# Hydrologic Characteristics and Water Budget for Swift Creek Reservoir, Virginia, 1996

By S.C. Skrobialowski and M.J. Focazio

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## CONVERSION FACTORS AND VERTICAL DATUM

| Multiply | By | To obtain |
|---|---|---|
| **Length** | | |
| inch (in.) | 25.4 | millimeter |
| foot (ft) | 0.3048 | meter |
| mile (mi) | 1.609 | kilometer |
| **Area** | | |
| square mile ($mi^2$) | 259.0 | hectare |
| square mile ($mi^2$) | 2.590 | square kilometer |
| **Volume** | | |
| cubic foot ($ft^3$) | 0.028317 | cubic meter |
| **Flow** | | |
| foot per second (ft/s) | 0.3048 | meter per second |
| cubic foot per second ($ft^3/s$) | 0.02832 | cubic meter per second |
| cubic foot per second per square mile [$(ft^3/s)/mi^2$] | 0.01093 | cubic meter per second per square kilometer |

**Vertical Datum:** In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

# Hydrologic Characteristics and Water Budget for Swift Creek Reservoir, Virginia, 1996

By Stanley C. Skrobialowski and Michael J. Focazio

## Abstract

The Swift Creek Reservoir, which was build in 1965, provides water for public supply to Chesterfield County, Virginia. Development within the drainage basin and especially in areas adjacent to the reservoir has prompted concern about the long-term effects of development on the water quality. In order to address these water-quality concerns, the quantity of water entering the reservoir was investigated. This report presents a preliminary water budget for the Swift Creek Reservoir, Virginia.

The residual volume for 1996, the difference between total inputs and outputs, was about 12 million cubic feet of water (Mft$^3$). The residual is considered to be the total of all errors associated with measured, estimated, and assumed hydrologic characteristics. Total input volume to the reservoir was 3,800 Mft$^3$. About 1,870 Mft$^3$ drained from monitored tributaries, an estimated 1,620 Mft$^3$ drained areas adjacent to the reservoir, and 314 Mft$^3$ fell directly on the reservoir as precipitation. Total output volume from the reservoir was 3,780 Mft$^3$. About 421Mft$^3$ was withdrawn for public water supply, 3,130 Mft$^3$ discharged at the dam, and 226 Mft$^3$ evaporated from the water surface of the reservoir.

# INTRODUCTION

Swift Creek Reservoir was constructed in 1965 in Chesterfield County for public water supply (fig. 1). The Swift Creek Water Plant (SCWP) has a service capacity of about 12 Mgal/d, and currently supplies water to about 90,000 people in the county (George DuVal, Swift Creek Water Plant, oral commun., 1997). Chesterfield County experienced rapid development within the last 10 years and a 14 percent increase in population between 1990 and 1995. Currently (1996), most of the urban development within the Swift Creek Basin has been in areas adjacent to the reservoir. Protection of the reservoir as a valuable economic and recreational resource is an important goal of the Chesterfield County Department of Utilities and residents in the surrounding communities. County officials and residents are concerned about the effects of existing and future development within the Swift Creek Basin on the quality of water in the reservoir.

In 1995, the U.S. Geological Survey (USGS), in cooperation with the Chesterfield County Department of Utilities, began a study to determine hydrologic inputs and outputs for the Swift Creek Reservoir and to develop a water budget for the reservoir. Knowledge of hydrologic inputs and outputs is needed by the county to support efforts to estimate loads of selected chemical constituents transported to the reservoir.

## Purpose and Scope

This report presents a hydrologic characterization of inputs and outputs and a preliminary water budget for the Swift Creek Reservoir, Va., for the period January 1, 1996 through December 31, 1996. Continuous stage (stream-water level) data were collected and more than 180 discharge measurements were made to determine discharge input from nine main tributaries that drain to the reservoir. Precipitation data were used to compute precipitation input directly on the reservoir and to estimate direct runoff from ungaged areas adjacent to the reservoir. Computed discharge from the Reservoir dam, supply withdrawals, and estimated evaporation were used to characterize total hydrologic output from the reservoir. The change in storage for the reservoir also was computed. Groundwater flow inputs and outputs were not monitored, but were assumed to balance for the study period. The effects of transpiration were not considered.

## Description of Study Area

Swift Creek drainage basin encompasses 64 $mi^2$ upstream from the earthen dam that impounds Swift Creek to create the reservoir. The dam is about 400 ft wide and capped with a concrete weir and spillway. Discharge from the reservoir passes over the weir, down the spillway, to a buffer pool, and it is routed to the original creek channel.

The Swift Creek drainage basin is located entirely within the Piedmont Physiographic Province (fig. 1). Although areas adjacent to the reservoir have been developed for residential use, most of the land in the drainage basin is undeveloped. Soil drainage characteristics in the basin range from well drained to very poorly drained; however, most of the basin soils are either well drained or moderately well drained (Hodges and others, 1978; Reber and others, 1988).

The climate of the area is classified as humid subtropical. Mean annual precipitation, for the Richmond Va., area from 1961 through 1990, was about 43 inches, and the mean annual temperature was about 57°F, according to the Virginia State Climatologist's Office (Dustin Hux, Virginia State Climatologist Office, oral commun., 1997).

## Acknowledgments

The author gratefully acknowledges cooperation of Mr. Roy Covington and Mr. George DuVal from the Chesterfield County Department of Utilities, Mr. Weedon Cloe and other members of the Swift Creek Water Plant staff provided surface-water stage records, rainfall records, and water-supply withdrawal data for the study period. Ms. Jean P. Campbell of the U.S. Geological Survey contributed significantly to planning and collection of data for this study.

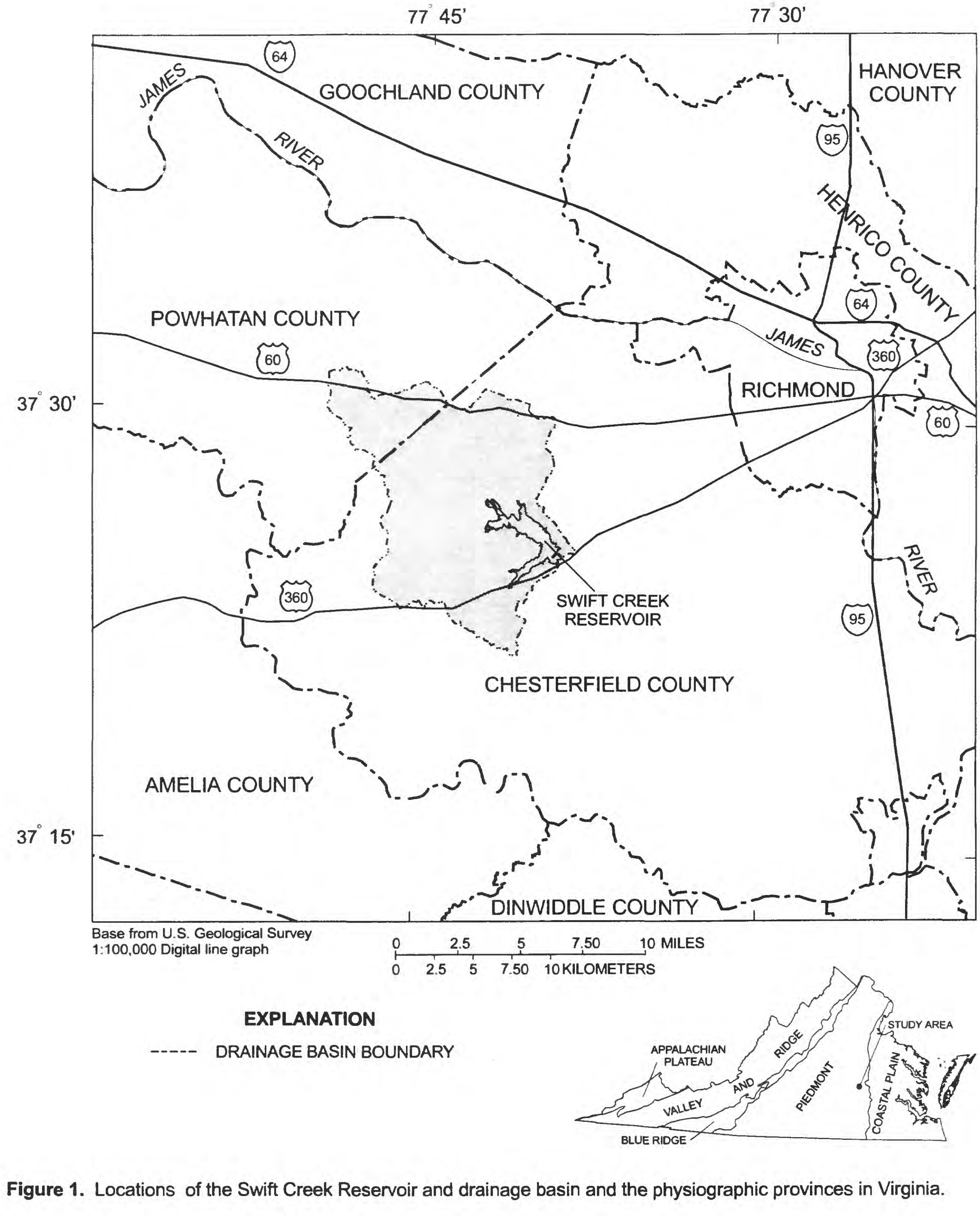


**Figure 1.** Locations of the Swift Creek Reservoir and drainage basin and the physiographic provinces in Virginia.

## METHODS OF STUDY

A general reservoir water budget includes hydrologic inputs to and outputs from the atmosphere, surface-water flows, ground-water flows, and changes in storage during a specified period of time. Because measuring all components of the water budget is difficult, some simplifying assumptions must be made. The residual of the water-budget equation (eq. 1) reflects assumptions and errors owing to inaccuracies associated with measured and estimated components (Winter, 1981). For example, if evaporation is not measured, and ground-water inflow and outflow are assumed to balance, then evaporation, any errors associated with the ground-water assumption, and errors associated with any measured component of the water-budget equation are represented by the residual component.

$$\text{Input} - \text{Output} = \Delta\text{storage} \pm \text{residual}, \qquad (1)$$

where

| | | |
|---|---|---|
| Input | is | direct precipitation on the reservoir water surface + measured inflows + estimated direct runoff, |
| Output | is | measured withdrawals + measured outflow + estimated evaporation, |
| Δstorage | is | measured change in storage in the reservoir, and |
| residual | is | ground-water inputs + ground-water outputs + measurement errors + estimation errors. |

For this study, the ground-water inputs are assumed to balance ground-water outputs. The residual, therefore represents errors in measurements, estimates, and assumptions.

### Drainage and Surface Areas

Drainage areas and surface areas were delineated by the USGS on 7.5-minute topographic quadrangle maps. Errors in actual drainage area computations may result from land form changes that may have occurred since the most recent map revisions; for example, changes resulting from highway drainage and stormflow routing. Drainage and surface areas for this report were determined according to methods described by the U.S. Inter-Agency River Basin Committee (1951). The reservoir water-surface area, 2.49 $mi^2$, was computed for a water-surface elevation of 177 ft above sea level (National Geodetic Vertical Datum of 1929).

### Data Collection and Processing

Staff from SCWP collected continuous stage data at nine selected reservoir inflow sites with manometer and electronic data logging equipment. Data loggers were referenced to an outside staff gage and reference marks, and standard datum controls were established as described by Kennedy (1990). Staff from SCWP operated and maintained the manometers and data loggers. Water-level data, collected and stored at 5-minute intervals, were retrieved quarterly, edited and adjusted for drift and fouling, as recommended by the equipment manufacturer (Weedon Cloe, Swift Creek Water Plant, oral commun., 1997), then provided to USGS staff for processing discharge data.

Conventional and nonconventional methods were used by the USGS to make more than 170 discharge measurements between October 1995 and January 1997. Conventional current-meter, volumetric, flume, and float methods were used to measure discharge, throughout a range in stage (Rantz and others, 1982a; Buchanan and Somers, 1984). Nonconventional discharge measurement methods included the use of a small stainless steel trough, of known width, and calibrated containers to make volumetric discharge measurements for low flows at the outflow site and an inflow site with a dam and weir. These volumetric measurements define the stage-discharge rating for these sites at low flows.

Stage data and discharge measurements were collected at low, medium, and high flows to construct a base stage-discharge rating curve for each inflow site, an example of which is shown in figure 2. The base stage-discharge rating curve can change over time because of the accumulation of debris, beaver dams, scour, fill, or other natural or artificial modifications in stream channel features that control the stage at the site being monitored. Periodic discharge measurements were made to determine the validity of the current stage-discharge rating curve. If a large permanent change in the rating was needed, then a new stage-

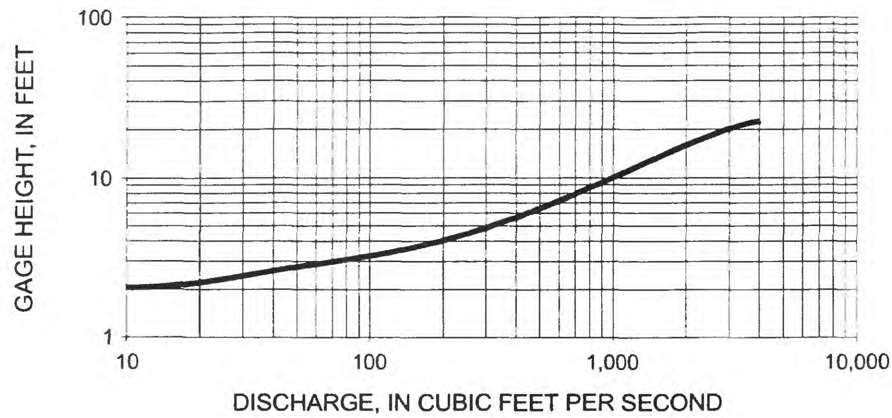


**Figure 2.** Typical logarithmic rating curve. (Modified from Kennedy, 1984.)

discharge rating curve was drawn. For temporary changes, the rating curve was shifted to fit the modified stage-discharge relation. Shift adjustments are temporary stage corrections applied to a range of the base stage-discharge rating curve to account for changes defined by the periodic discharge measurements (Kennedy, 1983). Shift adjustments were defined by discharge measurements that differed by more than 5 percent from the base stage-discharge rating curve.

Because eight of the monitored inflow sites have sand channel controls, they are affected by constant scour and fill and changes in the configuration of the streambed and are difficult to rate. Stage data were processed with applicable shift adjustments to compute daily discharges for nine selected inflow sites according to methods described by Rantz and others (1982b).

Staff from SCWP operated and maintained three tipping-bucket raingages (fig. 3) interfaced to data loggers. The raingages were located close to the reservoir and clear of vegetation and structures to avoid collection interferences.

## HYDROLOGIC CHARACTERISTICS

Total hydrologic input to the reservoir was calculated as the sum of discharge at the continuous monitoring inflow sites, mean annual precipitation on the reservoir water surface, and estimated direct runoff from areas adjacent to the reservoir. Total hydrologic output from the reservoir was calculated as the sum of the discharge at the reservoir outflow, water supply withdrawals by SCWP, and estimated evaporation loss from the reservoir surface.

Estimates of ground-water inflow and outflow volumes within the drainage basin are beyond the scope of this report. Cooke and others (1986) suggest that significant error in short-term hydrologic budgets may result if the ground-water component is not considered. For this study, however, it was assumed that ground-water inflow is balanced by ground-water outflow and that the change in ground-water storage is negligible during a year.

### Inputs

Surface-water inflow, direct runoff, and precipitation were either measured or estimated to determine total input to the reservoir. Discharge and stage data were used to determine input for nine selected inflow sites to the reservoir (fig. 3). Direct runoff from areas adjacent to the reservoir was estimated from inflow runoff computations and mean annual precipitation. Total mean precipitation falling directly on the reservoir surface was estimated on the basis of precipitation data collected at three sites within the watershed.

