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Test and application of
MIT river basin simulation model (MITSIM)
to the Kansas River

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NOTATION

$Q_s(t,n)$	Inflow to node s during month n of year t
$D_s(t,n)$	Release from node s during month n of year t
$W_s(t,n)$	Water available in reservoir s during month n of year t
$S_s(t,n)$	Water stored in reservoir s at the beginning of month n of year t
$EV_s(t,n)$	Evaporation of reservoir s during month n of year t
$ev_s(n)$	Monthly evaporation coefficient
$RA_s(t,n)$	Reservoir Surface area at the beginning of month n of year t
$TR_s(n)$	Reservoir target release of month n
$SMAX_s(n)$	Maximum storage of reservoir s during month n
$SMIN_s(n)$	Minimum storage of reservoir s during month n
$V_s^*(n)$	Maximum available storage capacity of reservoir s during month n
$EM_s(t,n)$	Water diversion at node s during month n of year t
$RM_s(t,n)$	Return flow from a municipal and industrial (M&I) node during month n of year t
e	Consumptive use coefficient

I. Introduction

In 1985 the Kansas Geological Survey initiated a research program to investigate the methodologies for water-resources planning so that the future supply and demands (quality and quantity) of a given study area are satisfied. As one approach to the problem, a model which minimizes the discounted total cost (capital cost plus the operation and maintenance) of a multi-component water-resources system over time was adopted. This led to the development of a linear-integer programming model formulated after a transportation model. This model successfully identifies the system components and their scale and time of developments with the minimum total discounted cost. It was further concluded that a simulation model is also required to determine the operational behavior of the system so identified over time. A simulation model developed at MIT (MITSIM) capable of simulating the behavior of multi-component system with many supply and demand nodes is adopted and tested using data available for the Kansas River basin. With the test of this model and the development and testing of the linear-integer programming planning model, the goals set in 1985 are basically achieved. These goals were to develop, adopt, and test a set of optimization and simulation models which may be used for multi-basin water-resources planning.

The development, adoption, and testing of these two models are only one step in the development of research tools for automated water-resources planning. Whereas in their present forms these models are operational, their efficiencies and sophistications must be the subject of further research.

The availability of water for users along the Kansas River depends on the runoff from the basin and the yields that can be maintained from the coordinated operations of the three large reservoirs, Milford, Tuttle Creek, and Perry. In 1984, Black & Veatch Engineering-Architects conducted a study to estimate the reservoir yields under coordinated operations of the reservoirs. A simulation model was used to determine the reliable flows in the Kansas River at Wamego,

Topeka, Lecompton, and Bonner Springs under 1950 and 2035 conditions, respectively. The estimated reliable flows are flows that satisfy all demands in the study periods.

This report presents some results on the reliable flows estimated by using the MIT simulation model (MITSIM). The inflow quantities and demands used in this report are the same as those used in the Black & Veatch report. However, different operating rules are used in this study. The results of this study are compared with those obtained by Black & Veatch (1984).

II. Study area, water demands, and monthly inflows

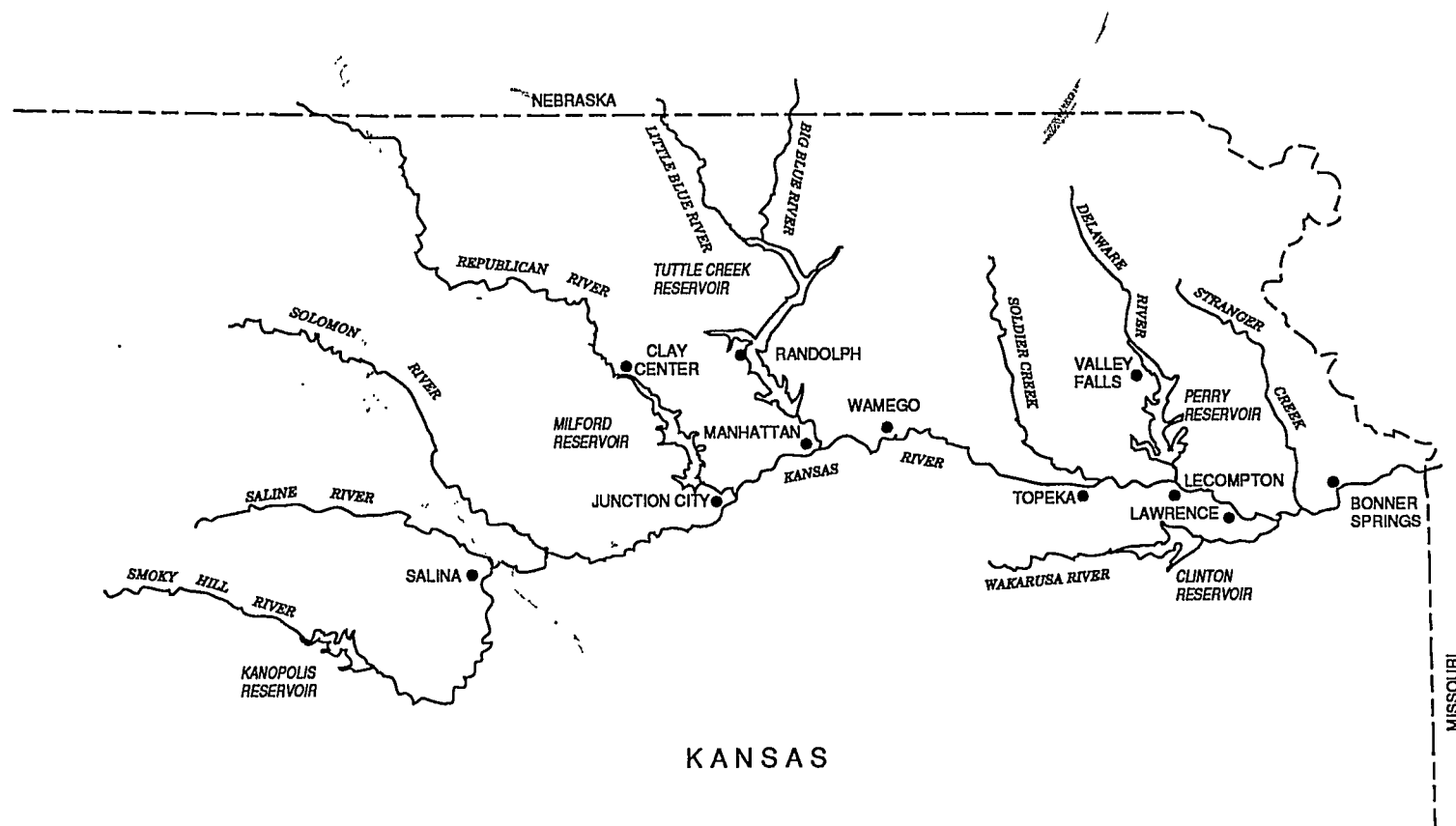
II.1. Study area and physical features of reservoirs

II.1.1. Study area

The Kansas River basin is a subbasin of the Missouri River basin. The study area (Figure 2.1) is the main stem of the Kansas River from Junction City to Bonner Springs including Tuttle Creek, Milford, and Perry reservoirs. Junction City, Bonner Springs, and four reservoirs are nodes that define the system boundary. Since Clinton Lake is located far downstream in the study area, the yields from the Tuttle Creek, Milford, and Perry reservoirs, to a large extent, play a crucial role in water supply of the study area under drought conditions. Water in Clinton Lake would be available only for cities located downstream from Lecompton. Water demands for irrigation, industry, and municipal purposes upstream from Junction City including water demands at Junction City will be lumped into the water-balance equation for the Junction City node.

II.1.2. Physical features of reservoirs

The basic features of three reservoirs are summarized in Table 2.1. Table 2.2 through Table 2.7 show the storage-area-elevation relationships of reservoirs for 1980 and 2035 conditions (Black & Veatch, 1980).



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Figure 2.1 Kansas River Study Area

Table 2.1 Reservoir Information

Reservoir Name	Tuttle Creek	Milford	Perry
Location	Big Blue River in Pattwatomie county, 5.0 miles north of Manhattan	Republican River in Geary County, 5.0 miles north-west of Junction City	Delaware River in Jefferson County, 4.5 miles north-west of Perry
Drainage Area	9,628 sq. miles	24,880 sq. miles	1,117 sq. miles
Dam Type	Compacted earthfill dam		
Close Date of Dam	March 15, 1962	Jan. 16, 1967	March 21, 1969
*Original Storage (acre-feet)	2,367,000	1,115,000	727,000
a. Flood Control	1,942,000	700,000	484,000
b. Water Supply	197,000	300,000	150,000
c. Sedimentation	228,000	115,000	93,000
*1980 Conservation Storage and Sedimentation (a-ft)	335,000	388,800	222,500
*2035 Conservation Storage and Sedimentation (a-ft)	119,000	287,000	138,000

*Source: Black & Veatch study (1984).

Table 2.2
 Characteristic Curve of Tuttle Creek Reservoir (1980 condition)

Elevation (ft.-m.s.l.)	Capacity (acre-ft)	Surface Area (acres)
1024	0	1050
1026	2970	1060
1034	17700	2580
1038	29900	3510
1040		4050
1042	46100	
1046	67000	5920
1050	93800	6890
1054	122000	
1056		7900
1058	154000	
1060		8850
1062	189000	
1068	251000	11100
1072	297000	12300
1075	335000	13400

Table 2.3
 Characteristic Curve of Tuttle Creek Reservoir (2035 condition)

Elevation (ft.-m.s.l.)	Capacity (acre-ft.)	Surface Area (acres)
1024	0	1050
1026	1060	1060
1034	6290	2580
1038	10600	3510
1040		4050
1042	16400	
1046	23800	5920
1050	33300	6890
1054	43300	
1056		7900
1058	54700	
1060		8850
1062	67110	
1068	89200	11100
1072	106000	12300
1075	119000	13400

Table 2.4
Characteristic Curve of Milford Reservoir (1980 condition)*

1080.0	0	1490
1095.0	9400	1490
1100.0	19100	2490
1105.0	34400	
1107.5		4130
1110.0	55200	
1115.0	82400	6020
1120.0	115500	
1122.5		7990
1125.0	155600	
1130.0	203900	10380
1135.0	259400	
1137.5		13010
1140.0	324400	
1144.4	388800	15710

Table 2.5
Characteristic Curve of Milford Reservoir (2035 condition)*

Elevation (ft.-m.s.l.)	Capacity (acre-ft.)	Surface Area (acres)
1080.0	0	1490
1095.0	6940	1490
1100.0	14100	2490
1105.0	25400	
1107.5		4130
1110.0	40700	
1115.0	60800	6020
1120.0	85300	
1122.5		7990
1125.0	114900	
1130.0	150500	10380
1135.0	191500	
1137.5		13010
1140.0	239500	
1144.4	287000	15710

*Source: Black & Veatch (1984)

Table 2.6
Characteristic Curve of Perry Reservoir (1980 condition)*

Elevation (ft.-m.s.l.)	Capacity (acre-ft.)	Surface Area (acres)
850.0	0	0
855.0	3500	1300
860.0	13800	2380
863.0	22300	3230
867.5	39100	
970.0	50700	5000
875.0	79100	6420
877.5	96100	
880.0		7700
882.5	135000	
885.0		9320
887.5	181000	
891.5	222500	11630

Table 2.7
Characteristic Curve of Perry Reservoir (2035 condition)*

Elevation (ft.-m.s.l.)	Capacity (acre-ft.)	Surface Area (acres)
850.0	0	0
855.0	2150	1300
860.0	8460	2380
863.0	13700	3230
867.6	24000	
970.0	31000	5000
875.0	48500	6420
877.5	58900	
880.0		7700
882.5	82800	
885.0		9320
887.5	111000	
891.5	138500	11630

*Source: Black & Veatch (1984)

Table 2.8
Kansas River Irrigation (acre-feet)

County	1956		1980		2035	
	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion
<u>Adjacent to Kansas River</u>						
Douglas	484	418	781	674	9,790	8,450
Geary	1,040	898	5,420	4,679	3,380	2,920
Jefferson	352	304	2,670	2,300	4,390	3,790
Johnson	264	228	2,480	2,140	4,390	3,790
Leavenworth	134	116	308	266	540	466
Pottawatomie	2,680	2,310	7,610	6,560	13,200	11,400
Riley	1,820	1,570	3,150	2,715	14,200	12,300
Shawnee	2,820	2,430	13,800	11,900	18,600	16,100
Wabaunsee	826	713	1,500	1,300	5,400	4,660
Wyandotte	<u>112</u>	<u>96.7</u>	<u>275</u>	<u>237</u>	<u>405</u>	<u>350</u>
Subtotals	10,600	9,100	38,000	32,800	74,300	64,200
<u>Upstream from Kansas River</u>						
Clay	2,240	1,930	9,800	8,460	11,100	9,560
Cloud	3,780	3,260	25,500	22,000	26,300	22,700
Dickinson	1,550	1,340	6,060	5,230	12,200	10,500
Ellsworth	756	652	2,100	1,810	3,380	2,920
Lincoln	430	370	2,830	2,440	5,400	4,660
Mitchell	2,080	1,800	7,600	6,560	23,000	19,800
Ottawa	1,366	1,180	5,250	4,530	14,200	12,300
Republic	10,200	8,800	75,000	64,700	74,600	64,400
Saline	<u>3,330</u>	<u>2,870</u>	<u>17,600</u>	<u>15,200</u>	<u>31,000</u>	<u>26,800</u>
Subtotals	25,700	22,200	151,700	130,900	201,200	173,700
TOTALS	36,300	31,300	189,700	163,700	275,500	237,900

Source: Black & Veatch, 1984

Table 2.9
Kansas River Municipal and Industrial Water Use

User	Annual Quantity, million gallons					
	1956		1980		2035	
	Withdrawal	Depletion	Withdrawal	Depletion	Withdrawal	Depletion
Board of Public Utilities Kansas City	0	0	41.6	0	0	0
Johnson County Water District No. 1	1,810	1,090	10,100	6,060	26,700	16,000
City of Bonner Springs	91.3	54.8	364	218	795	477
Public Wholesale Water Supply District No. 1, Gardner	0	0	0	0	2,230	1,340
Cooperative Farm Chemicals, Lawrence	0	0	1,090	567	1,900	989
City of Lawrence	783	470	2,480	1,490	4,340	2,600
Kansas Power & Light- Lawrence Energy Center	2,960	332	2,310	1,960	2,310	1,960
Kansas Power & Light- Tecumseh Energy Center	22,400	223	2,570	694	1,200	1,020
City of Topeka	4,670	2,800	9,290	5,570	17,900	10,700
Southeastern Public Service Co., Topeka	387	232	604	362	604	362
Rural Water District No. 4, Shawnee Co.	0	0	142	85.2	548	329
Goodyear, Topeka	568	227	1,130	452	2,170	868
City of Rossville	0	0	49.2	29.5	125	75.0
Kansas Power & Light- Jeffrey Energy Center	0	0	4,220	4,030	30,800	27,700
City of Wamego	131	78.6	199	119	324	194
City of Manhattan	1,100	660	2,140	1,280	4,160	2,496
City of Ogden	72.0	43.0	113	67.8	287	172
City of Junction City	747	448	1,000	600	2,760	1,660
City of Abilene	302	181	405	243	1,028	617
City of Salina	<u>1,890</u>	<u>1,130</u>	<u>2,690</u>	<u>1,610</u>	<u>6,820</u>	<u>4,090</u>
TOTALS	38,169	8,144	42,608	26,551	111,791	76,840

Source: Black & Veatch, 1984

II.2. Water demands

The water in the Kansas River system is heavily used for irrigation, industry, and municipal purposes. Projected water demands for the water users in the Kansas River basin depend on water rights, water-quality control requirement, and the economic development of the basin. The projected water demand in the basin for 1980 and 2035 conditions are shown in Tables 2.8 and 2.9, in which withdrawals are equal to total water diversion from the Kansas River and depletions are equal to total water diversions minus total water returns to the river. These values are average annual values. The water rights for different reaches in the study area are grouped at Wamego, ~~Topoka~~, Lecompton, and Bonner Springs. The water rights of the city of Lawrence and the city of Olathe are included in the water demand at Bonner Springs. Projected seasonal variations of water demands for 1980 and 2035 at the four stations are shown in Tables A.1 to A.8 of Appendix A. These numbers in Appendix A are equal to average annual depletions multiplied by monthly demand factors. The months of June, July, August, and September have the highest water demands in a year. The projected water demands for the year 2035 are about two to three times of the 1980 values.

