follow stormwater design criteria | Sheridan County | – | – | None<br>Ordinance only |

# 9.10 Implementation Schedule and Interim Milestones for Nonpoint Source Management Measures

To attain the targets identified in this implementation plan, a series of milestones and a schedule for their completion are necessary to track progress as implementation continues on in the watershed. These are summarized in Table 9.22.

**Table 9.22** Implementation Milestones and Schedule for the Goose Creek Watershed

| Implementation Tasks | Indicator | Milestone (short term–2012) | Indicator (medium term–2014) | Target Completion Date (long term–2017) |
|---|---|---|---|---|
| **GOAL: Reduce Septic Tank Contributions to Impairments** | | | | |
| Conduct a septic inventory for the entire watershed using aerial photos and ground-truthing and update septic database. Refine spatial queries for final priority septic map. | Updated spatial database of all septic permits. | 1 updated database | 0 | 0 |

**Table 9.22** Implementation Milestones and Schedule for the Goose Creek Watershed

| Implementation Tasks | Indicator | Milestone (short term–2012) | Indicator (medium term–2014) | Target Completion Date (long term–2017) |
|---|---|---|---|---|
| Mail self-assessment forms to septic permittees and follow decision matrix described in Figure 9.1 to determine upgrades. | Number of septic systems contacted and addressed voluntarily using steps identified in Figure 9.1 | 73<br>(Priority 1 septic systems) | 156<br>(Priority1 and 2 septic systems) | 862 |
| **GOAL: Assist Landowners in Catchments Listed Above in Obtaining Funding to Implement Specific Recommendations in Individual Grazing Management Plans** | | | | |
| Complete a survey of all creeks in the watershed to identify those segments that are accessed directly by livestock. | Creek survey in GIS format identifying locations of livestock with access to creek | 1 survey | 0 | 0 |
| Eliminate direct sources of *E. coli* to the stream by installing fencing and providing alternative water sources to exclude direct access to cattle along all creeks in the watershed that currently are accessed by livestock. | Percent of stream fencing determined necessary in creek survey (see previous task) | 10% | 50% | 100% |
| Develop grazing management plan for all AFOs, ranches, and farms. | Catchments with grazing management plans completed | McCormick Creek<br>Soldier Creek (GC4) | Beaver Creek (BG9)<br>Sackett Creek (LG19)<br>Park Creek (BG13) | Big Goose Creek (BG4 through BG 18) |
| Implement AFO and pasture management improvement for 4,800 cattle. | Number of cattle incorporated into grazing and AFO improvements | 300 | 2,500 | 4,800 |
| **GOAL: Information and Education** | | | | |
| Develop public education program for feeding wildlife. | Number of signs reminding people not to feed waterfowl or wildlife | 10 | 10 | 10 |
| Continue public education program for pet waste management. | Number of signs and bag dispensers to control pet waste at parks | 10 | 10 | 10 |
| Set up education booth at Sheridan County fair to provide water quality information and education. | Number of people that receive information at fair booth | 100 | 500 | 1,000 |
| Develop a hands-on seminar hosted by vendors to demonstrate proper installation and maintenance of construction stormwater control for construction projects. | Number of seminars held per year | 1 | 3 | 3 |
| Develop a materials check-out program for local schools to access water quality and watershed management materials. | Number of teachers that check out materials | 2 | 10 | 50 |

**Table 9.22** Implementation Milestones and Schedule for the Goose Creek Watershed

| Implementation Tasks | Indicator | Milestone (short term–2012) | Indicator (medium term–2014) | Target Completion Date (long term–2017) |
|---|---|---|---|---|
| Host additional septic system workshops. | Number of septic system workshops per year | 3 | 3 | 3 |
| Conduct annual training sessions for municipal personnel. | Number of training sessions | 1 | 1 | 1 |

# 9.11 Criteria to Determine if Load Reductions/Targets are Being Achieved

The water quality criterion required to determine if load reductions are being achieved for the summer recreation season (May 1 through September 30) is 126 organisms per 100 mL, measured as a geometric mean of five samples obtained during separate 24-hour periods within a 30-day time span. This water quality criterion is derived directly from the water quality standards for bacteria established by the State of Wyoming (Table 7.1). *E. coli* is the bacteria parameter with a numeric water quality standard for Wyoming waters. In 1986 the U.S. EPA recommended that *E. coli* replace fecal coliform bacteria in state water quality standards (U.S. EPA 1986). This recommendation is reflected in current Wyoming water quality standards and in the water quality targets identified for this TMDL.