#### Gaged Inflow Sites

Daily discharge records were computed on the basis of stage data and discharge measurements collected at nine inflow sites. Discharge records are considered fair to poor for the nine inflow sites monitored for this report. A rating of "fair" means

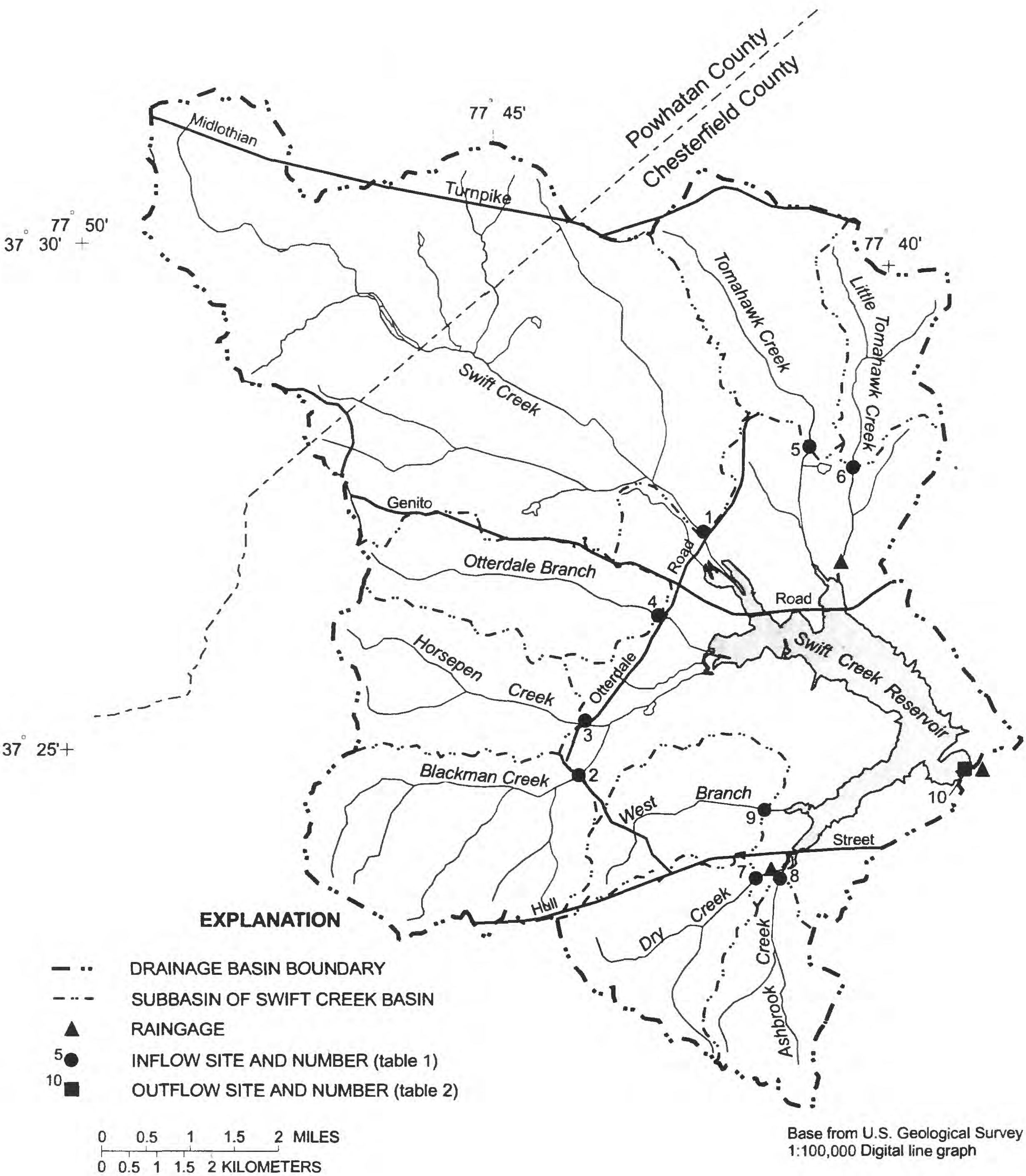


**Figure 3.** Subbasins and data-collection sites in the Swift Creek drainage basin, Virginia.

**Table 1.** *Drainage area and discharge data for nine gaged inflow sites to Swift Creek Reservoir, Virginia, 1996*
[mi$^2$, square mile; Mft$^3$, Million cubic feet; ft$^3$/s, cubic feet per second]

| Site number | USGS station number | Inflow stream name | Drainage area (mi$^2$) | Total annual discharge (Mft$^3$) | Daily mean discharge | | Annual runoff | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Maximum (ft$^3$/s) | Minimum (ft$^3$/s) | Mft$^3$/mi$^2$ | inches |
| 1 | 02041810 | Swift Creek | 21.4 | 461.1 | 161 | 0.32 | 21.5 | 9.28 |
| 2 | 02041820 | Blackman Creek | 5.80 | 296.5 | 227 | .65 | 51.1 | 22.01 |
| 3 | 02041830 | Horsepen Creek | 3.72 | 163.4 | 93 | .11 | 43.9 | 18.91 |
| 4 | 02041840 | Otterdale Branch | 3.59 | 165.0 | 142 | .29 | 46.0 | 19.78 |
| 5 | 02041850 | Tomahawk Creek | 4.20 | 213.2 | 69 | .04 | 50.8 | 21.86 |
| 6 | 02041860 | Little Tomahawk Creek | 2.31 | 189.9 | 247 | .01 | 82.2 | 35.40 |
| 7 | 02041870 | Dry Creek | 2.96 | 157.8 | 86 | 0 | 53.3 | 22.95 |
| 8 | 02041880 | Ashbrook Creek | 2.37 | 104.6 | 73 | 0 | 44.1 | 19.01 |
| 9 | 02041890 | West Branch | 2.75 | 111.0 | 126 | 0 | 40.4 | 17.38 |
| | | Total | 49.1 | 1,862.5 | | | | |

that about 95 percent of the daily discharges are within 15 percent of the true discharge; "poor" means that the daily discharges have less than "fair" accuracy (Novak, 1985). Most stream channels in the area have shifting sand channel controls that are difficult to rate especially at low stages (Rantz and others, 1982b). Discharge ratings for some inflow sites at high stages are not well defined because of insufficient peak-discharge measurement data and because of the inability to measure discharge at some sites at high stages. Rating curves for sites with insufficient peak-discharge data were extended to cover the recorded range in stage, and the extensions were based on channel, overflow, and flood-plain characteristics. Daily discharge data were estimated for periods of missing stage records based on comparison of hydrographs, drainage area, and precipitation data.

Discharge measurements were made monthly at most inflow sites to characterize base flow and document any shifting control conditions. Discharge measurements were made at medium and high flows during or after periods of heavy rainfall to define ratings or to confirm previous measurements.

The total drainage area for the nine inflow sites is about 49 mi$^2$ (table 1). All the gaged inflow sites (fig. 3) drain forest and undeveloped lands. West Branch drains the most developed land and is the inflow site closest to the reservoir. The Little Tomahawk Creek subbasin has the smallest drainage area, and the highest runoff per unit area, and the Swift Creek subbasin has the largest drainage area, the highest annual discharge, and the lowest runoff per unit area.

### Swift Creek

Runoff in 1996 for Swift Creek (table 1) was about 22 $Mft^3/mi^2$. Although the Swift Creek subbasin has the largest drainage area, it had the lowest computed runoff of the nine gaged inflow sites. The highest measured discharge was 206 $ft^3/s$, and the highest instantaneous discharge was 215 $ft^3/s$ on September 6, 1996. Of the 18 discharge measurements made, between October 1995 and January 1997, 16 were made during the January through December 1996 study period (fig. 4). Daily mean discharge was not estimated for any days during the study period. Total annual discharge for Swift Creek was 461 $Mft^3$ (table 1), about 25 percent of the measured total annual discharge for all gaged inflow sites.

### Blackman Creek

Runoff in 1996 for Blackman Creek (table 1) was about 51 $Mft^3/mi^2$. The highest measured discharge was 387 $ft^3/s$, and the highest instantaneous discharge was 443 $ft^3/s$ on January 19, 1996. Of the 17 discharge measurements made, between October 1995 and January 1997, 15 were made during the January through December 1996 study period (fig. 5). Daily mean discharge was estimated for September 5–6, 1996, because of equipment power failure. Total annual discharge for Blackman Creek was 296 $Mft^3$ (table 1), about 16 percent of the measured total annual discharge for all gaged inflow sites.

### Horsepen Creek

Runoff in 1996 for Horsepen Creek (table 1) was about 44 $Mft^3/mi^2$. The highest measured discharge was 96 $ft^3/s$, and the highest instantaneous discharge was 140 $ft^3/s$ on January 19, 1996. Of the 23 discharge measurements made, between October 1995 and January 1997, 19 were made during the January through December 1996 study period (fig. 6). Daily mean discharge was estimated for September 5–6, 1996, because of power failure. Total annual discharge for Horsepen Creek was 163 $Mft^3$ (table 1), about 9 percent of the measured total annual discharge for all gaged inflow sites.

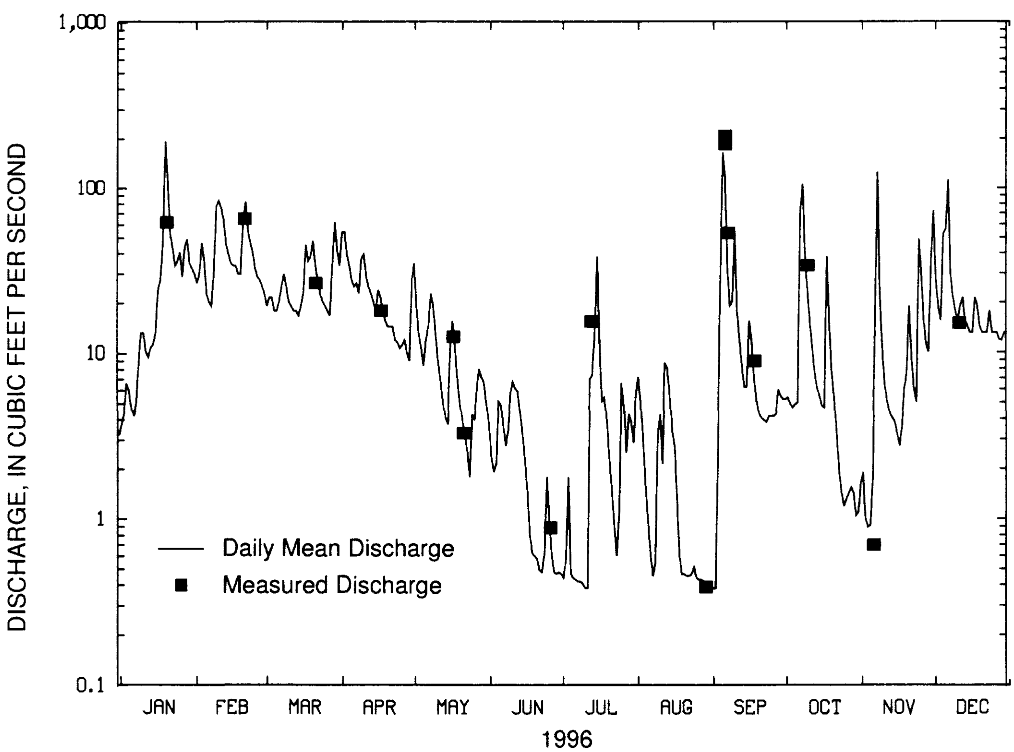


**Figure 4.** Daily mean and measured discharge for Swift Creek, Virginia. (USGS Station No. 02041810.)

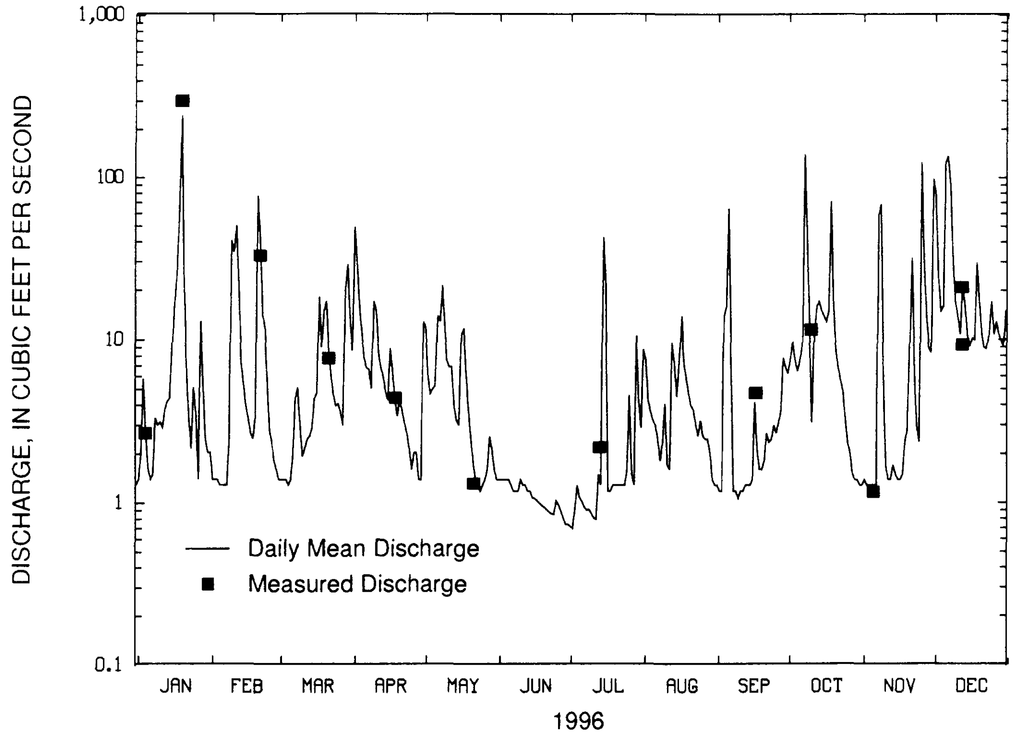


**Figure 5.** Daily mean and measured discharge for Blackman Creek, Virginia. (USGS Station No. 02041820.)

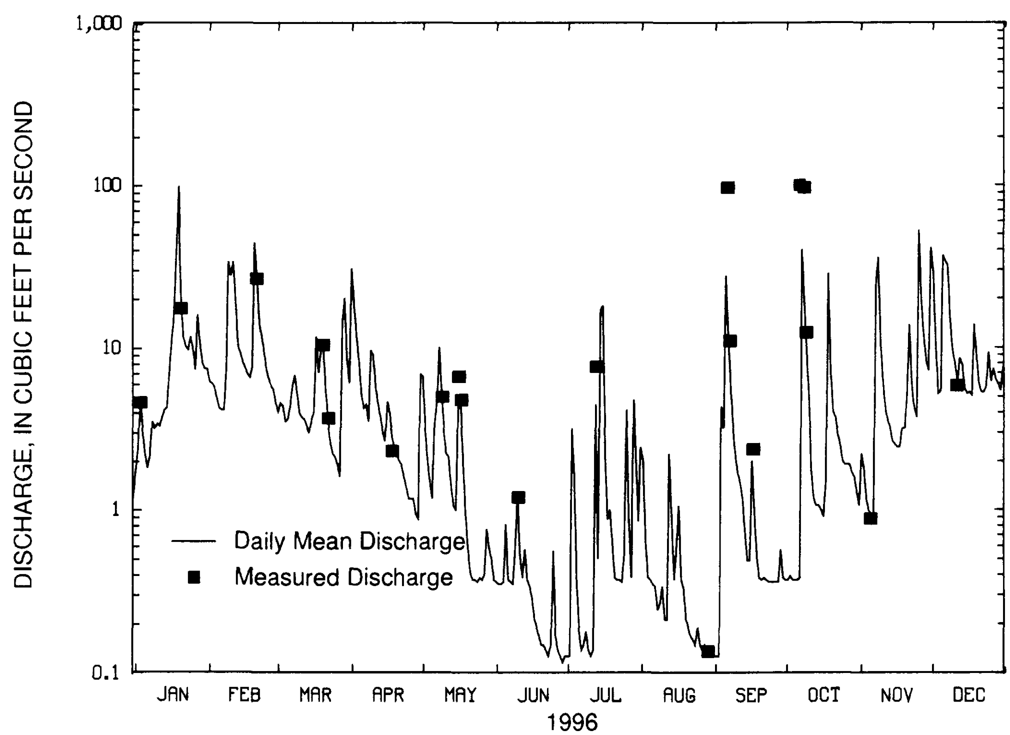


**Figure 6.** Daily mean and measured discharge for Horsepen Creek, Virginia. (USGS Station No. 02041830.)

### Otterdale Branch

Runoff in 1996 for Otterdale Branch (table 1) was about 46 $Mft^3/mi^2$. The highest measured discharge was 155 $ft^3/s$, and the highest instantaneous discharge was 473 $ft^3/s$ on January 19, 1996. Of the 23 discharge measurements made, between October 1995 and January 1997, 20 were made during the January through December 1996 study period (fig. 7). Daily mean discharge was estimated for September 5–6, 1996, due to equipment power failure. SCWP returns about 0.22 $ft^3/s$ at a flush site upstream from the monitoring site, and it ceases flushing operations for about 2 days each month (Weedon Cloe, Swift Creek Water Plant, oral commun., 1997). Total annual discharge, for Otterdale Branch, adjusted for 0.22 $ft^3/s$ returned by SCWP, was 165 $Mft^3$ (table 1), about 9 percent of the measured total annual discharge for all gaged inflow sites.

### Tomahawk Creek

Runoff in 1996 for Tomahawk Creek (table 1) was about 51 $Mft^3/mi^2$. The highest measured discharge was 58.7 $ft^3/s$, and the highest instantaneous discharge was 114 $ft^3/s$ on September 10, 1996. Of the 20 discharge measurements made, between October 1995 and January 1997, 17 were made during the January through December 1996 study period (fig. 8). Daily mean discharge was estimated for periods in July 1996 because of equipment malfunction. Total annual discharge for Tomahawk Creek was 213 $Mft^3$, about 11 percent of the measured total annual discharge for all gaged inflow sites.

### Little Tomahawk Creek

In 1996, Little Tomahawk Creek had the highest runoff, about 82 $Mft^3/mi^2$ (table 1), of the nine inflow sites. The highest measured discharge was 66.5 $ft^3/s$, and the highest instantaneous discharge was 878 $ft^3/s$ on September 6, 1996. Of the 19 discharge measurements made, between October 1995 and January 1997, 15 were made during the January through December 1996 study period (fig. 9). Mean daily discharge was estimated for periods in June and July 1996 because of equipment malfunction. Total annual discharge for Little Tomahawk Creek was 190 $Mft^3$ (table 1), about 10 percent of the measured total annual discharge for all gaged inflow sites.