II.2.1 Monthly inflows

The streamflow records show that the period from November 1952 through May 1957 represents a drought with about 2% chance of annual occurrence. Since the 1950's, both in-state and out-of-state water depletion have increased significantly (see Tables 2.8 and 2.9). In addition, a new interstate compact for the Big Blue River was signed in 1971. Consequently, the streamflows recorded in the 1950's must be reduced accordingly before they can be used for the operational study for the years 1980 and 2035 conditions. The monthly net inflows to each of three reservoirs are based on historical streamflow records for the drought period subtracting estimated depletions and lake evaporation and adding precipitation over the lake surface. The stream-gaging stations used in the analysis were the Republican River at Clay Center, the Big Blue

River at Randolph, and the Delaware River at Valley Falls (see Figure 2.1). The estimated depletions reflect (1) interstate water compacts, (2) additional upstream depletion, and (3) flow that must be passed through the reservoirs to satisfy senior downstream water rights. The reduced (adjusted) flows are listed in Table B.1 of Appendix B. The estimated net monthly inflows based on the reduced values to each reservoir are shown in Figure 2.2. The net-inflow sequences for the 2035 condition practically the same as those for the 1980 condition are not presented herein. Figure 2.2 shows that inflows to Tuttle Creek Reservoir are larger than the other two. For the reservoir system, the critical drought period apparently occurred from August 1956 through February 1957.

The Smoky Hill River is a tributary of the Kansas River (see Figure 2.1). Flow from the Smoky Hill River enters the Kansas River at Junction City. The magnitude of flow is affected by the water demands upstream from Junction City (see Tables 2.8 and 2.9). At the Junction City node, a water-balance equation is used to determine the streamflows downstream from Junction City. These flows are the inflows to the Kansas River as listed in Table B.2 of Appendix B.

The surface runoff from the intervening drainage area between two neighboring nodes from recorded incremental inflows from November 1952 to May 1957 is used as basic data in this study (see Table B.3 of Appendix B).

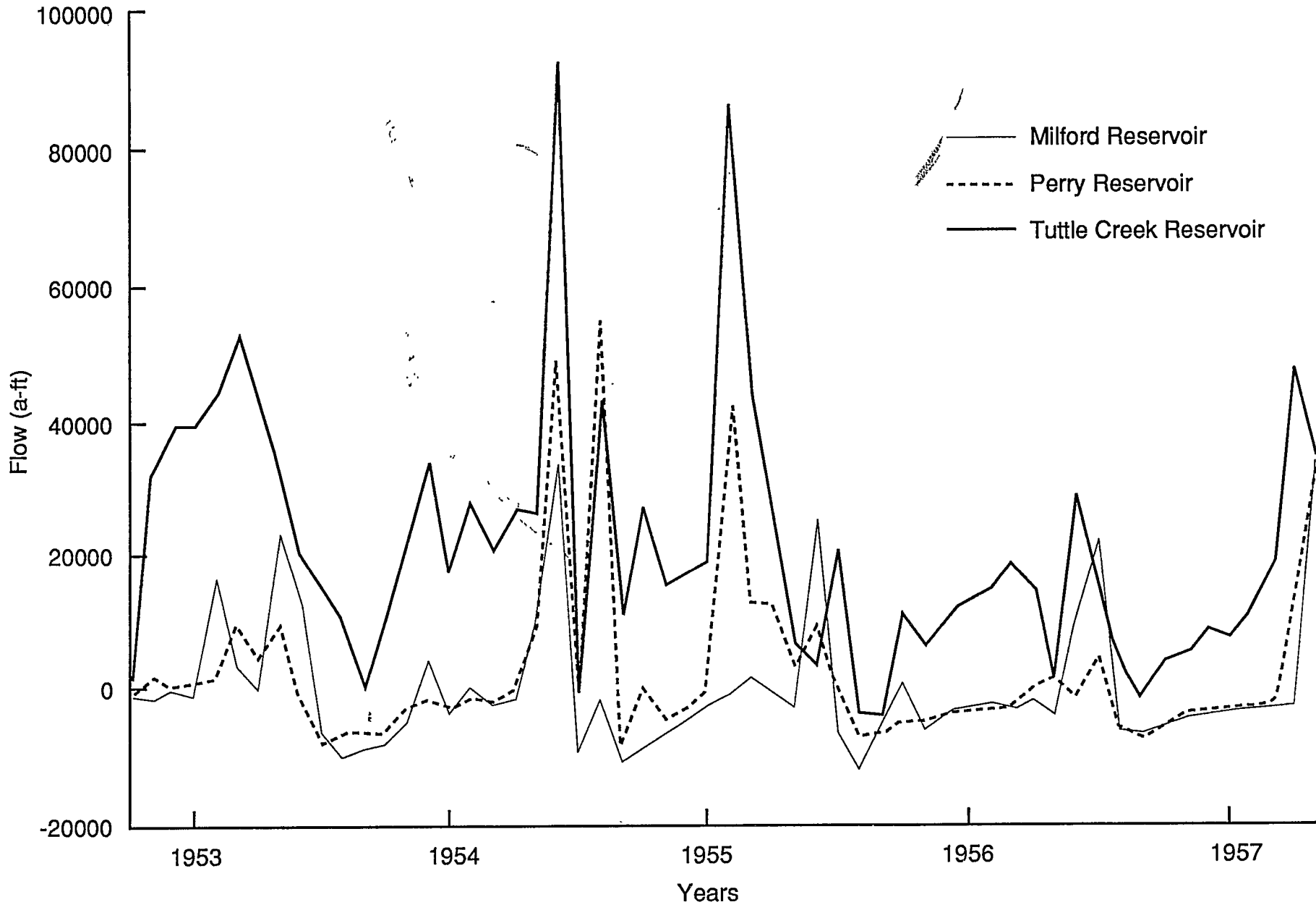


Figure 2.2 Net Monthly Inflow to Reservoirs

III. Simulation model

The simulation model developed at MIT (Strezepek and Lenton, 1978) was used to evaluate the physical performance of the Kansas River system on a monthly basis. The MIT model is a comprehensive river-basin planning model originally used as a tool to study the integrated development of the Vardar/Axios River basin in Greece and Yugoslavia. The original model was modified for this study.

III.1. Network representation

In order to simulate the behavior of the river system over time, the system must be simplified conceptually into a network of nodes and arcs. A node represents a physical component (e.g., a reservoir) of the system whose behavior may modify downstream-flow characteristics, or a location on the stream for monitoring the flow. Different types of nodes incorporated in the model are shown in Figure 3.1 and described in the following section. All nodes are connected by directed arcs which represent natural or manmade connections of a river system and the direction of flow. The network enables the model to trace flow throughout the river system in a straightforward way.

III.2. Nodes and nodal operations

III.2.1 Inflow node and terminal node

Inflow nodes are boundary nodes, where inflow (input) hydrographs are defined. Terminal nodes are also boundary nodes, where outflow hydrographs are computed.

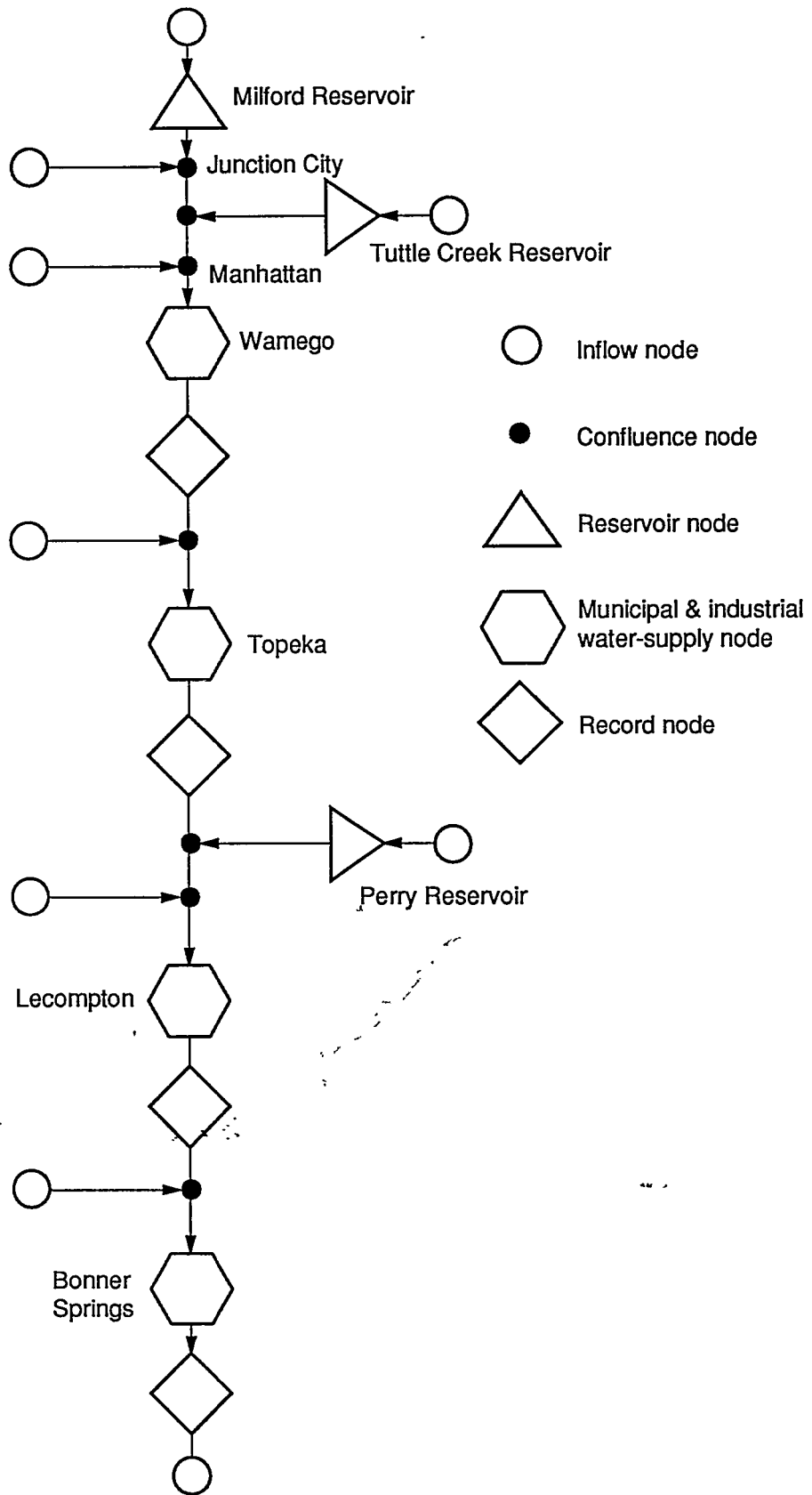


Figure 3.1 Network representation of Kansas River Study Area

III.2.2. Reservoir node

A reservoir node is used to represent a storage reservoir. The reservoir is operated according to a specified release rule. The rule used is the standard operating policy (Fiering, 1967). Each reservoir is assumed to follow the standard operating policy independently.

The parameters used in the reservoir node are shown in Figure 3.2a and all units are in 10^6m^3 . The water available in reservoir s during month n of year t is given by

$$W_s(t, n) = S_s(t, n) - EV_s(t, n) \quad (3.1)$$

Where

Q_s = inflow to reservoir s during month n of year t .

$S_s(t, n)$ = water stored in reservoir s at the beginning of month n of year t .

$EV_s(t, n)$ = evaporation of reservoir s during month n of year t and is given by

$$EV_s(t, n) = 1000 \times ev_s(n) \times RA_s(t, n) \quad (3.2)$$

where

$ev_s(n)$ = evaporation coefficient of month n (mm/month).

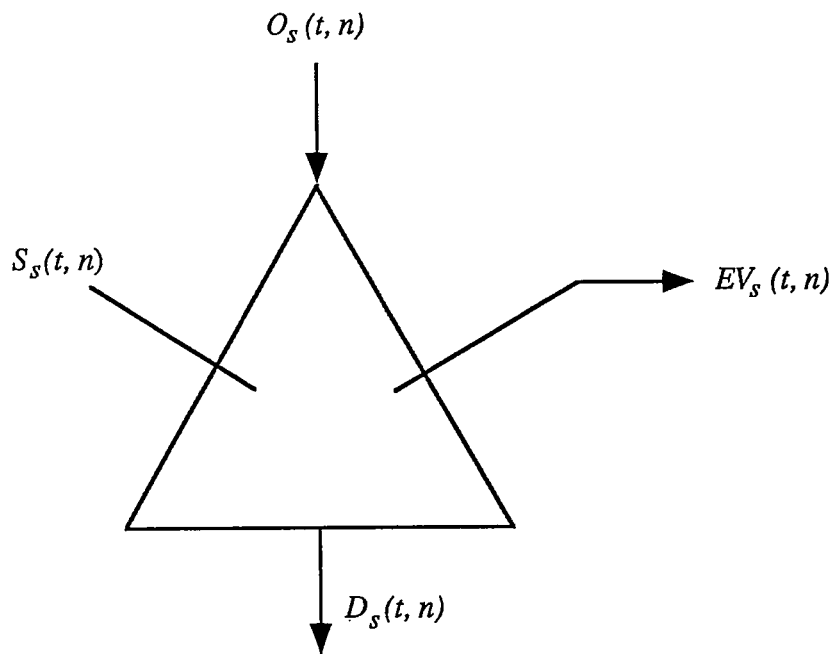
$RA_s(t, n)$ = reservoir surface area at the beginning of month n of year t (km^2).

The standard operating rule is shown in Figure 3.2b. In Figure 3.2b, the abscissa is available water $W_s(t, n)$ and the ordinate is the release from reservoir s in month n of year t , $D_s(t, n)$. The target release is denoted by $TR_s(n)$. The maximum available storage capacity of reservoir s is

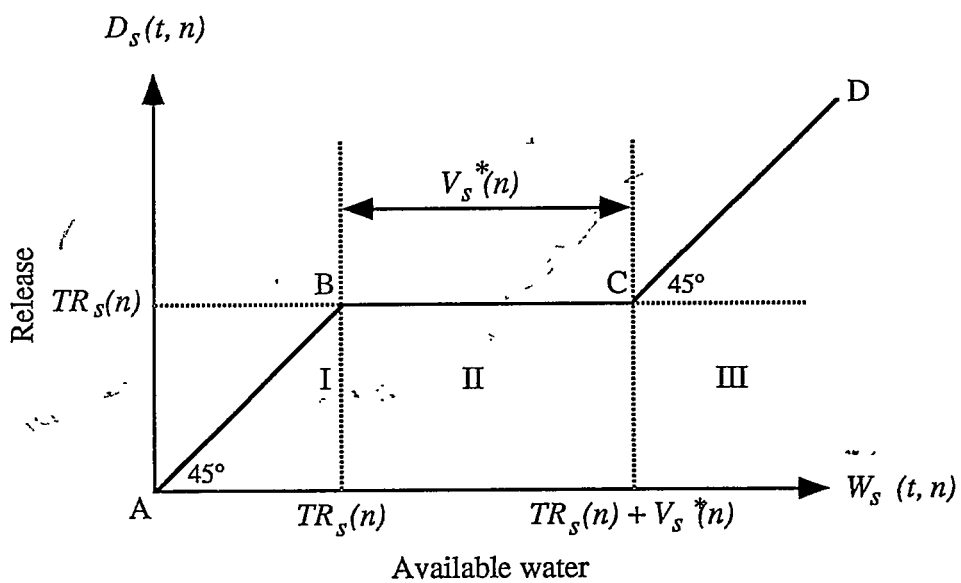
$$V_s^*(n) = SMAX_s(n) - SMIN_s(n) \quad (3.3)$$

where

$SMAX_s(n)$, $SMIN_s(n)$ = maximum and minimum storages of reservoir s , respectively.



a) Reservoir node and flow variables



b) Operating Rule for Month n

Fig. 3.2 Reservoir Node and its Operating Rule

The standard policy operates the reservoir according to the following rules depending on available water $W_s(t,n)$:

- (1) If $W_s(t,n)$ is less than or equal to target release $TR_s(n)$, release all available water (line AB in Figure 3.2b).
- (2) If available water is larger than the target release, but less than or equal to $TR_s(n) + V_s^*(n)$, release a part of available water to meet the target release and store the rest until the maximum allowance storage is reached (line BC in Figure 3.2b).
- (3) If $W_s(t,n)$ is larger than $TR_s(n) + V_s^*(n)$, release the target amount and spill the excess water (line CD in Figure 3.2b).

Using standard operation rule to operate reservoirs requires target releases from each reservoir as input to the model. Since the target releases of the three reservoirs of the Kansas River are not known in this study, trial values of target releases must be selected. For comparison purposes, the initial and final reservoir storages for the simulation period must be the same as those given by the Black & Veatch study (1984). Based on those terminal storage values, reservoir target releases are adjusted by trial-and-error method until the minimum instream flows reach their maximum values. The final target releases determined in this manner for each reservoir are listed in Tables 3.1 and 3.2. The final reservoir storages are listed in Table 3.3. The final storages shown in Table 3.3 for the simulation model are very close to those from the Black & Veatch study.

