Descriptions of the Program Changes (1989–97) and a User Manual for a Transit-Loss Accounting Program Applied to Fountain Creek Between Colorado Springs and the Arkansas River, Colorado

By Gerhard Kuhn, E.L. Samuels, W.D. Bemis, *and* R.D. Steger

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CONVERSION FACTORS

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic hectometer
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
cubic foot per second per mile [(ft^3/s)/mi]	0.01760	cubic meter per second per kilometer
mile (mi)	1.609	kilometer

ACRONYMS

Acronym	Meaning in this Report
CCS	City of Colorado Springs
FAP	Fryingpan-Arkansas Project
NSF	Native streamflow
SECWCD	Southeastern Colorado Water Conservancy District
SR_Kx	Subreach known quantity (x is a number)
SR_Ux	Subreach unknown quantity (x is a number)
SS_Kx	Stream-segment known quantity (x is a number)
SS_Ux	Stream-segment unknown quantity (x is a number)
TRF	Transmountain return flow
WWTF	Wastewater-treatment facility

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Abstract

Since April 1989, a FORTRAN computer program has been used to compute transit losses for transmountain return flows (TRF's) in Fountain Creek. The transit-loss accounting program, which was developed as a result of a study completed in 1987 and is described in a previous report, enables daily accounting of (1) the TRF's, (2) the transit losses for the TRF's, and (3) the native streamflow (NSF) (nontransmountain water) in Fountain Creek between the City of Colorado Springs (CCS) and the Arkansas River. After 1989, a number of changes were made to the accounting program; however, the program and the changes never have been documented completely. To document the accounting program, a study was done by the U.S. Geological Survey, in cooperation with the City of Colorado Springs, Department of Public Utilities, and the Southeastern Colorado Water Conservancy District (SECWCD) to document the program changes and the use of the Fountain Creek transit-loss accounting program. Specifically, this report (1) describes the computational steps and procedures of the accounting program; (2) describes the changes that were made to the program in 1991–92 and in 1994–95; (3) provides a user manual; and (4) documents the procedures for maintaining the accounting program, the auxiliary programs, and the numerous output files.

Changes to the accounting program that were made during 1991–92 and during 1994–95 included (1) adding the capability to account for diversion of the TRF's; (2) allowing for the input of TRF's at locations other than at the CCS wastewater-treatment facility; (3) incorporating an additional streamflow-gaging station into the program computations; and (4) adding the capability for the SECWCD to account for TRF's derived from the Fryingpan-Arkansas Project. The program also was modularized to make it more understandable and to make the changes easier to implement.

To compute the estimated quantities of TRF and the associated transit losses, the accounting program uses two sets of computations. The first set of computations is made between any two adjacent gaging stations (stream-segment computations); these computations estimate the loss or gain in NSF between the two adjacent gaging stations. The second set of computations is made between any two adjacent nodes (subreach computations); the actual transit-loss computations are made in the subreach computations, using the result from the stream-segment computations.

Use of the accounting program is simplified through an interactive program display that has four options used to (1) compute transit losses on a day-to-day basis, (2) analyze different NSF diversion alternatives, (3) recompute the transit losses for a previous day, and (4) view or change

the ditch-accounts data. The program display also queries the user for the required inputs of the return-flow, gaging-station, and diversion discharge data; the input data are redisplayed to allow for error checking and to reinput the data if necessary. Maintenance of the accounting program primarily requires the annual archiving of the output files generated by the program; the archiving procedure is partly automated through the use of a computer script code.

INTRODUCTION

Since 1989, the Fountain Creek transit-loss accounting program (hereinafter, usually referred to as the accounting program or the program) has been used to account for return flows of transmountain water (water imported from the western slope of the Continental Divide) in Fountain Creek between the City of Colorado Springs (CCS) and the Arkansas River (fig. 1). The program incorporates the results of a study completed in 1987 (Kuhn, 1988) that developed methods to (1) determine transit losses for the transmountain return flows (TRF's) in Fountain Creek and (2) quantify the TRF's and the associated transit losses on a daily basis. The results of the 1987 study would enable the CCS to totally reuse its transmountain water supplies because, under Colorado water law, transmountain water can be used and reused until totally consumed, provided that such water can be identified and quantified (Radosevich and others, 1976, p. 88–89, 93–95). The water exchanges and other arrangements that would be used by the CCS to use and reuse the TRF's are described in a report by the Gronning Engineering Company (1986).

The accounting program is a FORTRAN computer program that enables daily accounting of (1) the TRF's, (2) transit losses for the TRF's, and (3) the native streamflows (NSF's) (nontransmountain water) in Fountain Creek. Following a period of testing to ensure the accuracy of the program and to familiarize users with the operating procedures, the accounting program was put in operation in April 1989.

After 1989, the procedures that the CCS used in the use and reuse of the TRF's were changed. Also, during that time, the Fountain Valley Conduit, a component of the transmountain Fryingpan-Arkansas Project (FAP) (Bureau of Reclamation, 1972), became fully operational. The conduit provides supplementary municipal water to the CCS and other nearby communities. The Southeastern Colorado Water Conservancy District (SECWCD) manages the transmountain water imported by the FAP and needed to be able to account for the additional TRF's in Fountain Creek. The modifications in the CCS TRF use and reuse program, the introduction of FAP TRF's into Fountain Creek, and the associated changes in the accounting procedures for these TRF's required that changes be made to the accounting program.

The accounting program has been in operation for about 8 years and has been changed considerably during that time; however, the program and the changes never have been documented completely. To ensure that the accounting program can continue to be used as long as needed, the use of the program and the changes made to it need to be documented. Documenting the accounting program not only benefits future applications or changes of the accounting program, but it also improves the understanding of the program by those currently (1997) using it. Therefore, in 1997, the U.S. Geological Survey (USGS), in cooperation with the City of Colorado Springs, Department of Public Utilities, and the SECWCD, completed a study to document the program changes and the use of the Fountain Creek transit-loss accounting program.

Purpose and Scope

This report (1) describes the computational steps and procedures of the original transit-loss accounting program; (2) describes the changes that were made to the program in 1991–92 and in 1994–95; (3) provides a user manual for the current (1997) version of the program; and (4) documents the procedures for maintaining the current version of the accounting program, the auxiliary programs, and the numerous output data files generated during each year of operating the accounting program. This report describes the assumptions and methods used in the accounting program, the required inputs, and the resulting outputs. The descriptions of the program are not a line-by-line description of the computer code, but rather a general explanation of the computational steps. Presentation of the computer codes is beyond the scope of this report.

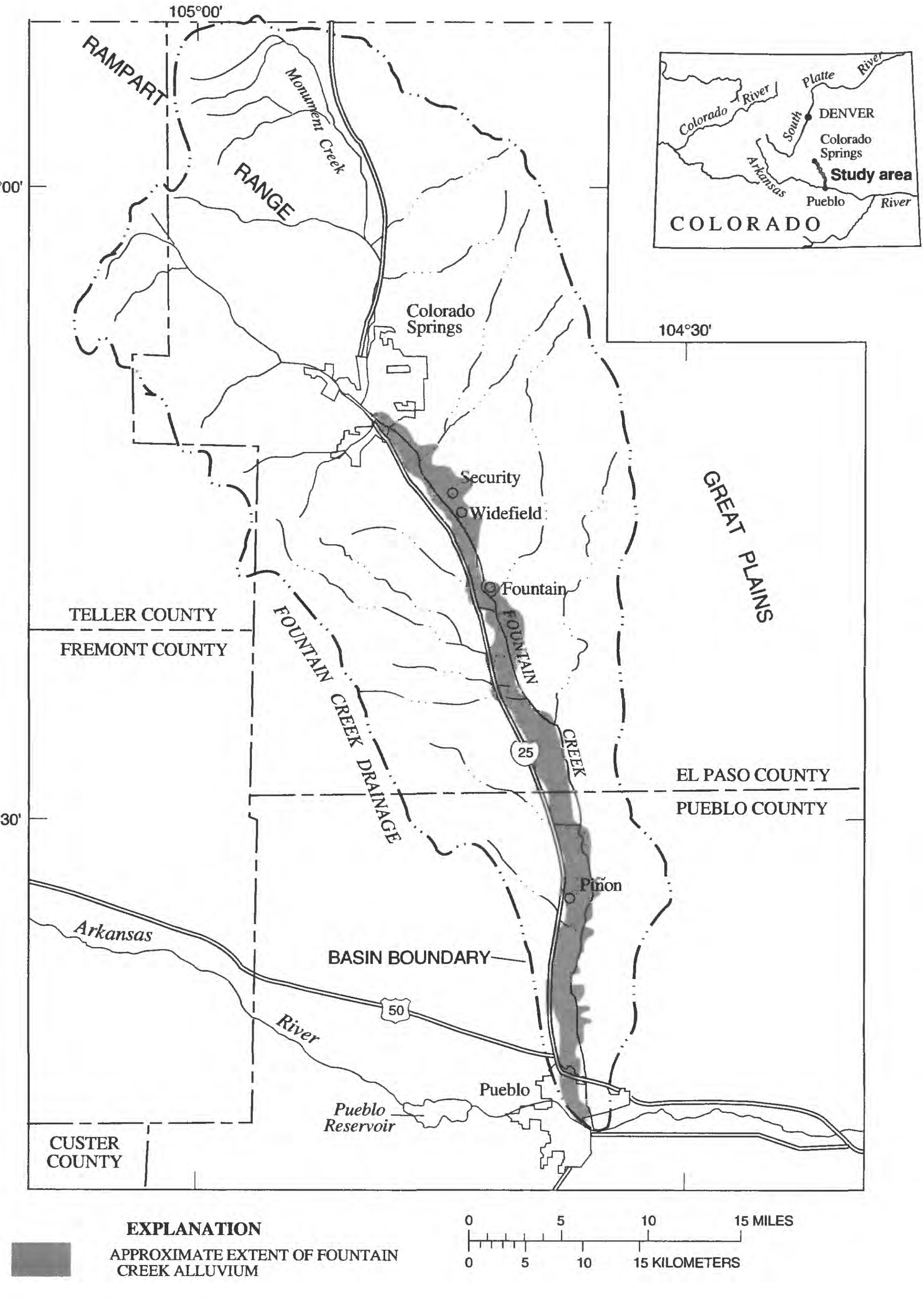

Figure 1. Location of study area.

Acknowledgments

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DESCRIPTION OF THE ORIGINAL TRANSIT-LOSS ACCOUNTING PROGRAM

A clear description and understanding of the original accounting program is necessary before the changes made to the program can be described and understood. The following sections describe: (1) The system of subreaches, nodes, and stream segments used in the accounting program [and in the transit-loss study (Kuhn, 1988)]; (2) the input data requirements; (3) the computations, including the assumptions used; and (4) the resulting output.

System of Subreaches, Nodes, and Stream Segments

The study area for the transit-loss study (Kuhn, 1988) consisted of Fountain Creek and the adjoining alluvial aquifer (fig. 1) that is hydraulically connected to Fountain Creek. Because of the hydraulic connection, water in Fountain Creek may flow into (recharge) the aquifer, and water in the aquifer may discharge back into Fountain Creek; this process can be highly dynamic in time and in location. To determine the transit losses associated with the TRF's, a stream/aquifer model (Land, 1977) was used in the transit-loss study (Kuhn, 1988). To apply the stream/aquifer model and the transit-loss study results (the accounting program), the study reach (fig. 1) was divided into a system of subreaches, nodes, and stream segments (fig. 2) because of the variable hydraulic and hydrologic conditions along Fountain Creek.

The reasoning used in defining the hydrologic system (fig. 2; table 1) is described in Kuhn (1988, p. 14–19, 29). For this report, the following details are provided: (1) Fourteen subreaches, 16 nodes, and 4 stream segments were defined; (2) the subreaches are parts of the study reach having uniform hydraulic and hydrologic characteristics (Kuhn, 1988, table 3); (3) the nodes, which delimit the subreaches, primarily are defined on the basis of locations of streamflow-gaging stations and streamflow diversions along Fountain Creek; (4) the set of subreaches between the gaging-station nodes (fig. 2; table 1) are the stream segments (not specifically indicated in fig. 2 or table 1); and (5) the subreach (not numbered in fig. 2 and table 1) between nodes A and A1 is used in the accounting program only for purposes of streamflow routing, not for transit-loss computations.

In the transit-loss study (Kuhn, 1988), three types of loss were considered: bank storage, channel storage, and evaporative. The magnitude of each of these types of loss was estimated for each of the 14 subreaches for a variety of streamflow conditions in Fountain Creek, ranging from 1 to 100 ft^3/s for TRF and from 0 to 1,000 ft^3/s for NSF. The bank-storage and channel-storage transit losses were estimated using the stream/aquifer model, and the evaporative transit losses were estimated using pan-evaporation data; the methods and results of these analyses are described in Kuhn (1988). The results of these analyses, which are coded into the accounting program, could be used to provide a daily estimate of: (1) The quantity of TRF and NSF at each of the 15 nodes (table 1, excluding node A) and (2) the quantity of transit loss associated with the TRF as it is routed through each subreach from the upstream node to the downstream node of the subreach (fig. 2; table 1).

It is important to remember that the accounting program is not the stream/aquifer model, nor does the program contain any of the components or algorithms of the stream/aquifer model. Rather, the accounting program incorporates the results of using the stream/aquifer model; these results quantify the transit losses for a large range of TRF and NSF conditions in Fountain Creek.

Input Data Requirements

To compute estimated quantities of TRF and transit loss using the accounting program, the following data are required: (1) Daily quantities of TRF and native return flow discharged into Fountain

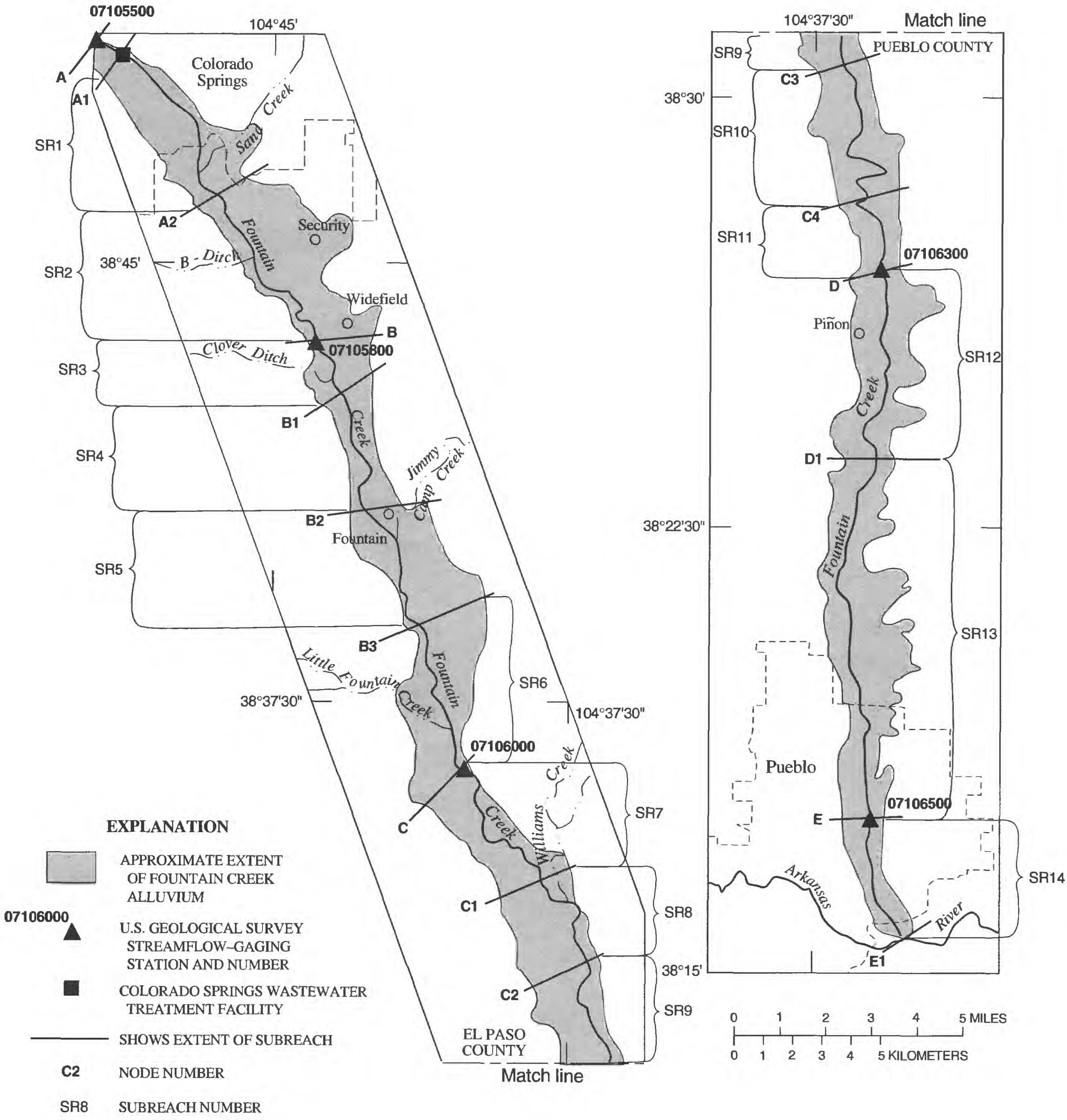

Figure 2. Subreaches, nodes, and streamflow-gaging stations along Fountain Creek used in the original transit-loss accounting program.