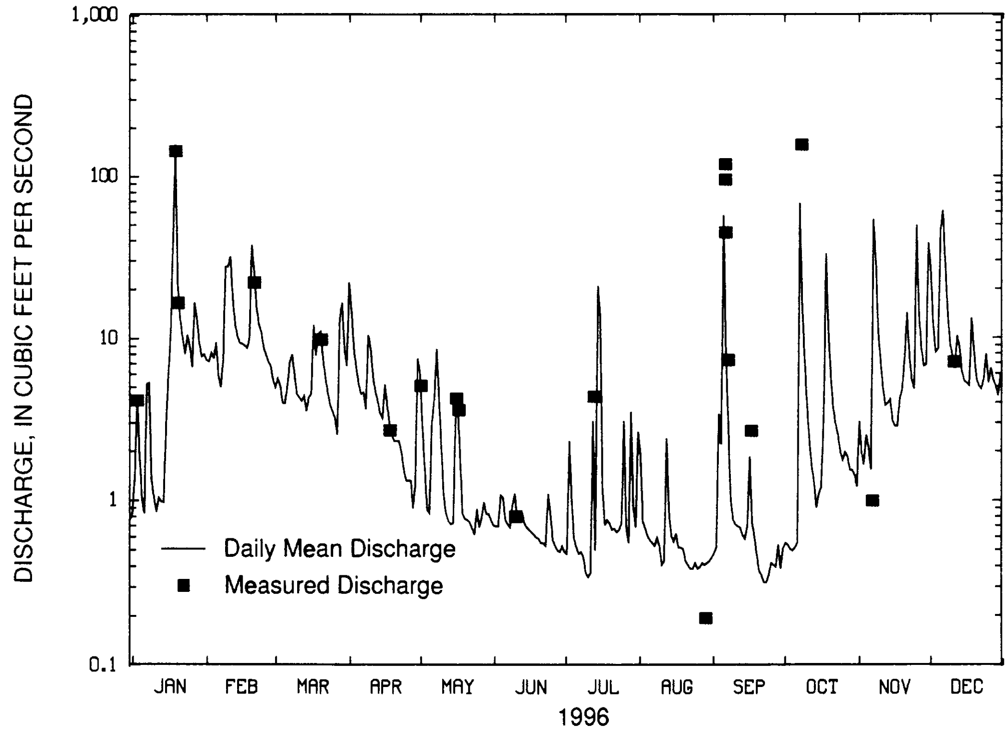


**Figure 7.** Daily mean and measured discharge for Otterdale Branch, Virginia. (USGS Station No. 02041840.)

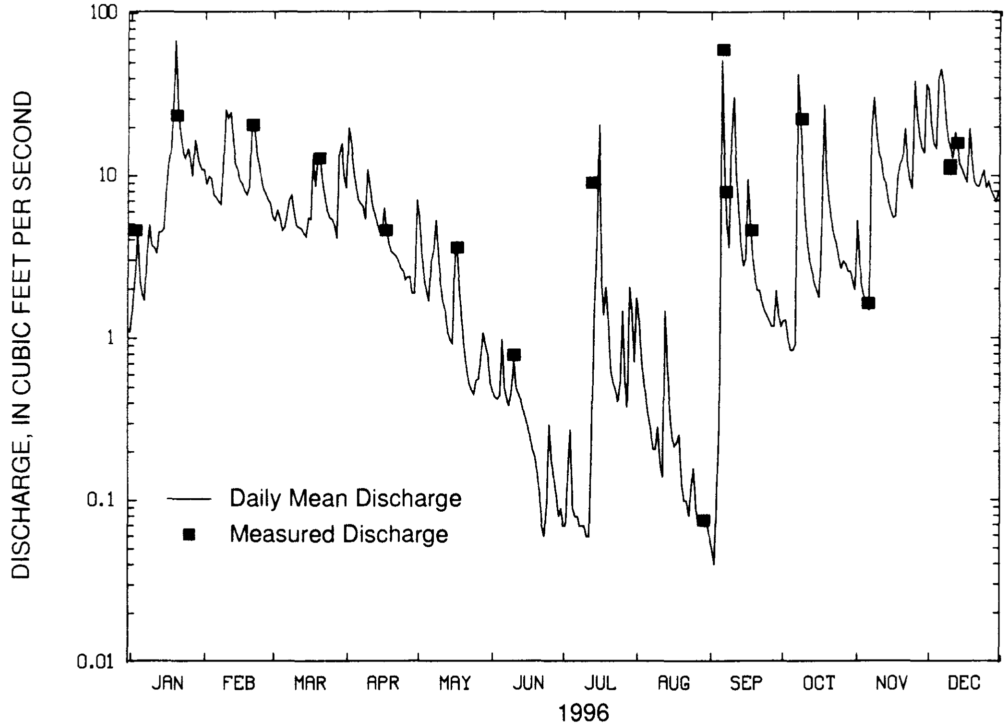


**Figure 8.** Daily mean and measured discharge for Tomahawk Creek, Virginia. (USGS Station No. 02041850.)

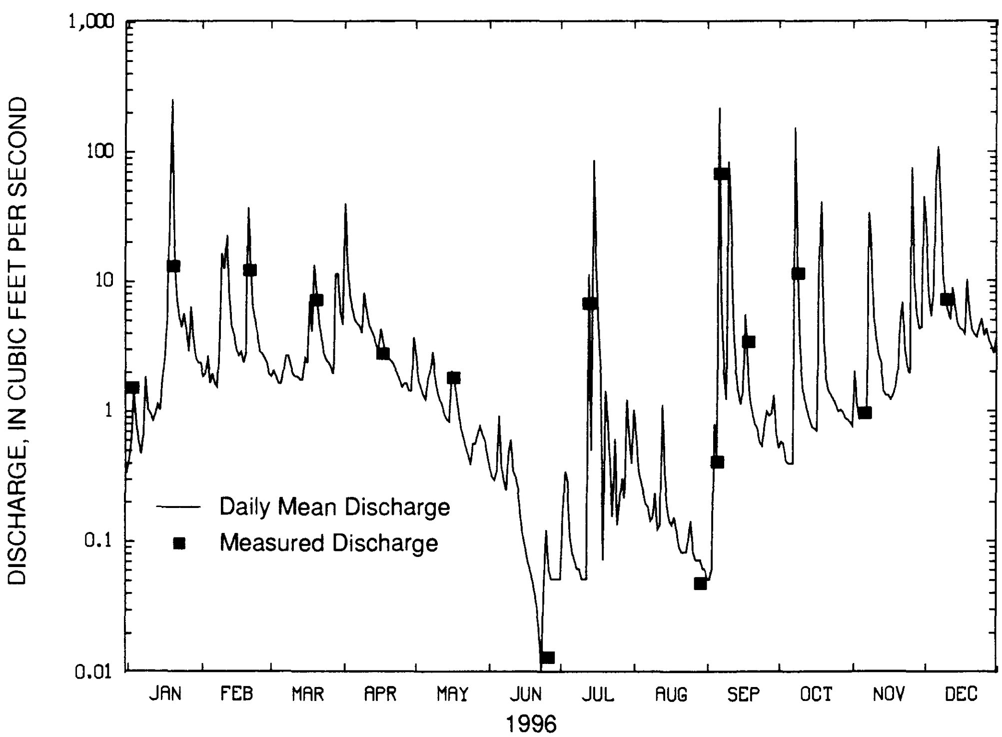


**Figure 9.** Daily mean and measured discharge for Little Tomahawk Creek, Virginia. (USGS Station No. 02041860.)

### Dry Creek

Runoff in 1996 for Dry Creek (table 1) was about 53 $Mft^3/mi^2$. The highest measured discharge was 282 $ft^3/s$, and the highest instantaneous discharge was 748 $ft^3/s$ on September 6, 1996. Of the 17 discharge measurements made, between October 1995 and January 1997, 16 were made during the January through December 1996 study period (fig. 10). Daily mean discharge was not estimated for any days during the study period. Total annual discharge for Dry Creek was 158 $Mft^3$ (table 1), about 8 percent of the measured total annual discharge for all gaged inflow sites. Zero flow was reported for periods during June and July.

### Ashbrook Creek

Runoff in 1996 for Ashbrook Creek (table 1) was about 44 $Mft^3/mi^2$. The highest measured discharge was 78.8 $ft^3/s$, and the highest instantaneous discharge was 175 $ft^3/s$, January 19, 1996. Of the 16 discharge measurements made, between October 1995 and January 1997, 14 were made during the January through December 1996 study period (fig. 11). Daily mean discharge was not estimated for any days during the study period. Total annual discharge for Ashbrook Creek was 105 $Mft^3$ (table 1), about 6 percent of the measured total annual discharge for all gaged inflow sites. Zero flow was reported for periods between June and October.

### West Branch

Runoff in 1996 for West Branch (table 1) was about 40 $Mft^3/mi^2$. The highest measured discharge was 243 $ft^3/s$, and the highest instantaneous discharge, September 6, 1996, was 635 $ft^3/s$. Of the 20 discharge measurements made, between October 1995 and January 1997, 18 were made during the January through December 1996 study period (fig. 12). Daily mean discharge was not estimated for any days during the study period. Total annual discharge for West Branch was 111 $Mft^3$ (table 1), about 6 percent of the measured total annual discharge for all gaged inflow sites. Zero flow was reported for periods in June and July.

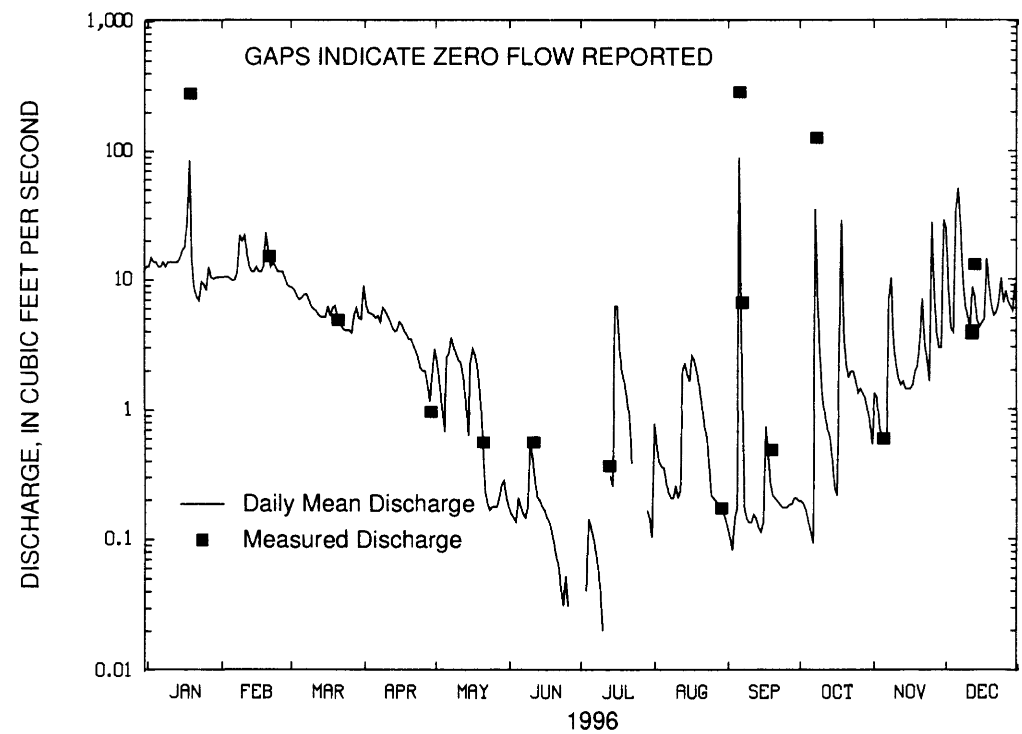


**Figure 10.** Daily mean and measured discharge for Dry Creek, Virginia. (USGS Station No. 02041870.)

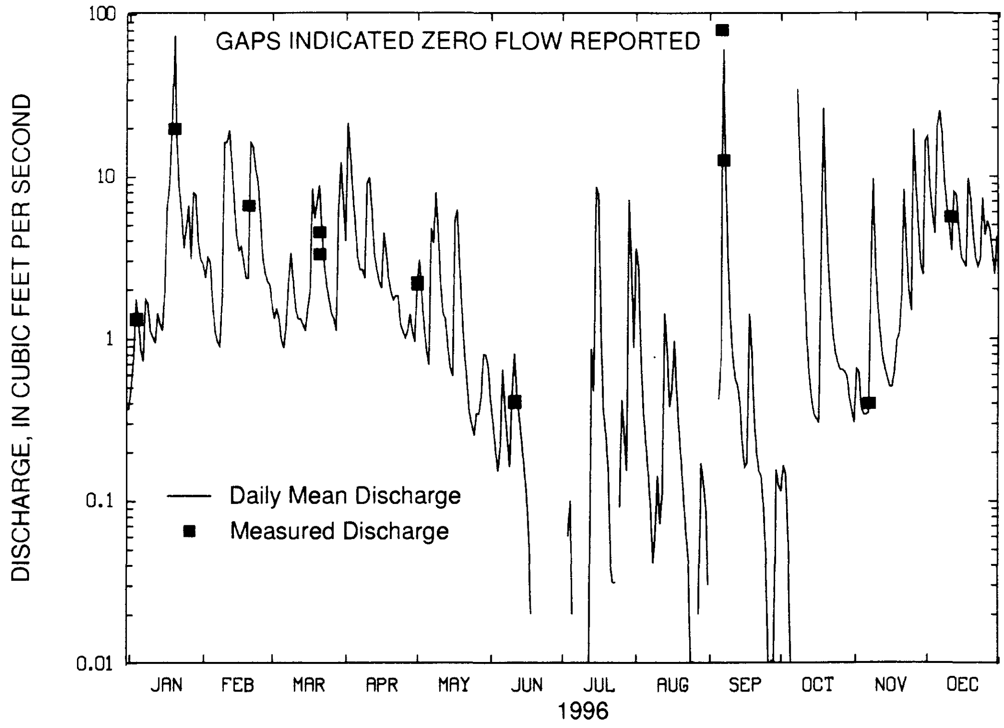


**Figure 11.** Daily mean and measured discharge for Ashbrook Creek, Virginia. (USGS Station No. 02041880.)

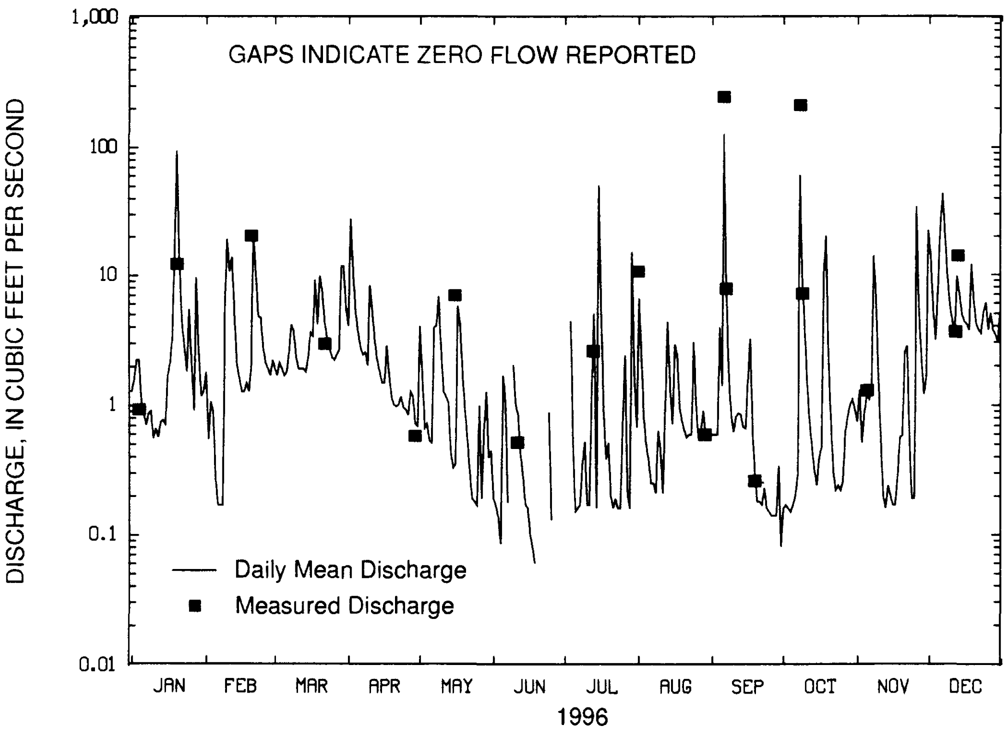


**Figure 12.** Daily mean and measured discharge for West Branch, Virginia. (USGS Station No. 02041890.)

### Direct Precipitation

Mean annual precipitation for Richmond, Va, between 1961 and 1990, is about 43 in. Annual precipitation for the Richmond area in 1996 was about 53 inches (Dustin Hux, oral commun., 1997). The precipitation component of the water budget was determined for the reservoir water-surface area by computing the arithmetic mean of precipitation at three raingages installed near the reservoir (fig. 3).

Precipitation totals ranged from about 53.8 to 57.0 in. The mean precipitation computed for the reservoir was 54.4 in., and the total direct precipitation input computed for the reservoir water-surface area at an elevation of 177 ft was 314 $Mft^3$ for 1996.

### Direct Runoff

Direct runoff refers to the volume of water that enters the reservoir by overland flow from ungaged areas adjacent to the reservoir. Methods developed by other investigators to estimate direct runoff for storms (Cooke and others, 1986) were not considered for this study because runoff monitoring of ungaged areas adjacent to the reservoir was initiated in October 1996, and insufficient data currently are available.

In order to provide a range of possible direct runoff from the ungaged areas to the reservoir, three methods were used. The minimum direct runoff would result if it is assumed that direct runoff would not exceed the least runoff per unit area computed for the nine measured inflow sites. The maximum direct runoff would result if it is assumed that all precipitation that fell on the ungaged area discharged to the reservoir. The mean direct runoff method would result if it is assumed that runoff from the ungaged area is equivalent to the mean runoff per unit area computed for the nine inflow sites.

Because the Swift Creek subbasin (table 1) had the least runoff of the gaged inflow sites (21.5 $Mft^3/mi^2$ or 9.28 in.), annual runoff data for this subbasin were used to estimate the minimum direct runoff. The minimum runoff for the gaged inflow sites was applied to the ungaged areas (12.82 $mi^2$), and the minimum direct runoff to the reservoir was calculated to be 275 $Mft^3$ for 1996.