III.2.3 Municipal and industrial water supply (M&I) node

M&I node represents concentrated water demand for industry and other users (Figure 3.3a). The operating rule in the original model is shown in Figure 3.3b and can be described by the following equations:

$$EM_s(t, n) = Q_s(t, n), \text{ if } Q_s(t, n) \leq TM_s(n) \quad (3.4)$$

$$EM_s(t, n) = TM_s(n), \text{ if } Q_s(t, n) > TM_s(n) \quad (3.5)$$

Table 3.1
Reservoir Target Releases for Simulation model
 (10⁶ x m³, 1980 condition)

Month	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
January	33.18	13.41	15.94
February	33.18	14.20	14.12
March	33.18	11.19	16.28
April	33.18	11.15	8.60
May	33.18	18.87	2.22
June	33.18	18.82	17.51
July	33.18	18.09	1.86
August	33.18	10.69	14.26
September	33.18	17.09	15.78
October	33.18	15.40	16.31
November	33.18	14.85	15.54
December	33.18	15.85	16.23

Table 3.2
Reservoir Target Releases for Simulation model
 (10⁶ x m³, 2035 condition)

Month	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
January	21.57	12.98	11.22
February	21.57	13.06	9.33
March	21.57	12.96	11.77
April	21.57	13.19	1.87
May	21.57	12.98	1.87
June	21.57	13.32	16.87
July	21.57	12.62	1.87
August	21.57	8.19	10.41
September	21.57	11.75	14.67
October	21.57	12.52	11.72
November	21.57	12.62	10.72
December	21.57	12.88	10.09

Table 3.3
Initial and Final Reservoir Storages (acre-feet)

Reservoir	1980 condition			2035 condition		
	Initial	Final		Initial	Final	
		MITSIM	B & V		MITSIM	B & V
Tuttle Creek	335,000	43,476	43,436	119,000	14,039	14,089
Milford	388,800	57,320	57,228	287,000	48,832	48,896
Perry	222,500	43,447	43,280	138,000	23,436	23,436

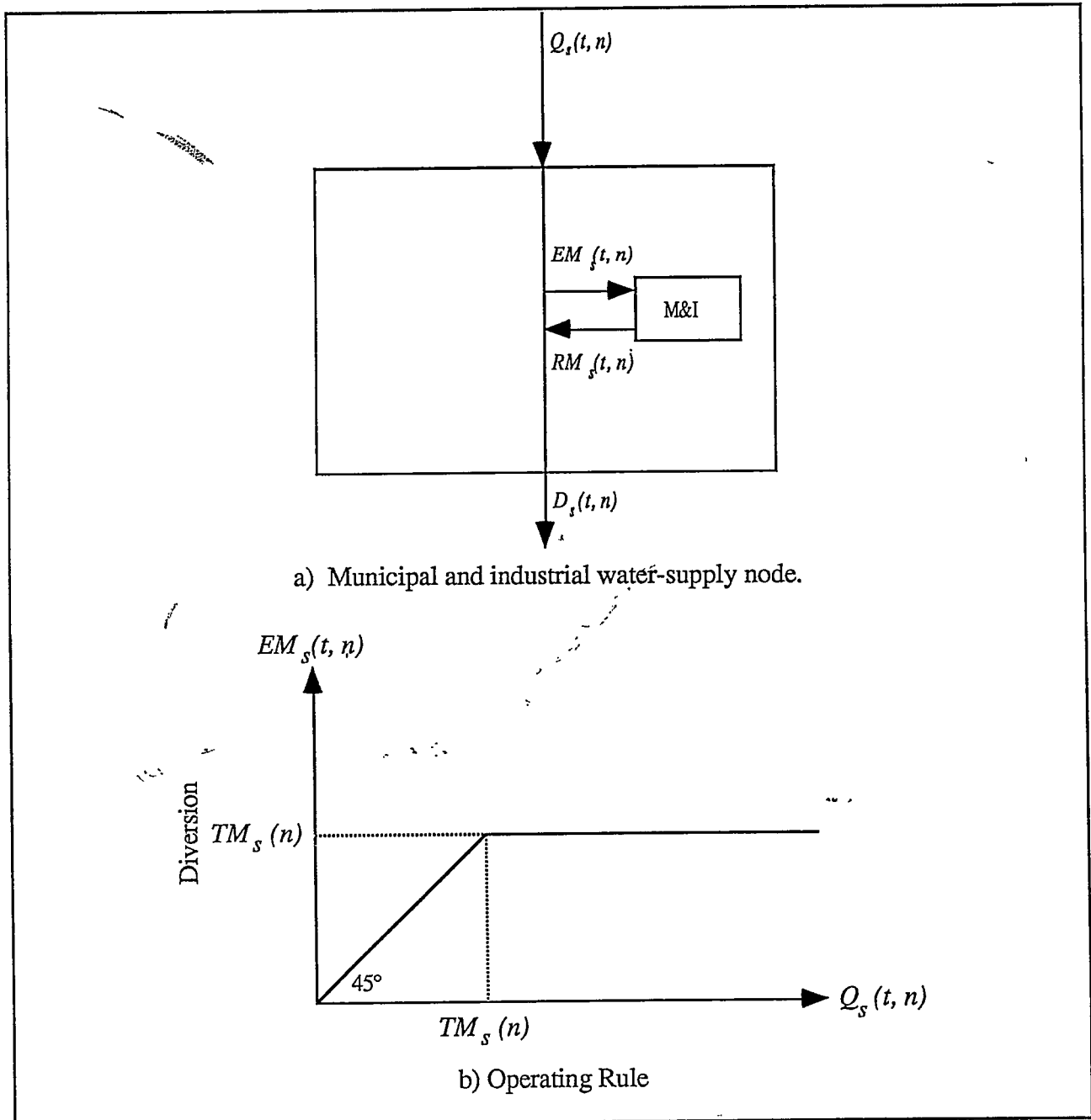


Fig. 3.3 Municipal and Industrial node and its diversion rule.

where

$EM_s(t,n)$ = actual diversion for the node s during month n of year t .

$TM_s(n)$ = target diversion for month n .

$RM_s(n)$ = return flow from M&I node s during month n of year t .

$$RM_s(t, n) = (1 - e) \times EM_s(n) \quad (3.6)$$

where

e = consumptive use coefficient, $0 \leq e \leq 1$.

However, for this study, the condition given by Equation (3.4) is not valid because target water supply, $TM_s(n)$, should be satisfied. $TM_s(n)$ represents water demand at a given node. Therefore, e in (3.6) is set to be zero. Then, the water balance equation of M&I node is

$$D_s(t, n) = Q_s(t, n) - TM_s(t, n) \quad (3.7)$$

III.2.4 Confluence node

The confluence node designates the joining of natural tributaries or manmade channels (see Figure 3.4). The water-balance equation for the confluence node s is

$$D_s(t, n) = Q_s^1(t, n) + Q_s^2(t, n) \quad (3.8)$$

where

$D_s(t,n)$ = outflow from the node s during month n of year t .

$Q_s^1(t,n)$ = first channel inflow to node s in month n of year t .

Q_s^2 = second channel inflow to node s in month n of year t .

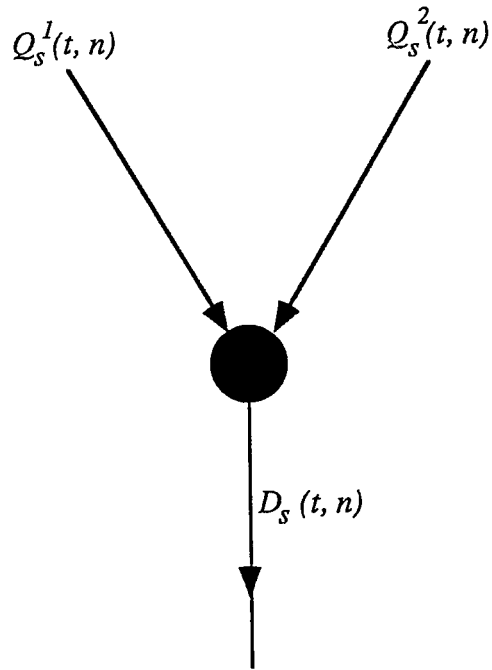


Fig. 3.4 Confluence

III.2.5 Recording Node

This node is used to monitor the instream flow and to check whether the minimum flow required for navigation, water quality or fish and wildlife is violated. The water balance is simply

$$D_s(t, n) = Q_s(t, n) \quad (3.9)$$

where

$Q_s(t, n)$ = inflow to node s in month n of year t .

$D_s(t, n)$ = outflow of node s in month n of year t .

For each month of the simulation period, the final result of operation sought for at a given node is the downstream flow from that node. If there is no gain or loss of water between two neighboring nodes s and $s + 1$, Equation 3.9 becomes

$$Q_{s+1}(t, n) = D_s(t, n) \quad (3.10)$$

III.3 Computation procedure

The simulation model is operated based on the water-balance procedure at each and every node in the system for each time step from the upstream node to the downstream node. The model starts calculation for the first month of the simulation from starting node to the downstream node until the terminal node of the system is reached. After the completion of this cycle, the model repeats the computational procedure for the next time step until the end of simulation period is reached.

For comparison, it is necessary to describe briefly the computation procedure of the Black & Veatch simulation model. In the Black & Veatch study, the model is operated from the upstream node to the downstream node in a trial-and-error manner. A constant release rate from Tuttle Creek Reservoir is set. This constant release rate is maintained throughout the drought period except when smaller releases are adequate to meet the target flow at Wamego. Operationally, a target downstream flow value at Wamego is first selected. Releases from Milford Reservoir are used to make up any deficit from Wamego target flow. The model should run many times by adjusting the Wamego target value until all of Milford Reservoir conservation storage is required to maintain the target value at Wamego. Once this "optimum" steady flow has been reached, the process can be moved downstream through the Topeka node to the Lecompton node. The procedure of setting target flow at Lecompton and controlling release from Perry Reservoir is similar to that used at Wamego. At this time, only adjusting the releases from Perry Reservoir reaches the maximized target value by many runs so that the conservation storage in Perry will be evacuated.

IV. Results and comparison

The objective of this study is to determine the operation of the Kansas River system under 1950's drought condition and the 1980 and 2035 conditions of reservoir storages and water demands with a simulation model. The results are presented and discussed in this chapter.

Figures 4.1 to 4.20 and Appendix C show the results of the operation with MIT Simulation Model (MITSIM) of the Kansas River system with three existing reservoirs: Tuttle Creek, Milford, and Perry. For comparison, the Black & Veatch results are also shown in Figures 4.1 to 4.20. It is noted that both of the models have been run under the same inflow sequences, water demands, and the initial reservoir storages. It is found that both sets of results are very close.

The minimum instream flow observed at Wamego, Topeka, Lecompton, and Bonner Springs are listed in Table 4.1. These minimum instream flows calculated by this model can be sustainable during the operation period. Table 4.1 shows that (1) under 1980 conditions, instream flow from stations gains more than 150 cubic feet per second from Wamego to Bonner Springs; however, under 2035 conditions, the instream flow loses more than 100 cubic feet per second, and (2) the values of downstream flow based on the MIT simulation model are decreased by 5.9% to 8.0% with reference to Black & Veatch values under 1980 conditions. Furthermore, these values are decreased 4.0% and 8.7% for Wamego and Topeka, and are increased 3.1% and 3.7% for Lecompton and Bonner Springs over the Black and Veatch study for year 2035 conditions.

Table 4.1
Minimum Streamflow Rate

Stations	Flow Rate (cfs)			
	1980 condition		2035 condition	
	B & V	MITSIM	B & V	MITSIM
Wamego	749	692 (-7.5%)	467	448 (-4.0%)
Topeka	692	636 (-8.0%)	232	212 (-8.7%)
Lecompton	931	869 (6.7%)	431	444 (3.1%)
Bonner Springs	904	851 (-5.9%)	363	377 (3.7%)

Note: Numbers in parentheses in the table are increases or decreases with reference to the Black & Veatch (1984) values.

VI. Summary and conclusion

In this study, the MIT Simulation Model (MITSIM) is tested by its application to the Kansas River basin to investigate water-supply potential of three existing reservoirs: Milford, Tuttle Creek, and Perry. As a detailed monthly simulation model, MITSIM incorporates a complex system of surface reservoirs, rivers, channels, and water-supply nodes and evaluates the physical performance of the system. This model has been found to be capable of being used for several types of planning studies.

In this study, 1953-1956 drought period inflow has been chosen for flow input data. Under the condition of reservoir storage and water diversions along the river for 1980 and 2035, respectively, the flow in the system has been simulated. The results are also compared with the results of the Black & Veatch study (1984). As a consequence, the MIT simulation model is found to be a useful tool for long-term analysis of multi-component reservoir systems.

References

- (1) Lenton, Roberto L., and Kenneth M. Strzepek, "Theoretical and Practical Characteristics of the MIT River Basin Simulation Model," Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Dept. of Civil Engineering, Massachusetts Institute of Technology, Report No. 225, August 1977.
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- (3) Strzepek, Kenneth M., et al., "Users Manual for MIT River Basin Simulation Model," Ralph M. Parsons Laboratory for Water Resources and Hydrodynamics, Dept. of Civil Engineering, Massachusetts Institute of Technology, Report No. 242, December 1979.
- (4) Black & Veatch, "Report on Kansas River Water Supply for Kansas River Alliance," Project No. 11016, January, 1984.
- (5) Yu, Yun-Sheng, et al., "A Study of Low-flow Operation of Milford and Elk City Lakes in Kansas," Kansas Water Resources Research Institute, October 1980.
- (6) Fiering, Myron B., "Streamflow Synthesis," Harvard University Press, 1967.

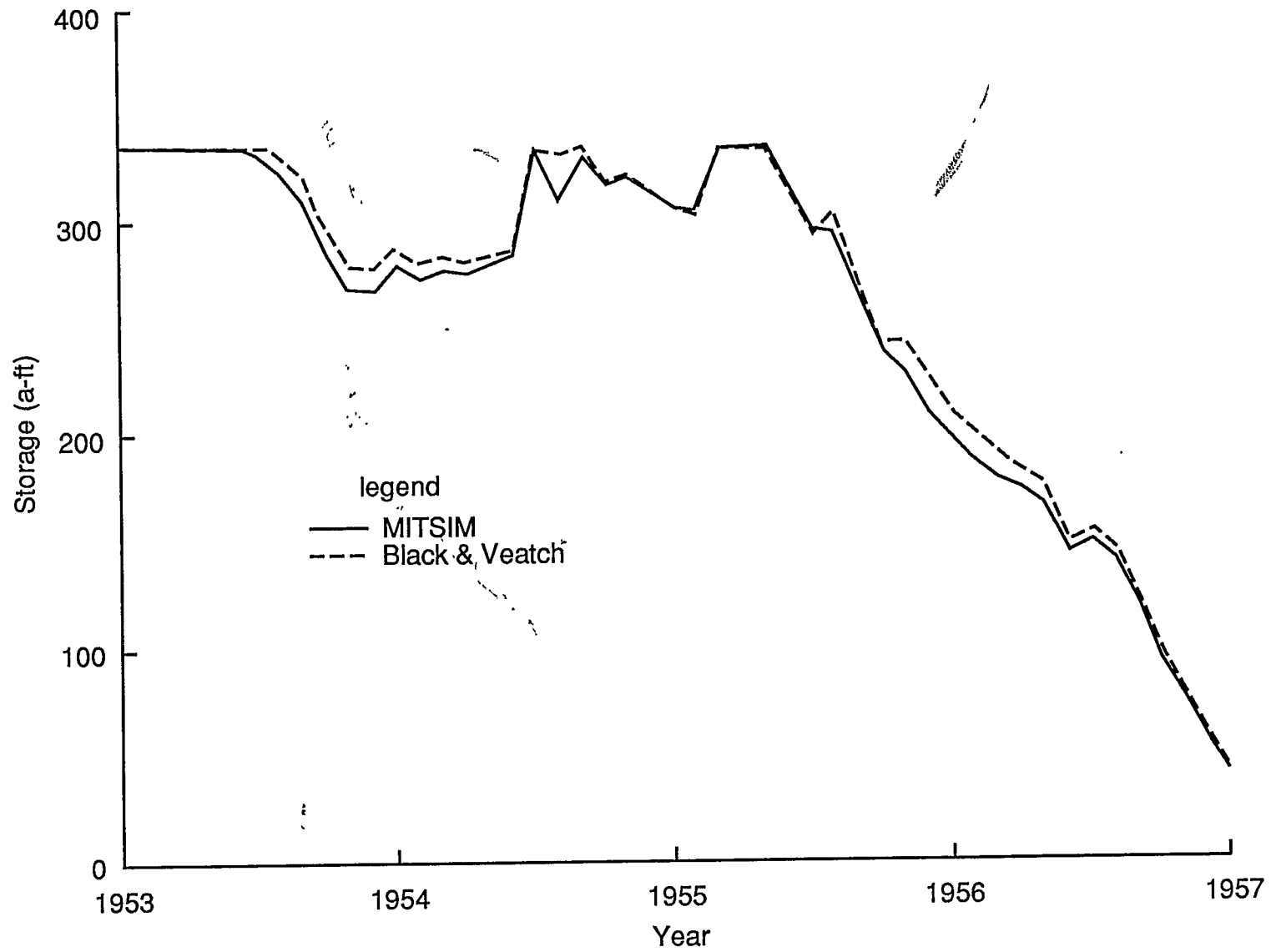


Figure 4.1 Storage in Tuttle Creek Reservoir (1980)