Table 1. Subreaches and nodes along Fountain Creek used in the original transit-loss accounting program

Subreach between two adjacent nodes (fig. 2)	Node number (fig. 2)	Node description	Diversions at node
	A	Gaging station 07105500 Fountain Creek at Colorado Springs	None
	A1	Fountain Creek at Colorado Springs wastewater-treatment facility	Fountain Mutual Canal; Laughlin Ditch
SR1			
	A2	Fountain Creek at Stubbs and Miller Ditch	Stubbs and Miller Ditch
SR2			
	B	Gaging station 07105800 Fountain Creek at Security	None
SR3			
	B1	Fountain Creek at Chilcotte Ditch	Chilcotte Ditch; Crabb Ditch; Miller Ditch; Lock Ditch[1]; North Liston and Love Ditch[1]
SR4			
	B2	Fountain Creek at Lock Ditch	None[1]
SR5			
	B3	Fountain Creek at Owen and Hall Ditch	Owen and Hall Ditch; South Liston and Love Ditch
SR6			
	C	Gaging station 07106000 Fountain Creek near Fountain	Tom Wanless Ditch; Talcott and Cotton Ditch
SR7			
	C1	Fountain Creek at Robinson Ditch	Robinson Ditch; Dr. Rogers Ditch[2]
SR8			
	C2	Fountain Creek at Burke Ditch	Burke Ditch; Toof and Harmon Ditch
SR9			
	C3	Fountain Creek at Wood Valley Ditch	Wood Valley Ditch
SR10			
	C4	Fountain Creek at Sutherland Ditch	Sutherland Ditch; Lincoln Ditch
SR11			
	D	Gaging station 07106300 Fountain Creek near Piñon	McNeil Ditch; Caulfield Ditch; Olin Ditch
SR12			
	D1	Fountain Creek at Greenview Ditch	Greenview Ditch; Cactus Ditch
SR13			
	E	Gaging station 07106500 Fountain Creek at Pueblo	None
SR14			
	E1	Fountain Creek at the mouth	None

[1]Diversion points for the Lock Ditch and North Liston and Love Ditch, which were at node B2 (Kuhn, 1988, table 2), were moved to the diversion point for the Chilcotte Ditch after the transit-loss study was completed.

[2]Dr. Rogers Ditch was added to the accounting program after the transit-loss study was completed.

Creek at the CCS wastewater-treatment facility (WWTF); (2) daily mean discharge at each of the five gaging stations along Fountain Creek (fig. 2; table 1); and (3) daily mean discharge at each of the diversions (table 1) operating along Fountain Creek. Return-flow discharge data are readily available from the CCS, which has accurate and reliable accounting procedures for its water-supply and return-flow systems. Discharge data for the diversions are readily available from the Colorado Division of Water Resources, Water District 10 water commissioners, who administer the diversion priorities for Fountain Creek and maintain daily information of diversion quantities.

Daily mean discharge data at the gaging stations are available from a closely monitored, automated data-collection system that is described in the "Streamflow-Gaging Station Network on Fountain Creek" (p. 12–14) section. Because of an approximate 1-day traveltime between the CCS WWTF and the mouth of Fountain Creek, different 24-hour periods are used at each of the gaging stations to compute daily mean discharge (fig. 3). It is evident from figure 3 that data over a 2-day period are needed to compute the transit loss for the TRF release on a given day; however, all the required input data are not available until after the 2-day period has ended. Therefore,

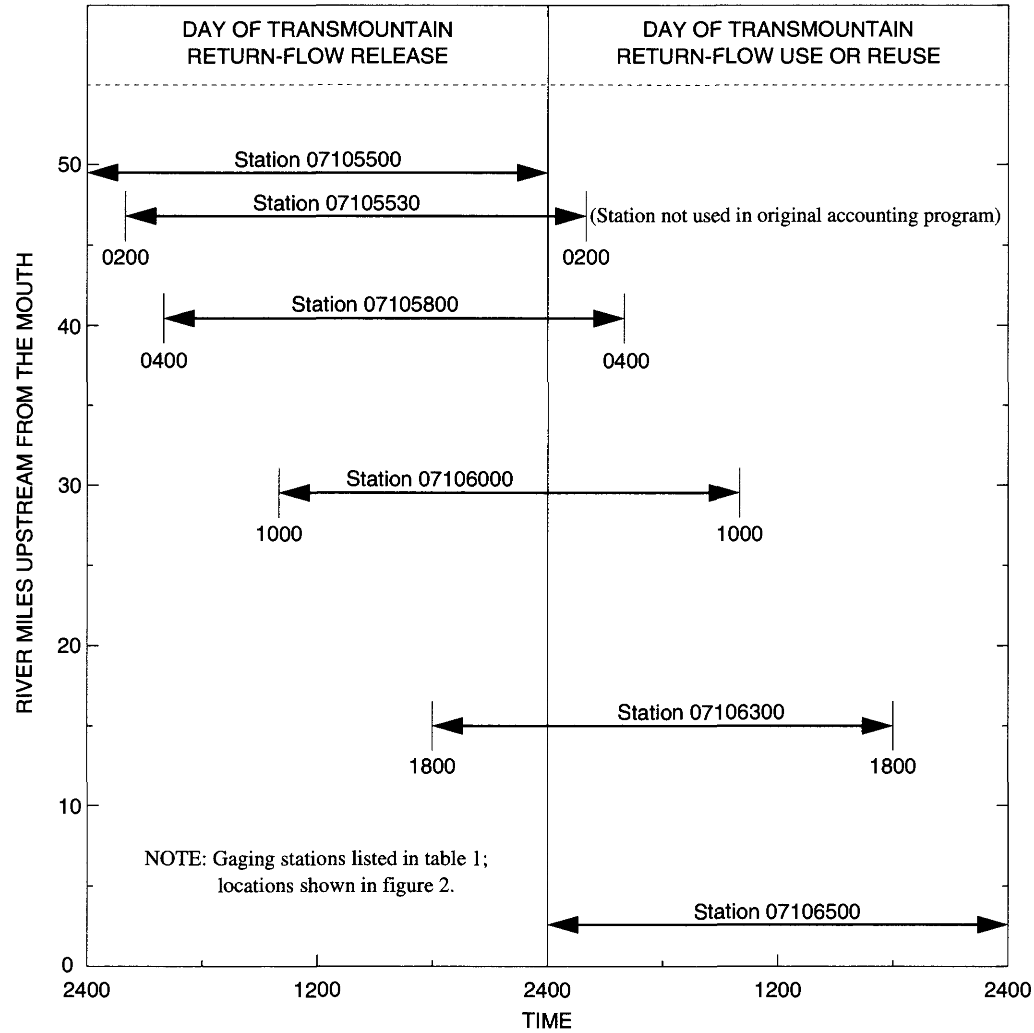

Figure 3. Time periods used in computing provisional daily mean discharges at streamflow-gaging stations on Fountain Creek for input to the transit-loss accounting program.

although the input data are needed on a near real-time basis, the transit-loss computations for a given release day are not made on a real-time basis, and the computation day (the day after the "use or reuse day" in fig. 3) lags the release day by 2 or more days. (At some times, such as during weekends or during periods of highly variable discharge in Fountain Creek, the water commissioners may not operate the accounting program each consecutive day; thus, two or more computations may be made at one time to bring the computations up to date.)

Daily mean discharges input to the accounting program are provisional (subject to revision) because (1) the 24-hour periods that are different from a midnight (2400 hours) to midnight period at some gaging stations (fig. 3) are never used in computing published discharge data and (2) the discharges are computed on a near real-time basis and may be adjusted later with more up-to-date stage-discharge shift data. The resulting error in transit-loss calculation was not considered to be substantial (Kuhn, 1988, p. 88). The TRF and the native return-flow quantities that are input to the program are for a normal 24-hour period to facilitate administration of the TRF use and reuse program. Diversion data that are input also are for a normal 24-hour period, primarily because the quantity of streamflow diverted remains fairly constant from day to day.

Once initiated, the accounting program queries the user for the required input data: (1) The TRF and the native return-flow quantities discharged at the CCS WWTF, (2) the discharge at each gaging station (table 1, fig. 3), and (3) the diversion at each ditch (table 1). These data are input manually to the program for each day of transit-loss computations; however, the diversion data, once input, only need to be reentered when the diversions change from the previous day. All input data, the accounting program computations, and the output results are expressed in cubic feet per second, unless noted otherwise.

Program Computations

In computing the estimated quantities of TRF in Fountain Creek and the associated transit losses, the accounting program uses two sets of computations. The first set of computations is made between any two adjacent gaging stations (stream-segment computations); these computations estimate the loss or gain in NSF between the two adjacent gaging stations. The second set of computations is made between any two adjacent nodes (subreach computations); the actual transit-loss computations are made in the subreach computations, using the result from the stream-segment computations. The stream-segment computations are completed for a stream segment, then the subreach computations are completed for each subreach within the stream segment. When the subreach computations are completed for all subreaches within a stream segment, the stream-segment computations are repeated for the next stream segment, followed again by the subreach computations; the process continues until computations are completed downstream through subreach 14.

Assumptions Used in the Computations

To compute estimated transit losses using the accounting program, an assumption must be made in the stream-segment computations that the quantity of TRF at the downstream gaging station is the same as at the upstream gaging station. This assumption is necessary because, at this point in the computations, the quantity of TRF at the downstream gaging station is not known. Although this assumption results in some error in estimating the loss or gain in NSF between the gaging stations, these errors are not substantial (Kuhn, 1988, p. 88). Because of this assumption, the computed quantity of NSF at the end of the downstream subreach within a stream segment is somewhat different from the NSF at the beginning of the next stream-segment computations (see the "Program Output" section, p. 12). This discrepancy in NSF computation has been corrected in the program version currently (1997) in use (see the "Changes to Program Output" section, p. 22). To perform the transit-loss computations, the input data also are assumed to be accurate.

Stream-Segment Computations

After the data are input, the accounting-program computations begin with the stream-segment computations, which are diagramed in figure 4. To perform the stream-segment computations, the following stream-segment known quantities (SS_Kx, where x is a number) need to be defined:

1. SS_K1 (fig. 4), which is the total streamflow at the upstream gaging station. If the upstream gaging station is station 07105500, then SS_K1 is equal to the sum of the daily mean discharge at station 07105500 and the total return flow (sum of TRF and native return flow) discharged into Fountain Creek at the CCS WWTF; otherwise, SS_K1 is equal to the daily mean discharge at the upstream gaging station.
2. SS_K2 (fig. 4), which is the TRF at the upstream gaging station. If the upstream gaging station is station 07105500, then SS_K2 is equal to the TRF discharged at the CCS WWTF; otherwise, SS_K2 is equal to SR_U3 (the TRF at the downstream node) from the last subreach computation of the previous stream segment (see fig. 5 and the "Subreach Computations" section, p. 9–12).
3. SS_K3 (fig. 4), which is the NSF at the upstream gaging station. SS_K3 is equal to SS_K1 minus SS_K2.
4. SS_K4 (fig. 4), which is the total streamflow at the downstream gaging station. SS_K4 is equal to the daily mean discharge at the downstream gaging station.
5. SS_K5 (fig. 4), which is the total NSF diversion in the stream segment. The NSF diversions are input individually for each ditch and the program

sums the diversions for all ditches within the stream segment.

6. SS_K6 (fig. 4), which is the stream-segment channel length, in miles. SS_K6 is derived from the subreach channel lengths that were determined in the transit-loss study (Kuhn, 1988, table 3). The channel lengths for all subreaches within a stream segment were summed and are included in the program code.

The unknown quantity in the stream-segment computations is SS_U1 (fig. 4); the following steps are used in the stream-segment computations to derive the unknown quantity:

1. Compute an initial estimate of NSF at the downstream gaging station; this estimate is equal to SS_K4 (the total streamflow at the downstream gaging station) minus SS_K2 (the TRF at the upstream gaging station) (see the "Assumptions Used in the Computations" section, p. 8).
2. Compute a revised estimate of NSF at the downstream gaging station; this estimate is equal to SS_K5 (the total NSF diversion in the stream segment) plus the result from computation step 1. The revised estimate of NSF at the downstream gaging station is the conditional NSF, provided there had not been any NSF diversions in the stream segment.
3. Compute the estimated total NSF loss or gain in the stream segment; the total NSF loss or gain is equal to SS_K3 (the NSF at the upstream gaging station) minus the result of computation step 2.
4. Compute SS_U1 [the estimated NSF loss or gain in the stream segment, in cubic feet per second per mile (fig. 4)], which is equal to the result from computation step 3 divided by SS_K6 (the stream-segment channel length).

When the stream-segment computations are completed, the accounting-program computations proceed to the subreach computations; the result from computation step 4 of the stream-segment computations is used in the subreach computations. Because node E (fig. 2, table 1) is the last gaging station, the stream-segment computations are not made for subreach 14 (there is no downstream gaging station to define a stream segment); therefore, NSF loss or gain is assumed to be zero in subreach 14 (Kuhn, 1988, p. 81).

Subreach Computations

The subreach computations are diagramed in figure 5; to perform the subreach computations, the following subreach known quantities (SR_Kx, where x is a number) need to be defined:

1. SR_K1 (fig. 5), which is the TRF at the upstream node. For most subreaches, SR_K1 is equal to SR_U3 (the TRF at the downstream node) from the computations for the previous subreach (fig. 5). For a subreach with the upstream node at node A1, B, C, D, or E (fig. 2; table 1), SR_K1 is equal to SS_K2 (the TRF at the upstream gaging station) from the stream-segment computations (fig. 4).
2. SR_K2 (fig. 5), which is the NSF at the upstream node. For most subreaches, SR_K2 is equal to SR_U1 (the NSF at the downstream node) from the computations for the previous subreach (fig. 5). For a subreach with the upstream node at node B, C, D, or E (fig. 2; table 1), SR_K2 is equal to SS_K3 (the NSF at the upstream gaging station) from the stream-segment computations (fig. 4); however, if the upstream node is node A1, then SR_K2 is equal to the sum of (1) the daily mean discharge at station 07105500 (node A, table 1), (2) the native return-flow discharge at the CCS WWTF, and (3) the estimated NSF loss or gain between nodes A and A1 (fig. 2; table 1). The estimated NSF loss or gain between nodes A and A1 is computed by multiplying SS_U1 [the stream-segment NSF loss or gain (fig. 4)] by the channel length between nodes A and A1 (0.6 mi).
3. SR_K3 (fig. 5), which is the total NSF diversion between the nodes. The NSF diversions are input individually for each ditch, and the program sums the diversions for all ditches within the subreach.
4. SR_K4 (fig. 5), which is the subreach channel length, in miles. Values for SR_K4 were determined in the transit-loss study (Kuhn, 1988, table 3) and are included in the program code.