Runoff data from all nine gaged inflow sites were used to estimate the mean direct runoff for 1996. The mean runoff for the inflow sites was about 38 $Mft^3/mi^2$. The mean runoff for the gaged inflow sites was applied to the ungaged area, and the mean direct runoff to the reservoir was calculated to be about 490 $Mft^3$ for 1996.

Mean rainfall data were used to estimate the maximum direct runoff. The mean rainfall for the reservoir, 54.4 in., was applied to the direct runoff area, resulting in a maximum direct runoff of about 1616 $Mft^3$.

The maximum runoff estimate was used to compute the water budget (eq. 1) for the Swift Creek Reservoir. Actual direct runoff probably is between the mean and maximum estimates. Strahler (1975) compared two drainage basins of different sizes, about one acre and about 310 $mi^2$, and states that almost all the rainfall on the small basin ran off and more than half the rainfall on the large basin was retained as ground water or evaporated. The direct runoff from ungaged areas would be expected to produce more runoff per unit area than the rest of the basin. In addition, about one-third of the direct runoff area is developed mostly for residential land use, and the remaining two-thirds of the area is undeveloped or developing. Strahler (1975) determined that urbanization increases surface runoff and decreases ground-water recharge. Storm sewers and channels associated with urban or developed areas receive runoff from impervious surfaces, such as rooftops, streets, driveways, bike paths, parking lots, lawns, and yards. Stormwater routing reduces infiltration and increases overland flow and flood peaks (Strahler, 1975).

## Outputs

Outputs from the reservoir were either measured or estimated. The reservoir water surface elevation at the SCWP intake was monitored on a daily basis by SWCP staff and near the outflow every 15-minutes by a transducer and recorded by a data logger. Stage and discharge data collected at the reservoir outflow were used to determine a base discharge rating curve, and daily supply withdrawals were recorded by SWCP staff. Evaporation was estimated from free water surface and evaporation pan data collected and published by the National Oceanic and Atmospheric Administration (NOAA) (National Oceanic and Atmospheric Administration, written commun., 1996). A pan-to-lake coefficient of 0.74 was applied to evaporation pan data to estimate total evaporation from the reservoir.

### Outflow and Storage

Total discharge for the reservoir was determined to be the sum of annual discharge at the outflow and supply withdrawals. Although seepage through the dam was observed throughout the study period, it was assumed to be negligible and, therefore, not measured for this study. Previous to this study, the weir and spillway often were observed dry, especially during summer months. Discharge and stage data for the outflow site were collected and processed by use of methods similar to those previously described in the section "Data Collection and Processing" (Rantz and others, 1982a, Rantz and others, 1982b, Buchanan and Somers, 1984). Daily supply withdrawals, recorded in the operator's log and provided by SCWP (Weedon Cloe, written commun., 1996), were summed to estimate the annual water-supply withdrawal.

Annual runoff for the outfall, adjusted for supply withdrawals, was 55.1 Mft$^3$/mi$^2$. The highest measured discharge was 1,300 ft$^3$/s, and the highest instantaneous discharge determined from the stage-discharge rating was 2,680 ft$^3$/s on September 6, 1996. Seven discharge measurements made during the January through December 1996 study period were used to determine the stage-discharge rating (fig. 13). Total annual discharge at the outflow was 3,130 Mft$^3$ (table 2).

Data from a bathymetric survey, provided by SCWP (George DuVal, Swift Creek Water Plant, written commun., 1996), were processed, and a linear rating was developed to determine the relation of storage capacity to reservoir stage. Reservoir water-surface elevations were converted to the arbitrary staff gage datum and applied to the rating. The difference in stage between January 1, 1996 (2.1 ft. recorded by SCWP staff) and December 31, 1996 (2.2 ft. recorded by the data logger) resulted in a storage gain of about 7.4 Mft$^3$ for the study period.

### Withdrawals

Public supply withdrawals from the reservoir by SCWP were recorded, in thousands of gallons per day, in the plant operator's log. Withdrawal data were converted to cubic feet and summed for the study period. Withdrawal for public supply in 1996 was 421 Mft$^3$.

Water is withdrawn from the reservoir between April and October to irrigate a golf course in the Swift Creek Basin. The estimated annual withdrawal for the golf course was determined from the maximum estimated daily withdrawal (George DuVal, oral commun., 1997). Because irrigation withdrawal data were incomplete for the study period and the maximum annual irrigation withdrawal represents less than 0.2 percent of the total output from the reservoir, water withdrawn for the golf course was not included in the water budget for this study.

### Evaporation

Staff from SCWP began collecting pan evaporation data at the reservoir in August 1996; however, these data were not used for this study because annual pan coefficients are not valid when computing evaporation for periods of less than one year (Winter, 1981). Evaporation from the reservoir water-surface was estimated (1) from NOAA

**Table 2.** Drainage area and discharge data for outflow site, Swift Creek Reservoir, Virginia, 1996

[mi$^2$, square mile; Mft$^3$, Million cubic feet; ft$^3$/s, cubic feet per second; in., inch]

| Site number | USGS station number | Outflow stream name | Drainage area (mi$^2$) | Total annual discharge (Mft$^3$) | Daily mean discharge | | Annual runoff | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Maximum (ft$^3$/s) | Minimum (ft$^3$/s) | Mft$^3$/mi$^2$ | in. |
| 10 | 02041900 | Swift Creek Dam | 64.4 | 3,130 | 1,700 | 0 | 48.6 | 20.90 |

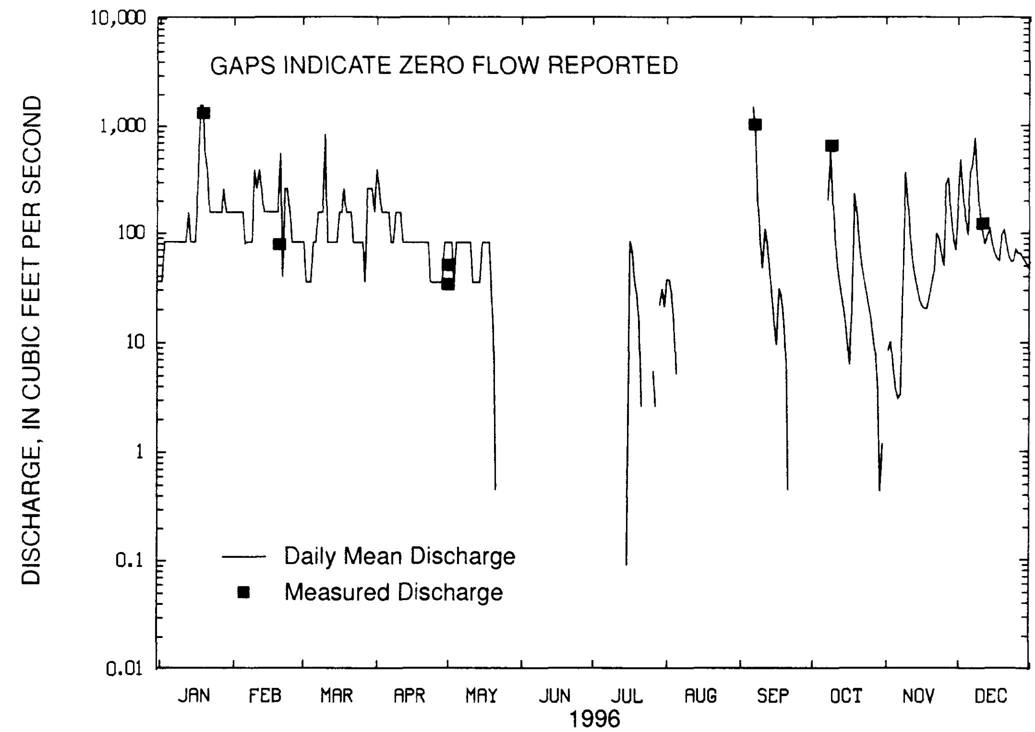


**Figure 13.** Daily mean and measured discharge for Swift Creek Reservoir Dam. (USGS Station No. 02041900.)

free water surface (FWS) evaporation maps (Farnsworth and others, 1982), (2) from published maps of historical May through October 1956–70 pan evaporation data for the United States (Farnsworth and others, 1982), and (3) from monthly pan evaporation measured at three different sites (NOAA, written commun., 1996) near the reservoir and adjusted with the appropriate pan coefficient from NOAA (Farnsworth and others, 1982).

The FWS evaporation is defined as the evaporation from a thin film of water having no appreciable heat storage. FWS equals lake evaporation when the change in heat storage is negligible in the lake. Consequently, FWS cannot be used for lake evaporation where there are heat inputs, such as power-plant thermal discharges, or if the time period analyzed includes seasonal thermal effects. These FWS criteria were met for this study because a year-long period was analyzed in a lake having no known additional sources of thermal inputs. The mean annual FWS evaporation and mean May through October FWS evaporation published by NOAA (Farnsworth and others, 1982) are listed in table 3.

The mean May through October pan evaporation, published by NOAA (Farnsworth and others, 1982), and measured pan evaporation, from three nearby weather stations (NOAA, written commun., 1996) were adjusted by the appropriate pan coefficient 0.74 (Farnsworth and others, 1982) and listed in table 3. The percent of annual evaporation represented by the May through October time period was analyzed at several stations throughout the United States (Farnsworth and others, 1982). Results from a station at Chapel Hill, North Carolina (the closest station to Swift Creek), showed that the May through October evaporation accounted for about 66 percent of the annual total. The annual pan evaporation therefore, was calculated by dividing the May through October values by 0.66 (table 3).

The pan evaporation measured in 1996 at three nearby weather reporting stations and the long-term average pan data published by NOAA

**Table 3.** May through October and annual evaporation from pans and free water surface, 1982, and three evaporation reporting stations, 1996

[FWS, free water surface; in., inch; %, percent]

| May through October evaporation | | | Annual evaporation | | |
|---|---|---|---|---|---|
| FWS Evaporation[1] (in.) | Pan evaporation[1] (in.) | Average pan evaporation from three stations in 1996 (in.) | FWS Evaporation[1] (in.) | Pan evaporation (May-October adjusted by 66%) (in.) | Average pan evaporation for 1996 from three stations (May-October adjusted by 66%)[2] (in.) |
| 27 | 26 | 26 | 38 | 39 | 39 |

[1]Farnsworth and others, 1982

[2]National Oceanic and Atmospheric Administration, written commun., 1996.

are similar. Additionally, the annual pan evaporation and the annual FWS evaporation are very similar (39 and 38 in., respectively). A value of 39 in., or 226 $Mft^3$, therefore, was used for the evaporation component in the water-budget equation.

## WATER BUDGET

Hydrologic inputs and outputs (table 4) were measured or estimated to determine a preliminary water budget for Swift Creek Reservoir. Total input for the reservoir for 1996 was about 3,800 $Mft^3$, determined from total annual discharge for all gaged inflow sites, precipitation, and estimated direct runoff (table 1). The total output from the reservoir for 1996 was about 3,780 $Mft^3$, determined from total annual discharge at the dam, recorded supply withdrawals, and evaporation estimates. The measured change in reservoir storage was about 7.4 $Mft^3$, and the residual computed from the water budget equation was 12 $Mft^3$.

**Table 4.** Hydrologic inputs, outputs, residual, and change in storage of Swift Creek Reservoir

[$Mft^3$, million cubic feet]

| Component | Input ($Mft^3$) | Output ($Mft^3$) | Residual ($Mft^3$) | Change in reservoir storage ($Mft^3$) |
|---|---|---|---|---|
| Inflows | 1,862 | | | |
| Direct precipitation | 314 | | | |
| Direct runoff | 1,616 | | | |
| Supply withdrawal | | 421 | | |
| Discharge at dam | | 3,126 | | |
| Evaporation | | 226 | | |
| Total | 3,792 | 3,773 | 12 | 7 |

Errors in the water budget may be reduced by refining the method by which components are calculated. Errors also may be reduced by changing the time period for which components are calculated. Errors in measured components can be reduced through continued monitoring and refinement of methodology. Components that were estimated for this study (evaporation and direct runoff) could be measured in subsequent studies. Subsequent studies also may include the contribution of the ground-water component to the water budget equation. Estimating the water budget for a water year instead of a calendar year also may reduce errors. A water year, October through September, usually begins and ends during a stable hydrologic period; input and output changes are not as dramatic or frequent in comparison to a calendar year.

Continual stage data, precipitation data, and more that 170 discharge measurements were used to characterize hydrologic inputs for Swift Creek Reservoir. The area drained by the nine inflow sites consists of 76 percent of the total drainage area of the Swift Creek Basin and contributed about 49 percent of the total input to the reservoir (fig. 14). The direct runoff area covers about 20 percent of the total drainage area and contributed about 43 percent of the total input to the reservoir. Direct runoff was estimated assuming that the area was 100 percent impervious. The reservoir covers about 4 percent of the drainage area, and direct

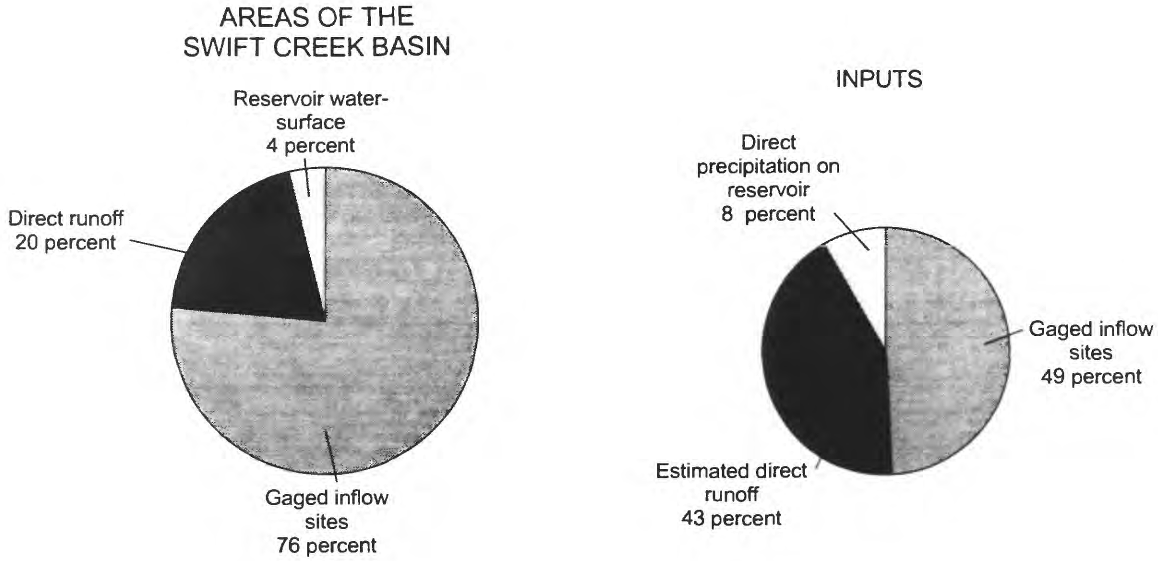


**Figure 14.** Areas and contribution of input components to Swift Creek Reservoir, Virginia, 1996.

precipitation on the reservoir water-surface accounted for about eight percent of the total input. Continued collection of stage data and discharge measurements are needed to characterize inflows to the reservoir. Stage-discharge ratings curves for sand channel streams during low flows are difficult to define even if discharge measurements were made daily (Rantz and others, 1982b). Rating curves for some inflow sites could be refined with the addition of high-flow discharge data.

Direct runoff contributes a large percentage of flow to the overall water budget and it is the most crudely approximated component (table 4). Direct runoff was estimated by assuming that all rain falling on the areas adjacent to the reservoir flowed to the reservoir. The contribution of this component warrants additional investigation to refine the water budget for the reservoir.

Measured discharge at the outflow, recorded supply withdrawals, and estimated evaporation were characterized as outputs from the reservoir. Discharge at the outflow accounted for about 83 percent of the total output from the reservoir (fig. 15). Supply withdrawals and evaporation accounted for about 11 percent and 6 percent of the output from the reservoir, respectively.

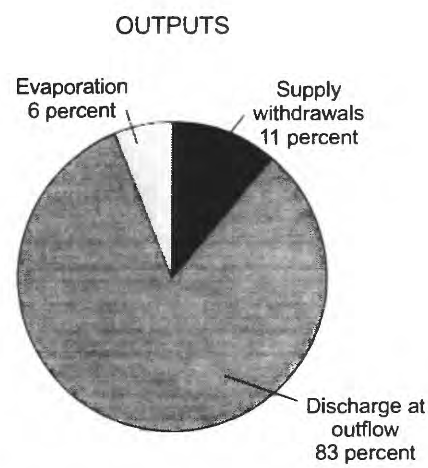


**Figure 15.** Distribution of output components for Swift Creek Reservoir, Virginia, 1996.

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# APPENDIX TABLES

## APPENDIX A.—DISCHARGE SUMMARY FOR SWIFT CREEK AT ROUTE 667 NEAR HALLSBORO, VIRGINIA, 1996

Swift Creek drains 21.4 $mi^2$ of wetlands and undeveloped land. Stage data were collected beneath the bridge on Route 667 (also known as Otterdale Road). A sand and gravel bar controls the water level in the gage pool under normal and low-flow conditions. Debris and beaver dams also may control the water level of the gage pool at low and medium flows.

Discharge measurements were made during low flow by wading with current meter. Conventional current-meter discharge measurements were made from the bridge during high flow.