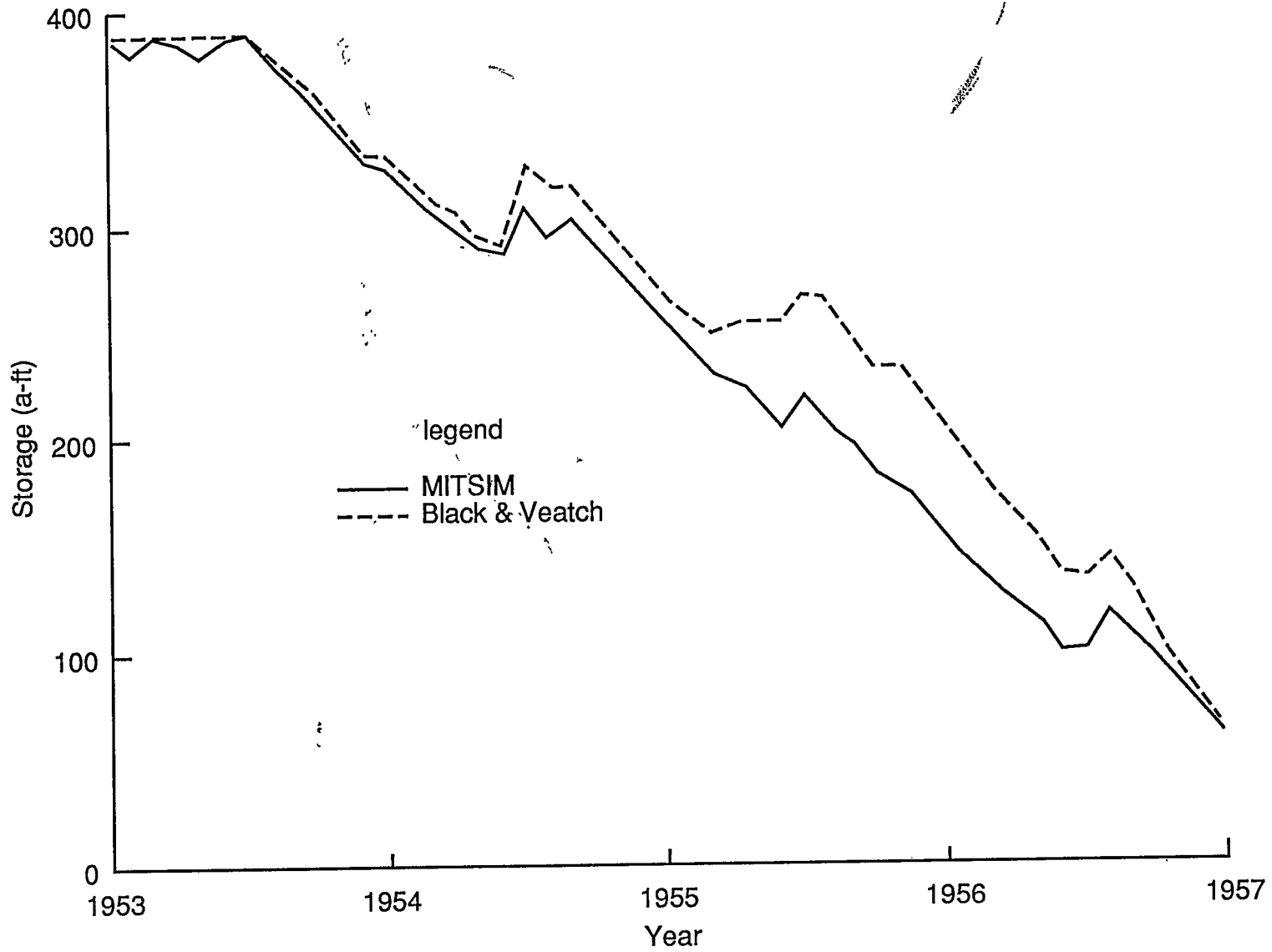


Figure 4.2 Storage in Milford Reservoir (1980)

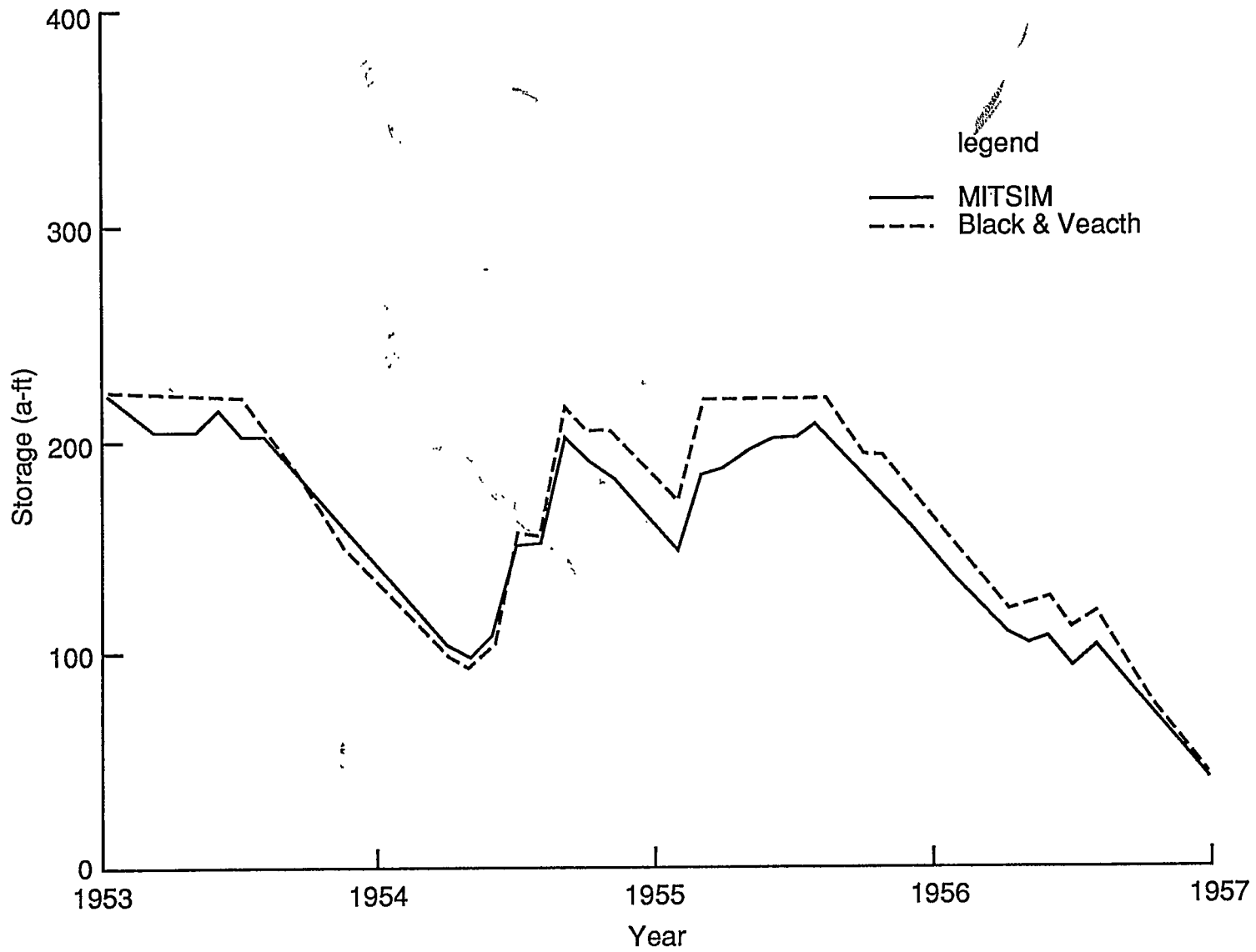


Figure 4.3 Storage in Perry Reservoir (1980)

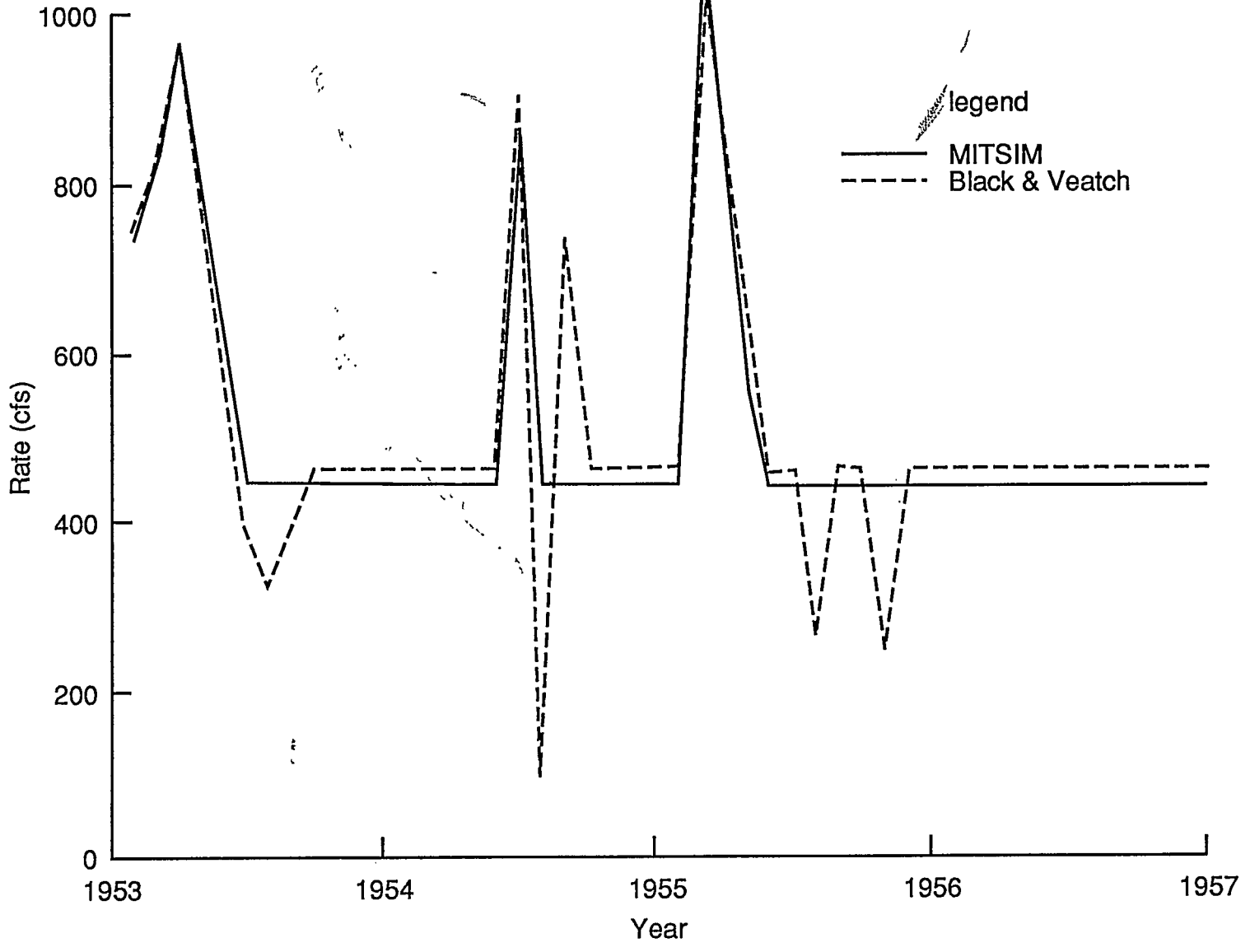


Figure 4.4 Release from Tuttle Creek Reservoir (1980)

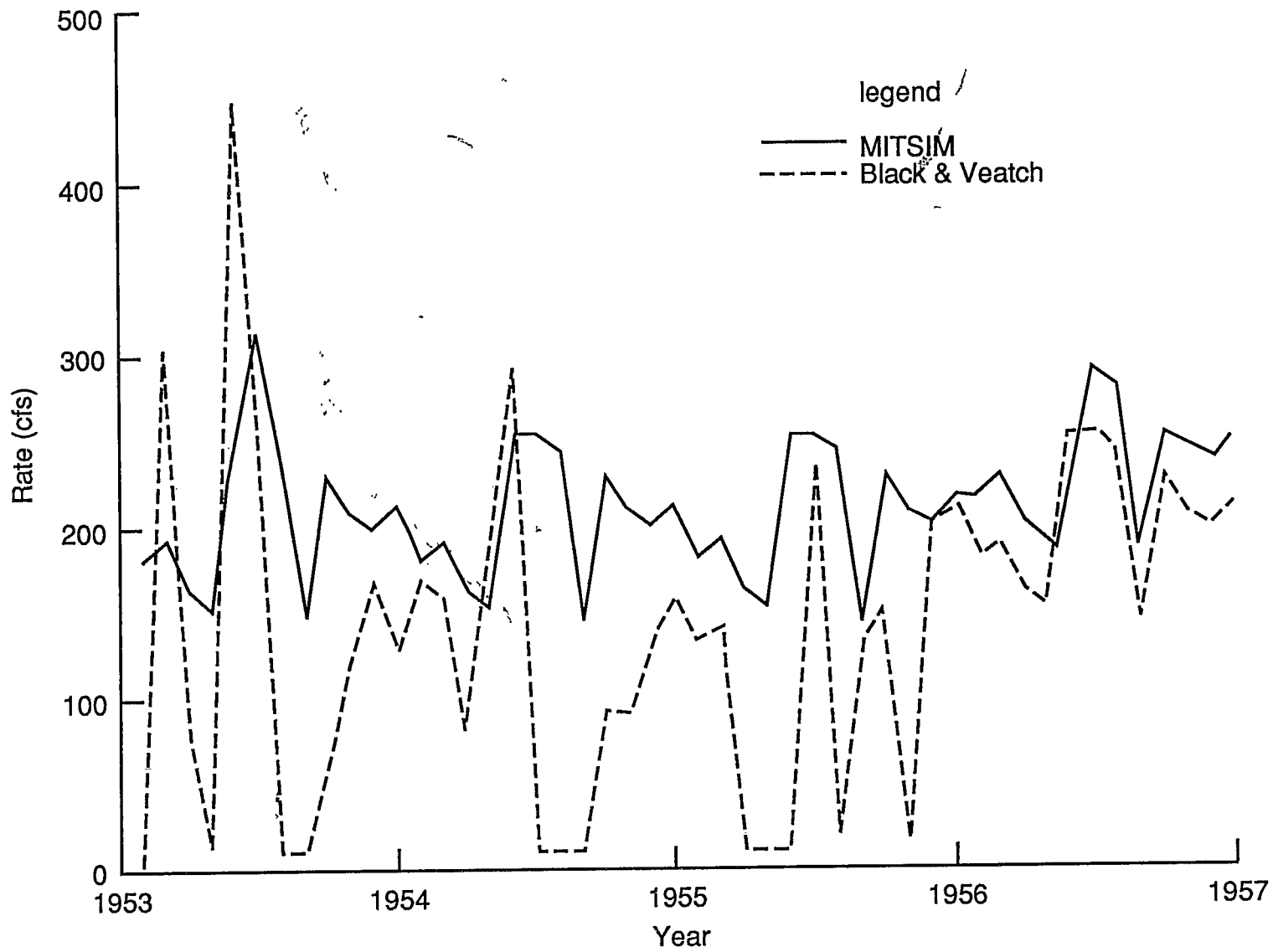


Figure 4.5 Release from Milford Reservoir (1980)