The unknown quantities in the subreach computations are SR_U1, SR_U2, and SR_U3 (fig. 5); the following steps are used in the subreach computations to derive the unknown quantities:

1. Compute the NSF at the upstream node that is to be routed through the subreach to the downstream

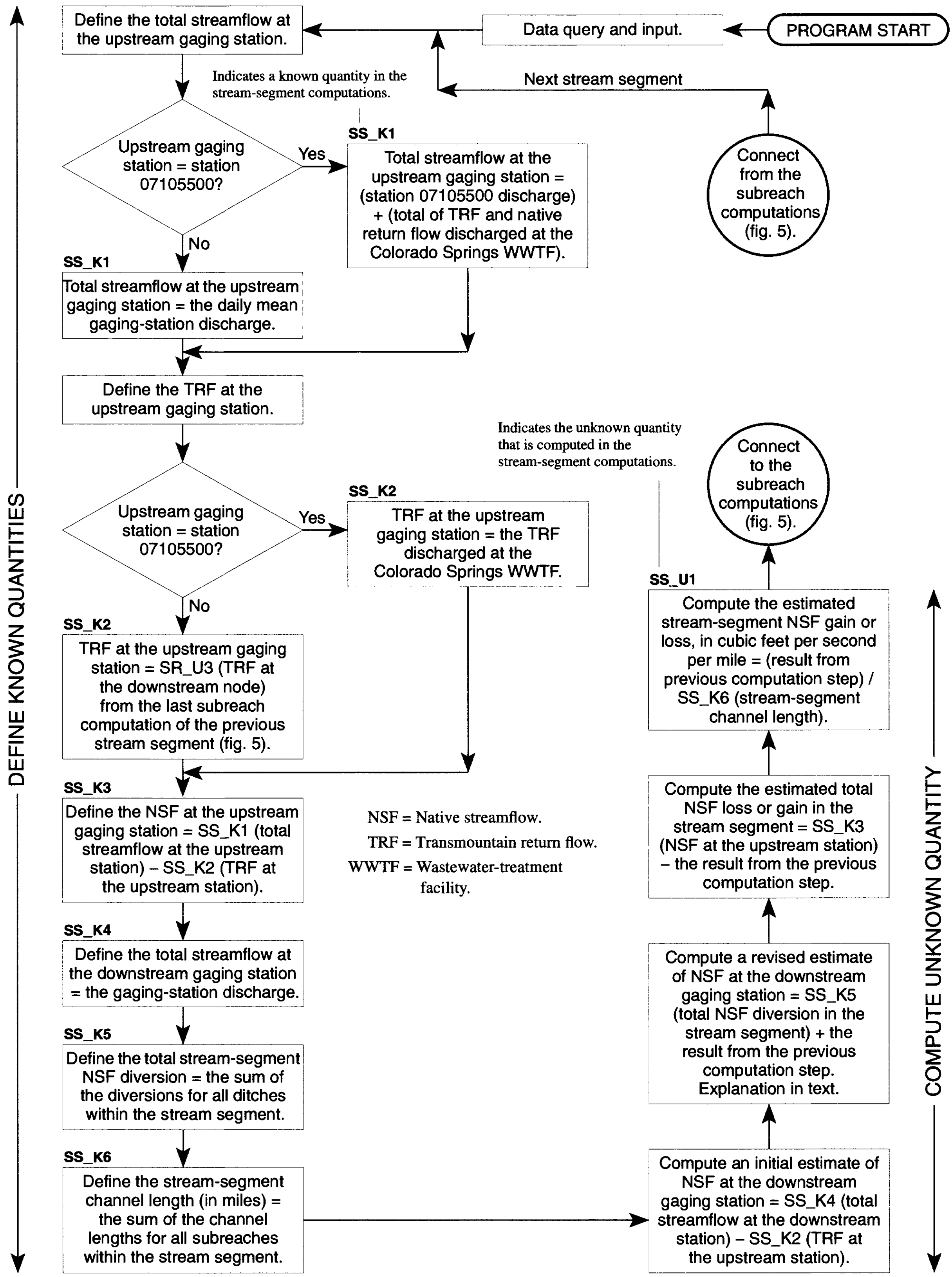

Figure 4. Stream-segment computations of the Fountain Creek transit-loss accounting program.

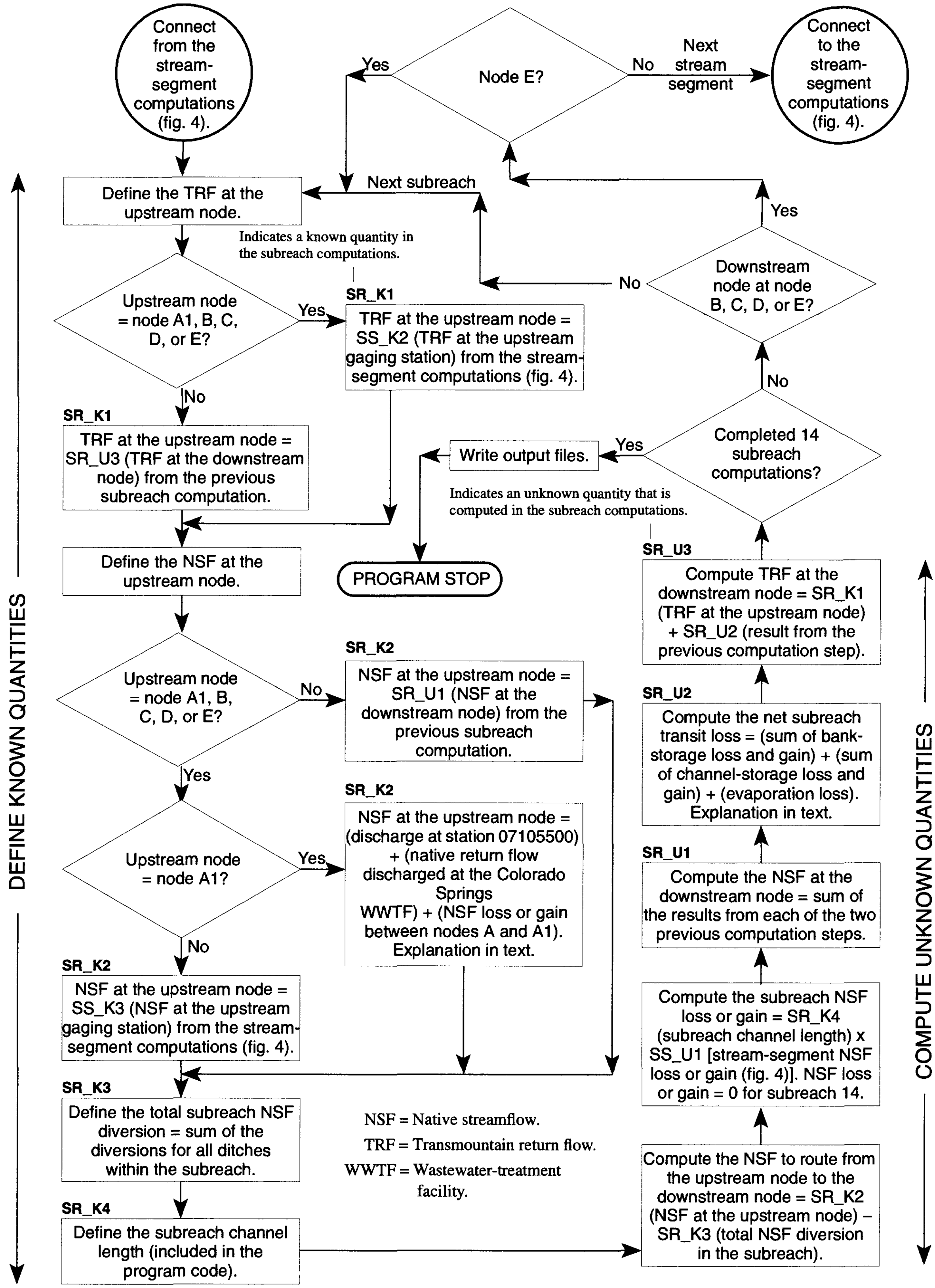

Figure 5. Subreach computations of the Fountain Creek transit-loss accounting program.

node. The NSF to be routed is equal to SR_K2 (the NSF at the upstream node) minus SR_K3 (the total NSF diversion in the subreach) (fig. 5).

2. Compute the subreach NSF loss or gain, which is equal to the product of SR_K4 (the subreach channel length) (fig. 5) times SS_U1 (the stream-segment NSF loss or gain) (fig. 4). The subreach NSF loss or gain for subreach 14 is assumed to be zero (see the "Stream-Segment Computations" section, p. 8–9).

3. Compute SR_U1 (the NSF at the downstream node), which is equal to the sum of the results from computation steps 1 and 2. Because the downstream node of a subreach becomes the upstream node for the next subreach, SR_U1 becomes SR_K2 (the NSF at the upstream node) in the computations for the next subreach (fig. 5).

4. Compute SR_U2 (fig. 5). As described in the "System of Subreaches, Nodes, and Stream Segments" section (p. 4), transit loss consists of bank-storage loss, channel-storage loss, and evaporative loss. Because Fountain Creek and the adjoining alluvial aquifer are hydraulically connected, Kuhn (1988, p. 59–65) determined in the transit-loss study that some of the bank-storage transit loss (aquifer recharge) on a given day would return to Fountain Creek over time (aquifer discharge); this return would be a gain from bank storage. Kuhn (1988, p. 66, 72) also concluded that the channel-storage transit loss on one day became an equivalent gain from channel storage on the next day. The results of the transit-loss study (Kuhn, 1988) enable computation of the bank-storage and channel-storage components of transit loss or gain and computation of the evaporation-loss component of transit loss; these results are included in the computer code of the subreach computations. The sum of all the losses and gains results in the net subreach transit loss or gain (SR_U2 in fig. 5). SR_U2 is negative if there is a net transit loss and is positive if there is a net transit gain.

5. Compute SR_U3 (the TRF at the downstream node), which is equal to the sum of SR_K1 (the TRF at the upstream node) and SR_U2 (the result from computation step 4). Because the downstream node of a subreach becomes the upstream node for the next subreach, SR_U3 becomes SR_K1 (the TRF at the upstream node) in the computations for the next subreach (fig. 5).

The subreach computations are repeated for each subreach within the stream segment. When computations are completed for all subreaches within a stream segment [the downstream node is at gaging station (node B, C, or D, table 1)], the program computations return to the stream-segment computations; however, if the downstream node is at station 07106500 (node E, table 1), then the subreach computations are continued for the last subreach (see the "Stream-Segment Computations" section, p. 8–9). When computations have been completed for all 14 subreaches, the total transit loss and the estimated quantity of TRF at the mouth of Fountain Creek are known.

Program Output

Output for the original accounting program presented detailed results for (1) the TRF quantities, (2) the NSF quantities, and (3) the input data quantities (table 2). The output presented results for the transit-loss computations and streamflow accounting for each subreach; however, in administering the TRF use and reuse program, only the final results (at subreach 14) are needed. The discrepancy in the NSF discharge value described in the "Assumptions Used in the Computations" section (p. 8) can be seen in the output. The native inflow for subreaches 3, 7, 12, and 14 is different from the native outflow of the previous subreach, whereas the native inflow for the other subreaches (2, 4–6, 8–11, and 13) is the same as the native outflow in the previous subreaches.

STREAMFLOW-GAGING STATION NETWORK ON FOUNTAIN CREEK

The gaging-station network on Fountain Creek originally consisted of five stations between the CCS and the Arkansas River (figs. 2 and 3; table 1). A sixth gaging station (station 07105530 in fig. 3) was added to the network in 1995; this station actually was established in October 1989 to obtain discharge and water-quality data, but was not incorporated into the accounting program until 1995. Each gaging station is equipped with a data-collection platform that scans a sensor for gage-height (stage) data every 15 minutes,

Table 2. Example output from the original Fountain Creek transit-loss accounting program

FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 01-26-94
[ALL FLOW QUANTITIES IN CUBIC FEET PER SECOND]

T R A N S I T L O S S C O M P U T A T I O N S

SUBREACH	TRANSMTN INFLOW	INITIAL LOSS	ILOSS ADJ.FAC.	ADJUSTED ILOSS	GAINS FROM BS.	CHANNEL LOSS	CHANNEL GAIN	EVAP LOSS	TOTAL LOSS/GAIN	TRANSMTN OUTFLOW
1	35.00	3.70	0.98	3.62	3.71	3.50	3.50	0.021	0.07	35.07
2	35.07	4.50	0.99	4.46	2.80	3.42	3.39	0.021	-1.72	33.35
3	33.35	0.64	0.99	0.63	0.32	3.32	3.22	0.006	-0.42	32.94
4	32.94	2.16	0.98	2.12	0.97	3.24	3.06	0.014	-1.33	31.61
5	31.61	1.67	0.99	1.65	1.03	3.13	2.87	0.011	-0.90	30.71
6	30.71	1.71	0.99	1.69	0.76	3.02	2.68	0.013	-1.29	29.42
7	29.42	1.11	1.01	1.12	0.72	2.92	2.51	0.009	-0.82	28.60
8	28.60	0.96	1.00	0.97	0.36	2.83	2.36	0.008	-1.08	27.52
9	27.52	1.35	1.01	1.36	0.58	2.71	2.20	0.010	-1.30	26.22
10	26.22	1.34	1.01	1.35	1.21	2.61	2.08	0.012	-0.69	25.52
11	25.52	0.58	1.00	0.58	0.27	2.54	1.97	0.006	-0.88	24.64
12	24.64	1.05	0.99	1.04	2.30	2.53	1.83	0.012	0.56	25.20
13	25.20	2.64	0.99	2.60	2.73	5.05	3.29	0.023	-1.65	23.54
14	23.54	0.70	1.00	0.70	2.21	2.43	1.45	0.006	0.52	24.07

N A T I V E F L O W C O M P U T A T I O N S — TRANSMOUNTAIN SUMMARY

SUBREACH	DITCHES IN SUBREACH	NATIVE INFLOW	TOTAL DIVERSN	NET NAT. INFLOW	NATIVE GAIN/LOSS	NATIVE OUTFLOW	TRANSMTN INFLOW	TRANSMTN OUTFLOW	* PERCENT TR. LOSS
1	1,2	35.65	10.00	25.65	4.46	30.11	35.00	35.07	0.20
2	3	30.11	0.00	30.11	4.89	35.00	35.07	33.35	-4.91
3	None	36.65	0.00	36.65	2.26	38.91	33.35	32.94	-1.19
4	4,5,6,7,8	38.91	0.00	38.91	5.91	44.82	32.94	31.61	-3.80
5	None	44.82	0.00	44.82	5.04	49.87	31.61	30.71	-2.56
6	9,10	49.87	0.00	49.87	6.78	56.65	30.71	29.42	-3.68
7	11,12	60.58	0.00	60.58	-1.42	59.15	29.42	28.60	-2.34
8	13,14	59.15	2.93	56.22	-1.19	55.04	28.60	27.52	-3.09
9	15,16	55.04	0.00	55.04	-1.61	53.42	27.52	26.22	-3.73
10	17	53.42	0.00	53.42	-1.85	51.57	26.22	25.52	-1.98
11	18,19	51.57	0.00	51.57	-1.00	50.58	25.52	24.64	-2.52
12	20,21,22	55.36	0.00	55.36	3.23	58.59	24.64	25.20	1.59
13	23,24	58.59	0.00	58.59	6.77	65.36	25.20	23.54	-4.73
14	None	66.46	0.00	66.46	0.00	66.46	23.54	24.07	1.50
								TOTAL =	-31.23

STREAMFLOW INFORMATION

GAGING STATION	MEAN DAILY GAGE HEIGHT	SHIFT	DISCHARGE
07105500	0.00	0.00	20.00
07105800	0.00	0.00	70.00
07106000	0.00	0.00	90.00
07106300	0.00	0.00	80.00
07106500	0.00	0.00	90.00

NATIVE RETURN FLOW RELEASED 01-26-94=15.00
TRANSMOUNTAIN RETURN FLOW RELEASED 01-26-94=35.00
QUANTITY AVAILABLE FOR EXCHANGE 01-27-94=24.07

DIVERSION INFORMATION

DITCH		DIVERSION	DITCH		DIVERSION
1	FOUNTAIN MUTUAL	10.00	13	ROBINSON	0.00
2	LAUGHLIN	0.00	14	DR. ROGERS	2.93
3	STUBBS & MILLER	0.00	15	BURKE	0.00
4	CHILCOTTE	0.00	16	TOOF & HARMON	0.00
5	CRABBE	0.00	17	WOOD VALLEY	0.00
6	MILLER	0.00	18	SUTHERLAND	0.00
7	LOCK	0.00	19	LINCOLN	0.00
8	LISTON & LOVE N	0.00	20	MCNEIL	0.00
9	OWEN & HALL	0.00	21	CAULFIELD	0.00
10	LISTON & LOVE S	0.00	22	OLIN	0.00
11	TOM WANLESS	0.00	23	GREENVIEW	0.00
12	TALCOTT & COTTON	0.00	24	CACTUS	0.00

* PERCENT TRANSIT LOSS IS TOTAL LOSS/GAIN AS A % OF RELEASE AMOUNT.

stores the data, and transmits the stored data every 4 hours to a satellite. Additionally, each data-collection platform is programmed to transmit every 15 minutes when threshold gage-height limits are exceeded during times of high flow. The data are retransmitted from the satellite to satellite downlinks and transferred to the streamflow data base contained in the USGS computer system.