Table A1. Daily mean discharge, in cubic feet per second, at Swift Creek at Route 667 near Hallsboro, Va., 1996

Station Number 02041810
Latitude 372718 Longitude 0774211
Drainage Area 21.4 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 3.2 | 22 | 16 | 45 | 29 | 3.1 | .39 | 4.6 | .33 | 4.4 | .93 | 30 |
| 2 | 3.7 | 25 | 18 | 45 | 16 | 2.0 | .37 | 6.0 | .32 | 4.4 | 1.4 | 61 |
| 3 | 5.5 | 39 | 18 | 33 | 11 | 1.6 | .49 | 4.2 | .32 | 4.5 | 1.6 | 23 |
| 4 | 5.0 | 30 | 15 | 28 | 9.0 | 1.8 | 1.5 | 2.3 | 2.3 | 4.1 | .85 | 16 |
| 5 | 3.9 | 19 | 15 | 23 | 7.0 | 4.3 | .39 | 1.3 | 20 | 3.9 | .75 | 13 |
| 6 | 3.5 | 17 | 17 | 21 | 10 | 4.1 | .37 | .81 | 138 | 4.1 | .77 | 44 |
| 7 | 4.1 | 16 | 21 | 22 | 12 | 3.0 | .36 | .52 | 96 | 4.2 | 1.5 | 47 |
| 8 | 6.9 | 26 | 25 | 19 | 19 | 2.3 | .35 | .38 | 27 | 61 | 14 | 94 |
| 9 | 11 | 65 | 21 | 31 | 16 | 2.9 | .35 | .45 | 16 | 89 | 105 | 25 |
| 10 | 11 | 70 | 17 | 33 | 11 | 4.7 | .34 | 2.7 | 17 | 33 | 18 | 18 |
| 11 | 8.5 | 63 | 16 | 24 | 7.5 | 5.6 | .32 | 3.6 | 44 | 20 | 8.9 | 15 |
| 12 | 7.9 | 53 | 15 | 21 | 5.8 | 5.1 | .32 | 1.8 | 15 | 13 | 5.4 | 13 |
| 13 | 9.0 | 38 | 15 | 19 | 4.2 | 4.9 | 5.8 | 7.3 | 10 | 9.2 | 4.3 | 16 |
| 14 | 9.4 | 33 | 14 | 17 | 3.4 | 3.5 | 6.1 | 6.8 | 7.1 | 6.5 | 3.6 | 18 |
| 15 | 11 | 29 | 16 | 15 | 3.1 | 2.6 | 11 | 4.7 | 5.2 | 5.1 | 3.4 | 13 |
| 16 | 20 | 28 | 19 | 20 | 8.8 | 1.8 | 32 | 2.8 | 5.2 | 4.6 | 3.2 | 12 |
| 17 | 23 | 28 | 38 | 18 | 13 | 1.2 | 10 | 2.3 | 13 | 4.0 | 2.7 | 11 |
| 18 | 38 | 25 | 30 | 15 | 9.2 | .67 | 4.3 | 1.1 | 9.8 | 3.9 | 2.3 | 11 |
| 19 | 161 | 25 | 32 | 13 | 6.0 | .52 | 4.5 | .51 | 5.9 | 32 | 3.1 | 18 |
| 20 | 92 | 51 | 40 | 12 | 4.2 | .50 | 3.2 | .39 | 4.4 | 13 | 5.0 | 16 |
| 21 | 45 | 69 | 28 | 12 | 3.3 | .48 | 1.9 | .39 | 3.6 | 6.6 | 6.2 | 12 |
| 22 | 36 | 46 | 23 | 12 | 2.7 | .41 | 1.3 | .38 | 3.4 | 4.5 | 16 | 11 |
| 23 | 28 | 39 | 19 | 10 | 2.1 | .40 | .79 | .38 | 3.3 | 2.7 | 7.8 | 11 |
| 24 | 30 | 34 | 17 | 9.7 | 1.5 | .52 | .50 | .39 | 3.2 | 1.6 | 5.1 | 11 |
| 25 | 34 | 27 | 16 | 8.9 | 3.6 | 1.5 | .88 | .43 | 3.5 | 1.2 | 4.2 | 15 |
| 26 | 24 | 24 | 15 | 9.3 | 3.3 | .83 | 5.5 | .37 | 3.5 | 1.0 | 41 | 11 |
| 27 | 37 | 23 | 14 | 10 | 4.9 | .51 | 4.1 | .36 | 3.5 | 1.1 | 25 | 11 |
| 28 | 41 | 21 | 29 | 8.4 | 6.7 | .40 | 2.1 | .36 | 3.6 | 1.2 | 13 | 11 |
| 29 | 29 | 19 | 52 | 7.5 | 6.0 | .39 | 3.6 | .35 | 5.0 | 1.3 | 9.3 | 10 |
| 30 | 27 | --- | 35 | 23 | 5.6 | .40 | 3.2 | .34 | 4.6 | 1.2 | 8.4 | 9.9 |
| 31 | 25 | --- | 28 | --- | 4.2 | --- | 2.4 | .34 | --- | .88 | --- | 11 |
| TOTAL | 793.6 | 1004 | 694 | 584.8 | 249.1 | 62.03 | 108.72 | 58.65 | 474.07 | 347.18 | 322.70 | 637.9 |
| MEAN | 25.6 | 34.6 | 22.4 | 19.5 | 8.04 | 2.07 | 3.51 | 1.89 | 15.8 | 11.2 | 10.8 | 20.6 |
| MAX | 161 | 70 | 52 | 45 | 29 | 5.6 | 32 | 7.3 | 138 | 89 | 105 | 94 |
| MIN | 3.2 | 16 | 14 | 7.5 | 1.5 | .39 | .32 | .34 | .32 | .88 | .75 | 9.9 |
| CFSM | 1.20 | 1.62 | 1.05 | .91 | .38 | .10 | .16 | .09 | .74 | .52 | .50 | .96 |
| IN. | 1.38 | 1.75 | 1.21 | 1.02 | .43 | .11 | .19 | .10 | .82 | .60 | .56 | 1.11 |

CAL YR 1996 TOTAL 5336.75 MEAN 14.6 MAX 161 MIN .32 CFSM .68 IN. 9.28

## APPENDIX B.—DISCHARGE SUMMARY FOR BLACKMAN CREEK NEAR HALLSBORO, VIRGINIA, 1996

Blackman Creek drains 5.80 $mi^2$ of undeveloped land. Stage data were collected upstream of the bridge on Route 667. The data-collection site is located in a low gradient reach of the stream. The actual low-water control is unknown; however, vegetation, channel debris, or backwater from downstream wetlands may control the water level in the gage pool under normal and low-flow conditions. The gage pool is deep with low surface velocities observed at times. The stream channel controls stage during periods of high flow.

Discharge measurements were made during low flow by use of floats or by wading with current meter. Float discharge estimates were computed by multiplying the surface velocity, corrected by the standard vertical velocity profile, to the cross-sectional area of the stream. The surface velocity was determined by measuring the amount of time float travels within a measured distance between two cross-sections (Rantz, 1982b). Conventional current meter discharge measurements were made from the bridge during high flow.

Table B1. Daily mean discharge, in cubic feet per second, at Blackman Creek near Hallsboro, Va., 1996

Station Number 02041820
Latitude 372454 Longitude 0774338
DRAINAGE AREA 5.80
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.3 | 1.3 | 1.3 | 46 | 11 | 1.3 | .67 | 8.2 | 1.2 | 5.8 | 1.2 | 92 |
| 2 | 1.9 | 1.3 | 1.3 | 26 | 5.6 | 1.3 | .65 | 7.0 | 1.1 | 7.1 | 1.3 | 73 |
| 3 | 5.4 | 1.3 | 1.3 | 14 | 4.4 | 1.3 | .87 | 4.0 | 1.1 | 9.1 | 1.2 | 23 |
| 4 | 2.5 | 1.2 | 1.2 | 9.9 | 4.7 | 1.3 | 1.2 | 3.4 | 13 | 7.0 | 1.2 | 14 |
| 5 | 1.5 | 1.2 | 1.3 | 7.3 | 4.9 | 1.3 | 1.0 | 3.0 | 15 | 6.0 | 1.2 | 15 |
| 6 | 1.3 | 1.2 | 1.9 | 6.3 | 13 | 1.2 | .95 | 2.8 | e60 | 7.0 | 1.2 | 115 |
| 7 | 1.4 | 1.2 | 4.1 | 6.2 | 12 | 1.1 | .88 | 2.3 | e7.5 | 8.6 | 1.2 | 128 |
| 8 | 3.1 | 2.3 | 4.8 | 4.7 | 20 | 1.1 | .84 | 1.7 | 1.1 | 131 | 55 | 86 |
| 9 | 2.8 | 38 | 2.8 | 16 | 11 | 1.1 | .85 | 2.2 | 1.1 | 38 | 64 | 30 |
| 10 | 2.9 | 32 | 1.8 | 14 | 7.0 | 1.3 | .80 | 3.8 | 1.0 | 11 | 6.3 | 16 |
| 11 | 2.7 | 47 | 2.0 | 7.9 | 6.4 | 1.2 | .75 | 1.6 | 1.1 | 2.9 | 1.6 | 13 |
| 12 | 3.5 | 19 | 2.3 | 6.4 | 6.4 | 1.2 | .74 | 1.5 | 1.1 | 9.9 | 1.3 | 10 |
| 13 | 3.9 | 6.9 | 2.4 | 5.6 | 3.7 | 1.1 | 1.4 | 9.0 | 1.2 | 15 | 1.3 | 20 |
| 14 | 4.1 | 5.1 | 2.7 | 4.5 | 3.0 | 1.1 | 1.2 | 6.7 | 1.2 | 16 | 1.6 | 15 |
| 15 | 8.3 | 3.7 | 4.1 | 4.0 | 2.8 | 1.0 | 40 | 4.2 | 1.2 | 14 | 1.4 | 9.9 |
| 16 | 15 | 3.1 | 4.4 | 8.3 | 10 | .99 | 20 | 6.7 | 1.3 | 13 | 1.3 | 8.5 |
| 17 | 23 | 2.5 | 17 | 6.0 | 11 | .96 | 1.1 | 13 | 3.9 | 12 | 1.3 | 9.5 |
| 18 | 55 | 2.3 | 8.4 | 4.0 | 6.2 | .93 | 1.1 | 6.8 | 2.0 | 14 | 1.4 | 9.3 |
| 19 | 227 | 3.1 | 14 | 3.2 | 3.6 | .90 | 1.2 | 5.5 | 1.5 | 67 | 2.2 | 28 |
| 20 | 22 | 72 | 16 | 4.0 | 2.4 | .88 | 1.2 | 4.4 | 1.5 | 15 | 2.6 | 16 |
| 21 | 6.9 | 38 | 8.3 | 3.5 | 1.7 | .85 | 1.2 | 3.7 | 1.7 | 8.5 | 8.4 | 9.8 |
| 22 | 3.1 | 13 | 5.8 | 2.9 | 1.3 | .82 | 1.2 | 3.5 | 2.5 | 6.5 | 30 | 8.4 |
| 23 | 2.0 | 11 | 4.4 | 2.5 | 1.2 | .80 | 1.2 | 2.8 | 2.2 | 5.4 | 6.0 | 8.2 |
| 24 | 4.8 | 5.3 | 3.7 | 2.0 | 1.1 | .79 | 1.2 | 2.4 | 2.3 | 4.6 | 2.8 | 10 |
| 25 | 3.3 | 2.6 | 3.8 | 1.5 | 1.2 | .96 | 1.5 | 3.0 | 2.8 | 3.1 | 2.2 | 16 |
| 26 | 1.3 | 2.2 | 3.4 | 1.9 | 1.3 | .91 | 4.3 | 2.4 | 2.5 | 2.2 | 117 | 10 |
| 27 | 12 | 1.7 | 2.8 | 1.9 | 1.5 | .83 | 1.4 | 2.3 | 2.9 | 1.9 | 28 | 12 |
| 28 | 5.3 | 1.5 | 19 | 1.3 | 2.4 | .75 | 1.2 | 2.3 | 3.4 | 1.4 | 13 | 10 |
| 29 | 2.3 | 1.3 | 27 | 1.3 | 2.0 | .69 | 9.9 | 1.9 | 7.3 | 1.3 | 8.4 | 9.1 |
| 30 | 1.9 | --- | 12 | 12 | 1.5 | .69 | 4.0 | 1.3 | 6.4 | 1.3 | 7.8 | 8.6 |
| 31 | 1.9 | --- | 8.0 | --- | 1.3 | --- | 2.7 | 1.2 | --- | 1.2 | --- | 14 |
| TOTAL | 433.4 | 322.3 | 193.3 | 235.1 | 165.6 | 30.65 | 107.20 | 124.6 | 152.1 | 446.8 | 373.4 | 847.3 |
| MEAN | 14.0 | 11.1 | 6.24 | 7.84 | 5.34 | 1.02 | 3.46 | 4.02 | 5.07 | 14.4 | 12.4 | 27.3 |
| MAX | 227 | 72 | 27 | 46 | 20 | 1.3 | 40 | 13 | 60 | 131 | 117 | 128 |
| MIN | 1.3 | 1.2 | 1.2 | 1.3 | 1.1 | .69 | .65 | 1.2 | 1.0 | 1.2 | 1.2 | 8.2 |
| CFSM | 2.41 | 1.92 | 1.08 | 1.35 | .92 | .18 | .60 | .69 | .87 | 2.48 | 2.15 | 4.71 |
| IN. | 2.78 | 2.07 | 1.24 | 1.51 | 1.06 | .20 | .69 | .80 | .98 | 2.87 | 2.39 | 5.43 |

CAL YR 1996 TOTAL 3431.75 MEAN 9.38 MAX 227 MIN .65 CFSM 1.62 IN. 22.01

# APPENDIX C.—DISCHARGE SUMMARY FOR HORSEPEN CREEK NEAR HALLSBORO, VIRGINIA, 1996

Horsepen Creek drains 3.72 $mi^2$ of undeveloped land. Stage data were collected about 30 ft downstream of Route 667 through which the creek is routed by a single corrugated metal pipe. The data-collection site is located in a low gradient reach of the stream. The actual low-water control is unknown; however, vegetation, channel debris, or backwater from downstream wetlands may control the water level in the gage pool under normal and low-flow conditions. The stream channel controls the water level at high flow.

Discharge measurements were made during low flow by wading with current meter or by a parshall flume. Discharge measurements are difficult to collect at high flows; unmeasured discharge was observed flowing over Route 667 and in overflow channels that originate upstream of and bypass the data-collection site. High-flow discharge measurements were made with an 8 ft wading rod held from the bank or with float.

Table C1. Daily mean discharge, in cubic feet per second, at Horsepen Creek near Hallsboro, Va., 1996

Station Number 02041830
Latitude 372524 Longitude 0774333
Drainage Area 3.72 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.6 | 5.8 | 3.8 | 29 | 6.3 | .34 | .12 | 2.3 | .12 | .35 | 1.0 | 39 |
| 2 | 2.2 | 5.7 | 4.3 | 17 | 3.1 | .33 | .12 | 1.9 | .12 | .35 | 2.1 | 28 |
| 3 | 4.5 | 5.4 | 4.1 | 11 | 2.0 | .33 | 3.0 | .64 | .12 | .37 | 1.7 | 10 |
| 4 | 2.9 | 4.6 | 3.3 | 7.7 | 1.4 | .34 | 1.5 | .36 | 4.1 | .35 | 1.1 | 4.9 |
| 5 | 2.1 | 4.0 | 3.4 | 4.9 | 1.1 | .77 | .32 | .35 | 3.0 | .35 | .93 | 5.1 |
| 6 | 1.7 | 3.9 | 4.1 | 4.0 | 3.2 | .35 | .17 | .33 | e26 | .35 | .88 | 35 |
| 7 | 2.0 | 3.9 | 5.5 | 4.2 | 4.5 | .34 | .13 | .32 | e11 | .36 | .89 | 32 |
| 8 | 3.3 | 6.7 | 6.4 | 3.3 | 9.5 | .33 | .14 | .23 | 5.3 | 38 | 23 | 30 |
| 9 | 3.0 | 32 | 4.9 | 9.1 | 5.0 | .56 | .17 | .25 | 3.1 | 18 | 34 | 14 |
| 10 | 3.2 | 26 | 3.7 | 8.5 | 2.9 | 1.2 | .13 | .32 | 2.1 | 8.3 | 10 | 9.0 |
| 11 | 3.1 | 32 | 3.5 | 5.4 | 2.1 | .49 | .12 | .20 | 1.6 | 4.2 | 5.6 | 7.5 |
| 12 | 3.5 | 18 | 3.4 | 4.3 | 2.0 | .36 | .13 | .20 | 1.4 | 1.6 | 3.9 | 5.8 |
| 13 | 3.9 | 9.6 | 3.1 | 3.5 | 1.3 | .54 | 4.2 | 2.1 | 1.1 | 1.1 | 3.3 | 8.1 |
| 14 | 4.0 | 8.7 | 2.8 | 2.9 | 1.0 | .35 | .47 | .83 | .70 | 1.0 | 3.0 | 7.4 |
| 15 | 6.4 | 7.7 | 3.4 | 2.5 | .93 | .32 | 16 | .35 | .46 | 1.0 | 2.5 | 5.3 |
| 16 | 10 | 7.1 | 3.8 | 4.4 | 4.3 | .27 | 17 | .55 | .46 | .94 | 2.4 | 4.9 |
| 17 | 14 | 6.5 | 11 | 3.7 | 4.2 | .20 | 2.1 | 1.0 | 1.9 | .85 | 2.3 | 5.0 |
| 18 | 31 | 6.2 | 6.6 | 2.7 | 2.0 | .18 | .82 | .35 | .91 | 1.4 | 2.3 | 4.8 |
| 19 | 93 | 7.3 | 9.0 | 2.3 | .93 | .16 | .94 | .31 | .49 | 27 | 3.0 | 13 |
| 20 | 20 | 42 | 9.7 | 2.1 | .56 | .14 | .60 | .20 | .36 | 6.7 | 3.0 | 8.4 |
| 21 | 11 | 25 | 5.2 | 1.9 | .39 | .14 | .36 | .18 | .35 | 3.8 | 5.1 | 5.6 |
| 22 | 9.6 | 13 | 3.4 | 1.8 | .35 | .13 | .35 | .16 | .36 | 3.5 | 13 | 5.0 |
| 23 | 9.2 | 11 | 2.5 | 1.5 | .35 | .12 | .35 | .15 | .35 | 2.8 | 5.2 | 5.0 |
| 24 | 11 | 8.7 | 2.1 | 1.3 | .34 | .14 | .34 | .14 | .34 | 2.4 | 4.0 | 5.4 |
| 25 | 9.3 | 6.8 | 2.0 | 1.1 | .36 | .53 | .51 | .18 | .34 | 1.9 | 3.5 | 8.8 |
| 26 | 6.9 | 6.0 | 1.8 | 1.1 | .35 | .16 | 3.9 | .14 | .34 | 1.8 | 50 | 5.8 |
| 27 | 15 | 5.5 | 1.5 | 1.1 | .38 | .13 | .80 | .13 | .34 | 1.8 | 18 | 7.0 |
| 28 | 10 | 5.2 | 13 | .88 | .72 | .12 | .36 | .14 | .34 | 1.8 | 11 | 6.0 |
| 29 | 7.6 | 4.3 | 19 | .83 | .55 | .11 | 4.5 | .13 | .54 | 1.6 | 7.8 | 5.6 |
| 30 | 7.0 | --- | 7.9 | 6.5 | .47 | .12 | 2.1 | .13 | .36 | 1.5 | 6.8 | 5.1 |
| 31 | 7.0 | --- | 5.7 | --- | .35 | --- | .80 | .12 | --- | 1.2 | --- | 7.1 |
| TOTAL | 319.0 | 328.6 | 163.9 | 150.51 | 62.93 | 9.60 | 62.55 | 14.69 | 68.00 | 136.67 | 231.30 | 343.6 |
| MEAN | 10.3 | 11.3 | 5.29 | 5.02 | 2.03 | .32 | 2.02 | .47 | 2.27 | 4.41 | 7.71 | 11.1 |
| MAX | 93 | 42 | 19 | 29 | 9.5 | 1.2 | 17 | 2.3 | 26 | 38 | 50 | 39 |
| MIN | 1.6 | 3.9 | 1.5 | .83 | .34 | .11 | .12 | .12 | .12 | .35 | .88 | 4.8 |
| CFSM | 2.77 | 3.05 | 1.42 | 1.35 | .55 | .09 | .54 | .13 | .61 | 1.19 | 2.07 | 2.98 |
| IN. | 3.19 | 3.29 | 1.64 | 1.51 | .63 | .10 | .63 | .15 | .68 | 1.37 | 2.31 | 3.44 |