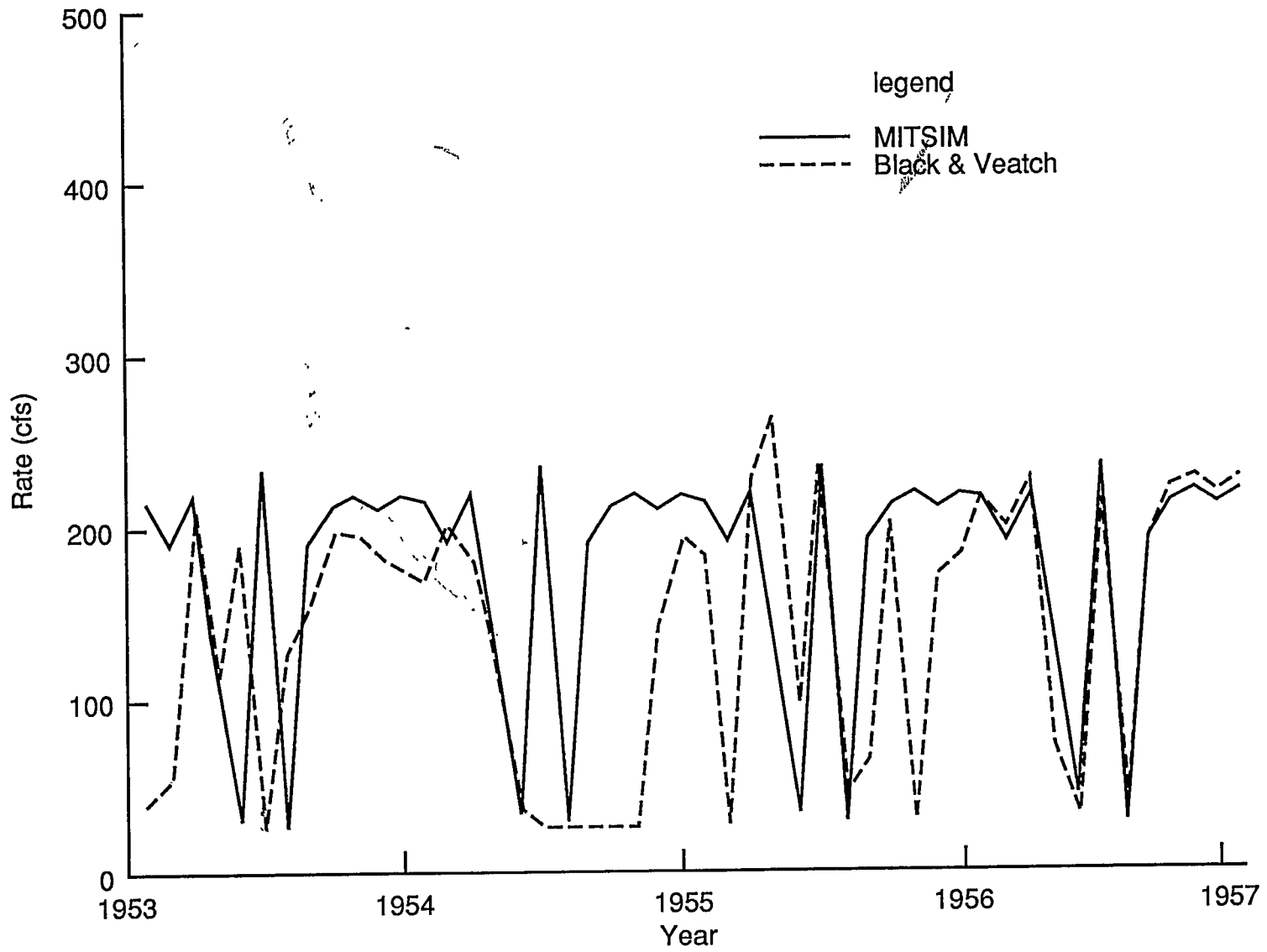


Figure 4.6 Release from Perry Reservoir (1980)

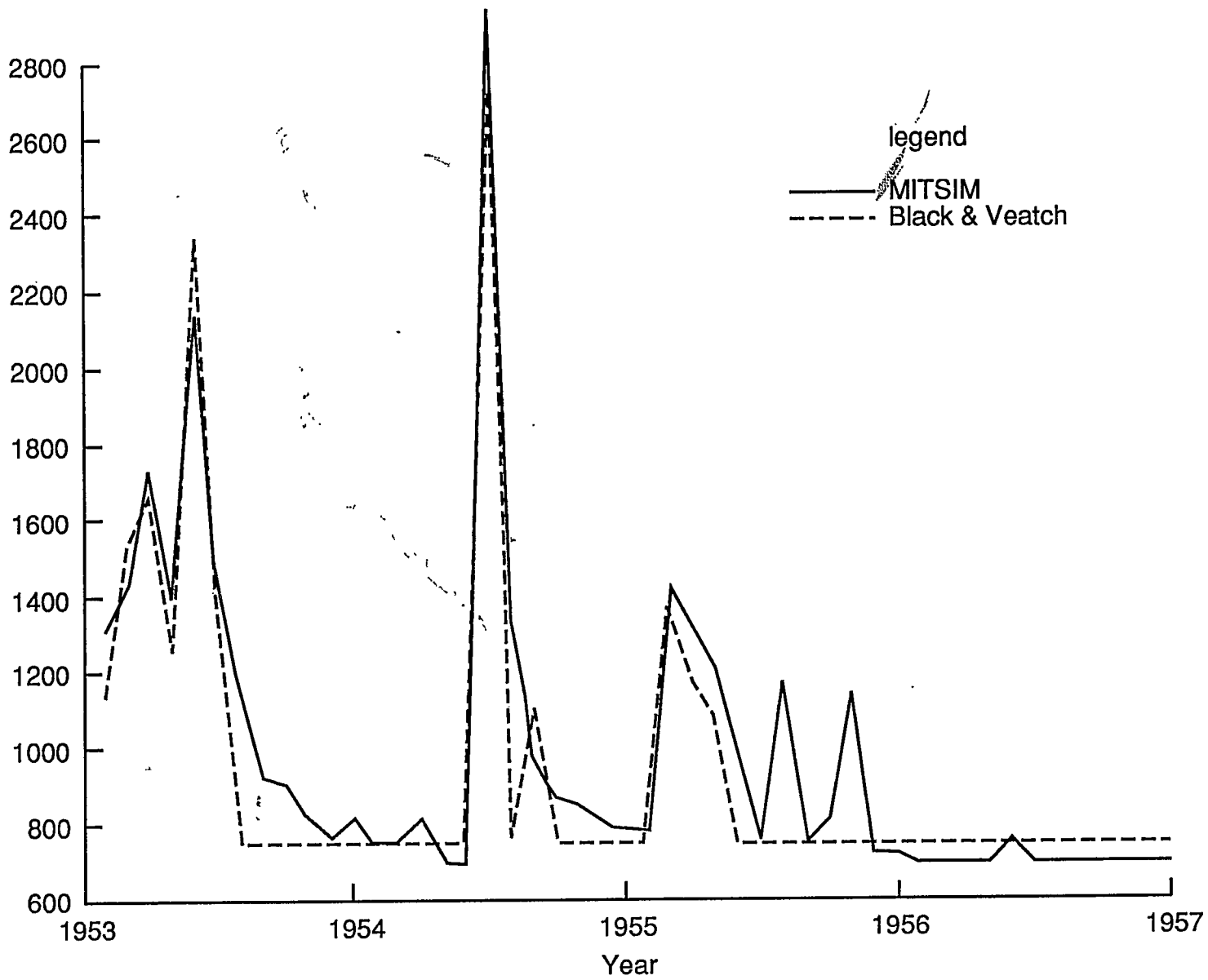


Figure 4.7 Downstream Flow from Wamego (1980)

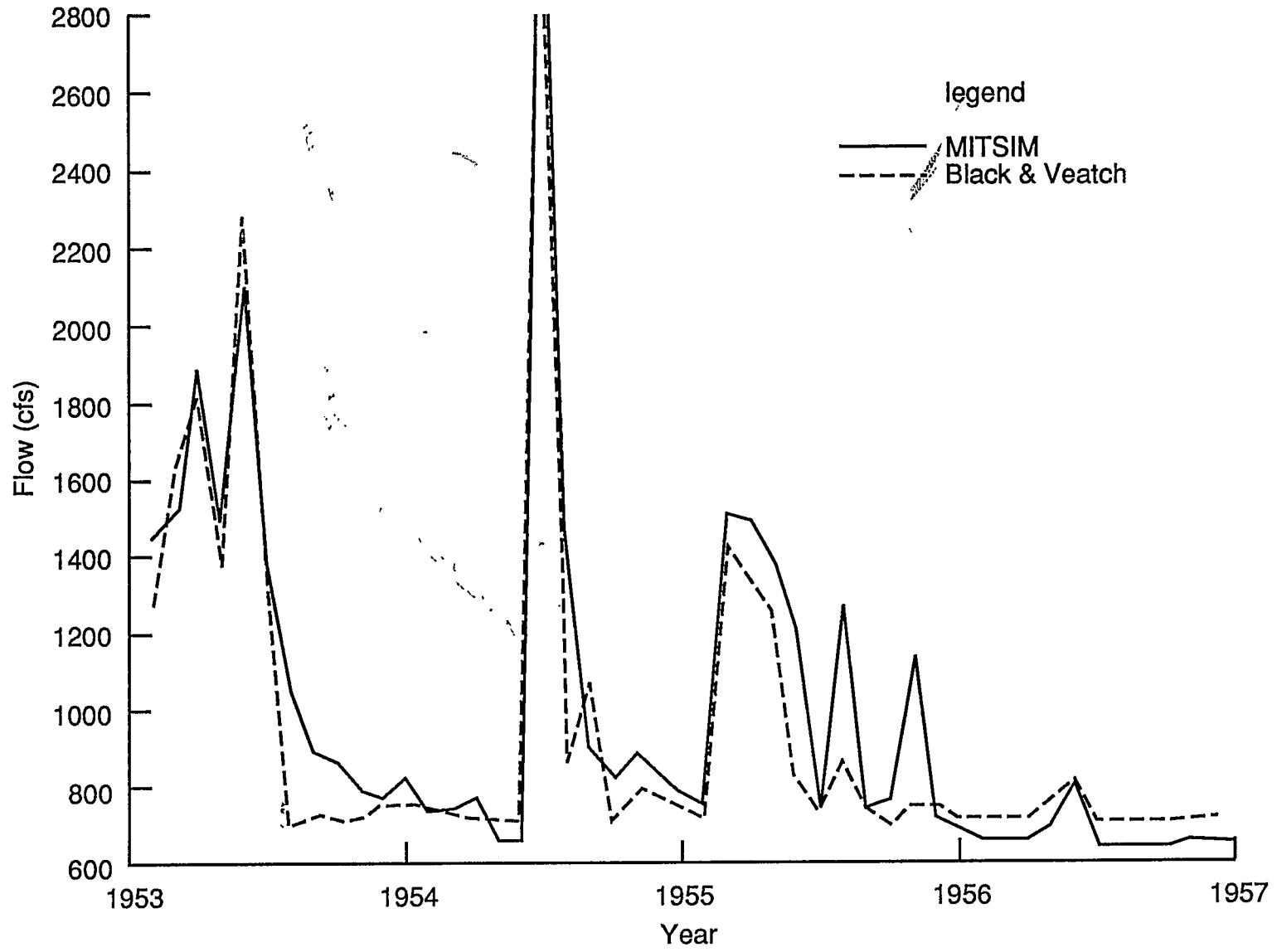


Figure 4.8 Downstream Flow from Topeka (1980)

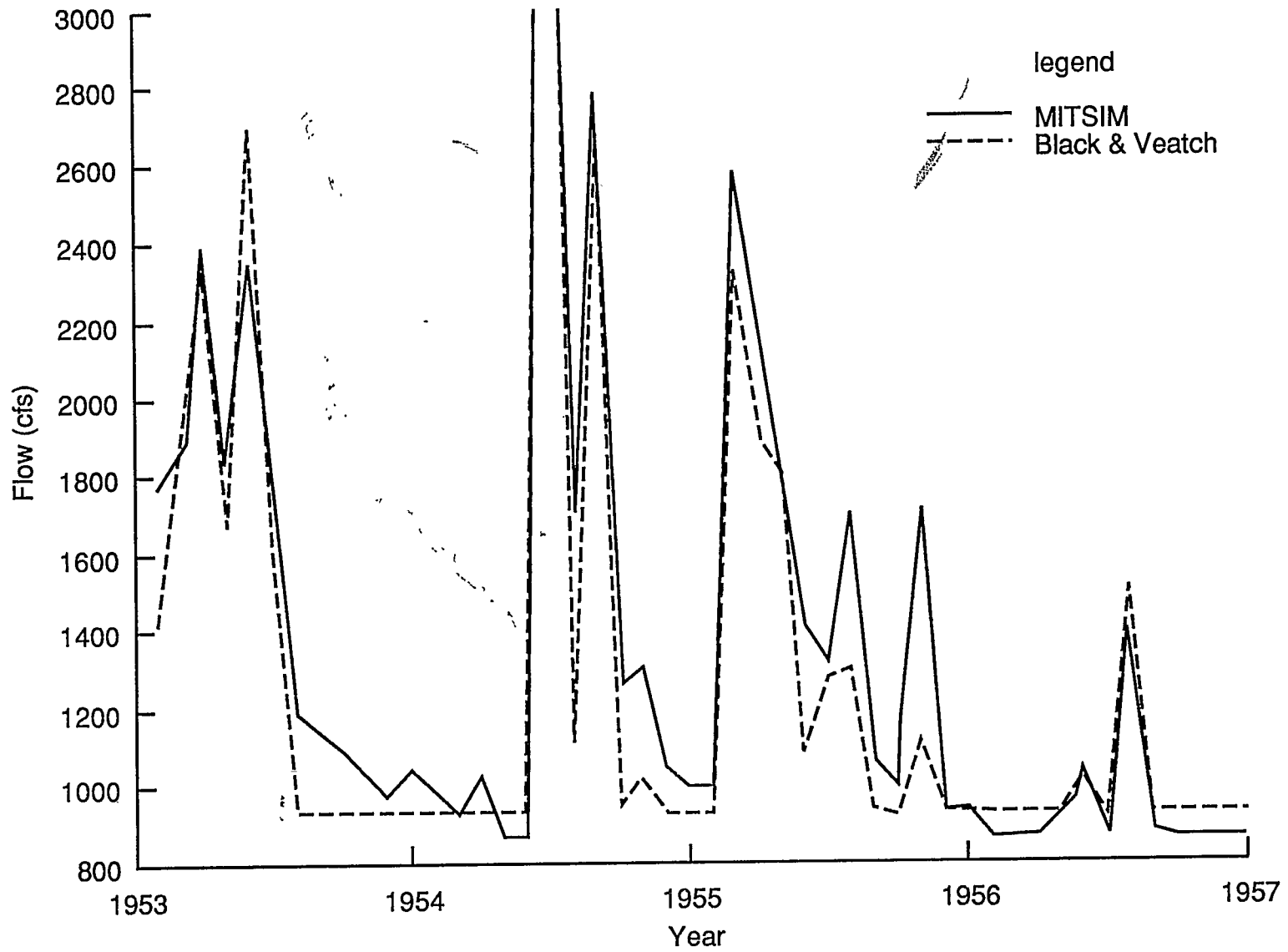


Figure 4.9 DownStream Flow from Lecompton (1980)

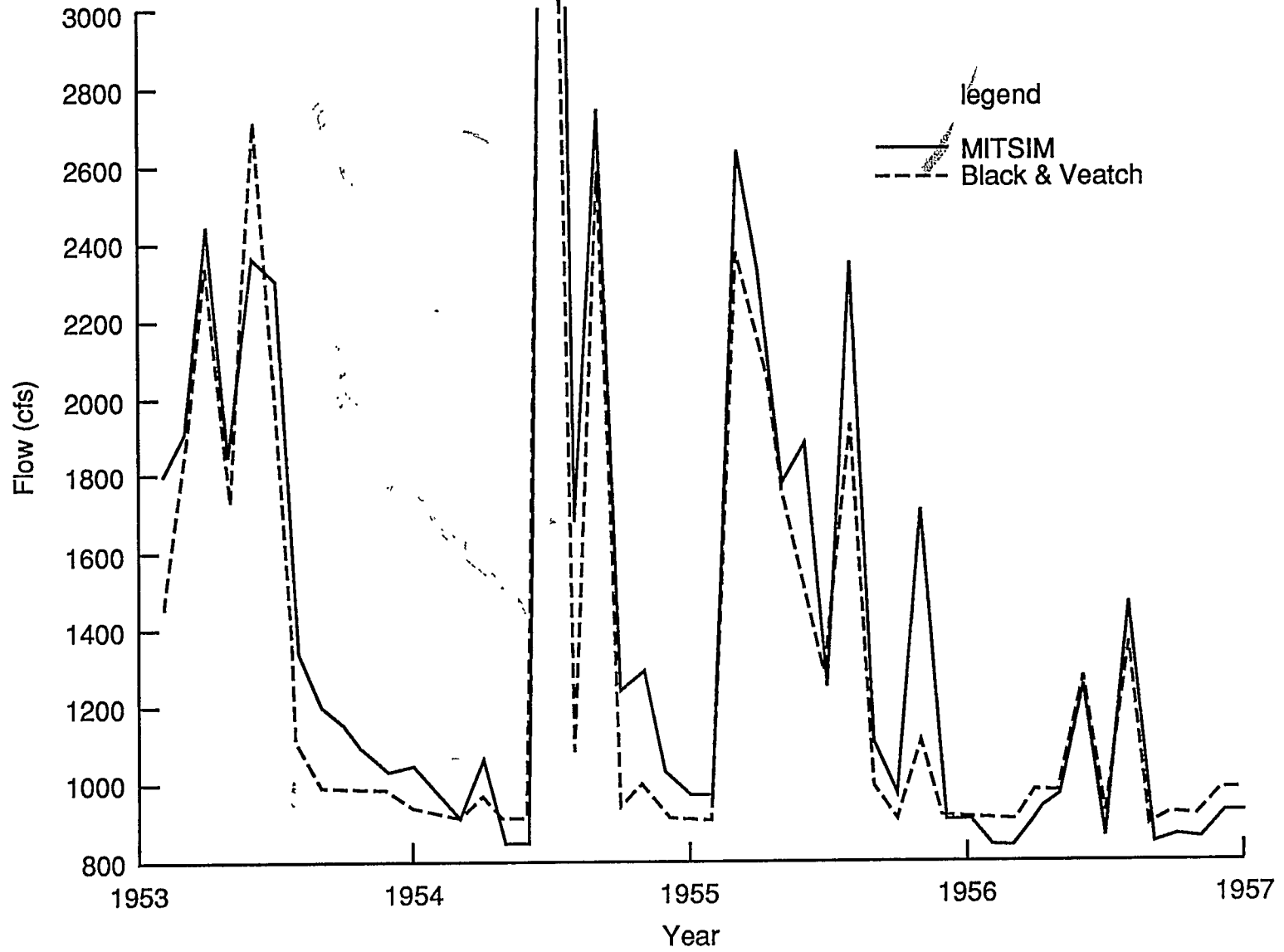


Figure 4.10 Downstream Flow from Bonner Springs (1980)