The sediment criterion for Little Goose Creek and Goose Creek in the City of Sheridan is a 50 mg/L TSS as both an in-stream measurement and for storm drains discharging to creeks in the city (Table 9.23). See Section 8.2 for more details on how this criterion was derived. In addition, the TMDL aims to bring the creeks back into full-support status for all designated uses. In Wyoming, aquatic life uses are assessed with the use of the RIVPACs, which measures the observed macroinvertebrates to the expected taxa for a given stream, and the WSII.

**Table 9.23** Criteria to Assure Implementation Plan will Achieve Water Quality Targets

| Indicators to Measure Progress | Target Value or Goal | Short-term (2 years) | Medium-term (5 years) | Long-term (7 years) |
|---|---|---|---|---|
| *E. coli* average 30-day geometric mean | 126 cfu/100 mL | 400 cfu/100 mL | 200 cfu/100 mL | 126 cfu/100 mL |
| TSS Concentration | 50 mg/L | 100 mg/L | 80 mg/L | 50 mg/L |
| RIVPACS O/E | 0.836 | 0.662 | 0.75 | 0.836 |
| WSII | 77.5% | 55.0% | 65% | 77.5% |

# 9.12 Monitoring

The monitoring goals of this project are to document progress in achieving improved water quality conditions in the Goose Creek Watershed as nonpoint source control management strategies are implemented. Specifically, the objectives are as follows:

- Obtain information necessary to ensure that water quality loading and concentration targets for pathogen are met.
- Obtain a detailed record of water quality data to assess whether the established target levels and threshold values are protective of designated uses.
- Evaluate BMP effectiveness and load reductions that result from implementation efforts.

Successful development and implementation of the monitoring plan will provide flexibility for adapting to new information and changes in the watershed.

To document this progress, a monitoring program is needed to examine and report on the performance of each management strategy. Two types of performance monitoring are proposed in this implementation plan: 1) implementation monitoring, and 2) effectiveness monitoring. Implementation monitoring assesses whether the proposed management strategies were implemented and, if they have been implemented, the progress that has been achieved. Effectiveness monitoring is used to check if the selected strategies are effectively reducing pollutant loading. The following subsections present implementation and effectiveness monitoring methods proposed for organizations that will be involved in execution of this implementation plan.

## *9.12.1 Implementation Monitoring*

Each organization should monitor implementation of management strategies by tracking the progress and accomplishments of each activity. A centralized database could be used by organizations to monitor implementation of the proposed management strategies. A status column should be added to the database to track actual implementation progress.

## *9.12.2 Effectiveness Monitoring*

Effectiveness monitoring is used to check if the selected strategies are reducing pollutant loading. Effectiveness monitoring may be quantitative (e.g., laboratory analysis of pathogen concentrations in water from specific catchments, or in water exiting private property or developments) or qualitative (e.g., visual observation of sediment reduction in the water passing through a fenced riparian area), depending on the BMP implemented and the overall scope of the project. Although quantitative monitoring methods will document progress toward improved conditions, qualitative methods can also provide an effective measurement of implementation progress. Other examples of qualitative effectiveness monitoring include photograph documentation of improvement in streambank vegetation and cover. Qualitative monitoring could also include documentation of relative sediment volume (i.e., high, medium, or low) collected from detention ponds or filters in stormwater treatment systems. Although these methods do not provide quantitative information on the effectiveness of the projects, they do illustrate progress and can be combined with other monitoring efforts to show success of implementation activities.

Quantitative effectiveness monitoring is required to document actual progress toward improved water quality conditions and can only be achieved through water quality assessments. Therefore, the success in reducing the load of *E. coli* and sediment will be measured by contributions monitored at or near the mouths of major tributary points.