CAL YR 1996 TOTAL 1891.35 MEAN 5.17 MAX 93 MIN .11 CFSM 1.39 IN. 18.91

## APPENDIX D.—DISCHARGE SUMMARY FOR OTTERDALE BRANCH NEAR HALLSBORO, VIRGINIA, 1996

Otterdale Branch drains 3.59 $mi^2$ of undeveloped land. Stage data were collected downstream of the bridge on Route 667. A sand and gravel bar controls the water level in the gage pool under normal and low-flow conditions. Debris, at times, controls the water level of the gage pool at low and medium flows. The stream channel controls the water level at high flow. About 0.223 $ft^3/s$ is returned as inflow pumpage from Swift Creek Reservoir by SCWP for supply-line flushing (Weedon Cloe, Swift Creek Water Plant, oral commun., 1997).

Discharge measurements were made during low flow by wading with current meter. Conventional current-meter discharge measurements were made from the bridge during high flow. During periods of high flow, the bridge restricts flow and accumulates debris. Discharge measurements made under these conditions indicate a non-standard vertical velocity profile; the highest velocities observed during a discharge measurement were not measured closest the water surface. Additional velocity data were made during events under these conditions, when time permitted.

Table D1. Daily mean discharge, in cubic feet per second, at Otterdale Branch near Hallsboro, Va., 1996

Station Number 02041840
Latitude 372628 Longitude 0774240
Drainage Area 3.59 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .75 | 6.6 | 4.5 | 20 | 5.5 | .64 | .44 | 2.4 | .41 | .46 | 1.1 | 35 |
| 2 | 1.3 | 6.5 | 5.1 | 13 | 2.6 | .63 | .43 | 1.7 | .43 | .50 | 2.8 | 24 |
| 3 | 3.9 | 7.4 | 4.6 | 7.6 | 1.5 | .63 | 2.1 | .68 | .47 | .49 | 1.8 | 11 |
| 4 | 1.7 | 6.8 | 3.6 | 5.9 | .80 | .98 | .92 | .61 | 3.1 | .46 | 1.5 | 7.4 |
| 5 | .91 | 8.6 | 3.6 | 4.7 | .76 | .95 | .53 | .55 | 2.0 | .45 | 2.3 | 7.8 |
| 6 | .75 | 5.3 | 4.6 | 4.1 | 2.7 | .69 | .47 | .52 | e52 | .47 | 1.9 | 41 |
| 7 | 4.7 | 4.5 | 6.5 | 4.2 | 3.8 | .65 | .43 | .50 | e7.1 | .50 | 1.4 | 56 |
| 8 | 4.8 | 6.7 | 7.2 | 3.3 | 7.8 | .62 | .44 | .48 | 2.7 | 62 | 49 | 26 |
| 9 | 1.2 | 25 | 5.4 | 9.5 | 4.0 | .85 | .41 | .54 | .96 | 15 | 27 | 13 |
| 10 | .93 | 25 | 4.1 | 7.9 | 2.0 | 1.0 | .33 | .48 | .70 | 6.7 | 9.9 | 8.4 |
| 11 | .77 | 29 | 3.9 | 5.2 | .99 | .71 | .31 | .37 | .65 | 3.6 | 6.5 | 7.0 |
| 12 | .94 | 16 | 3.7 | 4.3 | .76 | .75 | .33 | .39 | .63 | 2.2 | 4.5 | 5.9 |
| 13 | .89 | 11 | 4.0 | 3.7 | .68 | .76 | 2.8 | 2.2 | .62 | 1.5 | 3.5 | 9.4 |
| 14 | .88 | 9.3 | 3.2 | 3.1 | .65 | .66 | .45 | .77 | .56 | 1.2 | 3.6 | 7.8 |
| 15 | 2.4 | 8.5 | 3.9 | 2.9 | .66 | .62 | 19 | .55 | .53 | .82 | 3.8 | 5.6 |
| 16 | 5.3 | 8.4 | 4.1 | 4.7 | 2.9 | .60 | 12 | .51 | .63 | 1.0 | 2.8 | 4.9 |
| 17 | 9.4 | 8.2 | 11 | 3.5 | 3.4 | .58 | 1.1 | .57 | 1.7 | 1.1 | 2.6 | 4.8 |
| 18 | 34 | 7.9 | 7.1 | 2.7 | 1.6 | .56 | .64 | .47 | .68 | 2.8 | 2.6 | 4.6 |
| 19 | 142 | 9.0 | 9.7 | 2.3 | .75 | .54 | .69 | .47 | .55 | 30 | 3.8 | 12 |
| 20 | 20 | 34 | 10 | 2.1 | .70 | .53 | .66 | .46 | .43 | 10 | 4.4 | 7.5 |
| 21 | 12 | 23 | 6.7 | 2.1 | .69 | .50 | .60 | .39 | .34 | 5.3 | 6.7 | 5.1 |
| 22 | 9.1 | 14 | 5.2 | 2.1 | .67 | .50 | .61 | .37 | .32 | 3.4 | 13 | 4.6 |
| 23 | 7.2 | 11 | 4.2 | 1.8 | .61 | .48 | .58 | .35 | .29 | 2.7 | | |
| 24 | 9.5 | 9.9 | 3.5 | 1.4 | .56 | 1.0 | .60 | .35 | .29 | 2.3 | 5.0 | 5.0 |
| 25 | 8.1 | 8.0 | 3.2 | 1.2 | .81 | .75 | .66 | .38 | .32 | 1.8 | 4.4 | 7.2 |
| 26 | 6.0 | 7.2 | 2.9 | 1.2 | .62 | .52 | 2.8 | .35 | .38 | 1.6 | 45 | 4.8 |
| 27 | 15 | 6.5 | 2.3 | 1.2 | .71 | .48 | .61 | .36 | .37 | 1.8 | 13 | 5.9 |
| 28 | 12 | 6.1 | 12 | .81 | .89 | .45 | .50 | .38 | .36 | 1.7 | 7.8 | 5.0 |
| 29 | 8.5 | 5.0 | 15 | 1.1 | .75 | .44 | 3.2 | .37 | .49 | 1.4 | 6.1 | 4.6 |
| 30 | 7.0 | --- | 7.8 | 6.8 | .75 | .48 | .83 | .38 | .35 | 1.4 | 6.2 | 4.0 |
| 31 | 7.2 | --- | 6.1 | --- | .69 | --- | .62 | .39 | --- | 1.3 | --- | 5.3 |
| TOTAL | 339.12 | 334.4 | 178.7 | 134.41 | 52.30 | 19.55 | 56.09 | 19.29 | 80.36 | 165.95 | 251.0 | 355.0 |
| MEAN | 10.9 | 11.5 | 5.76 | 4.48 | 1.69 | .65 | 1.81 | .62 | 2.68 | 5.35 | 8.37 | 11.5 |
| MAX | 142 | 34 | 15 | 20 | 7.8 | 1.0 | 19 | 2.4 | 52 | 62 | 49 | 56 |
| MIN | .75 | 4.5 | 2.3 | .81 | .56 | .44 | .31 | .35 | .29 | .45 | 1.1 | 4.0 |
| * | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 | -.21 |
| MEAN** | 10.7 | 11.3 | 5.55 | 4.27 | 1.48 | .44 | 1.60 | .41 | 2.47 | 5.14 | 8.16 | 11.3 |
| CFSM** | 2.98 | 3.14 | 1.54 | 1.19 | .41 | .12 | .44 | .11 | .69 | 1.43 | 2.27 | 3.15 |
| IN.** | 3.45 | 3.40 | 1.78 | 1.33 | .47 | .14 | .51 | .13 | .77 | 1.65 | 2.54 | 3.61 |

CAL YR 1996 TOTAL 1986.17 MEAN 5.43 MAX 142 MIN .29 CFSM 1.51 IN. 20.58
TOTAL** 1909.90 MEAN** 5.21 CFSM** 1.45 IN.** 19.78

* Inflow from pumpage, in cubic feet per second, from Swift Creek Reservoir.
** Adjust for inflow pumpage.

## APPENDIX E.—DISCHARGE SUMMARY FOR TOMAHAWK CREEK NEAR HALLSBORO, VIRGINIA, 1996

Tomahawk Creek drains 4.20 $mi^2$ of undeveloped forest land. Stage data were collected about 30 ft downstream of the access road through which the creek is routed by three corrugated metal pipes. A sand and gravel bar controls the water level in the gage pool under normal and low-flow conditions.

Discharge measurements were made during low flow by wading with current meter. High-flow discharge measurements are difficult to make at Tomahawk Creek; the site is not wadeable and platforms for suspension measurements are not available for high-stage measurements. An 8 ft wading rod was used at the downstream end of the corrugated metal pipes to determine the highest measured discharge.

Table E1. Daily mean discharge, in cubic feet per second, at Tomahawk Creek near Hallsboro, Va., 1996

Station Number 02041850
Latitude 372808 Longitude 0774054
Drainage Area 4.20 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | 8.9 | 5.3 | 20 | 5.6 | .48 | .07 | 1.8 | .06 | 1.2 | 2.0 | 37 |
| 2 | 2.3 | 10 | 6.2 | 16 | 3.2 | .44 | .07 | 1.3 | .05 | 1.3 | 5.4 | 34 |
| 3 | 4.5 | 9.7 | 5.5 | 11 | 2.4 | .43 | e.15 | .76 | .04 | 1.3 | 2.9 | 21 |
| 4 | 2.4 | 7.7 | 4.6 | 8.8 | 2.0 | .45 | e.28 | .54 | .12 | .98 | 2.1 | 16 |
| 5 | 1.9 | 7.4 | 4.8 | 7.2 | 1.7 | 1.0 | e.09 | .43 | .28 | .86 | 1.8 | 15 |
| 6 | 1.7 | 7.0 | 5.8 | 6.8 | 3.0 | .50 | e.08 | .34 | 52 | .86 | 1.7 | 40 |
| 7 | 3.3 | 6.7 | 7.2 | 6.5 | 3.5 | .43 | e.08 | .28 | 13 | .93 | 1.5 | 46 |
| 8 | 5.0 | 12 | 7.6 | 5.4 | 5.4 | .39 | e.07 | .21 | 5.2 | 43 | 20 | 37 |
| 9 | 3.7 | 26 | 5.9 | 11 | 3.3 | .50 | e.07 | .21 | 3.6 | 23 | 31 | 23 |
| 10 | 3.6 | 23 | 4.9 | 8.7 | 2.2 | .73 | e.07 | .29 | 18 | 12 | 19 | 17 |
| 11 | 3.3 | 25 | 4.8 | 6.5 | 1.7 | .50 | e.06 | .17 | 31 | 5.8 | 14 | 15 |
| 12 | 4.5 | 17 | 4.7 | 5.9 | 1.5 | .46 | e.06 | .14 | 11 | 3.9 | 13 | 13 |
| 13 | 4.5 | 12 | 4.4 | 5.1 | 1.1 | .42 | e.23 | 1.5 | 6.4 | 3.0 | 9.9 | 19 |
| 14 | 4.7 | 11 | 4.2 | 4.5 | .99 | .37 | e1.2 | .64 | 3.8 | 2.6 | 9.1 | 15 |
| 15 | 8.1 | 9.4 | 5.5 | 4.3 | .94 | .33 | e4.0 | .37 | 2.8 | 2.2 | 7.1 | 12 |
| 16 | 12 | 9.0 | 5.4 | 6.4 | 3.3 | .29 | e21 | .25 | 3.1 | 2.0 | 6.2 | 11 |
| 17 | 15 | 8.1 | 13 | 4.6 | 3.3 | .25 | 2.5 | .22 | 9.7 | 1.8 | 5.6 | 10 |
| 18 | 29 | 7.7 | 8.6 | 3.8 | 2.0 | .21 | 1.4 | .23 | 5.2 | 4.8 | 5.7 | 9.2 |
| 19 | 69 | 8.6 | 13 | 3.4 | 1.3 | .19 | 2.1 | .26 | 3.1 | 28 | 10 | 20 |
| 20 | 25 | 21 | 13 | 3.3 | .88 | .15 | 1.3 | .13 | 2.4 | 11 | 12 | 13 |
| 21 | 18 | 20 | 9.2 | 3.2 | .67 | .11 | .65 | .10 | 2.0 | 7.4 | 13 | 9.4 |
| 22 | 14 | 14 | 7.4 | 3.0 | .54 | .07 | .54 | .10 | 2.0 | 5.5 | 20 | 8.8 |
| 23 | 13 | 12 | 6.1 | 2.7 | .49 | .06 | .49 | .08 | 1.7 | 4.4 | 12 | 8.7 |
| 24 | 15 | 9.9 | 5.5 | 2.6 | .46 | .10 | .41 | .12 | 1.5 | 3.9 | 9.6 | 9.8 |
| 25 | 13 | 8.4 | 5.4 | 2.3 | .56 | .30 | .55 | .16 | 1.4 | 3.2 | 8.4 | 11 |
| 26 | 10 | 7.8 | 4.9 | 2.4 | .57 | .18 | 1.5 | .09 | 1.3 | 2.7 | 39 | 8.5 |
| 27 | 17 | 7.2 | 4.1 | 2.4 | .76 | .14 | .55 | .07 | 1.2 | 3.0 | 24 | 9.3 |
| 28 | 14 | 6.8 | 14 | 1.9 | 1.1 | .11 | .38 | .08 | 1.2 | 2.9 | 18 | 8.2 |
| 29 | 12 | 5.6 | 16 | 1.9 | .92 | .08 | 2.1 | .07 | 2.0 | 2.6 | 15 | 7.6 |
| 30 | 11 | --- | 10 | 7.2 | .80 | .09 | 1.5 | .07 | 1.4 | 2.6 | 14 | 7.0 |
| 31 | 11 | --- | 8.4 | --- | .54 | --- | .72 | .07 | --- | 2.3 | --- | 7.9 |
| TOTAL | 353.0 | 338.9 | 225.4 | 178.8 | 56.72 | 9.76 | 44.27 | 11.08 | 186.55 | 191.03 | 353.0 | 519.4 |
| MEAN | 11.4 | 11.7 | 7.27 | 5.96 | 1.83 | .33 | 1.43 | .36 | 6.22 | 6.16 | 11.8 | 16.8 |
| MAX | 69 | 26 | 16 | 20 | 5.6 | 1.0 | 21 | 1.8 | 52 | 43 | 39 | 46 |
| MIN | 1.5 | 5.6 | 4.1 | 1.9 | .46 | .06 | .06 | .07 | .04 | .86 | 1.5 | 7.0 |
| CFSM | 2.71 | 2.78 | 1.73 | 1.42 | .44 | .08 | .34 | .09 | 1.48 | 1.47 | 2.80 | 3.99 |
| IN. | 3.13 | 3.00 | 2.00 | 1.58 | .50 | .09 | .39 | .10 | 1.65 | 1.69 | 3.13 | 4.60 |

CAL YR 1996 TOTAL 2467.91 MEAN 6.74 MAX 69 MIN .04 CFSM 1.61 IN. 21.86

## APPENDIX F.—DISCHARGE SUMMARY FOR LITTLE TOMAHAWK CREEK NEAR HALLSBORO, VIRGINIA, 1996

Drainage from 2.31 $mi^2$ of undeveloped forest land was monitored at Little Tomahawk Creek. Stage data were collected about 30 ft downstream of a gravel road through which the creek is routed via three corrugated metal pipes. A sand and gravel bar controls the water level in the gage pool under normal and low-flow conditions. The stream channel is the stage control for medium and high flows. Evidence of over-bank flow was observed, and confirmed with stage data, during extreme high flows.