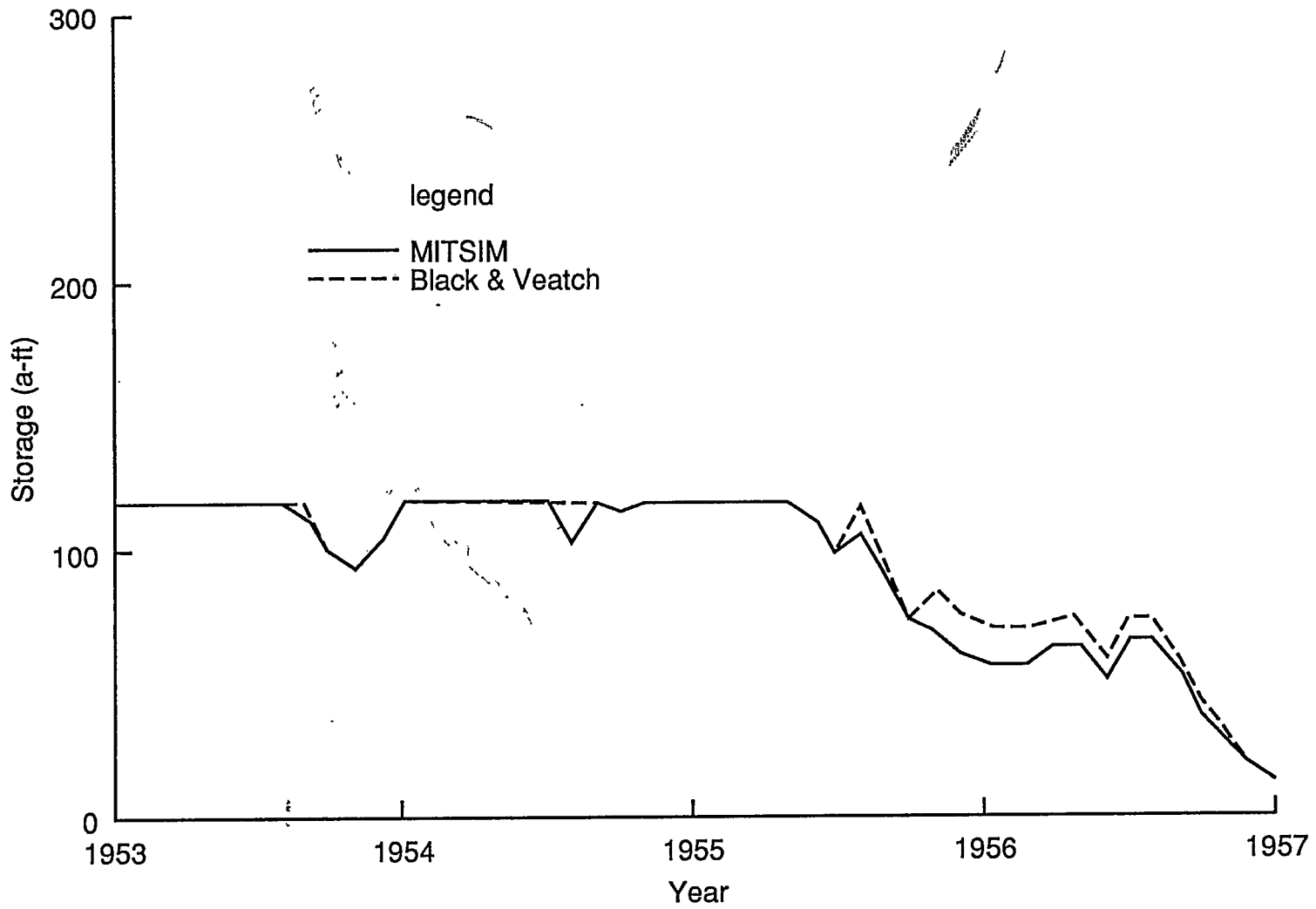


Figure 4.11 Storage in Tuttle Creek Reservoir (2035)

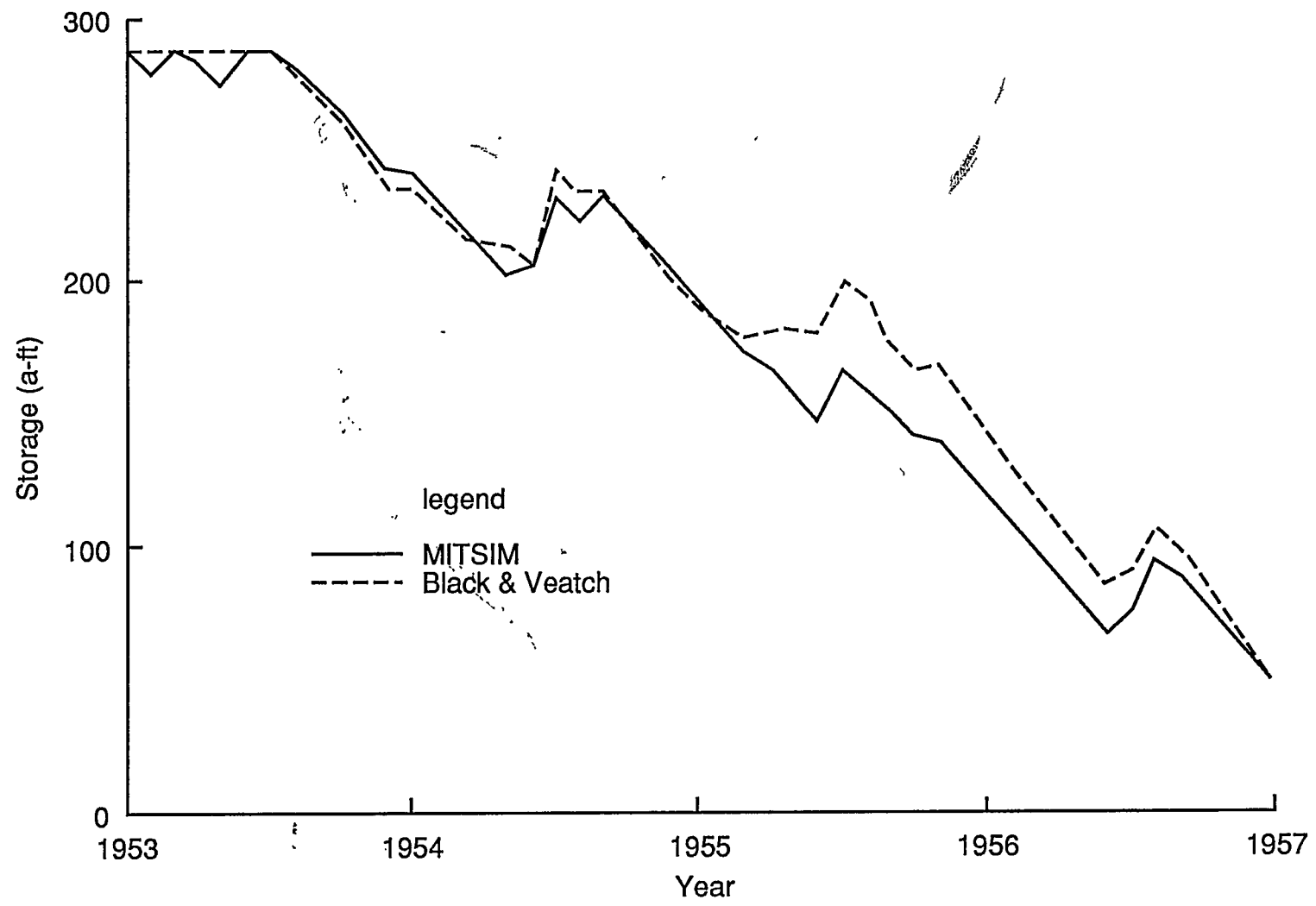


Figure 4.12 Storage in Milford Reservoir (2035)

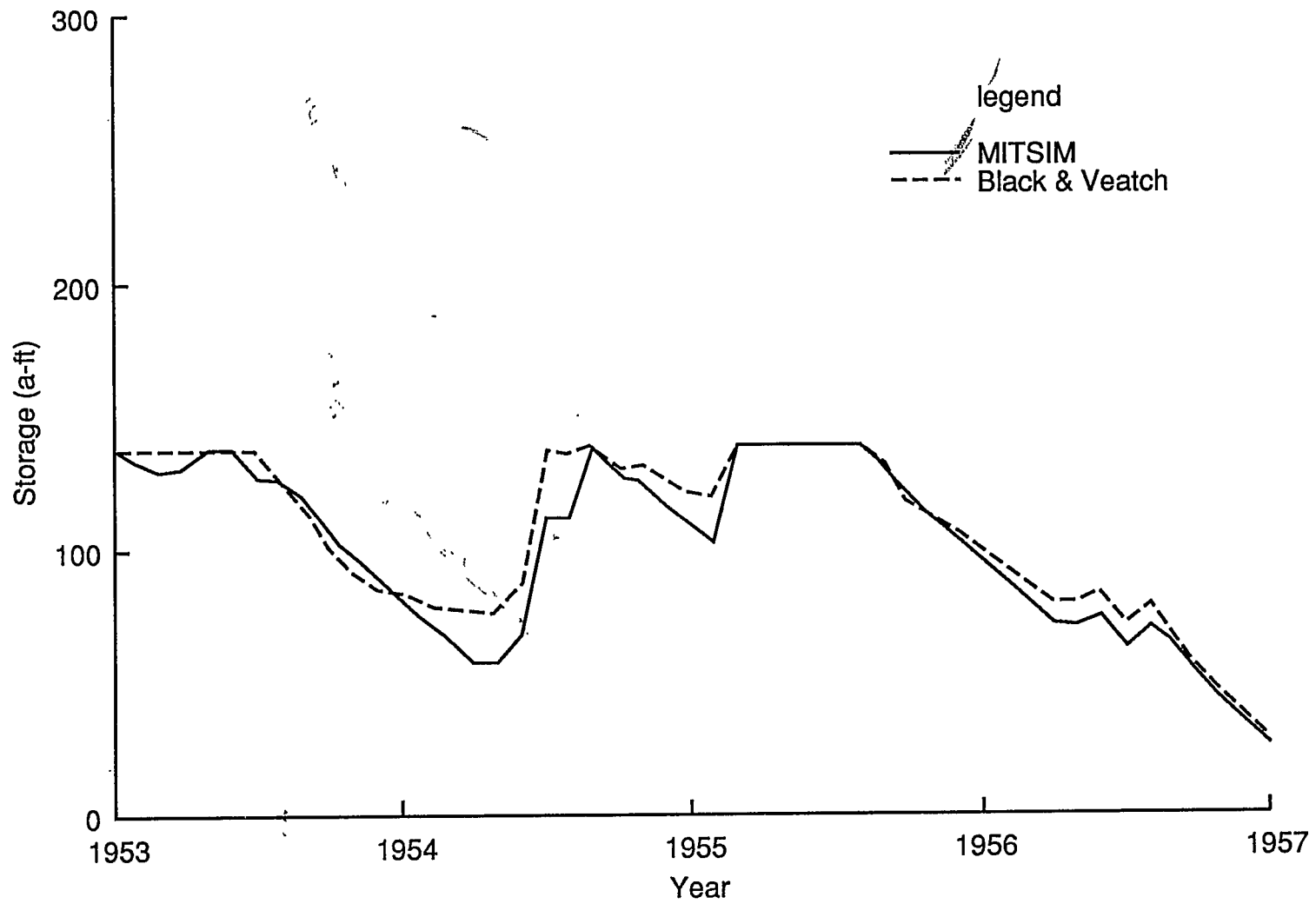


Figure 4.13 Storage in Perry Reservoir (2035)

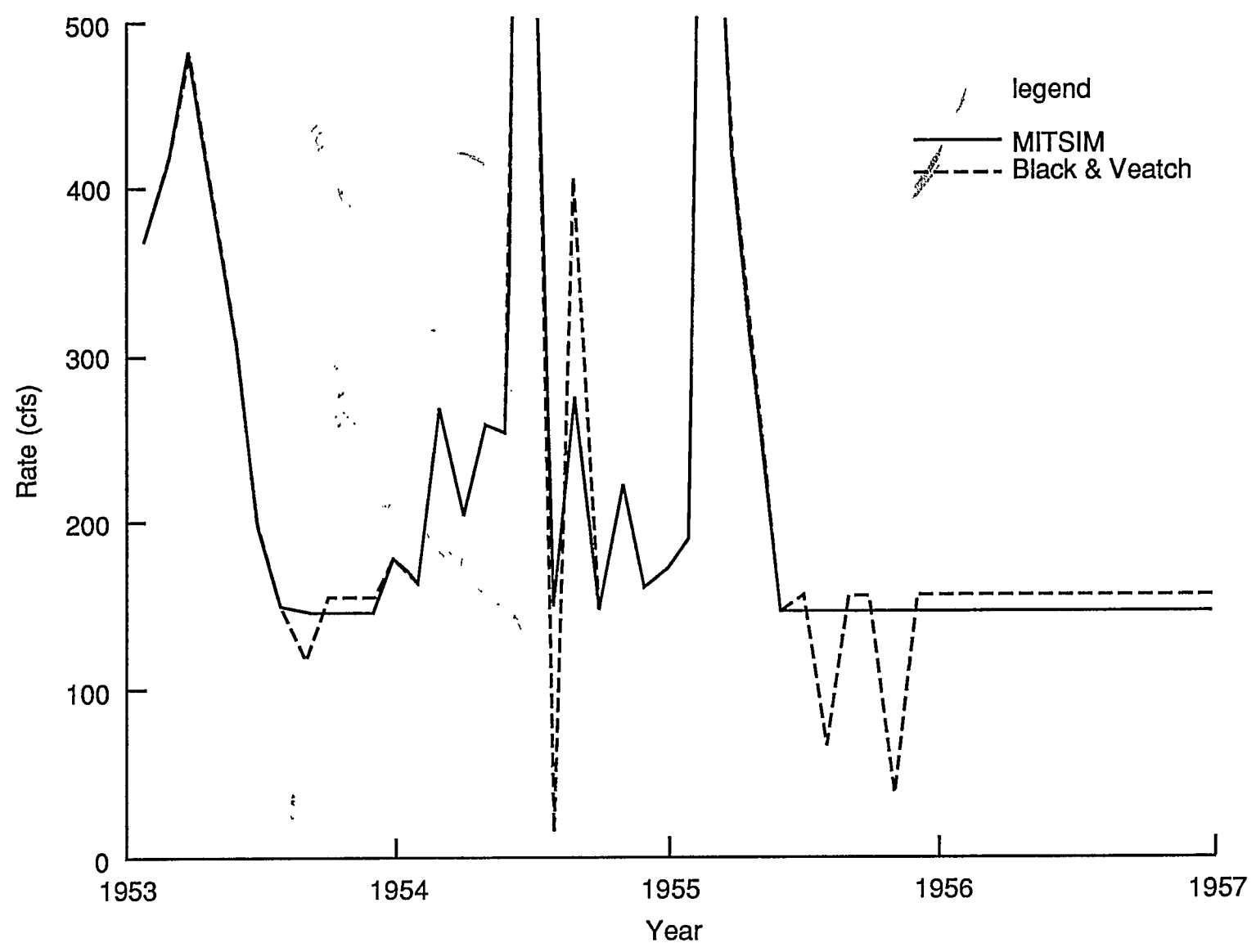


Figure 4.14 Release From Tuttle Creek Reservoir (2035)