Discharge data are computed from the gage-height data using a stage-discharge rating developed from discharge measurements that are made at variable gage heights. The sand, shale, and cobble channels at all of the gaging stations are extremely unstable and require discharge measurements at weekly to biweekly frequencies, depending on the extent of hydraulic changes in the channel conditions. Because of changes in the channel conditions, the stage-discharge relations at the gaging stations may differ from the stage-discharge rating that was developed. Therefore, to compute the current correct discharge, corrections are made to the stage-discharge rating by applying shifts to the transmitted gage-height data; the shifts usually are distributed on the basis of time and stage. The discharges are calculated by the computer as they are received from the satellite downlink and stored in the data base. The discharge data are checked for accuracy on a daily basis, including weekends; during high flows and extreme low flows, the data may be checked several times a day. Shift adjustments also are made if the discharge at a gaging station does not appear consistent with discharge at the adjacent stations, after allowing for possible known inflows and diversions between the stations.

The discharges that are computed at 15-minute intervals and stored in the data base are retrieved automatically on a nightly basis by additional computer programs developed for that purpose. These programs compute the daily mean discharge for each gaging station for the appropriate 24-hour period (fig. 3) and write the discharges to a data file accessible by the agencies that use the accounting program. The daily mean discharge data also are reviewed daily by USGS personnel; any corrections in these data that are needed as a result of changes in the applied shifts are loaded into a second data file of revised discharges for use as needed (see the "Transit-Loss Accounting Program Files" section, p. 27–30).

Operation of these gaging stations requires thorough knowledge of the hydrology of Fountain Creek and the ability to interpret the changing channel and control conditions at each station. The entire process of providing the most accurate real-time discharge data as possible for the accounting program requires constant and intensive attention.

CHANGES TO THE TRANSIT-LOSS ACCOUNTING PROGRAM DURING 1991–92

In 1991, the CCS planned to modify the TRF use and reuse program to enable ditch owners along Fountain Creek to purchase and divert some of the TRF's to supplement their NSF diversions. This diversion (1) would benefit the ditch owners, especially those having the more junior water rights, by providing an additional source of irrigation water and (2) would benefit the CCS by decreasing transit losses because losses would not accrue downstream to the mouth of Fountain Creek for the diverted TRF's. Through an agreement with the SECWCD, the diverted TRF's were considered to be return-flow deliveries of FAP water, and the diverted TRF's could be exchanged by the CCS for equivalent quantities of FAP water being stored in Pueblo Reservoir (Thomas C. Simpson, SECWCD, oral commun., 1997).

In addition, the CCS wanted to include TRF's in the accounting program that resulted from water use on the Fort Carson Military Reservation (south of the CCS and west of Fountain Creek; not shown in figs. 1 and 2) and that entered Fountain Creek through Clover Ditch (actually a drain) in the vicinity of station 07105800 (fig. 2). Finally, besides changing the program to accommodate the proposed diversion of TRF's for irrigation and the additional TRF source, the physical structure of the program was changed to make it more modular, and the program output also was changed.

The changes to the program are described in the next four sections of this report; the modified accounting program that resulted from these changes was put in operation in April 1992. Although these and subsequent changes made to the program were considerable, the changes primarily affected the input and output handling of the various discharge quantities; the basic algorithms used to calculate transit losses (Kuhn, 1988, p. 76–85) were not changed.

Program Modularization

The original accounting program consisted of a main program and five subroutines. In analyzing the program code to determine (1) what changes would be needed to account for the TRF diversions and the additional TRF source and (2) where the program code would need to be changed, it became obvious that the changes could be made more easily if the program were modularized. Thus, many aspects of the data input, computational procedures, and data output, especially the repetitive processes, were recoded into individual subroutines. Descriptions of this recoding or of the resulting subroutines is not necessary for the purposes of this report; however, the modularization process and the program changes resulted in an accounting program having 26 subroutines. During this process, a complete list of all the program variables was created and some variable names were changed to make them more descriptive. Modularizing the program code and creating the variable list provided a better understanding of the program code, especially for persons just beginning to learn the program, and made the task of changing the program much simpler.

Changes to Account for Diversion of Transmountain Return Flows

To account for the diversion of TRF's, the primary change needed in the accounting program was to provide a mechanism to specify a TRF diversion at a specific location. A diversion of TRF could be easily specified at any of the nodes, using a method similar to how the NSF diversions are specified. However, the purchaser of a TRF for diversion must incur the transit loss for the diverted TRF, from the point of discharge (at the CCS WWTF) to the point of diversion. Also, the quantity of TRF to be diverted needs to be known prior to the actual diversion, which makes the needed program changes more difficult. Consider this example:

> On Monday, the water commissioner is notified by a ditch owner along Fountain Creek of an intent to purchase and divert 5 ft^3/s of TRF for 5 days beginning on Tuesday. Because of transit losses from the CCS WWTF downstream to the ditch diversion point, there are two possibilities: (1) The ditch owner can purchase and divert the equivalent of 5 ft^3/s per day at the CCS WWTF, in which case the quantity of TRF available at the diversion point is not known until after the diversion has been made; or (2) the ditch owner can purchase and divert the equivalent of 5 ft^3/s at the ditch diversion point, in which case the TRF purchase quantity needed at the CCS WWTF is not known until after the diversion has been made.

For purposes of water administration and for a capability that could be added easily to the accounting program, the second possibility just described was the best option. Therefore, the program was changed to account for diversion of a specific quantity of TRF at a given node (an NSF or a TRF diversion point) by calculating the quantity of TRF that would need to be purchased at the CCS WWTF for the specified TRF diversion. The TRF purchase quantity is derived by the following additional computation steps in the subreach computations:

1. Transit-loss computations for the total quantity of TRF are identical to the computations in the original accounting program (fig. 5).
2. If a subreach has a specified TRF diversion, the program computes the ratio of the TRF diversion quantity to the total TRF quantity at the upstream node of the subreach.
3. The program assigns a proportion of the total transit loss in the previous (upstream) subreach to the TRF diversion quantity on the basis of the ratio computed in step 2.
4. The program adds the transit-loss proportion computed in step 3 to the specified TRF diversion quantity, resulting in an estimate of the TRF purchase quantity at the upstream node of the previous subreach.
5. The program computes a new ratio between the TRF purchase quantity just estimated and the total TRF at the upstream node of the current subreach and then returns to computation step 3.
6. The program repeats computation steps 3–5 for each upstream subreach, but the ratio from step 5 rather than the ratio from step 2 is used in the subsequent step 3 computations. The TRF purchase quantity changes in each subreach as the computations proceed back through subreach 1, at which point the TRF purchase quantity

necessary for the TRF diversion that was specified on input is known.

7. The program then returns to the subreach where the TRF diversion was specified, subtracts the specified TRF diversion quantity from the total TRF quantity, and proceeds with the normal transit-loss calculations for the remaining subreaches using the reduced TRF quantity. The computations just described are repeated for each TRF diversion that is specified in the input data.

Therefore, in the example, the water commissioner would tell the ditch owner to divert 5 ft^3/s each day as requested, but the amount of TRF (at the CCS WWTF) needed to be purchased for each day of the TRF diversion would not be known until about 2 days later, after the accounting program had been used to compute the transit losses for that day (see the "Input Data Requirements" section, p. 7).

Changes to Account for an Additional Transmountain Return-Flow Source

The changes to the program needed to account for TRF's that enter Fountain Creek via Clover Ditch were quite simple. This TRF quantity is specified during data input, and the program adds the value to the calculated TRF in Fountain Creek at node B (station 07105800 in fig. 2 and table 1). The sum of the two TRF quantities then is a single TRF quantity for the remaining transit-loss computations.

Changes to Program Output

The accounting-program output was changed considerably as a result of the other program changes just described. Much of the detailed transit-loss information listed in the original output (table 2) is not listed in the new output (table 3); however, for each day of transit-loss calculations, this detailed information is written to a separate output file that is archived on a yearly basis. The new output first lists a summary of the input discharge data and then lists the NSF and the TRF diversion (EXCHANGE DIVERSION, table 3), if any, at each ditch; the TRF purchase quantity (EXCHANGE RELEASE, table 3) also is listed for each TRF diversion. A summary of the NSF and the TRF computations and discharge quantities then is listed for each subreach. The new output also provides a second page of output (table 3) that lists a number of discharge quantities needed by the CCS and the water commissioners in administering the TRF use and reuse program for Fountain Creek. The quantities listed on page 2 of the output (table 3) are calculated by the accounting program at the end of a daily run; a detailed explanation of these quantities is available from the agencies.

Another program feature added during the 1991–92 changes was a calculation of transit losses as if there had not been any TRF diversions. This calculation provided a means to compare the total amount of TRF delivered to any location for actual TRF diversions to the hypothetical case of no TRF diversions. The diversion of TRF generally results in smaller overall transit losses; the comparison calculation provided a means for the CCS to quantify the differences. This comparison also is shown on the second page of the revised program output (table 3).

CHANGES TO THE TRANSIT-LOSS ACCOUNTING PROGRAM DURING 1994–95

In 1994, the CCS wanted to incorporate an additional gaging station into the accounting program. In addition, the SECWCD wanted to be able to account for FAP TRF's that are discharged to Fountain Creek at the CCS WWTF and by the communities of Security, Widefield, and Fountain (figs. 1 and 2). The SECWCD also wanted the capability to account for diversion of the FAP TRF's that would be similar to the capability for diversion of the CCS TRF's added as part of the 1991–92 program changes. Lastly, the CCS wanted the capability to account for additional diversion of TRF's that would not be exchanged for FAP water stored in Pueblo Reservoir. These changes to the accounting program, which were put in operation in April 1995, are described in the following sections.

Changes to Incorporate an Additional Streamflow-Gaging Station

The additional gaging station on Fountain Creek (station 07105530 in fig. 6) is about 1 mi downstream from the CCS WWTF. To use this gaging station in the accounting program, an additional subreach, node, and stream segment were created; in

Table 3. Example output from the Fountain Creek transit-loss accounting program after the 1991–92 changes

FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 07-21-94 [ALL FLOW QUANTITIES IN CUBIC FEET PER SECOND]

INPUT DATA SUMMARY

RELEASE DATA

TOTAL TRANSMOUNTAIN RETURN FLOW AT WWTF:	35.00
NATIVE RETURN FLOW AT WWTF:	15.00
FT. CARSON TRANSMOUNTAIN TO FOUNTAIN CREEK:	5.00
SUPPLEMENTAL RELEASE FROM CCS UPSTREAM RES:	0.00

STREAMFLOW DATA

STATION	NAME	DISCHARGE
07105500	AT COLO. SPRINGS	20.00
07105800	AT SECURITY	80.00
07106000	NEAR FOUNTAIN	100.00
07106300	NEAR PINON	90.00
07106500	AT PUEBLO	100.00

DIVERSION DATA

DITCH	NAME	NATIVE DIVERSION	EXCHANGE DIVERSION	*EXCHANGE RELEASE	DITCH	NAME	NATIVE DIVERSION	EXCHANGE DIVERSION	*EXCHANGE RELEASE
1	FOUNTAIN MUTUAL	2.00	0.00	0.00	13	ROBINSON	0.00	0.00	0.00
2	LAUGHLIN	0.00	0.00	0.00	14	DR. ROGERS	2.93	0.00	0.00
3	STUBBS & MILLER	0.00	0.00	0.00	15	BURKE	0.00	4.00	4.70
4	CHILCOTTE	0.00	5.00	5.45	16	TOOF & HARMON	0.00	0.00	0.00
5	CRABBE	0.00	0.00	0.00	17	WOOD VALLEY	0.00	0.00	0.00
6	MILLER	0.00	0.00	0.00	18	BANNISTER	0.00	0.00	0.00
7	LOCK	10.00	0.00	0.00	19	SUTHERLAND	0.00	0.00	0.00
8	LISTON & LOVE N	0.00	0.00	0.00	20	LINCOLN	0.00	0.00	0.00
9	OWEN & HALL	0.00	0.00	0.00	21	MCNEIL	0.00	0.00	0.00
10	LISTON & LOVE S	0.00	0.00	0.00	22	CAULFIELD	0.00	0.00	0.00
11	TOM WANLESS	0.00	0.00	0.00	23	OLIN	0.00	0.00	0.00
12	TALCOTT & COTTON	0.00	0.00	0.00	24	GREENVIEW	0.00	0.00	0.00

NOTE: * Exchange release calculated in transit loss program.
(B) Exchange release accountable to balancing account.

TRANSIT LOSS COMPUTATIONS SUMMARY

SUBREACH	DITCHES IN SUBREACH	NATIVE INFLOW	NATIVE DIVERSN	NATIVE GN/LS	NATIVE OUTFLOW	TRNSMTN INFLOW	EXCHANGE DIVERSN	TRNSMTN GN/LS	TRNSMTN OUTFLOW	*PERCENT TRM LOSS
1	1,2	35.78	2.00	5.35	39.13	35.00	0.00	-0.87	34.13	-2.48
2	3	39.13	0.00	5.87	45.00	34.13	0.00	-0.90	33.23	-2.64
3	None	46.77	0.00	3.39	50.16	38.23(A)	0.00	-1.28	36.95	-3.35
4	4,5,6,7,8	50.16	10.00	8.87	49.03	36.95	5.00	-0.46	31.49	-1.43
5	None	49.03	0.00	7.57	56.60	31.49	0.00	-0.60	30.89	-1.90
6	9,10	56.60	0.00	10.17	66.77	30.89	0.00	-0.51	30.39	-1.64
7	11,12	73.61	0.00	-1.42	72.19	30.39	0.00	-0.41	29.98	-1.35
8	13,14	72.19	2.93	-1.19	68.07	29.98	0.00	-0.36	29.62	-1.20
9	15,16	68.07	0.00	-1.61	66.46	29.62	4.00	-0.27	25.34	-1.07
10	17	66.46	0.00	-1.85	64.61	25.34	0.00	-0.31	25.03	-1.24
11	18,19,20	64.61	0.00	-1.00	63.61	25.03	0.00	-0.31	24.72	-1.23
12	21,22	65.28	0.00	3.23	68.51	24.72	0.00	-0.21	24.51	-0.85
13	23,24	68.51	0.00	6.77	75.28	24.51	0.00	-0.38	24.13	-1.55
14	None	75.87	0.00	0.00	75.87	24.13	0.00	-0.32	23.81	-1.32

NOTE: (A) Transmountain inflow to subreach 3 adjusted by amount of Ft. Carson transmtn return flow.
* Percent transit loss based on loss/gain to subreach after SECWCD exchange diversion subtraction.