Discharge measurements were made during low flow by wading with current meter or by a parshall flume. Discharge measurements are difficult to make at high flows; the site is not wadeable and platforms for suspension measurements are not available for high-stage measurements. An 8 ft wading rod was used at the downstream end of the corrugated metal pipes to determine the highest measured discharge.

Table F1. Daily mean discharge, in cubic feet per second, at Little Tomahawk Creek near Hallsboro, Va., 1996

Station Number 02041860
Latitude 372753 Longitude 0774021
Drainage Area 2.31 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .41 | 1.8 | 1.8 | 39 | 2.6 | .37 | .05 | 1.0 | .05 | .51 | .75 | 44 |
| 2 | .59 | 1.9 | 2.0 | 13 | 1.7 | .31 | .14 | .60 | .05 | .57 | 2.0 | 26 |
| 3 | 1.4 | 2.6 | 1.8 | 7.6 | 1.5 | .29 | .34 | .34 | .06 | .55 | 1.1 | 7.6 |
| 4 | .81 | 1.6 | 1.6 | 5.9 | 1.3 | .34 | .29 | .28 | .78 | .41 | .85 | 5.2 |
| 5 | .58 | 1.9 | 1.6 | 4.9 | 1.2 | .90 | .11 | .23 | .45 | .39 | .88 | 8.2 |
| 6 | .46 | 1.6 | 2.0 | 4.6 | 1.7 | .37 | .08 | .19 | 214 | .39 | .92 | 61 |
| 7 | .64 | 1.5 | 2.6 | 4.4 | 2.0 | .29 | .07 | .18 | 6.1 | .39 | .95 | 107 |
| 8 | 1.8 | 3.4 | 2.6 | 3.9 | 2.8 | .24 | e.06 | .14 | 1.9 | 151 | 33 | 36 |
| 9 | 1.0 | 16 | 2.2 | 7.9 | 1.8 | .47 | e.06 | .15 | 1.2 | 15 | 17 | 11 |
| 10 | .93 | 12 | 1.9 | 5.8 | 1.4 | .59 | e.05 | .23 | 82 | 2.9 | 5.2 | 6.8 |
| 11 | .82 | 22 | 1.8 | 4.5 | 1.2 | .34 | e.05 | .12 | 33 | 1.5 | 3.5 | 5.7 |
| 12 | .93 | 7.9 | 1.8 | 4.1 | 1.1 | .31 | e.05 | .13 | 4.5 | 1.2 | 2.6 | 4.9 |
| 13 | 1.1 | 4.4 | 1.7 | 3.7 | .91 | .25 | 11 | 1.1 | 2.0 | 1.0 | 2.3 | 8.7 |
| 14 | .99 | 3.8 | 1.7 | 3.1 | .84 | .16 | .49 | .32 | 1.4 | .85 | 1.4 | 6.0 |
| 15 | 1.7 | 2.9 | 2.5 | 3.0 | .81 | .11 | 84 | .18 | 1.1 | .74 | 1.3 | 4.6 |
| 16 | 2.6 | 2.6 | 2.3 | 4.2 | 2.0 | .09 | 13 | .14 | 1.4 | .72 | 1.3 | 4.2 |
| 17 | 5.0 | 2.8 | 6.8 | 3.3 | 1.8 | .07 | e4.0 | .13 | 5.4 | .69 | 1.2 | 4.1 |
| 18 | 34 | 2.3 | 4.0 | 2.6 | 1.3 | .06 | e1.8 | .15 | 2.2 | 13 | 1.3 | 3.8 |
| 19 | 247 | 2.7 | 13 | 2.5 | .95 | .05 | e.07 | .12 | 1.2 | 40 | 1.5 | 10 |
| 20 | 18 | 36 | 8.0 | 2.4 | .72 | .04 | e1.4 | .09 | .95 | 3.4 | 2.0 | 5.6 |
| 21 | 7.5 | 13 | 4.7 | 2.3 | .62 | .03 | e.80 | .08 | .78 | 1.7 | 4.7 | 4.1 |
| 22 | 5.2 | 6.0 | 3.6 | 2.1 | .52 | .02 | e.37 | .08 | .73 | 1.4 | 6.7 | 3.8 |
| 23 | 4.3 | 4.8 | 2.7 | 1.9 | .45 | .01 | e.15 | .08 | .57 | 1.3 | 2.8 | 3.6 |
| 24 | 5.5 | 3.8 | 2.4 | 1.7 | .38 | e.05 | e.60 | .10 | .53 | 1.2 | 2.1 | 4.3 |
| 25 | 4.1 | 2.8 | 2.3 | 1.5 | .55 | e.12 | e.13 | .14 | .75 | 1.1 | 1.9 | 5.0 |
| 26 | 2.8 | 2.7 | 2.1 | 1.6 | .55 | e.06 | e.20 | .08 | .98 | .97 | 74 | 3.7 |
| 27 | 6.2 | 2.5 | 1.9 | 1.6 | .65 | e.05 | .30 | .07 | .90 | 1.0 | 9.8 | 4.2 |
| 28 | 3.5 | 2.3 | 11 | 1.4 | .75 | .05 | .21 | .07 | .93 | .96 | 5.3 | 3.4 |
| 29 | 2.5 | 1.9 | 11 | 1.4 | .65 | .05 | 1.2 | .07 | 1.3 | .86 | 4.2 | 3.1 |
| 30 | 2.3 | --- | 5.6 | 3.6 | .59 | .05 | .62 | .06 | .66 | .84 | 4.3 | 2.7 |
| 31 | 2.3 | --- | 4.5 | --- | .46 | --- | .39 | .06 | --- | .80 | --- | 3.5 |
| TOTAL | 366.96 | 171.5 | 115.5 | 149.5 | 35.80 | 6.14 | 122.08 | 6.71 | 367.87 | 247.34 | 196.85 | 411.8 |
| MEAN | 11.8 | 5.91 | 3.73 | 4.98 | 1.15 | .20 | 3.94 | .22 | 12.3 | 7.98 | 6.56 | 13.3 |
| MAX | 247 | 36 | 13 | 39 | 2.8 | .90 | 84 | 1.1 | 214 | 151 | 74 | 107 |
| MIN | .41 | 1.5 | 1.6 | 1.4 | .38 | .01 | .05 | .06 | .05 | .39 | .75 | 2.7 |
| CFSM | 5.12 | 2.56 | 1.61 | 2.16 | .50 | .09 | 1.70 | .09 | 5.31 | 3.45 | 2.84 | 5.75 |
| IN. | 5.91 | 2.76 | 1.86 | 2.41 | .58 | .10 | 1.97 | .11 | 5.92 | 3.98 | 3.17 | 6.63 |

CAL YR 1996 TOTAL 2198.05 MEAN 6.01 MAX 247 MIN .01 CFSM 2.60 IN. 35.40

## APPENDIX G.—DISCHARGE SUMMARY FOR DRY CREEK NEAR WINTERPOCK, VIRGINIA, 1996

Dry Creek drains 2.96 $mi^2$ of undeveloped land. Stage data were collected about 5 to 10 ft upstream of the bridge on the access road. The data-collection site is located in a low gradient reach of the stream. The actual low-water control is unknown; however, vegetation, channel debris, beaver dams, or backwater from the reservoir may control the water level in the gage pool under normal and low-flow conditions. The stream channel controls the water level at high flows.

Discharge measurements were made during low flow by wading with current meter, by float, or by a flume. Although the stream channel was not observed dry during the study period (Weedon Cloe, Swift Creek Water Plant, written commun., 1996), zero flow was reported for several days in June and July, and based on shift adjustments determined from discharge measurements and comparison of hydrographs with Ashbrook Creek and West Branch. Discharge measurements were difficult to make at high flows. High-flow discharge data were made by wading over the access road in the flood plain and by use of an 8 ft wading rod held from the bridge.

Table G1. Daily mean discharge, in cubic feet per second, at Dry Creek near Winterpock, Va., 1996

Station Number 02041870
Latitude 372355 Longitude 0774127
Drainage Area 2.96
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 12 | 10 | 8.4 | 8.6 | 2.8 | .17 | .00 | .76 | .12 | .19 | .52 | 28 |
| 2 | 12 | 10 | 8.3 | 6.1 | 2.2 | .15 | .00 | .49 | .10 | .19 | 1.3 | 24 |
| 3 | 14 | 10 | 7.9 | 5.3 | 1.6 | .14 | .04 | .38 | .08 | .18 | 1.2 | 8.5 |
| 4 | 13 | 10 | 7.1 | 5.2 | 1.0 | .13 | .14 | .35 | .14 | .16 | .71 | 4.1 |
| 5 | 13 | 9.7 | 6.7 | 5.1 | .64 | .20 | .12 | .34 | .17 | .13 | .58 | 3.8 |
| 6 | 12 | 9.4 | 6.9 | 4.8 | 2.4 | .17 | .10 | .26 | 86 | .11 | .58 | 33 |
| 7 | 12 | 9.5 | 7.3 | 5.0 | 2.6 | .15 | .08 | .22 | 3.1 | .09 | .53 | 50 |
| 8 | 13 | 11 | 7.4 | 4.5 | 3.4 | .14 | .06 | .20 | .17 | 34 | 6.9 | 26 |
| 9 | 12 | 21 | 6.7 | 5.8 | 2.9 | .17 | .04 | .20 | .14 | 6.9 | 10 | 10 |
| 10 | 13 | 19 | 6.0 | 5.5 | 2.6 | .56 | .02 | .25 | .13 | 2.6 | 3.2 | 6.1 |
| 11 | 13 | 21 | 5.7 | 5.0 | 2.3 | .40 | .00 | .20 | .13 | 1.2 | 2.2 | 5.1 |
| 12 | 13 | 15 | 5.5 | 4.6 | 2.2 | .27 | .00 | .23 | .15 | .87 | 1.7 | 4.0 |
| 13 | 13 | 12 | 5.1 | 4.1 | 1.7 | .20 | .30 | 1.9 | .14 | .68 | 1.5 | 8.5 |
| 14 | 13 | 11 | 4.9 | 3.8 | 1.1 | .19 | .25 | 2.2 | .12 | .60 | 1.6 | 7.0 |
| 15 | 14 | 11 | 4.9 | 3.9 | .60 | .17 | 6.1 | 1.8 | .11 | .39 | 1.4 | 4.7 |
| 16 | 16 | 12 | 4.9 | 4.5 | 2.2 | .16 | 6.1 | 1.6 | .13 | .24 | 1.4 | 4.2 |
| 17 | 17 | 11 | 6.0 | 4.3 | 2.8 | .14 | 2.9 | 2.5 | .72 | .21 | 1.4 | 4.5 |
| 18 | 27 | 11 | 5.0 | 3.9 | 2.5 | .13 | 1.9 | 2.3 | .44 | 2.4 | 1.5 | 4.8 |
| 19 | 81 | 12 | 5.8 | 3.6 | 2.0 | .11 | 1.6 | 1.9 | .26 | 28 | 1.9 | 14 |
| 20 | 13 | 22 | 6.0 | 3.3 | 1.3 | .09 | 1.2 | 1.5 | .21 | 3.8 | 2.1 | 8.6 |
| 21 | 8.2 | 16 | 5.0 | 3.3 | .59 | .07 | .84 | 1.1 | .20 | 2.2 | 3.2 | 6.1 |
| 22 | 7.0 | 12 | 4.6 | 3.0 | .23 | .06 | .38 | .73 | .19 | 1.7 | 6.9 | 5.1 |
| 23 | 6.6 | 13 | 4.1 | 2.7 | .18 | .04 | .00 | .60 | .18 | 1.9 | 3.1 | 5.4 |
| 24 | 9.2 | 12 | 3.9 | 2.4 | .16 | .03 | .00 | .38 | .17 | 1.9 | 2.4 | 6.4 |
| 25 | 8.8 | 11 | 3.9 | 2.0 | .17 | .05 | .00 | .21 | .17 | 1.6 | 1.6 | 10 |
| 26 | 7.9 | 11 | 3.9 | 1.9 | .17 | .03 | .03 | .20 | .17 | 1.3 | 27 | 6.4 |
| 27 | 12 | 11 | 3.7 | 1.9 | .17 | .00 | .00 | .19 | .18 | 1.4 | 7.8 | 7.9 |
| 28 | 10 | 9.8 | 5.1 | 1.5 | .20 | .00 | .00 | .18 | .18 | 1.3 | 3.8 | 6.5 |
| 29 | 9.7 | 8.7 | 5.8 | 1.1 | .25 | .00 | .16 | .17 | .20 | 1.2 | 2.9 | 6.0 |
| 30 | 9.9 | --- | 4.8 | 1.8 | .27 | .00 | .14 | .16 | .20 | .97 | 2.9 | 5.5 |
| 31 | 10 | --- | 4.7 | --- | .20 | --- | .10 | .14 | --- | .74 | --- | 8.9 |
| TOTAL | 445.3 | 362.1 | 176.0 | 118.5 | 43.43 | 4.12 | 22.60 | 23.64 | 94.40 | 99.15 | 103.82 | 333.1 |
| MEAN | 14.4 | 12.5 | 5.68 | 3.95 | 1.40 | .14 | .73 | .76 | 3.15 | 3.20 | 3.46 | 10.7 |
| MAX | 81 | 22 | 8.4 | 8.6 | 3.4 | .56 | 6.1 | 2.5 | 86 | 34 | 27 | 50 |
| MIN | 6.6 | 8.7 | 3.7 | 1.1 | .16 | .00 | .00 | .14 | .08 | .09 | .52 | 3.8 |
| CFSM | 4.85 | 4.22 | 1.92 | 1.33 | .47 | .05 | .25 | .26 | 1.06 | 1.08 | 1.17 | 3.63 |
| IN. | 5.60 | 4.55 | 2.21 | 1.49 | .55 | .05 | .28 | .30 | 1.19 | 1.25 | 1.30 | 4.19 |

CAL YR 1996 TOTAL 1826.16 MEAN 4.99 MAX 86 MIN .00 CFSM 1.69 IN. 22.95

## APPENDIX H.—DISCHARGE SUMMARY FOR ASHBROOK CREEK NEAR WINTERPOCK, VIRGINIA, 1996

Ashbrook Creek drains 2.37 $mi^2$ of developed and undeveloped land. Stage data were collected to determine the outflow of a small lake within a recently developed residential neighborhood. The low-water control is a broad crested rectangular weir in the dam that impounds the lake. The concrete dam is the high-water control. Flows from the lake discharge through the weir, over the dam, through a concrete chute and buffer pool before entering Swift Creek Reservoir.

Volumetric discharge measurements, made with a small trough, were used to rate the rectangular weir. Because wind produced waves on the lake that were observed to bias discharge measurements, only volumetric measurements made under calm wind conditions were used to construct the rating curve for low flow. The weir was observed dry during several days in June and July (Weedon Cloe, Swift Creek Water Plant, written commun., 1996); therefore, periods of no flow were reported for those days. For high flow, float measurements in the concrete chute were used to rate the dam. The rating is well defined, except for transitional flow regimes between weir only flow and initial overflow of the dam.