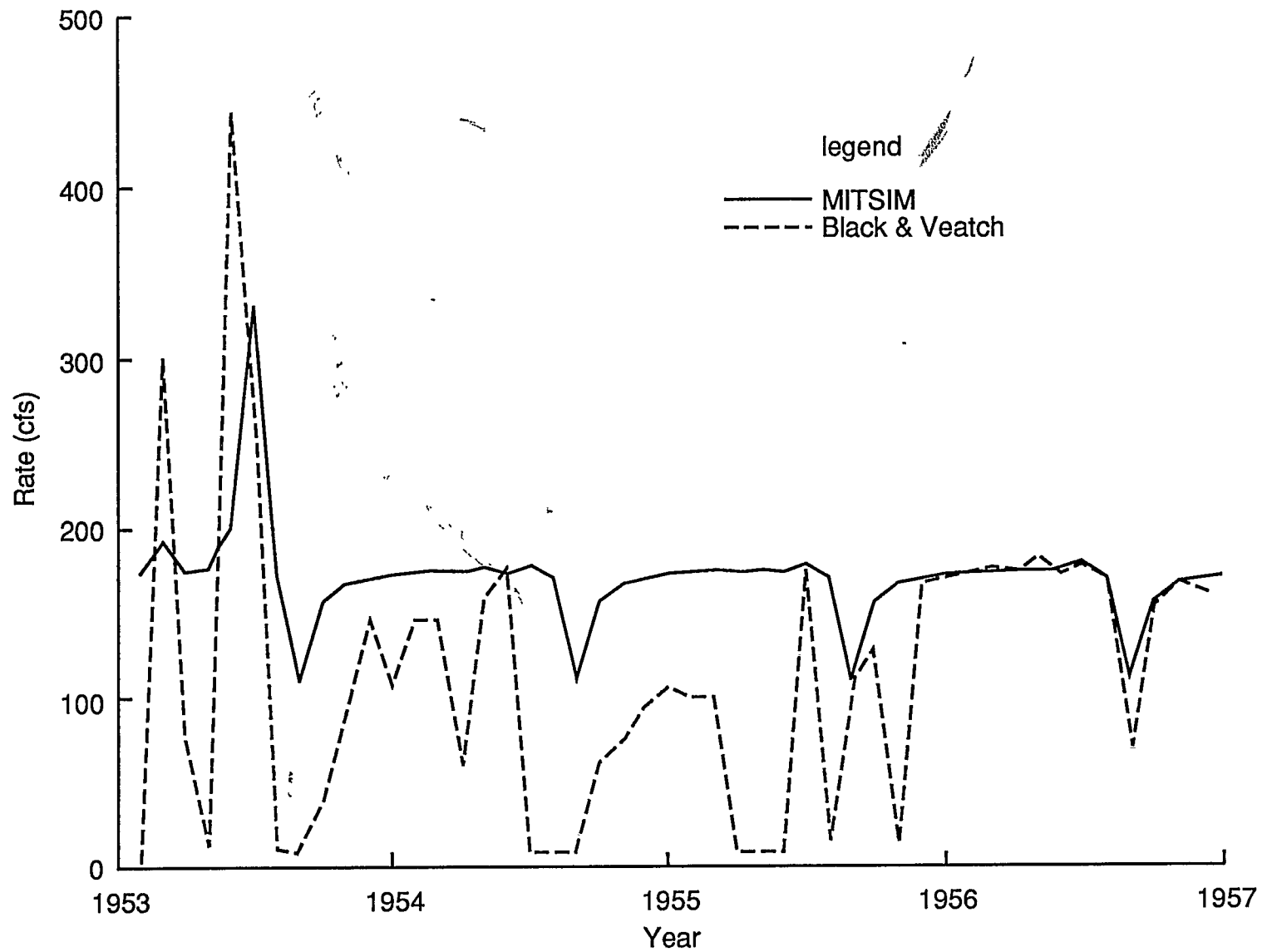


Figure 4.15 Release from Milford Reservoir (2035)

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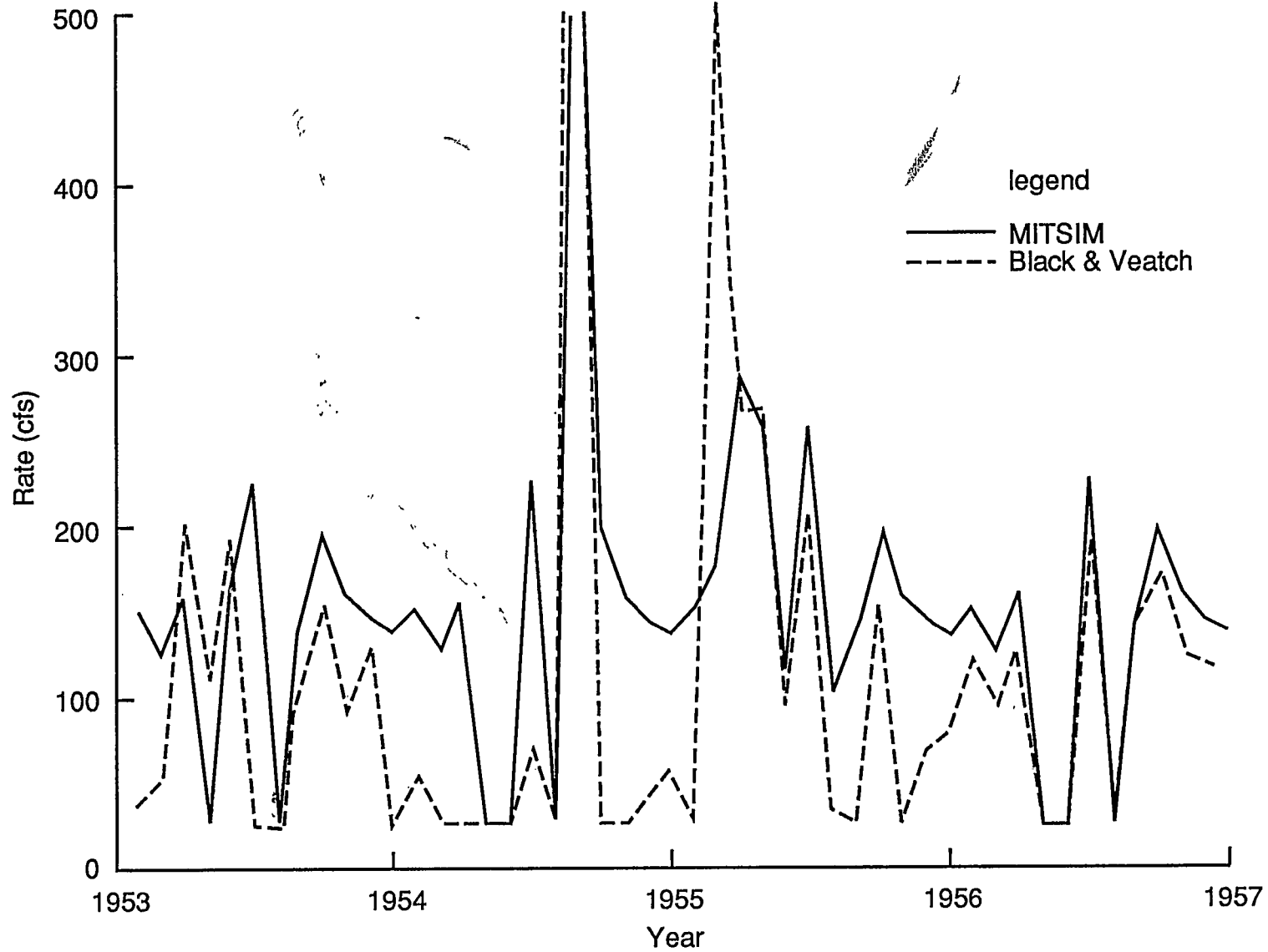


Figure 4.16 Release from Perry Reservoir (2035)

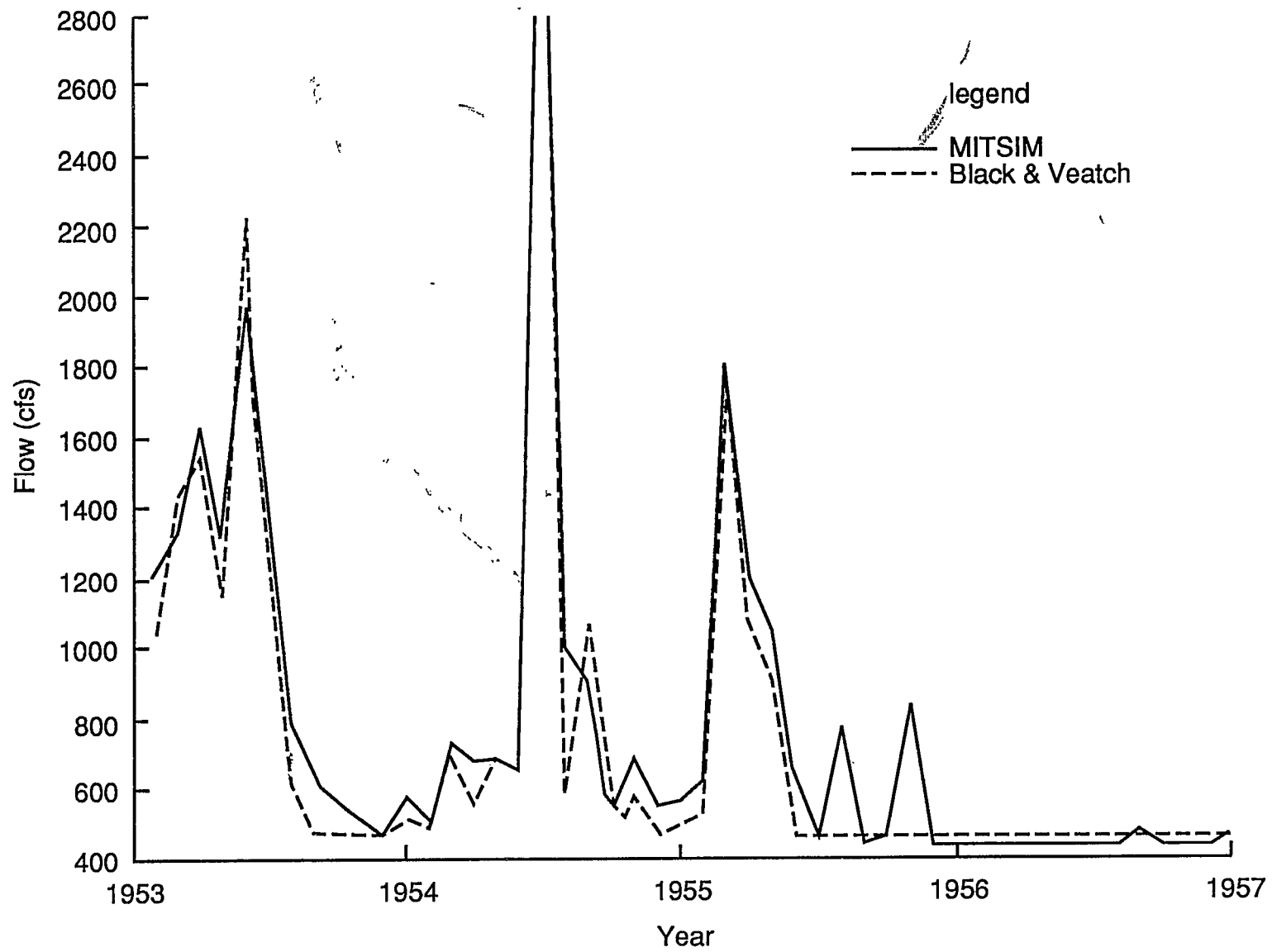


Figure 4.17 Downstream Flow from Wamego (2035)

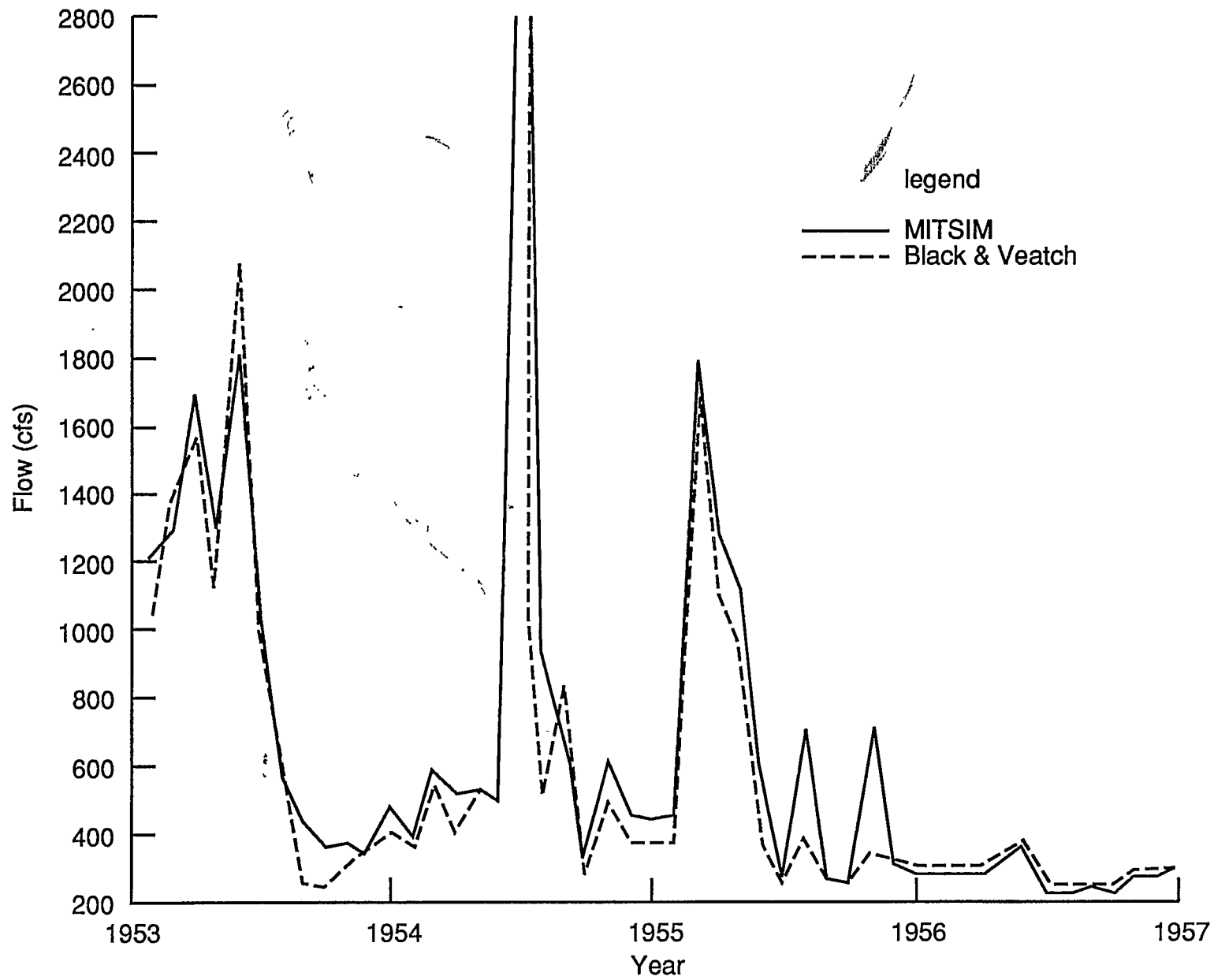


Figure 4.18 Downstream from Topeka (2035)

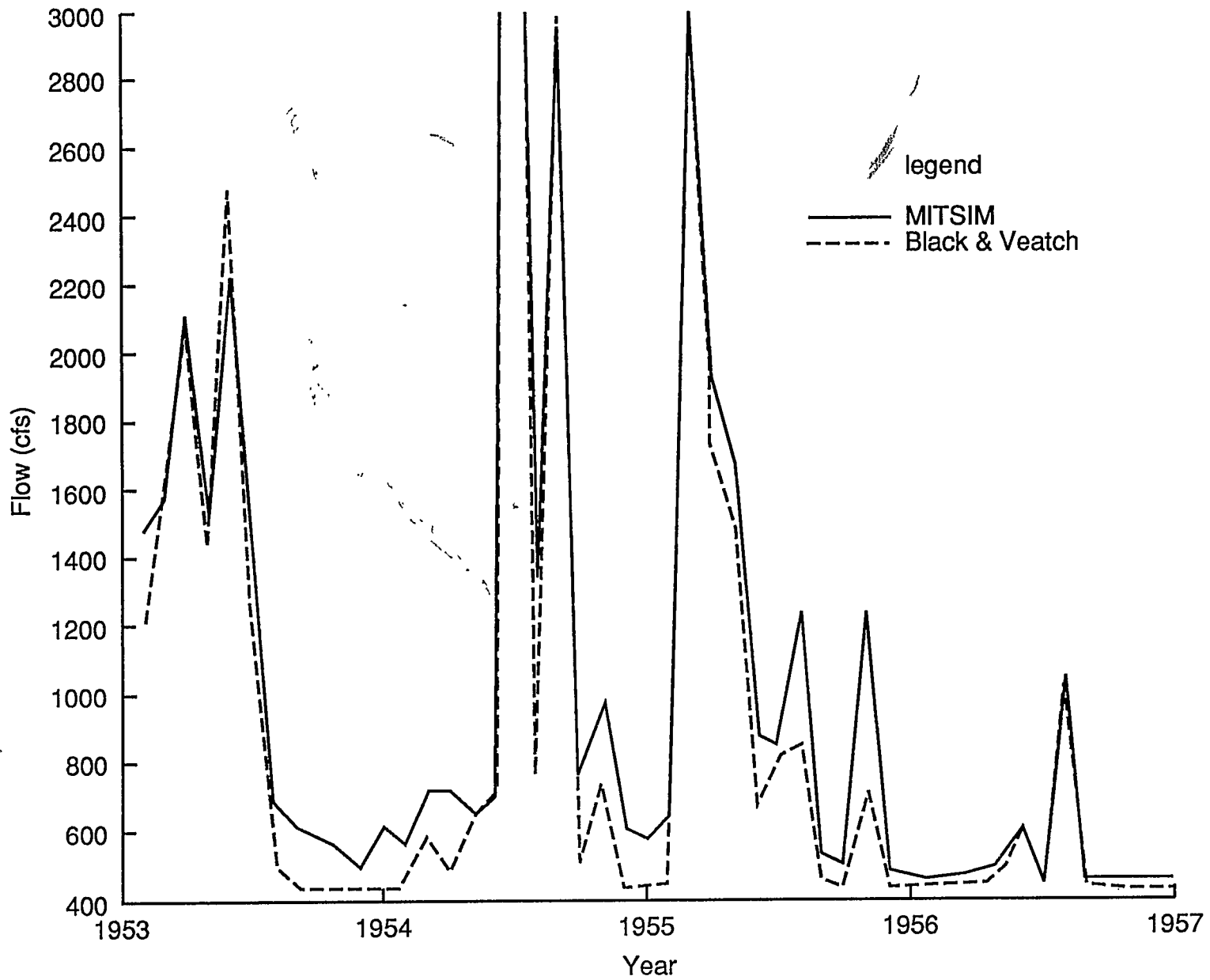


Figure 4.19 Downstream from Lecompton (2035)