Table 3. Example output from the Fountain Creek transit-loss accounting program after the 1991–92 changes—Continued

```
                         EXCHANGE SUMMARY
         RELEASE DATE = 07-21-94  EXCHANGE DATE = 07-22-94

CCS RELEASE
==============

NATIVE                 15.00
TRANSMOUNTAIN          35.00
     BAL ACCT           0.00
     SECWCD            10.15
     CCS TM            24.85
FT. CARSON              5.00
CCS SUPP TM             0.00


CCS EXCHANGEABLE INTO PUEBLO
==================================

SECWCD                10.15
CCSTM                 23.81

           * LOWEST GAGE FLOW
          ** GAGE ADJUSTMENT


SECWCD DELIVERIES
==================
SECWCD AT WWTF          10.15
SECWCD AVAILABLE
FOR DIVERSION            9.00
TRANSIT LOSS %         -11.34


CCS RELEASE W/O SECWCD EXCHANGE
================================

NATIVE                 15.00
TRANSMOUNTAIN          35.00
FT. CARSON              5.00
CCS SUPP TM             0.00
CCSTM EXC TO PUEBLO    30.12
TRANSIT LOSS %        -24.70


SECWCD EXCHANGE SAVINGS
========================
TRANSIT LOSS SAVINGS =  3.84

ADJUSTMENT TO BAL ACCT = .75(TRANSIT LOSS SAVINGS =  2.88 CFS =  5.71 AFPD

BAL ACCT DEDUCTION =  0.00 CFS =    0.00 AFPD DEDUCT FROM BAL ACCT
```

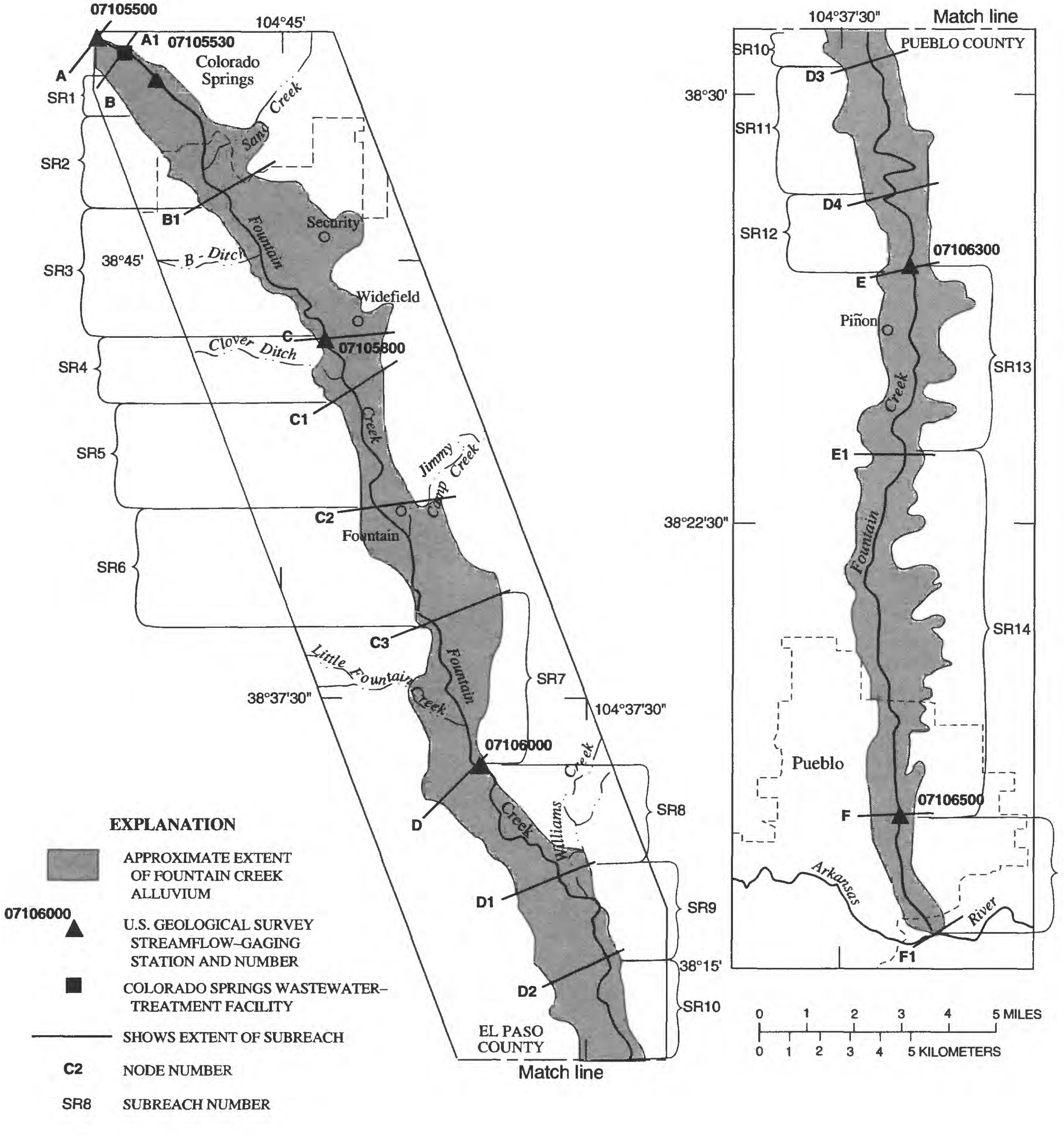

Figure 6. Subreaches, nodes, and streamflow-gaging stations along Fountain Creek used in the transit-loss accounting program after the 1994–95 changes.

essence, subreach 1 (SR1 in fig. 2 and in table 1) from the original hydrologic system was divided into two subreaches (SR1 and SR2 in fig. 6 and in table 4). The physical and hydraulic characteristics of the new subreaches (SR1 and SR2 in fig. 6) were derived by proportioning the characteristics (Kuhn, 1988, p. 14–20) of the original subreach (SR1 in fig. 2); the remaining subreaches and nodes also were renumbered (fig. 6 and table 4). Therefore, the transit-loss computations were identical to those for the original program, except for one additional stream-segment and one additional subreach computation (figs. 4 and 5). Including station 07105530 in the accounting program would improve calculation of transit losses because most of the NSF gains and losses that were prorated originally between stations 07105500 and 07105800 (nodes A and B in fig. 2) actually occur between stations 07105500 and 07105530 (nodes A and B in fig. 6).

Changes to Account for Transmountain Return Flows from the Fryingpan-Arkansas Project

In the stream/aquifer model (Land, 1977), computations can be made only for two streamflow entities; in the transit-loss study (Kuhn, 1988), the entities were TRF and NSF. In the accounting program, computations also can be made only for two streamflow entities. The changes to the accounting program that were needed to enable accounting of FAP TRF's required computations for three streamflow entities—CCS TRF, FAP TRF, and NSF. To enable accounting of the two TRF entities, the accounting program was changed to provide dual transit-loss computations—one set of computations would be for the CCS TRF's and one set of computations would be for the FAP TRF's. For each set of computations, all streamflow other than the TRF being considered (CCS or FAP) was assumed to be NSF. This method was agreed on by all the agencies involved in applying the accounting program (Gerhard Kuhn, U.S. Geological Survey, written commun., 1995).

The modularization of the program during the 1991–92 changes greatly facilitated implementing the changes needed to account for the CCS and the FAP TRF's. In the 1991–92 program changes, the actual transit-loss computations [the stream-segment and subreach computations (figs. 4 and 5)] for the CCS TRF's were contained in a primary subroutine that used five additional subroutines for the various components of the transit-loss computations. The primary subroutine that computed the transit losses for the CCS TRF's was duplicated to compute transit losses for the FAP TRF's. These changes, and other changes required during the 1994–95 revisions, resulted in additional modularization of the accounting program; several subroutines for obsolete or unused functions also were removed from the program. When completed, the changes made during 1994–95 resulted in a program with 30 subroutines. In the revised program, the primary transit-loss subroutines, one for the CCS TRF's and one for the FAP TRF's, used seven additional subroutines for the various components of the transit-loss computations.

To enable accounting of the FAP TRF diversions, the same methods that were implemented in the 1991–92 changes to account for the exchangeable CCS TRF diversions (see the "Changes to Account for Diversion of Transmountain Return Flows" section, p. 15–16) were used to account for the FAP TRF diversions.

Changes to Account for Additional Diversions of Transmountain Return Flows from Colorado Springs

The changes made to the accounting program during 1991–92 enabled accounting of the CCS TRF diversions that were exchanged for equivalent quantities of FAP water stored in Pueblo Reservoir. For the 1994–95 changes, the CCS wanted to enable accounting of an additional category of TRF diversion that would not be exchanged. To enable accounting of the nonexchangeable diversion category, the same methods that were implemented in the 1991–92 changes to account for the exchangeable diversion category (see the "Changes to Account for Diversion of Transmountain Return Flows" section, p. 15–16) were used to account for the nonexchangeable diversion category.

Changes to Program Output

The 1994–95 changes to the accounting program resulted in a program that would account for

Table 4. Subreaches and nodes along Fountain Creek used in the transit-loss accounting program after the 1994–95 changes

Subreach between two adjacent nodes (fig. 6)	Node number (fig. 6)	Node description	Diversions at node
	A	Gaging station 07105500 Fountain Creek at Colorado Springs	None
	A1	Fountain Creek at Colorado Springs wastewater-treatment facility	Fountain Mutual Canal; Laughlin Ditch
SR1			
	B	Gaging station 07105530 Fountain Creek at Janitell Road below Colorado Springs	None
SR2			
	B1	Fountain Creek at Stubbs and Miller Ditch	Stubbs and Miller Ditch
SR3			
	C	Gaging station 07105800 Fountain Creek at Security	None
SR4			
	C1	Fountain Creek at Chilcotte Ditch	Chilcotte Ditch; Crabb Ditch; Miller Ditch; Lock Ditch[1] North Liston and Love Ditch[1]
SR5			
	C2	Fountain Creek at Lock Ditch	None[1]
SR6			
	C3	Fountain Creek at Owen and Hall Ditch	Owen and Hall Ditch; South Liston and Love Ditch
SR7			
	D	Gaging station 07106000 Fountain Creek near Fountain	Tom Wanless Ditch; Talcott and Cotton Ditch
SR8			
	D1	Fountain Creek at Robinson Ditch	Robinson Ditch; Dr. Rogers Ditch
SR9			
	D2	Fountain Creek at Burke Ditch	Burke Ditch; Toof and Harmon Ditch
SR10			
	D3	Fountain Creek at Wood Valley Ditch	Wood Valley Ditch
SR11			
	D4	Fountain Creek at Sutherland Ditch	Bannister Ditch[2]; Sutherland Ditch; Lincoln Ditch
SR12			
	E	Gaging station 07106300 Fountain Creek near Piñon	McNeil Ditch; Caulfield Ditch; Olin Ditch
SR13			
	E1	Fountain Creek at Greenview Ditch	Greenview Ditch[3]
SR14			
	F	Gaging station 07106500 Fountain Creek at Pueblo	None
SR15			
	F1	Fountain Creek at the mouth	None

[1]Diversion points for the Lock Ditch and North Liston and Love Ditch, which were at node B2 (Kuhn, 1988, table 2), were moved to the diversion point for the Chilcotte Ditch after the transit-loss study was completed.

[2]The Bannister Ditch was added to the transit-loss accounting program in 1992.

[3]The Cactus Ditch (table 1) was removed from the transit-loss accounting program in 1992.

two TRF entities, three TRF diversion categories, NSF, and NSF diversions. To provide a descriptive printed output incorporating all the program changes, the program output was changed substantially, resulting in a four-page output (table 5). The first page of the revised output consists of:

1. A listing of all the TRF's (CCS and FAP) discharged into Fountain Creek at the CCS, Security, Widefield, and Fountain WWTF's; the TRF for Clover Ditch; and the native return flow at the CCS WWTF. [The TRF's from the Security, Widefield, and Fountain WWTF's currently (1997) are not used in the accounting program.]
2. The provisional daily mean discharge at the six gaging stations on Fountain Creek used in the accounting program, including the 24-hour period used in computing the discharge.
3. A listing of TRF diversion accounts for each of the diversions along Fountain Creek. This listing is an added output feature requested by the agencies that use the accounting program. To facilitate diversion of any of the three TRF categories, each ditch owner can purchase a given quantity of these TRF's at any time; this is the PURCHSD value in the output. Then, whenever the ditch owner wants to divert some TRF for irrigation, a request is made to the water commissioners, the diversion amount is input to the program for the appropriate days, and the accounting program computes the TRF purchase quantity needed at the CCS WWTF. For each day of TRF diversion, the TRF purchase quantity is added to the USED value in the output. The first set of values (FRY-ARK RETURN FLOWS) is for diversions of FAP TRF's; the second set of values (FRY-ARK 1ST USE EXCH) is for diversions of CCS TRF's that are exchanged for FAP water stored in Pueblo Reservoir; and the third set of values (CS REUSE WATER) is for diversions of CCS TRF's that are not exchanged. The diversion account quantities are in acre-feet, whereas most of the other output quantities are in cubic feet per second (CFS, table 5).

The second page of the revised output (table 5) lists for each ditch (1) the NSF diversion, (2) the TRF diversion for each TRF category, and (3) the TRF release for each TRF category. The TRF release quantity (RLEASE, table 5) is computed by the accounting program and is the same as the TRF purchase quantity described in the "Changes to Account for Diversion of Transmountain Return Flows" section (p. 15–16). The release quantity is converted to acre-feet and is summed into the USED account value on the first page of the revised output.

The third page of the revised output (table 5) first lists the FAP TRF and the CCS TRF subreach discharge quantities (top one-half of the page) and then lists the NSF subreach discharge quantities (bottom one-half of the page). For each of the three streamflow entities, the incoming discharge (INFLOW; NATIVE INFLOW), the diversion (DIVRSN; NATIVE DIVRSN), the transit gain or loss (GN/LS; NATIVE GN/LS), and the outgoing discharge (OUTFLOW; NATIVE OUTFLOW) are listed. The total inflow and outflow in each subreach are listed in the last two columns of the bottom one-half of the third output page.

On the third page of the revised output, the total inflow discharge for each subreach is the same as the total outflow discharge of the previous subreach, which also is true for the NSF inflow and outflow discharge quantities. The NSF inflow and the NSF outflow discharges were not the same for all subreaches in previous versions of the accounting program (tables 2 and 3) because of the required initial assumption that TRF at the downstream gaging station of a stream-segment is the same as at the upstream gaging station (see the "Assumptions Used in the Computations" section, p. 8). To correct this deficiency in the previous program versions, a repetitive capability was added to the computations of the current (1997) version of the program.

The repetitive capability consists of the following: (1) When computations are completed for all subreaches within a stream segment, the accounting program compares (a) the computed TRF at the end of the downstream subreach within the stream segment to (b) the initial TRF at the downstream gaging station of the stream segment, which was assumed to be equal to the TRF at the upstream gaging station (see the "Assumptions Used in the Computations" section, p. 8). (2) If there is more than a 1-percent difference between the two TRF quantities (a and b), the program repeats the stream-segment and the subreach computations for that stream segment; however, in the repeated stream-segment computations, the computed TRF (quantity a) is used to estimate NSF at the downstream gaging station (fig. 4, bottom box in COMPUTE UNKNOWN QUANTITY

Table 5. Example output from the Fountain Creek transit-loss accounting program after the 1994–95 changes

FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 03-21-1997 (Page 1/4)

TRANSMOUNTAIN AND NATIVE RETURN FLOWS, IN CFS

Colorado Springs transmountain return flow at CO.SPGS. WWTF:	36.35
Colorado Springs native return flow at CO.SPGS. WWTF:	10.22
Ft. Carson transmountain return flow via CLOVER DITCH:	1.55
Fry.-Ark. transmountain return flow at CO.SPRGS. WWTF:	0.81
Fry.-Ark. transmountain return flow at SECURITY WWTF:	0.00
Fry.-Ark. transmountain return flow at WIDEFIELD WWTF:	0.00
Fry.-Ark. transmountain return flow at FOUNTAIN WWTF:	0.00
Colorado Springs supplemental transmountain UPSTREAM RELEASE:	0.00

DAILY MEAN DISCHARGES AT THE GAGING STATIONS, IN CFS

NUMBER	NAME	24-HR TIME PERIOD FOR DISCHARGE	DISCHARGE
07105500	AT COLO. SPRINGS	03-21-1997-0000 to 03-21-1997-2400	28.00
07105530	AT JANITELL RD	03-21-1997-0200 to 03-22-1997-0200	95.00
07105800	AT SECURITY	03-21-1997-0400 to 03-22-1997-0400	103.00
07106000	NEAR FOUNTAIN	03-21-1997-1000 to 03-22-1997-1000	128.00
07106300	NEAR PINON	03-21-1997-1800 to 03-22-1997-1800	117.00
07106500	AT PUEBLO	03-22-1997-0000 to 03-22-1997-2400	133.00