In-stream monitoring is scheduled to occur periodically throughout the year by SCCD and includes physical, chemical, and biological parameters. The following subsection outlines the proposed procedures for quantitatively monitoring the effectiveness of the proposed management strategies.

### 9.12.3 Sampling Design and Parameters

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

- Seasonal monitoring throughout the year at catchment delineation points, tributaries, and major ditches and monitoring the selected sites for pathogens, total suspended sediment, and discharge
- Monitoring streams above and below large BMP installation projects to determine effectiveness of individual projects

### 9.12.4 Other Data Collection Needs

#### 9.12.4.1 BED LOAD ANALYSIS

Bed load refers to the sediment particles that are transported along the bed of a water way. These particles also have the potential to carry other constituents such as nutrients and bacteria. Traditional water quality grab samples do not account for bed load movement and therefore do not account for this portion of the total sediment load carried through the system. To understand the impact of bed load movement in this system sediment particle size samples will need to be deployed in various substrate types throughout the watershed and paired with a streamflow model such as HEC-RAS. Because the watershed includes remote, rural, agricultural, and urban settings, the need for representative samples is increased. These samples would also need to be collected seasonally because bed load transport is largely affected by stream power. Incorporating bed load transport into future TMDL efforts will aid in reducing the uncertainty associated with load estimates. Data on linkages of bed load, sediment depth, particle size, and macroinvertebrate indices would also improve future TMDL analyses.

#### 9.12.4.2 GROUNDWATER

Due to the probable relationship between irrigation runoff and leach fields, data documenting this interaction would be extremely helpful. To collect data to determine the effect of irrigation on leach fields, a series of groundwater wells should be established around 10 representative leach fields (in high and low groundwater-sensitivity areas and in irrigated and nonirrigated areas of the watershed) throughout the watershed where water quality samples and well level data would be gathered. The wells could be placed at increasingly greater distances from the leach field to determine the area of impact. To obtain representative data, samples should be collected prior to, during, and after an irrigation event. It may also be applicable to install piezometers around the leach field to determine the direction of groundwater flow prior to the installation of sampling wells.

These data would provide information about the relationship between irrigation runoff and leach fields. In particular, it would help determine whether irrigation water flushes leach fields and/or dilutes contaminants. This information could then be used in refining priorities for septic improvement projects.

#### 9.12.4.3 SOURCES

##### Wildlife

To estimate source loads from wildlife it is valuable to know the possible number of animals that may be contributing to the overall load. Currently there are no estimates on the populations of wildlife in the watershed. Furthermore, locations need to be identified where these animals congregate or spend large amounts of time.

Wildlife estimates should be conducted during winter months when big-game animals are most likely to be in higher densities, and easier to locate. For urban areas waterfowl counts should be conducted at local ponds or wetlands, and possibly even parse out the number of wild versus domestic waterfowl. In areas of known high densities of wildlife populations, exclosures could be placed on the property to determine the levels of wildlife grazing or impact for that area.

These data could be used to provide a more reliable estimate of wildlife contributions to *E. coli* loads. If these loads were determined to be a significant input efforts could be undertaken by wildlife officials to relocate problem animals or design programs to control herd sizes. Collecting data on big-game populations and waterfowl concentrations in urban areas would also be beneficial to allow TMDL targets to be specified to these very different types of wildlife sources.

### Livestock

A single poorly managed livestock operation could be responsible for a large proportion of contaminant loading in a watershed. Currently there are no reliable estimates for the numbers of livestock in the watershed. Without these data, it is difficult to determine whether the contaminant loading from livestock is an issue equally shared with all livestock owners, or more of a localized issue with a smaller number of poorly managed operations. Much of these data currently exists but have not yet been compiled and released for public review.

On public grazing land, linear transects could be established to indentify quantity of fecal deposits. These transect estimates could be used to identify grazing intensity as well potential problem areas. For AFOs or other high density operations, visual assessments should be completed that could identify obvious problems areas such as livestock in stream, unstable streambanks, no riparian buffer along the streambank, manure storage facilities located in close proximity to the stream, etc. Similar data could also be obtained using the AFO self-assessment form which the SCCD already has available.