Table H1. Daily mean discharge, in cubic feet per second, at Ashbrook Creek near Winterpock, Va., 1996

Station Number 02041880
Latitude 372356 Longitude 0774106
Drainage Area 2.37 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | .50 | 2.3 | 1.3 | 21 | 3.0 | .30 | .00 | 3.5 | .00 | .11 | .31 | 17 |
| 2 | .74 | 3.1 | 1.5 | 13 | 1.8 | .21 | .00 | 2.7 | .00 | .16 | .67 | 18 |
| 3 | 1.7 | 2.9 | 1.3 | 7.6 | 1.2 | .15 | .06 | .84 | .00 | .14 | .64 | 8.7 |
| 4 | 1.3 | 1.6 | .96 | 5.0 | .83 | .21 | .10 | .36 | .42 | .05 | .39 | 6.0 |
| 5 | .84 | 1.1 | .86 | 3.1 | .68 | .64 | .02 | .23 | .75 | .01 | .35 | 4.5 |
| 6 | .71 | .94 | 1.2 | 2.6 | 4.7 | .37 | .00 | .15 | 60 | .00 | .35 | 21 |
| 7 | 1.7 | .88 | 2.2 | 2.6 | 3.8 | .24 | .96 | .09 | 12 | .00 | .36 | 26 |
| 8 | 1.6 | 1.7 | 3.3 | 2.3 | 7.8 | .16 | .00 | .04 | 3.1 | 35 | 2.6 | 19 |
| 9 | 1.1 | 16 | 2.2 | 8.9 | 4.4 | .45 | .00 | .06 | 1.3 | 13 | 9.9 | 9.8 |
| 10 | 1.0 | 16 | 1.5 | 9.7 | 2.1 | .80 | .00 | .14 | .76 | 6.3 | 2.9 | 6.7 |
| 11 | .92 | 19 | 1.3 | 6.0 | 1.4 | .46 | .00 | .07 | .56 | 2.1 | 1.6 | 5.1 |
| 12 | 1.4 | 12 | 1.3 | 3.3 | 1.3 | .33 | .01 | .11 | .51 | 1.0 | 1.1 | 3.5 |
| 13 | 1.2 | 7.1 | 1.2 | 2.6 | .87 | .23 | .84 | 1.4 | .40 | .61 | .79 | 8.2 |
| 14 | 1.1 | 4.3 | 1.1 | 2.2 | .65 | .16 | .46 | .84 | .23 | .44 | .67 | 7.8 |
| 15 | 1.9 | 3.4 | 1.5 | 2.0 | .58 | .11 | 8.3 | .37 | .16 | .35 | .59 | 4.9 |
| 16 | 6.3 | 3.6 | 1.9 | 4.4 | 5.3 | .06 | 7.4 | .48 | .17 | .33 | .52 | 3.2 |
| 17 | 8.6 | 2.9 | 8.3 | 3.4 | 6.1 | .02 | 1.1 | .95 | 1.4 | .31 | .52 | 3.0 |
| 18 | 20 | 2.3 | 5.4 | 2.3 | 2.7 | .00 | .35 | .48 | .83 | 3.9 | .65 | 2.8 |
| 19 | 73 | 2.3 | 6.8 | 1.9 | 1.4 | .00 | .25 | .27 | .33 | 27 | 1.0 | 10 |
| 20 | 17 | 16 | 8.7 | 1.7 | .81 | .00 | .15 | .17 | .20 | 6.9 | 1.1 | 7.5 |
| 21 | 8.4 | 15 | 4.7 | 1.8 | .55 | .00 | .04 | .10 | .15 | 2.9 | 1.9 | 4.6 |
| 22 | 5.8 | 11 | 2.8 | 1.8 | .35 | .00 | .03 | .06 | .14 | 1.7 | 8.5 | 3.2 |
| 23 | 3.5 | 9.2 | 2.1 | 1.2 | .29 | .00 | .03 | .04 | .09 | 1.1 | 3.6 | 2.8 |
| 24 | 4.7 | 5.7 | 1.7 | 1.1 | .25 | .00 | .00 | .01 | .04 | .84 | 2.0 | 3.1 |
| 25 | 6.5 | 3.1 | 1.4 | 1.0 | .34 | .00 | .09 | .01 | .01 | .73 | 1.5 | 7.5 |
| 26 | 3.0 | 2.5 | 1.3 | 1.1 | .34 | .00 | .41 | .00 | .00 | .66 | 20 | 4.4 |
| 27 | 7.8 | 2.2 | 1.1 | 1.4 | .43 | .00 | .25 | .02 | .01 | .66 | 9.4 | 5.4 |
| 28 | 7.5 | 2.1 | 6.1 | 1.1 | .79 | .00 | .15 | .17 | .01 | .64 | 5.2 | 4.8 |
| 29 | 3.9 | 1.6 | 12 | .94 | .78 | .00 | 7.0 | .13 | .15 | .60 | 2.9 | 3.5 |
| 30 | 3.0 | --- | 6.9 | 2.1 | .66 | .00 | 2.8 | .09 | .12 | .44 | 2.5 | 2.5 |
| 31 | 2.8 | --- | 3.9 | --- | .41 | --- | .86 | .03 | --- | .37 | --- | 4.3 |
| TOTAL | 199.51 | 171.82 | 97.82 | 119.14 | 56.61 | 4.90 | 31.66 | 13.91 | 83.84 | 108.35 | 84.51 | 238.8 |
| MEAN | 6.44 | 5.92 | 3.16 | 3.97 | 1.83 | .16 | 1.02 | .45 | 2.79 | 3.50 | 2.82 | 7.70 |
| MAX | 73 | 19 | 12 | 21 | 7.8 | .80 | 8.3 | 3.5 | 60 | 35 | 20 | 26 |
| MIN | .50 | .88 | .86 | .94 | .25 | .00 | .00 | .00 | .00 | .00 | .31 | 2.5 |
| CFSM | 2.72 | 2.50 | 1.33 | 1.68 | .77 | .07 | .43 | .19 | 1.18 | 1.47 | 1.19 | 3.25 |
| IN. | 3.13 | 2.70 | 1.54 | 1.87 | .89 | .08 | .50 | .22 | 1.32 | 1.70 | 1.33 | 3.75 |

CAL YR 1996 TOTAL 1210.87 MEAN 3.31 MAX 73 MIN .00 CFSM 1.40 IN. 19.01

## APPENDIX I.—DISCHARGE SUMMARY FOR WEST BRANCH NEAR WINTERPOCK, VIRGINIA, 1996

West Branch drains about 2.75 $mi^2$ of forested and developed land and more residential land than all other measured inflow sites. Stage data were collected about 150 ft upstream of a footbridge in the Woodlake Community. A sand and gravel bar controls the water level in the gage pool under normal and low-flow conditions, and the stream channel is the control at high flows. A beaver dam or debris controlled the water level in the gage pool at low and medium flows during different times of the study period.

Discharge measurements were collected during low flow by wading with current meters or by a flume. Zero flow was reported for several days in June and July, when the stream channel was observed dry (Weedon Cloe, Swift Creek Water Plant, written commun., 1996). Conventional current-meter discharge measurements were made from the footbridge during high flows.

Table I1. Daily mean discharge, in cubic feet per second, at West Branch near Winterpock, Va., 1996

Station Number 02041890
Latitude 362430 Longitude 0774116
Drainage Area 2.75 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.5 | .51 | 1.6 | 26 | 1.6 | .16 | .00 | 6.5 | .59 | .16 | .74 | 22 |
| 2 | 2.1 | 1.0 | 2.0 | 9.7 | .63 | .13 | .00 | 2.1 | .59 | .17 | 1.3 | 14 |
| 3 | 2.1 | .83 | 1.8 | 4.8 | .68 | .08 | 4.3 | .78 | .59 | .16 | .51 | 5.3 |
| 4 | 1.0 | .25 | 1.6 | 3.4 | .50 | 1.6 | .43 | .48 | 3.9 | .15 | .85 | 3.1 |
| 5 | .80 | .16 | 1.7 | 2.6 | .48 | 1.0 | .15 | .37 | 1.4 | .17 | 1.2 | 7.9 |
| 6 | .66 | .16 | 2.4 | 2.3 | 3.7 | .17 | .16 | .25 | 126 | .20 | 1.1 | 24 |
| 7 | .81 | .16 | 3.9 | 2.4 | 3.8 | .00 | .17 | .25 | 7.7 | .29 | 1.3 | 43 |
| 8 | .84 | 5.0 | 3.5 | 1.9 | 6.4 | .00 | .35 | .21 | 1.6 | 60 | 14 | 20 |
| 9 | .52 | 18 | 2.2 | 7.8 | 2.5 | 2.0 | .52 | .63 | .83 | 9.3 | 6.8 | 9.4 |
| 10 | .62 | 10 | 1.8 | 5.0 | 1.2 | .99 | .17 | .45 | .62 | 3.8 | 1.5 | 5.6 |
| 11 | .53 | 13 | 1.8 | 2.9 | 1.1 | .83 | .17 | .21 | .81 | 1.4 | .53 | 4.3 |
| 12 | .70 | 4.6 | 1.8 | 2.1 | .99 | .42 | 1.4 | 1.0 | .86 | .74 | .20 | 3.6 |
| 13 | .72 | 1.9 | 1.7 | 1.7 | .41 | .28 | 5.0 | 4.3 | .84 | .48 | .16 | 9.6 |
| 14 | .67 | 1.5 | 2.2 | 1.4 | .31 | .17 | .16 | 1.3 | .68 | .32 | .24 | 6.9 |
| 15 | 1.6 | 1.2 | 3.4 | 1.4 | .33 | .16 | 50 | .71 | .66 | .24 | .20 | 4.9 |
| 16 | 2.0 | 1.2 | 3.2 | 2.7 | 5.4 | .10 | 5.2 | 2.9 | 1.6 | .39 | .17 | 4.3 |
| 17 | 3.1 | 1.4 | 8.6 | 1.6 | 3.9 | .08 | .86 | 2.4 | 3.2 | .47 | .17 | 4.1 |
| 18 | 13 | 1.2 | 3.9 | 1.1 | 1.6 | .06 | .38 | .96 | .63 | 9.7 | .28 | 3.7 |
| 19 | 88 | 1.9 | 9.3 | .95 | .87 | .00 | .51 | .76 | .30 | 20 | .56 | 12 |
| 20 | 13 | 20 | 7.1 | .92 | .52 | .00 | .20 | .64 | .18 | 2.1 | .58 | 6.1 |
| 21 | 4.2 | 9.8 | 4.1 | .95 | .29 | .00 | .16 | .56 | .18 | .72 | 2.5 | 4.1 |
| 22 | 2.6 | 4.5 | 3.1 | 1.1 | .18 | .00 | .19 | .59 | .17 | .31 | 2.8 | 3.7 |
| 23 | 1.7 | 4.4 | 2.6 | .90 | .17 | .00 | .16 | .59 | .23 | .22 | .49 | 3.5 |
| 24 | 5.1 | 2.6 | 2.2 | .87 | .16 | .86 | .16 | 3.0 | .16 | .24 | .19 | 5.0 |
| 25 | 1.9 | 2.0 | 2.1 | .79 | .94 | .13 | .74 | .95 | .15 | .22 | .19 | 6.0 |
| 26 | .85 | 1.8 | 2.3 | 1.2 | .18 | .00 | 2.4 | .53 | .14 | .26 | 34 | 3.7 |
| 27 | 9.0 | 1.6 | 2.5 | 1.1 | .61 | .00 | .21 | .63 | .14 | .62 | 5.2 | 5.0 |
| 28 | 2.4 | 2.1 | 11 | .68 | 1.2 | .00 | .16 | .90 | .14 | .81 | 2.2 | 3.7 |
| 29 | 1.1 | 1.8 | 11 | .65 | .37 | .00 | 15 | .59 | .34 | 1.0 | 1.2 | 3.4 |
| 30 | 1.2 | --- | 5.1 | 3.8 | .42 | .18 | 1.5 | .59 | .08 | 1.1 | 1.6 | 3.0 |
| 31 | 1.7 | --- | 3.8 | --- | .18 | --- | .67 | .59 | --- | .92 | --- | 5.3 |
| TOTAL | 166.02 | 114.57 | 115.3 | 94.71 | 41.62 | 9.40 | 91.48 | 36.72 | 155.31 | 116.66 | 82.76 | 260.2 |
| MEAN | 5.36 | 3.95 | 3.72 | 3.16 | 1.34 | .31 | 2.95 | 1.18 | 5.18 | 3.76 | 2.76 | 8.39 |
| MAX | 88 | 20 | 11 | 26 | 6.4 | 2.0 | 50 | 6.5 | 126 | 60 | 34 | 43 |
| MIN | .52 | .16 | 1.6 | .65 | .16 | .00 | .00 | .21 | .08 | .15 | .16 | 3.0 |
| CFSM | 1.95 | 1.44 | 1.35 | 1.15 | .49 | .11 | 1.07 | .43 | 1.88 | 1.37 | 1.00 | 3.05 |
| IN. | 2.25 | 1.55 | 1.56 | 1.28 | .56 | .13 | 1.24 | .50 | 2.10 | 1.58 | 1.12 | 3.52 |

CAL YR 1996 TOTAL 1284.75 MEAN 3.51 MAX 126 MIN .00 CFSM 1.28 IN. 17.38

## APPENDIX J.—DISCHARGE SUMMARY FOR SWIFT CREEK RESERVOIR DAM NEAR WINTERPOCK, VIRGINIA, 1996

Daily discharges for outflow at the reservoir dam were estimated for the period January 1 to May 20, 1996. Daily stage observations were recorded by SCWP staff to the nearest 0.1 ft for this period. Daily stage observations were converted to gage datum and applied to the rating to compute daily discharges. After May 20, 1996, reservoir stage data were collected by use of an electronic data logger; the stage sensor was referenced to an outside staff gage. Stage data were collected at 15-minute intervals, averaged hourly, and hourly values were stored by the data logger.

Volumetric discharge measurements were made on the weir at the dam. Wading discharge measurements were made by use of a current meter near the edge of the concrete apron, approximately 6 ft upstream from the weir. The top of the weir was dry at times, between late May and early October, and zero flow was reported for the periods that the reservoir water level was below the weir.

Table J1. Daily mean discharge adjusted for supply withdrawals, in cubic feet per second, for Swift Creek Reservoir at Dam near Winterpock, Va., 1996

Station Number 02041900
Latitude 372500 Longitude 0773857
Drainage Area 64.4 square miles
[MAX, maximum; MIN, minimum; CFSM, cubic feet per second per square mile; IN., inches; e, estimated]

| DAY | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | e51 | e182 | e102 | e182 | e105 | 17 | 14 | 50 | 14 | 14 | 12 | 205 |
| 2 | e52 | e184 | e102 | e436 | e103 | 17 | 15 | 50 | 16 | 12 | 20 | 533 |
| 3 | e103 | e183 | e52 | e294 | e104 | 16 | 14 | 41 | 15 | 14 | 22 | 278 |
| 4 | e104 | e183 | e53 | e183 | e103 | 14 | 14 | 28 | 13 | 13 | 19 | 155 |
| 5 | e104 | e182 | e52 | e182 | e54 | 14 | 14 | 18 | 13 | 12 | 17 | 113 |
| 6 | e102 | e 99 | e102 | e182 | e105 | 14 | 14 | 14 | 1480 | 13 | 15 | 397 |
| 7 | e102 | e102 | e102 | e181 | e104 | 15 | 17 | 14 | 899 | 13 | 15 | 480 |
| 8 | e102 | e103 | e182 | e102 | e104 | 18 | 16 | 13 | 220 | 221 | 46 | 834 |
| 9 | e102 | e103 | e183 | e102 | e104 | 17 | 15 | 13 | 97 | 593 | 416 | 341 |
| 10 | e103 | e436 | e183 | e184 | e104 | 14 | 17 | 13 | 61 | 219 | 229 | 170 |
| 11 | e103 | e293 | e910 | e184 | e104 | 14 | 15 | 13 | 122 | 99 | 114 | 119 |
| 12 | e102 | e437 | e102 | e183 | e104 | 13 | 13 | 14 | 91 | 62 | 71 | 95 |
| 13 | e183 | e293 | e102 | e102 | e51 | 15 | 14 | 13 | 57 | 47 | 53 | 111 |
| 14 | e102 | e184 | e102 | e105 | e52 | 18 | 14 | 14 | 41 | 39 | 44 | 127 |
| 15 | e103 | e184 | e103 | e104 | e52 | 18 | 14 | 14 | 26 | 30 | 37 | 97 |
| 16 | e104 | e184 | e104 | e105 | e51 | 17 | 99 | 13 | 22 | 24 | 34 | 80 |
| 17 | e294 | e184 | e183 | e104 | e103 | 18 | 81 | 13 | 43 | 19 | 33 | 73 |
| 18 | e1710 | e183 | e182 | e102 | e103 | 17 | 50 | 13 | 37 | 33 | 33 | 69 |
| 19 | e1710 | e183 | e293 | e103 | e105 | 18 | 41 | 14 | 28 | 253 | 39 | 115 |
| 20 | e614 | e184 | e182 | e104 | e105 | 17 | 29 | 14 | 18 | 169 | 47 | 125 |
| 21 | e436 | e615 | e184 | e104 | 49 | 17 | 17 | 14 | 12 | 95 | 59 | 95 |
| 22 | e183 | e56 | e183 | e93 | 28 | 18 | 14 | 14 | 11 | 66 | 119 | 76 |
| 23 | e183 | e293 | e105 | e89 | 17 | 18 | 13 | 16 | 12 | 53 | 108 | 70 |
| 24 | e183 | e293 | e103 | e89 | 18 | 17 | 13 | 15 | 12 | 45 | 81 | 70 |
| 25 | e183 | e183 | e102 | e38 | 14 | 15 | 14 | 14 | 13 | 37 | 65 | 87 |
| 26 | e182 | e103 | e102 | e38 | 14 | 15 | 18 | 13 | 12 | 30 | 324 | 79 |
| 27 | e183 | e103 | e103 | e51 | 14 | 15 | 17 | 14 | 14 | 24 | 364 | 80 |
| 28 | e295 | e102 | e51 | e55 | 14 | 14 | 14 | 14 | 13 | 20 | 166 | 73 |
| 29 | e183 | e102 | e294 | e55 | 14 | 18 | 35 | 13 | 12 | 17 | 105 | 69 |
| 30 | e182 | --- | e294 | e53 | 13 | 16 | 44 | 12 | 15 | 14 | 87 | 63 |
| 31 | e181 | --- | e293 | --- | 15 | --- | 35 | 14 | --- | 12 | --- | 68 |
| TOTAL | 8324 | 5916 | 5190 | 3889 | 2030 | 484 | 754 | 542 | 3439 | 2312 | 2794 | 5347 |
| MEAN | 269 | 204 | 167 | 130 | 65.5 | 16.1 | 24.3 | 17.5 | 115 | 74.6 | 93.1 | 172 |
| MAX | 1710 | 615 | 910 | 436 | 105 | 18 | 99 | 50 | 1480 | 593 | 416 | 834 |
| MIN | 51 | 56 | 51 | 38 | 13 | 13 | 13 | 12 | 11 | 12 | 12 | 63 |
| CFSM | 4.17 | 3.17 | 2.60 | 2.01 | 1.02 | .25 | .38 | .27 | 1.78 | 1.16 | 1.45 | 2.68 |
| IN. | 4.81 | 3.42 | 3.00 | 2.25 | 1.17 | .28 | .44 | .31 | 1.99 | 1.34 | 1.61 | 3.09 |

CAL YR 1996 TOTAL 41021 MEAN 112 MAX 1710 MIN 11 CFSM 1.74 IN. 23.70