PURCHASED AND USED TRANSMOUNTAIN RETURN FLOW ACCOUNTS, IN ACRE-FEET

		FRY-ARK RETURN FLOWS		FRY-ARK 1ST USE EXCH.		CS REUSE WATER	
	DITCH	PURCHSD	USED	PURCHSD	USED	PURCHSD	USED
1	FOUNTAIN MUTUAL	0.00	0.00	0.00	0.00	0.00	0.00
2	LAUGHLIN	0.00	0.00	0.00	0.00	0.00	0.00
3	STUBBS & MILLER	0.00	0.00	0.00	0.00	0.00	0.00
4	CHILCOTTE	0.00	0.00	0.00	0.00	0.00	0.00
5	CRABBE	0.00	0.00	0.00	0.00	0.00	0.00
6	MILLER	0.00	0.00	0.00	0.00	0.00	0.00
7	LOCK	0.00	0.00	0.00	0.00	0.00	0.00
8	LISTON & LOVE N	0.00	0.00	0.00	0.00	0.00	0.00
9	OWEN & HALL	0.00	0.00	0.00	0.00	0.00	0.00
10	LISTON & LOVE S	0.00	0.00	0.00	0.00	0.00	0.00
11	TOM WANLESS	0.00	0.00	0.00	0.00	0.00	0.00
12	TALCOTT & COTTON	0.00	0.00	0.00	0.00	0.00	0.00
13	ROBINSON	0.00	0.00	0.00	0.00	0.00	0.00
14	DR. ROGERS	0.00	0.00	0.00	0.00	0.00	0.00
15	BURKE	0.00	0.00	0.00	0.00	0.00	0.00
16	TOOF & HARMON	0.00	0.00	114.26	112.82	0.00	0.00
17	WOOD VALLEY	0.00	0.00	0.00	0.00	0.00	0.00
18	BANNISTER	0.00	0.00	0.00	0.00	0.00	0.00
19	SUTHERLAND	0.00	0.00	0.00	0.00	0.00	0.00
20	LINCOLN	0.00	0.00	0.00	0.00	0.00	0.00
21	MCNEIL	0.00	0.00	0.00	0.00	0.00	0.00
22	CAULFIELD	0.00	0.00	0.00	0.00	0.00	0.00
23	OLIN	0.00	0.00	0.00	0.00	0.00	0.00
24	GREENVIEW	0.00	0.00	0.00	0.00	0.00	0.00

Table 5. Example output from the Fountain Creek transit-loss accounting program after the 1994–95 changes—Continued

FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 03-21-1997 (Page 2/4)

NATIVE & TRANSMOUNTAIN DIVERSIONS, AND CALCULATED TRANSMTN RELEASES*, IN CFS

			FRY-ARK RETURN FLOWS		FRY-ARK 1ST USE EXCH.		CS REUSE WATER	
	DITCH	NATIVE DIVRSN	DIVRSN	RLEASE*	DIVRSN	RLEASE*	DIVRSN	RLEASE*
1	FOUNTAIN MUTUAL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	LAUGHLIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	STUBBS & MILLER	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	CHILCOTTE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	CRABBE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	MILLER	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	LOCK	0.00	0.00	0.00	0.00	0.00	0.00	0.00
8	LISTON & LOVE N	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	OWEN & HALL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
10	LISTON & LOVE S	0.00	0.00	0.00	0.00	0.00	0.00	0.00
11	TOM WANLESS	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	TALCOTT & COTTON	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	ROBINSON	0.00	0.00	0.00	0.00	0.00	0.00	0.00
14	DR. ROGERS	4.52	0.00	0.00	0.00	0.00	0.00	0.00
15	BURKE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
16	TOOF & HARMON	0.00	0.00	0.00	2.59	2.42_B	0.00	0.00
17	WOOD VALLEY	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	BANNISTER	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	SUTHERLAND	0.00	0.00	0.00	0.00	0.00	0.00	0.00
20	LINCOLN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	MCNEIL	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	CAULFIELD	0.00	0.00	0.00	0.00	0.00	0.00	0.00
23	OLIN	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	GREENVIEW	0.47	0.00	0.00	0.00	0.00	0.00	0.00

NOTES: * Transmountain releases calculated in transit loss program.
_B Exchange release accountable to balancing account.

Table 5. Example output from the Fountain Creek transit-loss accounting program after the 1994–95 changes--Continued

FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 03-21-1997 (Page 3/4)

COMPUTATIONS OF TRANSMOUNTAIN FLOWS, IN CFS

SUB-REACH	DITCHES IN SUBREACH	FRY-ARK TRANSMOUNTAIN... INFLOW	DIVRSN	GN/LS	OUTFLW	CO.SPGS TRANSMOUNTAIN... INFLOW	DIVRSN*	GN/LS	OUTFLW
1	1,2	0.81	0.00	-0.01	0.80	36.35	0.00	0.48	36.83
2	None	0.80	0.00	-0.01	0.79	36.83	0.00	0.42	37.25
3	3	0.79_S	0.00	-0.01	0.78	37.25	0.00	0.35	37.60
4	None	0.78_W	0.00	0.00	0.78	39.15_C	0.00	0.38	39.53
5	4,5,6,7,8	0.78	0.00	0.00	0.78	39.53	0.00	0.27	39.80
6	None	0.78_F	0.00	0.00	0.78	39.80	0.00	0.27	40.06
7	9,10	0.78	0.00	0.00	0.78	40.06	0.00	0.19	40.25
8	11,12	0.78	0.00	0.00	0.79	40.25	0.00	0.18	40.43
9	13,14	0.79	0.00	0.01	0.79	40.43	0.00	0.14	40.57
10	15,16	0.79	0.00	0.00	0.80	40.57	2.59	0.05	38.03
11	17	0.80	0.00	0.00	0.80	38.03	0.00	0.03	38.06
12	18,19,20	0.80	0.00	0.01	0.81	38.06	0.00	0.09	38.15
13	21,22	0.81	0.00	0.01	0.81	38.15	0.00	0.01	38.16
14	23,24	0.81	0.00	0.01	0.82	38.16	0.00	-0.09	38.07
15	None	0.82	0.00	0.01	0.83	38.07	0.00	0.01	38.07

NOTES: * Diversion is sum of SE EXCHANGE and CO.SPGS RE-USABLE diversions.
_S Transmntn. inflow adjusted 0.00 cfs for SECURITY FRY-ARK return flow.
_W Transmntn. inflow adjusted 0.00 cfs for WIDEFIELD FRY-ARK ret. flow.
_F Transmntn. inflow adjusted 0.00 cfs for FOUNTAIN FRY-ARK ret. flow.
_C Transmntn. inflow adjusted 1.55 cfs for FT.CARSON (Clover D.) ret. flow.

COMPUTATIONS OF NATIVE FLOWS, IN CFS

SUB-REACH	DITCHES IN SUBREACH	NATIVE INFLOW	NATIVE DIVRSN	NATIVE GN/LS	NATIVE OUTFLOW	TOTAL INFLOW*	TOTAL OUTFLOW*
1	1,2	35.66	0.00	21.71	57.37	72.82	95.00
2	None	57.37	0.00	2.52	59.90	95.00	97.93
3	3	59.90	0.00	4.73	64.63	97.93	103.00
4	None	64.63	0.00	2.53	67.15	103.00	107.46
5	4,5,6,7,8	67.15	0.00	6.61	73.76	107.46	114.33
6	None	73.76	0.00	5.63	79.39	114.33	120.23
7	9,10	79.39	0.00	7.58	86.97	120.23	128.00
8	11,12	86.97	0.00	-0.89	86.08	128.00	127.29
9	13,14	86.08	4.52	-0.74	80.82	127.29	122.18
10	15,16	80.82	0.00	-1.00	79.82	122.18	118.64
11	17	79.82	0.00	-1.15	78.66	118.64	117.52
12	18,19,20	78.66	0.00	-0.62	78.04	117.52	117.00
13	21,22	78.04	0.00	5.34	83.38	117.00	122.35
14	23,24	83.38	0.47	11.20	94.11	122.35	133.00
15	None	94.11	0.00	0.00	94.11	133.00	133.01

NOTES: * Totals are sum of FRY-ARK & CO.SPGS TRANSMOUNTAIN and NATIVE flows, including adjustments.

Table 5. Example output from the Fountain Creek transit-loss accounting program after the 1994–95 changes--Continued

```
FOUNTAIN CREEK TRANSIT LOSS COMPUTATIONS FOR RELEASE DATE: 03-21-1997 (Page 4/4)

                          EXCHANGE SUMMARY
       RELEASE DATE = 03-21-1997  EXCHANGE DATE = 03-22-1997


       CCS RELEASE
-------------------------------
NATIVE                    10.22
TRANSMOUNTAIN             36.35
  BAL ACCT                 0.00
  SECWCD                   2.42
  CCS TM                  33.93
FT. CARSON                 1.55
CCS SUPP TM                0.00
===============================


 CCS EXCHANGEABLE INTO PUEBLO
-------------------------------
SECWCD                     2.42
CCSTM                     38.07
===============================
 * LOWEST GAGE FLOW
** GAGE ADJUSTMENT


      SECWCD DELIVERIES
-------------------------------
SECWCD AT WWTF             2.42
SECWCD AVAILABLE
  FOR DIVERSION            2.59
TRANSIT LOSS %             7.19
===============================


CCS RELEASE W/O SECWCD EXCHANGE
-------------------------------
NATIVE                    10.22
TRANSMOUNTAIN             36.35
FT. CARSON                 1.55
CCS SUPP TM                0.00
CCSTM EXC TO PUEBLO       40.41
TRANSIT LOSS %             6.62
===============================


    SECWCD EXCHANGE SAVINGS
--------------------------------
TRANSIT LOSS SAVINGS = 0.08 CFS
================================

ADJUSTMENT TO BAL ACCT = .75(TRANSIT LOSS SAVINGS = 0.06 CFS = 0.12 AFPD)
BAL ACCT DEDUCTION =  0.00 CFS =   0.00 AFPD DEDUCT FROM BAL ACCT

COMMENTS TO TRANSIT LOSS COMPUTATIONS FOR THIS DATE:

  NONE
```

steps), rather than the TRF based on the initial assumption (quantity b). (3) The program continues to repeat the stream-segment and subreach computations until there is less than a 1-percent difference (convergence) between the newly computed TRF at the end of the downstream subreach within the stream segment and the previously computed TRF, which is used to initiate each of the repeated stream-segment computations.

The fourth page of the revised output (table 5) is similar to the second page of the output developed as part of the 1991–92 program changes (table 3). The quantities listed are used by the CCS and the water commissioners in the administration of the TRF use and reuse program.

TRANSIT-LOSS ACCOUNTING PROGRAM FILES

Before the operation of the current (1997) version of the accounting program can be described, information about the input and output files used by the program is needed. The accounting program resides on the USGS computer system that contains the streamflow data base; a master directory named **transit_loss** (fig. 7) has been established on the computer for the program users. The master directory consists of a three-level system of subordinate directories and files; the contents of the **nexttrloss, trloss,** and **meanday** directories and most files are described in the following sections. There also may be other directories and files in the **transit_loss** master directory, but they are not described in this report. The **transit_loss** master directory contains the following files (fig. 7):

daily.mean—contains the daily mean discharges at the six gaging stations used in the accounting program (see the "Streamflow-Gaging Station Network on Fountain Creek" section, p. 12–14).

revised.mean—contains the revised daily mean discharges at the six gaging stations used in the accounting program (see "Streamflow-Gaging Station Network on Fountain Creek" section, p. 12–14).

trl.cpl—contains the computer script code that, when executed, attaches to the **nexttrloss** directory and initiates the accounting program.

Contents of the Nexttrloss Directory

The **nexttrloss** directory (fig. 7) contains all the files that are either read from for input, written to for output, or both. Files and their contents that must exist prior to running the accounting program include:

acct.fil—contains data regarding the purchased and used TRF diversion quantities for each ditch. The file may be rewritten during a program run depending on the program option.

back1.fil—contains the data necessary to rerun the accounting program for the last day of computation. The file contains the contents of the *cmp_recov.fil, cs_recov.fil, divers.fil,* and *fa_recov.fil* files for the last computation; *back1.fil* is read and rewritten during each program run.

back2.fil—contains the data necessary to rerun the accounting program for the day prior to the last day of computation. The file contains the contents of the *cmp_recov.fil, cs_recov.fil, divers.fil,* and *fa_recov.fil* files for the day prior to the last computation; *back2.fil* is read and rewritten during each program run.

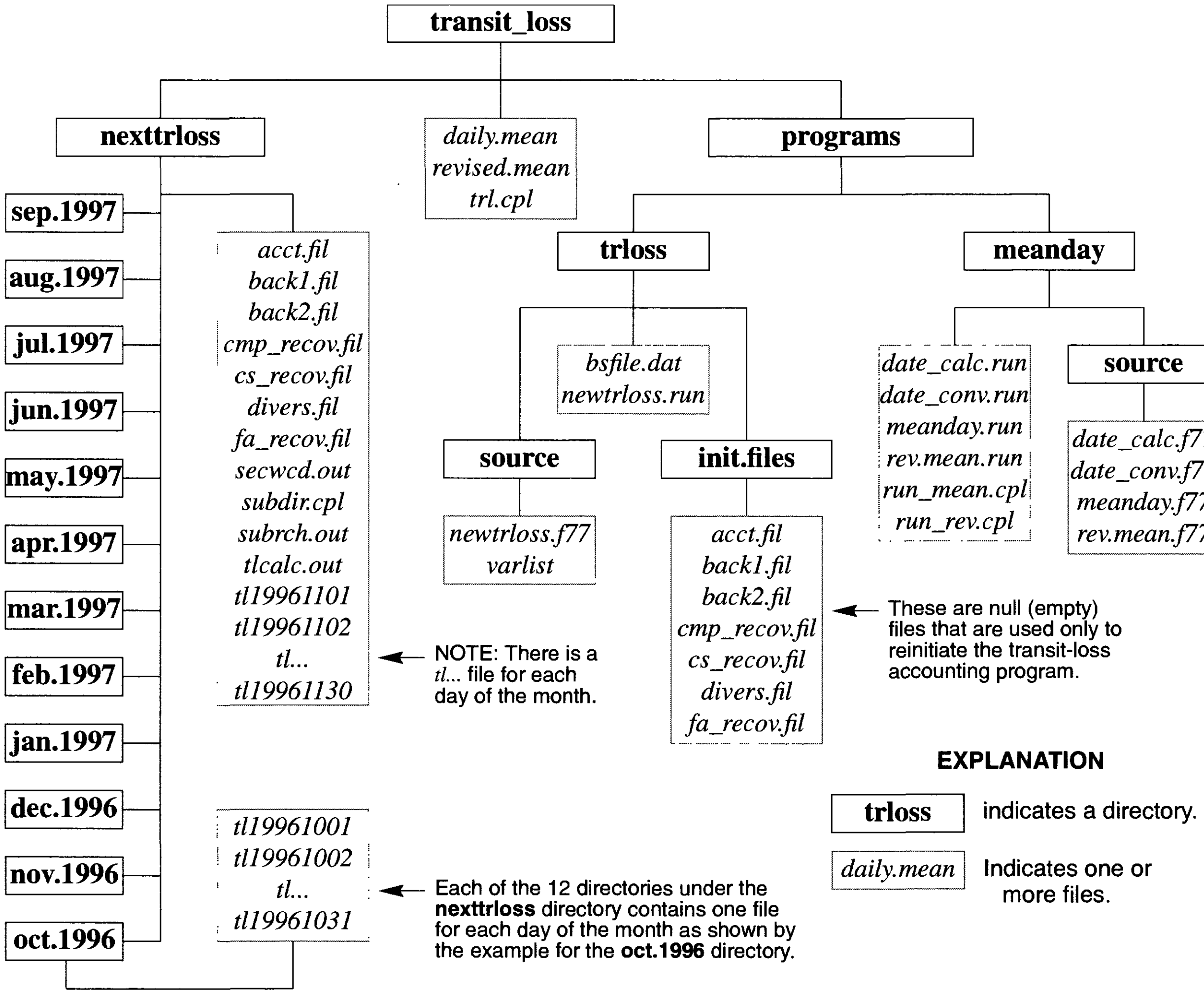

Figure 7. Directory and file structure of the **transit_loss** master directory.

cmp_recov.fil—contains a 60-day accounting of bank-storage and a 2-day accounting of channel-storage transit losses and gains (by subreach) for a comparison calculation. The file is read and rewritten during each program run.

cs_recov.fil—contains a 60-day accounting of bank-storage and a 2-day accounting of channel-storage transit losses and gains (by subreach) for the CCS TRF's. The file is read and rewritten during each program run.

divers.fil—contains the date, discharge, and diversion data input during the last program run. The file is read and rewritten during each program run.

fa_recov.fil—contains a 60-day accounting of bank-storage and a 2-day accounting of channel-storage transit losses and gains (by subreach) for the FAP TRF's. The file is read and rewritten during each program run.

secwcd.out—contains output data for diversion of the CCS TRF's that are exchanged for FAP water stored in Pueblo Reservoir. Output for each program run is appended to the file, which is used by the CCS water administration personnel.

subdir.cpl—contains the computer script code to create the monthly directories and to copy the daily output files for a given month to the appropriate directory. (This file is not required for a program run; see the "Procedures to Archive Current Output Files" section, p. 35–36)

subrch.out—contains subreach output of NSF and TRF discharge quantities for each day. Output for each program run is appended to the file, which is used by the CCS water administration personnel.

tlcalc.out—contains the subreach bank-storage and channel-storage gains/losses and the evaporation losses for the CCS TRF's and the FAP TRF's. Output for each program run is appended to the file.