If livestock distribution and quantity can be identified in a watershed, multiple analyses are available to estimate the potential loading from that population. With more accurate loading estimates, problem areas could be more easily recognized and prescribed grazing plans could be applied to areas of high risk.

### Stormwater

Stormwater runoff events can spur loading events that are completely uncharacteristic of baseline conditions. Stormwater runoff has the potential to collect contaminants from a wide range of sources and deliver them to a central location. Existing *E. coli* data from stormwater drains in the City of Sheridan range by four orders of magnitude. Additional drains and sampling events are necessary to narrow down the uncertainty associated with these samples.

To identify priority locations, stormwater samples should be taken from the outflows of storm drains during runoff events. Samples should be collected over three separate storm events. These events are difficult to predict and each will vary in duration and intensity, therefore, a minimum goal of 3 samples per storm event for each drain should be collected. Having multiple samples for each storm drain would help determine whether storms have similar repeatable effects, or if a high level of variability exists in the data.

These data would help direct TMDL efforts with regards prioritize implementation of stormwater BMPs. In addition, once priority outflows are located, drainage basins should be delineated and potential sources of contaminants could be located. If a single problem source could be identified in a drainage basin it could result in a lower cost BMP for that specific location rather than an upgrade to the entire stormwater system.

# CHAPTER 10 PUBLIC PARTICIPATION

Local experience and public participation were encouraged throughout the Goose Creek TMDL process. This public involvement provided SWCA with invaluable information about the Goose Creek watershed and in the development of *E. coli* and sediment reduction strategies. Because of the potential influence of the TMDL process on the local community and the dependence of any implementation plan on local participation, public involvement was viewed as a critical component of the Goose Creek watershed TMDLs.

The Goose Creek TMDLs were conducted in a process that was open to the public. The public was encouraged to participate and provided feedback throughout the TMDL process. Information was presented during the meetings in lay terms, yet with technical depth for the scientific community. Notices and announcements of public meetings and requests for comments were provided in the local newspaper (*The Sheridan Press*), the most widely circulated statewide newspaper (*Casper Star Tribune*), and on local radio broadcasts (*Public Pulse*), and were posted on the SCCD and WDEQ websites. Three public meetings were held at the Sheridan College CTEL auditorium in Sheridan, Wyoming. The dates and discussion topics for each public meeting are summarized as follows:

- The first public meeting was held on April 21, 2009 and focused on an overview of the general TMDL process, the work plan and schedule, a discussion of the problem identification, review of existing information and progress on watershed characterization. The next phase (TMDL analysis) was also presented and discussed.
- The second public meeting was held on December 10, 2009 and presented the findings of the TMDL analysis. The next phase (implementation and monitoring plan) were also presented and discussed.
- The third public meeting was held on July 27, 2010 and presented the implementation and monitoring plan.

In addition to the public meetings, an agency kickoff meeting was held on December 5, 2008. Numerous agencies contributed data, documents, valuable input, and extensive comments during the Goose Creek TMDL process and on the initial draft document. Representatives from the following agencies contributed to the completion of the Goose Creek TMDLs:

- EPA
- WDEQ
- SCCD
- USFS
- Wyoming Game and Fish Department
- Wyoming State Engineers Office
- Sheridan County
- City of Sheridan

The Goose Creek TMDL public draft was completed on August 6, 2010 and made available for public review on August 9, 2010. A 30-day public comment period from August 9 to September 7, 2010 was advertised in local newspapers (*The Sheridan Press*, *Casper Star Tribune*), and posted on the WDEQ and SCCD websites. The public draft TMDL was available in hard copy at the Sheridan County Library, the WDEQ Sheridan Field Office, and the SCCD office. The pubic draft TMDL was also available for electronic download from SWCAs client space and the WDEQ website. The only comments received during the 30-day comment period were from EPA. These EPA comments are addressed in this final document. A copy of EPA comments is provided in Appendix 4.

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