In addition, a file is created in the **nexttrloss** directory for each day of transit-loss computations; each file is named by the accounting program using the form *tlyyyymmdd* (fig. 7) where

tl=acronym for transit loss,
yyyy=four-digit year,
mm=two-digit month, and
dd=two-digit day.

The **nexttrloss** directory also contains 12 subordinate directories with a name using the form **mmm.yyyy** (fig. 7) where

mmm=three character abbreviation for month of the water year (oct, nov, dec, jan, feb, mar, apr, may, jun, jul, aug, and sep) and
yyyy=four-digit year.

Each monthly directory contains all of the daily output files (fig. 7) for the appropriate month; the daily output files for a month are moved from the **nexttrloss** directory to the monthly directories by an automated procedure (see the "Procedures to Archive Current Output Files" section, p. 35–36). The 12 monthly directories are defined on a water-year (October-September) basis.

Contents of the Trloss Directory

The **trloss** directory (fig. 7), which contains the source code and the executable files for the accounting program, consists of the following directories and files:

init.files—directory containing copies of the accounting program input files (see the "Contents of the **Nexttrloss** Directory", p. 27–29); these files are null files (do not contain any data) and are used only to reinitiate the accounting program. The files in the **init.files** directory are not used in the day-to-day program operation; only the files in the **nexttrloss** directory are used for that.

source—directory containing the FORTRAN source-code file (*newtrloss.f77*) for the accounting program and a file (*varlist*) listing of all the variable names used in the accounting program.

bsfile.dat—file containing the subreach data for the bank-storage component of transit loss for selected TRF and NSF discharges; the data were derived in the transit-loss study (Kuhn, 1988, tables 12–26). The file is read once at program start and the content is never changed.

newtrloss.run—file containing the executable accounting program.

Contents of the Meanday Directory

The **meanday** directory (fig. 7), which contains the source code and the executable files for the programs used in computing the daily discharge data, consists of the following directories and files:

source—directory containing the FORTRAN source-code files (*date_calc.f77, date_conv.f77, meanday.f77*, and *rev.mean.f77*) for the four executable program files that are used in computing the daily mean discharges and that are described in the next listings.

date_calc.run—file containing the executable code for a program (*date_calc.f77*) that calculates the dates for which a computation of daily mean discharge is to made by using either the *meanday.run* or *rev.mean.run* executable files.

date_conv.run—file containing the executable code for a program (*date_conv.f77*) that converts a date to a suitable output format.

meanday.run—file containing the executable code for a program (*meanday.f77*) that computes the daily mean discharges at the gaging stations for the appropriate 24-hour period (fig. 3).

rev.mean.run—file containing the executable code for a program (*rev.mean.f77*) that computes the daily mean discharges at the gaging stations for the appropriate 24-hour period (fig. 3) when there has been a change in the shift data

run_mean.cpl—file containing the computer script code used to (1) retrieve the 15-minute interval discharge data from the streamflow data base, (2) invoke the programs use to calculate and reform dates, (3) invoke the program used to compute daily mean discharges from the 15-minute data, and (4) write the daily mean discharge data to an output file.

run_rev.cpl—file containing the computer script code having the same functions as the *run_mean.cpl* file just described, except that the *run_rev.cpl* script code is used when there has been a change in the shift data for a previous daily mean discharge computation.

USER MANUAL FOR THE CURRENT (1997) VERSION OF THE TRANSIT-LOSS ACCOUNTING PROGRAM

The current (1997) version of the accounting program certainly is more complex than the original program described in the first part of this report; understanding the current version depends, in part, on an understanding of (1) the original accounting program, including figures 4 and 5; (2) the description of the two sets of program changes; and (3) the various input and output files used by the program. This section contributes to the understanding of the current version of the program by presenting descriptions of (1) the program options, (2) the data input and some internal data checks, and (3) additional discussion of the computational procedures to indicate where and how the 1991–92 and the 1994–95 program changes fit in the basic computational procedures (figs. 4 and 5).

Program Options

The first operation of the accounting program is to load into memory the data in the *bsfile.dat* file (see the "Contents of the **Trloss** Directory" section, p. 29); these data are used later in the subreach computations. Once this operation is completed, the program displays the available program options:

```
PROGRAM OPTIONS ARE:
-------------------------------------
1. Compute transit loss for a day in
   interactive mode.
2. Analyze diversion alternatives for
   current day.
3. Recompute transit loss for
   prior day.
4. View/update account tables.
5. Exit.

ENTER SELECTED OPTION:
```

The user selects one of the options, which (except option 5) are described briefly in the following sections.

Option 1

Option 1 is used in the day-to-day computations of transit-loss and TRF accounting; this option also is used to recompute the transit losses for the last computation date. The operational steps for option 1 are:

1. The program opens all the input files [see the "Contents of the **Nexttrloss** Directory" section (p. 27–29) for file descriptions] and reads the date and input data for the last transit-loss computation from the *divers.fil* file.
2. The program displays the date of the last computation and queries the user whether or not to continue.
3. If the choice is to continue, the program queries the user to input the next computation date; if the choice is not to continue, the program returns to the program options.
4. The program checks the input date to ensure that it is correct.
5. If the input date from step 3 is incorrect, the program returns to step 2 of this option.
6. If the input date is 1 day greater than the last computation date, the program (a) creates the daily output file (*tlyyyymmdd*) and opens it for writing; (b) writes the *back1.fil* file to the *back2.fil* file; (c) selectively writes the *cmp_recov.fil, cs_recov.fil, divers.fil*, and *fa_recov.fil* files to the *back1.fil* file; and (d) proceeds to the data input.
7. If the input date is the same as the last computation date, the program displays:

```
YOU HAVE THREE CHOICES:
-----------------------------------------
1. Recompute losses for that day.
2. Select another day.
3. Return to program start.

ENTER YOUR CHOICE (1,2, OR 3):
```

8. If choice 1 is selected, the program (a) reads the *back1.fil* file to reset the last computation date; (b) creates the daily output file (*tlyyyymmdd*) and opens it for writing; (c) if an output file already exists for the computation date, queries the user for permission to overwrite the existing file; (d) selectively writes the *back1.fil* file to the *cmp_recov.fil, cs_recov.fil, divers.fil,* and *fa_recov.fil* files to reestablish the accounting conditions prior to the last computation; and (e) proceeds to the data input.
9. If choice 2 is selected, the program queries the user to input a new date and returns to step 4 of this option.

Option 2

Option 2 is used to analyze different NSF diversion alternatives; usually, this analysis would be made for the current day, just after running the accounting program for the previous day. The required input data for the current day are not available yet because of the approximate 2-day lag in transit-loss computations (see the "Input Data Requirements" section, p. 6–7); therefore, it is assumed that the data from the previous day are used for input, except that alternative NSF diversion quantities could be specified. The operational steps for option 2 are:

1. The program opens all the input files (see the "Contents of the **Nexttrloss** Directory" section (p. 27–29) for file descriptions) and reads the date and input data for the last transit-loss computation from the *divers.fil* file.
2. The program displays the date of the last computation and queries the user whether or not to continue.
3. If the choice is to continue, the program (a) queries the user to input a name for the daily output file and opens it for writing; (b) increments the last computation date by one for use in the daily output file; and (c) proceeds to data input. None of the accounting-program input and output files, except the daily output file, are rewritten using option 2.
4. If the choice is not to continue, the program returns to the program options.

Option 3

Option 3 is used to recompute the transit losses for the day prior to the day of the last computation. When option 3 is used, the accounting program also needs to be reapplied to the last day of computations, even if there was no change in the input data for that date. The operational steps for option 3 are:

1. The program opens all the input files [see the "Contents of the **Nexttrloss** Directory" section (p. 27–29) for file descriptions] and reads the date and input data for the last transit-loss computation from the *divers.fil* file.
2. The program displays the date of the last computation and queries the user whether or not to continue.
3. If the choice is to continue, the program (a) reads the *back2.fil* file to reset the last computation date; (b) creates the daily output file (*tlyyyymmdd*) and opens it for writing; (c) if an output file already exists for the computation date, queries the user for permission to overwrite the existing file; (d) selectively writes the *back2.fil* file to the *cmp_recov.fil, cs_recov.fil, divers.fil,* and *fa_recov.fil* files to reestablish the accounting conditions for the day prior to the last computation; and (e) proceeds to the data input.
4. If the choice is not to continue, the program returns to the program options.

Option 4

Option 4 is used to view or update the PURCHASED and USED accounts data for each ditch and each TRF diversion category (FAP TRF diversions, CCS TRF diversions that are exchanged, and CCS TRF diversions that are not exchanged); the data displayed are the same as those listed on the first page of the daily output files (table 5), but in a different format. The operational steps for option 4 are:

1. The program opens the *acct.fil* file [see the "Contents of the **Nexttrloss** Directory" section (p. 27–29) for file descriptions] and reads the TRF diversion accounts data for the last transit-loss computation
2. The program lists the accounts data for each type of TRF diversion and queries the user for any changes (first for the PURCHASED accounts and then for the USED accounts), as shown in the display at the bottom of this page.
3. If the response to the display query is yes, the program displays additional queries to input (a) the total number of ditch accounts to change and (b) the ditch numbers for which the accounts data are to be changed. The program then queries the user to input the amount, in acre-feet, to be added or subtracted to each PURCHASED account. When the inputs are completed, the program returns to step 2 of this option so the user can check the updated account values and make additional changes if needed.
4. If the response to the display query is no, the program repeats the display in step 2, and the change queries described in step 3 are repeated; however, the queries, the input data, and the account updates apply to the USED account values.
5. When the user has completed the changes to both the PURCHASED and USED account values for the TRF diversion category indicated in the

TOTAL FRY-ARK WATER PURCHASED BY DITCH, IN ACRE-FEET

		PURCHASED	USED			PURCHASED	USED
1.	FOUNTAIN MUTUAL	0.00	0.00	13.	ROBINSON	0.00	0.00
2.	LAUGHLIN	0.00	0.00	14.	DR. ROGERS	0.00	0.00
3.	STUBBS & MILLER	100.00	33.87	15.	BURKE	150.00	55.62
4.	CHILCOTTE	0.00	0.00	16.	TOOF & HARMON	0.00	0.00
5.	CRABBE	0.00	0.00	17.	WOOD VALLEY	0.00	0.00
6.	MILLER	0.00	0.00	18.	BANNISTER	0.00	0.00
7.	LOCK	0.00	0.00	19.	SUTHERLAND	0.00	0.00
8.	LISTON & LOVE N	0.00	0.00	20.	LINCOLN	0.00	0.00
9.	OWEN & HALL	0.00	0.00	21.	MCNEIL	0.00	0.00
10.	LISTON & LOVE S	0.00	0.00	22.	CAULFIELD	0.00	0.00
11.	TOM WANLESS	0.00	0.00	23.	OLIN	0.00	0.00
12.	TALCOTT & COTTON	300.00	19.93	24.	GREENVIEW	0.00	0.00

Would you like to ADD/SUB to the "PURCHASED" amounts
for any of these DITCHES? (Y/N):

display, the program repeats steps 2–4 for each additional TRF diversion category (table 5).

6. When the account changes for all TRF diversion categories are completed, the program writes the updated account values to the *acct.fil* file and then returns to the program options.

Data Input

Data input has three major components: input of the TRF and native return-flow discharge data, input of the gaging-station discharge data, and input of the NSF and TRF diversion data. These data are compiled daily from various sources by the water commissioners prior to using the accounting program for a transit-loss computation. The program operation relating to the data input is described briefly in the following sections.

Return-Flow Discharge Data

To input the TRF and native return flow, the program uses a simple display to query the user for each return-flow quantity: (1) The TRF at the CCS WWTF, (2) the native return flow at the CCS WWTF, (3) the Fort Carson TRF, (4) the FAP TRF at the CCS WWTF, and (5) any supplemental TRF released upstream from the CCS WWTF. The program then displays all the return-flow data that were input and queries the user if the data are correct. If the response is no, then the program repeats the return-flow discharge data input; if the response is yes, then the program proceeds to the input of the gaging-station discharge data.

In the current (1997) version of the accounting program, the user is not queried to input TRF data for the Fountain, Security, and Widefield WWTF's because these data are not yet available. Therefore, the program sets the TRF discharges for these three WWTF's to zero; these sites, however, are included in the display of the input data and in the daily output files (table 5).

Streamflow-Gaging Station Discharge Data

The input of the gaging-station discharge data is very similar to the input of the return-flow discharge data. The program queries the user to input the daily mean discharge at each gaging station (fig. 3), displays all the input data for error checking, and repeats the data input if any errors were made. When the input data are correct, the program proceeds to the input of the diversion discharge data.

Diversion Discharge Data

Diversion discharge data can be input for NSF diversions and for three categories of TRF diversions. Input of the diversion data is similar to the program steps described in the "Option 4" section for updating the diversion accounts data. Input of the diversion discharge data begins with the NSF diversions; the program lists the diversion data from the last computation date, as shown in the display at the bottom of this page.

If the response to the display query is yes, the program operation is like step 3 of the "Option 4" section (p. 32); the program (1) queries the user for the total number of diversions to change, (2) queries the

```
==========================================================================
              NATIVE FLOW DIVERSIONS, IN CFS, RECORDED: 05-09-1997
--------------------------------------------------------------------------
  1. FOUNTAIN MUTUAL              0.00  I 13. ROBINSON                 0.00
  2. LAUGHLIN                     0.00  I 14. DR. ROGERS               0.00
  3. STUBBS & MILLER             33.87  I 15. BURKE                   55.62
  4. CHILCOTTE                    0.00  I 16. TOOF & HARMON            0.00
  5. CRABBE                       0.00  I 17. WOOD VALLEY              0.00
  6. MILLER                       0.00  I 18. BANNISTER                0.00
  7. LOCK                         0.00  I 19. SUTHERLAND               0.00
  8. LISTON & LOVE N              0.00  I 20. LINCOLN                  0.00
  9. OWEN & HALL                  0.00  I 21. MCNEIL                   0.00
 10. LISTON & LOVE S              0.00  I 22. CAULFIELD                0.00
 11. TOM WANLESS                  0.00  I 23. OLIN                     0.00
 12. TALCOTT & COTTON            19.93  I 24. GREENVIEW                0.00
==========================================================================

Would you like to change the values for any
of these NATIVE FLOW diversions? (Y/N):
```

user for the ditch numbers for which the diversion data are to be changed, (3) queries the user to input each new diversion quantity, and (4) repeats the display of the diversion data for error checking and additional changes. If the response is no, the program proceeds to the input of the TRF diversion discharge data.

The data input steps for each of the three TRF diversion categories (FAP TRF diversions, CCS TRF diversions that are exchanged, and CCS TRF diversions that are not exchanged) are identical. For each category, the program first queries the user if there are any TRF diversions for that particular category. If the response is yes, the program repeats the previous display of the NSF diversion table, but lists data for the appropriate TRF diversions from the last computation date. Changes to the TRF diversions are made in the same way as changes were made for the NSF diversions; when all the diversion data for a TRF category are correct, the program proceeds to the next category. If the response to the "any TRF diversions?" query is no for any TRF category, the program defines that TRF diversion at each ditch as zero and proceeds to the next TRF diversion category.

For each TRF diversion in each TRF diversion category, the accounting program makes three internal checks on the data. The first check is that the account balance for a ditch must be greater than zero before a TRF diversion can be specified. The account balance is computed by the program as the difference between the PURCHSD and the USED account values (table 5); the program also converts the balance to cubic feet per second. If the account balance is less than or equal to zero, the program only allows a TRF diversion of zero for that ditch. The second check is that the TRF diversion specified for a ditch may not be larger than the TRF account balance for that ditch. If the TRF diversion is larger than the account balance, the program defines the TRF diversion as zero, but the user can specify another TRF diversion quantity that is less than or equal to the account balance for that ditch.

The third check is that the sum of all TRF diversions in each TRF diversion category may not exceed the TRF release quantities that are input. For this check, however, the TRF release quantity is assumed to be 20 percent less than the actual release quantity. This assumption is used because the computed purchase quantity for each TRF diversion (see the "Changes to Account for Diversion of Transmountain Return Flows" section, p. 15–16) usually is larger than the specified diversion. Without this assumption, specifying a total TRF diversion quantity (for each TRF diversion category) that is equal to the TRF release quantity specified on input would be possible; in this case, because of (1) transit loss as the TRF moves downstream and (2) the TRF diversions, the TRF could be less than or equal to zero in the transit-loss computations. If the FAP TRF or the CCS TRF quantity is less than or equal to zero at any node in the computations, the program prints an error message, stops all computations, and returns to the program options. Use of the 20-percent reduction assumption decreases the likelihood of a program stop because the total of the specified TRF diversions always is less than the TRF release quantities specified on input.

In the third check just described, the accounting program defines the following TRF release quantities for each TRF diversion category: (1) For the FAP TRF diversions, the TRF release quantity is equal to the FAP release quantity at the CCS WWTF plus the FAP release quantities at the Security, Widefield, and Fountain WWTF's, when release data becomes available for these three WWTF's (see the "Return-Flow Discharge Data" section, p. 33); (2) for the CCS TRF diversions that are exchanged, the TRF release quantity is equal to the CCS TRF release quantity at the CCS WWTF plus the Fort Carson TRF; and (3) for the CCS TRF diversions that are not exchanged, the TRF release quantity is equal to the CCS TRF release-quantity sum computed in item 2, minus the sum of the CCS TRF diversions (in item 2) that are exchanged.

When input of all NSF and TRF diversion discharge data is completed, the accounting program sums the NSF and TRF diversions in each category by stream segment and by subreach for use in the stream-segment and subreach computations (figs. 4 and 5). After summing the diversion discharge data, the program writes all of the newly input TRF and native return-flow discharge data, gaging-station discharge data, and NSF and TRF diversion discharge data to the *divers.fil* file, and then proceeds to the transit-loss computations.

Transit-Loss Computations

Following the 1994–95 program changes, transit-loss computations were made by the accounting program for two TRF entities—the FAP and the CCS TRF's. The computations made for each TRF entity are identical to the computations in the original accounting program (figs. 4 and 5), except for

(1) adding TRF's at locations other than the CCS WWTF, (2) subtracting TRF's for diversion, (3) repeating the computations until the assumed and computed downstream TRF's have converged (see the "Changes to Program Output" section, p. 22), and (4) performing the upstream calculation to determine the TRF purchase quantity for any specified TRF diversion (see the "Changes to Account for Diversion of Transmountain Return Flows" section, p. 15–16). These exceptions have been briefly explained in the preceding sections of this report. In the current (1997) version of the accounting program, transit-loss computations are made first for the FAP TRF's, then computations are made for the CCS TRF's, and lastly the comparison computation is made (see the "Changes to Program Output" section, p. 16).

The transit-loss computation steps for the FAP TRF's and the CCS TRF's, which are made independently for each entity, basically consist of: (1) Completing the stream-segment computations (fig. 4) for each stream segment, but including any appropriate additional TRF sources and any TRF diversions; (2) completing the subreach computations (fig. 5) for each subreach (fig. 6, table 4) within the stream segment, again including any appropriate TRF sources and any TRF diversions; (3) repeating each set of stream-segment and subreach computations until the assumed downstream TRF has converged with the computed downstream TRF; (4) after convergence, performing the upstream calculation for each specified TRF diversion in each subreach to compute the TRF purchase quantity required for each TRF diversion; and (5) updating the TRF diversion USED accounts data with the computed TRF purchase quantities.

When the transit-loss computations are completed for the FAP TRF's, the program writes the resulting bank-storage and channel-storage loss and gain results to the *fa_recov.fil* file; when transit-loss computations are completed for the CCS TRF's, the program writes the resulting bank-storage and channel-storage loss and gain results to the *cs_recov.fil* file. Following the transit-loss computations for the FAP and the CCS TRF's, the program writes (1) all the updated TRF diversion USED accounts data to the *acct.fil* file, (2) all appropriate data to the *secwcd.out, subrch.out,* and *tlcalc.out* files, and (3) the appropriate results to the daily output file (*tlyyyymmdd*) (table 5). The program then (1) makes the transit-loss computations for the comparison calculation, (2) writes the resulting bank-storage and channel-storage loss and gain results to the *cmp_recov.fil* file, and (3) writes the results for the comparison calculation to the last page of the daily output file (table 5). [See the "Contents of the **Nexttrloss** Directory" section (p. 27–29) for file descriptions.] When all output has been written, the program closes all the input and output files and returns to the program options.

MAINTENANCE OF THE TRANSIT-LOSS ACCOUNTING PROGRAM

Maintenance of the current (1997) version of the accounting program is fairly simple. Proper maintenance of the program requires some knowledge of where the program files are located and what files are included in the program. In addition, some knowledge is needed about the procedures used to maintain and archive the current output files, where historic output files are archived, and where previous versions of the accounting program are archived. The USGS office in Pueblo maintains the accounting program and the associated auxiliary programs, archives the current output files, creates and maintains the historic output archives, and maintains the previous program archives.

Procedures to Archive Current Output Files

In the past, the daily output files were archived manually, which consisted of moving these files from the **nexttrloss** directory to directories for each month (fig. 7). Usually, the files were not moved on any regular schedule, and dozens to hundreds of files would accumulate in the **nexttrloss** directory. However, 2 or 3 months after the end of a water year, the daily output files were moved to the monthly directories, and the monthly directories then were archived to a reel-type magnetic tape. The contents of the other output files associated with the water year that just ended also were archived with the monthly directories containing the daily output files.

During preparation of this report, the manual archiving procedure was partly automated. This automation consisted of developing a computer script program that would (1) create the 12 monthly directories in the **nexttrloss** directory (fig. 7) at the beginning of the water year (mid-October) and (2) on the 15th day of each month, move the daily output files for the previous month to the appropriate monthly directory. After the end of a water year, the 12 monthly directories containing the daily output files, and the appropriate data from the other output files, still need to be archived manually.

Archive of Historic Output Files

All of the output data and files for each water year from 1989 through 1995 were written to a separate reel-type magnetic tape by the archiving software on the USGS computer system; these tapes were maintained and stored at the USGS office in Lakewood. Beginning in 1996, the accounting program output archives were maintained and stored at the USGS office in Pueblo. In 1997, the USGS computer system that contained the streamflow data base and transit-loss accounting program was replaced by a decentralized, Unix-based, work-station computer system; therefore, the output archives that were on reel-type magnetic tapes were transferred to mini-cartridge tapes to be more compatible with the new computer technology and storage media, and all the pre-1996 archives were transferred to the USGS office in Pueblo.

Archive of Previous Program Versions

During the preparation of this report, the current (1997) version and four previous versions of the transit-loss accounting program also were archived to a cartridge tape that is stored in the USGS office in Pueblo. The previous versions include (1) the original program without any user interface that was developed during the transit-loss study (Kuhn, 1988) and used in the example application described therein; (2) the program for the initial implementation in 1989 that was adapted from the original program by adding a user interface for data input and the capability for daily output files; (3) a later version of the initial implementation with an improved data-input interface and a slightly modified output; and (4) the version of the program that was put into use in 1992 after the 1991–92 program changes were completed. The program archive includes the needed input files, an example output file, and brief descriptions of the changes for each version. None of the auxiliary programs used to compute the daily mean discharge data at the gaging stations are included in the program archive.

USER PERSPECTIVE OF THE TRANSIT-LOSS ACCOUNTING PROGRAM

The accounting program described in this report is used as a management tool in the administration of NSF and TRF water rights along Fountain Creek. Use of the program in this capacity requires the continual cooperative efforts of several governmental entities: (1) the Colorado Division of Water Resources, (2) the CCS Water Resources Department, (3) the SECWCD, and (4) the USGS. Discussing the role of each governmental entity in the use of the accounting program is not the intent of this section; the intent is to indicate that the actual day-to-day operation of the accounting program is made by the Colorado Division of Water Resources. The offices of this State agency involved in using the accounting program are (1) the Water Division 2 Engineer's Office in Pueblo and (2) the District 10 Water Commissioner's Office in Colorado Springs. These two offices describe their use of the accounting program in the administration of water rights along Fountain Creek in the following paragraphs (Joseph D. Flory and Eddie L.Taylor, Colorado Division of Water Resources, written commun., 1997):

> Under Colorado Water Law, certain waters not native to a basin may be claimed for reuse as long as they can be distinguished from the native flows of the stream. Colorado Division of Water Resources personnel in Water District 10 in Colorado Springs use the transit-loss program as a tool to track non-native waters (primarily Colorado Springs transmountain return flows) in Fountain Creek so that they may be exchanged into upstream reservoirs or routed farther down the Arkansas River for diversion at the Colorado Canal for eventual reuse.
>
> The program enables the District 10 Water Commissioner to differentiate between native and non-native waters at various points along Fountain Creek. This permits holders of native water rights to divert water available to them under the priority system, while allowing the non-native waters to be routed on to the Arkansas River.
>
> Running the program requires a number of daily data inputs. The Water

Commissioner collects daily diversion data on the various ditches diverting below the outfall of the Colorado Springs wastewater-treatment plant. This requires three trips per week down the creek to retrieve data from recorders on the ditches. Colorado Springs Utilities calls in daily reports of water returning to the creek at their wastewater-treatment plant, and at the Fort Carson treatment plant, which obtains its water from Colorado Springs. These returns are divided into two components, the first of which is attributable to Colorado Springs' diversion of native water and the other of which is attributable to use of non-native transmountain water. The Water Commissioner also gathers daily streamflow data from the six gaging stations along the creek by accessing the Satellite Monitoring System via the USGS computer located in Denver.

The program tracks the different types of water by assessing a transit loss against the non-native flow as it progresses down the creek, taking into account the amount of native waters being diverted from, or being added to, the stream by way of tributary inflows or return flows from water use. Thus, the Water Commissioner is better able to determine the amount of native water available for diversion at each headgate.

SUMMARY

Since April 1989, a FORTRAN computer program has been used to compute transit losses for transmountain return flows (TRF's) that are discharged into Fountain Creek by the City of Colorado Springs (CCS). The transit-loss accounting program, which was developed as a result of a study completed in 1987, enables daily accounting of (1) the TRF's, (2) the transit losses for the TRF's, and (3) the native streamflows (NSF's) (nontransmountain water) in Fountain Creek from the CCS wastewater-treatment facility (WWTF) downstream to the Arkansas River.

In the years following 1989, a number of changes were made to the accounting program; however, the program and the changes made to it have never been documented completely. Therefore, the U.S. Geological Survey (USGS), in cooperation with the CCS and the Southeastern Colorado Water Conservancy District (SECWCD), completed a study to document the accounting program and prepared a report that: (1) Describes the computational steps and procedures of the original accounting program; (2) describes the changes that were made to the program in 1991–92 and in 1994–95; (3) provides a user manual; and (4) documents the procedures for maintaining the accounting program, the auxiliary programs, and the numerous output files.

Application of the accounting program is based on a system of 14 subreaches, 16 nodes, and 4 stream segments. The subreaches are parts of the study reach having uniform hydraulic and hydrologic characteristics, and the nodes, which delimit the subreaches, primarily are defined on the basis of location of streamflow-gaging stations and streamflow diversions along Fountain Creek. The stream segments are the set of subreaches between the gaging-station nodes. The accounting program requires input of the following data: (1) Daily quantities of TRF and native return flow discharged into Fountain Creek at the CCS WWTF; (2) daily mean discharge at each of the gaging stations along Fountain Creek; and (3) daily mean discharge at each diversion operating along Fountain Creek.

In computing the estimated quantities of TRF in Fountain Creek and the associated transit losses, the accounting program uses two sets of computations. The first set of computations is made between any two adjacent gaging stations (stream-segment computations); these computations estimate the loss or gain in NSF between the two adjacent gaging stations. The second set of computations is made between any two adjacent nodes (subreach computations); the actual transit-loss computations are made in the subreach computations, using the result from the stream-segment computations. The stream-segment computations are completed for a stream segment, then the subreach computations are completed for each subreach in the stream segment. When the subreach computations are completed for all subreaches in a stream segment, the stream-segment computations are repeated for the next stream segment, followed again by subreach computations; the process continues until computations are completed downstream through subreach 14.

Use of the accounting program is highly dependent on operation of a gaging-station network on Fountain Creek. The network originally consisted of five gaging stations and was expanded to six stations in 1995. Each station is equipped with a

data-collection platform that transmits data obtained at 15-minute intervals to a satellite; the data then are retransmitted to satellite downlinks and stored in a streamflow data base on the USGS computer system. The 15-minute data are retrieved automatically on a daily basis by additional computer programs that compute a daily mean discharge for each gaging station and write these data to files accessible by the program users.

In 1991–92, the accounting program was changed to (1) enable accounting of diversion of the TRF's and (2) include TRF's in the program that resulted from water use on the Fort Carson Military Reservation. Through an agreement with the SECWCD, the diverted TRF's could be exchanged by the CCS for equivalent quantities of Fryingpan-Arkansas Project (FAP) water being stored in Pueblo Reservoir. Besides changing the program to account for the diversion of the TRF's and the additional TRF source, the physical structure of the program was changed to make it more modular, and the program output also was changed.

In 1994–95, the accounting program was changed again to: (1) Incorporate an additional gaging station into the program computations; (2) enable the SECWCD to account for FAP TRF's that are discharged to Fountain Creek at the CCS WWTF and by the communities of Security, Widefield, and Fountain; (3) enable the SECWCD to also account for diversion of the FAP TRF's, similar to the capability implemented for diversion of the CCS TRF's as part of the 1991–92 program changes; and (4) enable the CCS to account for additional diversion of CCS TRF's that would not be exchanged for FAP water stored in Pueblo Reservoir. The program output also was changed extensively.

The accounting program resides on the USGS computer system that contains the streamflow data base; a master directory named **transit_loss** has been established on the computer for the program users. The master directory consists of a three-level system of subordinate directories and files; the **nexttrloss**, **trloss**, and **meanday** directories are the primary subordinate directories. The **nexttrloss** directory contains all the files that are either read for input, written to for output, or both; the **trloss** directory contains the source code and the executable files for the transit-loss accounting program; the **meanday** directory contains the source code and the executable files for the programs used in computing the daily discharge data.

Use of the accounting program is simplified through an interactive program display that has four options: option 1 is used in the day-to-day computations of transit-loss and TRF accounting and also is used to recompute the transit losses for the last computation date; option 2 is used to analyze different NSF diversion alternatives for the current day; option 3 is used to recompute transit losses for the day prior to the day of the last computation; and option 4 is used to view or change the PURCHASED and USED ditch accounts data for each of the three TRF diversion categories. The program display also queries the user for the required inputs of the return-flow discharge data, the gaging-station discharge data, and the diversion discharge data; the input data are redisplayed to allow for error checking and to reinput the data if necessary.

The computations for the current (1997) version of the accounting program basically consist of: (1) Completing the stream-segment computations for each stream segment, but including any appropriate additional TRF sources and any TRF diversions; (2) completing the subreach computations for each subreach in the stream segment, again including any appropriate TRF sources and any TRF diversions; (3) repeating each set of stream-segment and subreach computations until the assumed downstream TRF has converged with the computed downstream TRF; (4) after convergence, performing the upstream calculation for each specified TRF diversion in each subreach to compute the TRF purchase quantity required for each TRF diversion; and (5) updating the TRF diversion USED accounts data with the computed TRF purchase quantities.

Maintenance of the accounting program primarily requires the annual archiving of the output files generated by the program; the archiving procedure is partly automated through the use of a computer script code. Archives of historic output data and of previous versions of the accounting program are maintained in the USGS office in Pueblo.

REFERENCES

Bureau of Reclamation, 1972, Fryingpan-Arkansas Project: [Denver], Lower Missouri Region, 22 p.

Gronning Engineering Company, 1986, City of Colorado Springs Arkansas River exchange plan: Denver, paging unknown.

Kuhn, Gerhard, 1988, Methods to determine transit losses for return flows of transmountain water in Fountain Creek between Colorado Springs and the Arkansas River, Colorado: U.S. Geological Survey Water-Resources Investigations Report 87–4119, 183 p.

Land, L.F., 1977, Streamflow routing with losses to bank storage or wells: U.S. Geological Survey Computer Contribution, 117 p. [Available from National Technical Information Service, Springfield, VA 22161 as NTIS Report PB–271 535/AS.]

Radosevich, G.E., Nobe, K.C., Allardice, D., and Kirkwood, C., 1976, Evolution and administration of Colorado water law—1876–1976: Fort Collins, Colo., Water Resources Publications, 280 p.

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