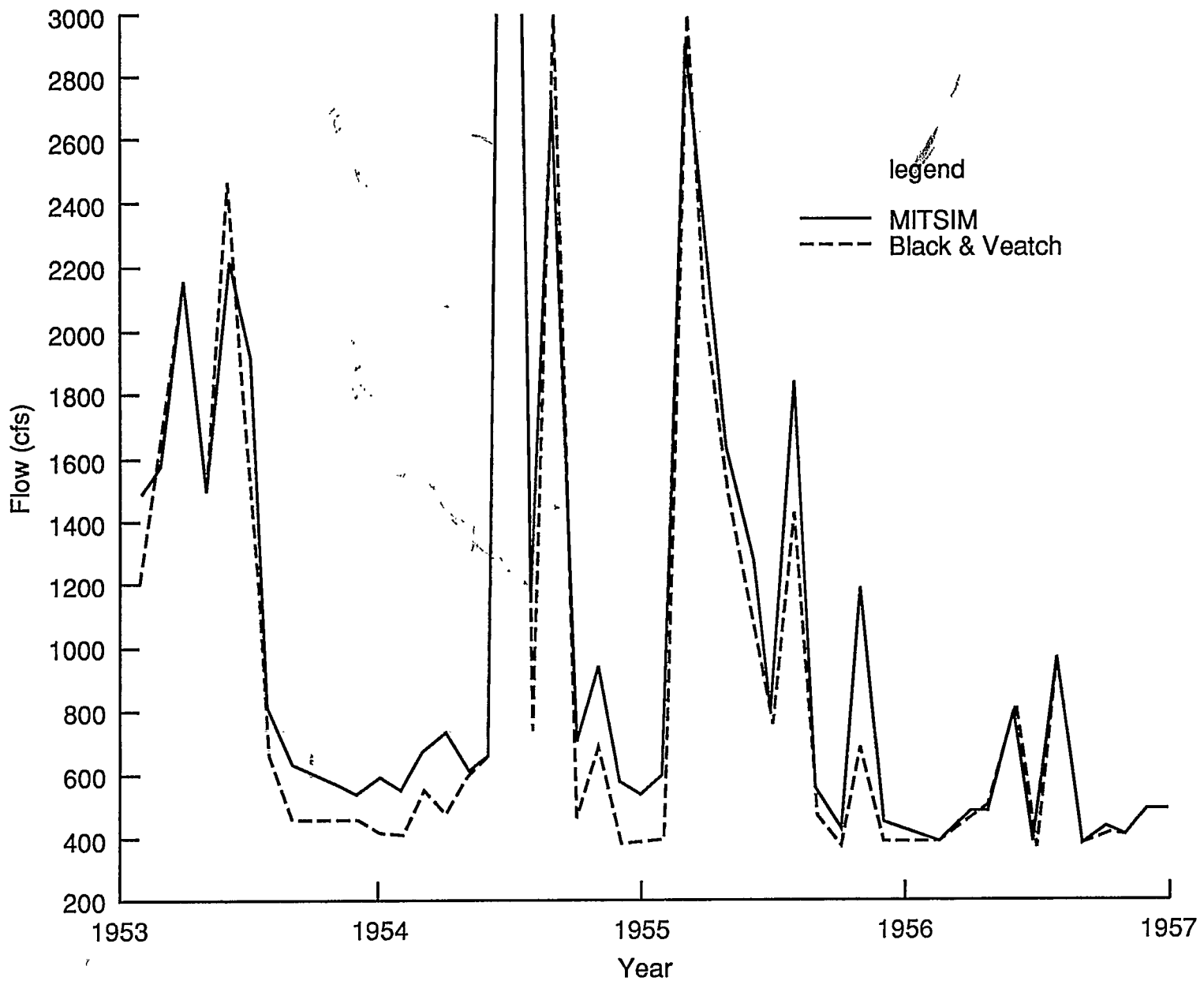


Figure 4.20 Downstream flow from Bonner Springs (2035)

Appendix A. Monthly Water Demands

Table A.1 Water Demand at Wamego (1980 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	95	95	112	112	112	201	201	201	173	112	112	95	1,621
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0
Agricultural	317	317	317	317	317	317	317	317	317	317	317	317	3,804
Total	412	412	429	429	429	518	518	518	490	429	429	412	5425

Table A.2 Water Demand at Topeka (1980 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	512	512	607	607	607	1,089	1,089	1,089	936	607	607	512	8,774
Industrial	935	935	935	935	935	1,430	1,430	1,430	1,430	935	935	935	13,200
Agricultural	920	920	920	920	920	920	920	920	920	920	920	920	11,040
Total	2,367	2,367	2,462	2,462	2,462	3,439	3,439	3,439	3,286	2,462	2,462	2,367	33,014

Table A.3 Water Demand at Lecompton (1980 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	0	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	102	102	102	102	102	102	102	102	102	102	102	102	1,224
Agricultural	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	102	102	102	102	102	102	102	102	102	102	102	102	1,224

Table A.4 Water Demand at Bonner Springs (1980 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	334	334	396	396	396	711	711	711	611	396	396	334	5,726
Industrial	449	449	449	449	449	686	686	686	686	449	449	449	6,336
Agricultural	287	287	287	287	287	287	287	287	287	287	287	287	3,444
Total	1,070	1,070	1,132	1,132	1,132	1,684	1,684	1,684	1,584	1,132	1,132	1,070	15,506

Table A.5 Water Demand at Wamego (2035 condition) /

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	288	288	341	341	341	612	612	612	526	341	341	288	4,931
Industrial	0	0	0	0	0	0	0	0	0	0	0	0	0
Agricultural	820	820	820	820	820	820	820	820	820	820	820	820	9,840
Total	1,108	1,108	1,161	1,161	1,161	1,432	1,432	1,432	1,346	1,161	1,161	1,108	14,771

Table A.6 Water Demand at Topeka (2035 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	1,470	1,470	1,743	1,743	1,743	3,129	3,129	3,129	2,688	1,743	1,743	1,470	25,200
Industrial	6,154	6,154	6,154	6,154	6,154	9,412	9,412	9,412	9,412	6,154	6,154	6,154	86,880
Agricultural	1,720	1,720	1,720	1,720	1,720	1,720	1,720	1,720	1,720	1,720	1,720	1,720	20,640
Total	9,344	9,344	9,617	9,617	9,617	14,261	14,261	14,261	13,820	9,617	9,617	9,344	132,720

Table A.7 Water Demand at Lecompton (2035 condition) /

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	0	0	0	0	0	0	0	0	0	0	0	0	0
Industrial	173	173	173	173	173	173	173	173	173	173	173	173	2,076
Agricultural	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	173	173	173	173	173	173	173	173	173	173	173	173	2,076

Table A.8 Water Demand at Bonner Springs (2035 condition)

Unit: Acre-ft

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
Municipal	1,099	1,099	1,303	1,303	1,303	2,339	2,339	2,339	2,010	1,303	1,303	1,099	18,839
Industrial	520	520	520	520	520	796	796	796	796	520	520	520	7,344
Agricultural	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,010	1,010	12,120
Total	2,629	2,629	2,833	2,833	2,833	4,145	4,145	4,145	3,816	2,833	2,833	2,629	38,303

Appendix B. Reduced (Adjusted) Monthly Inflows

Table B.1 Monthly Inflow to Reservoirs

Time	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1952			
November	36,900	1,940	2,420
December	46,100	5,150	3,050
Year: 1953			
January	46,100	1,640	4,040
February	50,400	20,500	3,620
March	58,800	6,010	11,500
April	48,000	2,280	7,550
May	32,800	25,100	11,500
June	27,000	20,000	2,710
July	26,100	2,370	300
August	18,400	0	180
September	7,190	0	220
October	17,300	0	320
November	29,200	0	480
December	40,800	8,500	870
Year: 1954			
January	24,100	0	260
February	32,400	2,500	680
March	27,200	1,380	690
April	31,500	0	1,450
May	30,700	14,100	12,900
June	10,000	37,600	56,500
July	8,210	0	2,060
August	54,300	16,900	62,300
September	21,400	0	1,220
October	36,600	0	6,000
November	24,100	0	680
December	23,600	0	1,040
Year: 1955			
January	23,600	0	1,930
February	95,000	720	47,200
March	52,400	5,370	17,300
April	33,200	1,530	15,400
May	9,880	0	6,730
June	8,990	31,800	15,600
July	29,600	0	6,120

Table B.1 Monthly Inflow to Reservoirs (con't.)

Time	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1955 (con't.)			
August	8,530	0	1,080
September	2,720	583	150
October	16,400	7,220	1,380
November	12,900	0	340
December	15,500	0	390
Year: 1956			
January	17,900	0	310
February	19,800	0	610
March	24,100	773	450
April	19,100	1,280	1,780
May	5,500	0	3,810
June	35,500	18,300	2,040
July	20,100	30,800	9,970
August	9,380	0	290
September	6,400	0	160
October	9,980	0	90
November	10,400	0	230
December	13,200	0	200
Year: 1957			
January	11,900	0	120
February	15,700	0	230
March	23,900	0	920
April	54,400	0	17,800
May	38,400	43,200	37,000

Table B.2 Monthly Incremental Flow to Kansas River

Time	Flows (a-ft)			
	Warrego	Topeka	Lecompton	Bonner Springs
(1)	(2)	(3)	(4)	(5)
Year: 1952				
November	0	0	12,200	1,880
December	3,390	1,870	12,990	0
Year: 1953				
January	3,760	10,300	6,700	2,800
February	7,050	6,900	10,200	3,300
March	13,170	12,400	16,700	4,600
April	7,570	8,500	12,300	3,600
May	0	0	13,300	1,600
June	10,730	0	14,900	28,000
July	7,300	0	6,500	10,300
August	4,940	1,590	3,370	5,130
September	3,030	740	1,760	4,780
October	2,920	620	1,270	4,280
November	0	2,570	0	4,730
December	0	2,860	0	1,390
Year: 1954				
January	0	1,750	1,670	1,530
February	870	990	380	0
March	4,410	0	2,660	3,200
April	0	0	6,000	0
May	0	0	11,400	0
June	39,010	32,940	106,900	0
July	20,610	9,730	14,040	0
August	10,800	0	102,300	0
September	5,870	0	14,360	0
October	5,670	4,570	12,840	0
November	4,340	3,800	1,040	0
December	4,000	1,870	0	0
Year: 1955				
January	4,530	0	2,370	0
February	4,930	7,590	53,400	4,940
March	13,500	12,430	22,400	16,800
April	7,660	13,390	16,880	700
May	11,230	15,790	11,050	30,070
June	150	2,100	20,800	0
July	11,730	9,600	25,200	40,700
August	2,420	2,950	7,940	5,370
September	0	0	2,040	0

Table B.2 Monthly Incremental Flow to Kansas River (con't.)

Time	Flows (a-ft)			
	Wamego	Topeka	Lecompton	Bonner Springs
(1)	(2)	(3)	(4)	(5)
Year: 1955 (con't.)				
October	0	2,210	21,500	0
November	0	1,690	1,620	0
December	0	0	2,410	0
Year: 1956				
January	0	0	210	0
February	0	0	1,710	0
March	0	0	0	5,100
April	0	2,240	7,530	4,200
May	0	5,280	12,250	15,010
June	0	0	600	0
July	0	0	47,200	0
August	5,820	0	3,170	0
September	697	0	1,360	2,250
October	0	0	80	1,000
November	312	0	660	5,200
December	1,140	0	0	5,420
Year: 1957				
January	1,100	0	0	2,150
February	950	0	0	7,700
March	0	0	600	8,990
April	0	8,080	9,700	26,400
May	0	65,800	50,400	0

Table B.3 Flow from Smoky Hill River to Kansas River

Flows (a-ft)			
	Time	Wamego	Topeka
	(1)	(2)	(3)
Year: 1952	November	21,170	15,490
	December	22,180	16,500
Year: 1953	January	20,510	14,830
	February	18,990	13,310
	March	24,030	18,350
	April	20,090	14,410
	May	77,660	71,980
	June	30,080	24,400
	July	17,660	71,980
	August	15,130	9,450
	September	10,940	5,260
	October	6,910	1,230
	November	7,290	1,610
	December	9,860	4,180
Year: 1954	January	7,390	1,710
	February	6,820	1,140
	March	8,250	2,570
	April	6,550	870
	May	0	0
	June	72,230	60,870
	July	18,860	13,180
	August	9,800	4,200
	September	5,400	0
	October	5,990	30
	November	5,130	0
	December	3,710	0
Year: 1955	January	5,040	0
	February	4,350	0
	March	5,830	0
	April	23,460	13,400
	May	6,020	340
	June	3,260	0
	July	17,360	9,260
	August	7,110	1,430
	September	8,400	2,720

Table B.3 Flow from Smoky Hill River to Kansas River (con't.)

Flows (a-ft)		
Time	Wamego	Topeka
(1)	(2)	(3)
Year: 1955 (con't.)		
October	30,110	24,430
November	5,040	0
December	4,460	0
Year: 1956		
January	4,390	0
February	3,740	0
March	5,510	0
April	6,270	0
May	3,980	0
June	0	0
July	0	0
August	0	0
September	0	0
October	2,540	0
November	2,800	0
December	1,290	0
Year: 1957		
January	390	0
February	1,660	0
March	2,190	0
April	30,780	0
May	109,000	76,160

Appendix C. Results

Table C1. Reservoir Storage (1980 condition)

Time	Storage (a-ft)		
	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1952			
December	335,000	388,800	222,500
Year: 1953			
January	334,994	379,561	213,612
February	334,994	388,547	205,784
March	334,994	384,835	204,084
April	334,994	378,072	204,658
May	334,994	387,869	214,355
June	331,476	388,786	202,864
July	322,518	376,479	201,649
August	308,220	367,803	190,261
September	283,081	353,939	177,681
October	268,304	341,447	164,774
November	267,535	329,404	152,652
December	279,526	325,132	140,362
Year: 1954			
January	272,788	314,259	127,698
February	278,396	305,244	116,930
March	276,190	296,902	104,421
April	280,552	287,860	98,896
May	284,112	286,658	109,993
June	334,994	308,992	152,292
July	309,900	294,318	152,839
August	331,827	302,542	203,570
September	317,892	288,679	191,991
October	322,517	276,188	184,764
November	314,931	264,146	172,842
December	308,837	251,375	160,723
Year: 1955			
January	305,038	240,502	149,729
February	334,994	229,709	185,479
March	334,994	225,356	189,579
April	334,994	217,844	190,003
May	317,712	202,543	202,929
June	296,412	219,079	204,327

Note: Results from MIT simulation model

Table C1. Reservoir Storage (1980 condition) con't.

Time	Storage (a-ft)		
	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1955 con't.			
July	294,784	204,407	208,931
August	267,885	195,733	198,443
September	240,986	182,457	185,794
October	228,412	177,186	173,947
November	210,897	165,144	161,687
Year: 1956			
January	188,178	141,501	136,302
February	180,119	129,989	125,464
March	175,910	121,040	112,714
April	167,470	113,280	107,519
May	144,683	97,980	109,527
June	151,853	101,018	97,367
July	142,799	117,148	105,824
August	122,107	108,477	94,548
September	96,248	94,618	81,911
October	76,455	82,130	68,775
November	58,068	70,090	56,405
December	43,476	57,320	43,447

Note: Results from MIT simulation model

Table C.2 Hydrograph (1980)

Time	Release from Tuttle Creek (cfs)	Release From Milford (cfs)	Flow at Wamego (cfs)	Flow at Topeka (cfs)	Release from Perry (cfs)	Flow at Lecompton (cfs)	Flow at Bonner Springs (cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year: 1953							
January	735	180	1,312	1,444	214	1,768	1,797
February	819	190	1,436	1,511	189	1,868	1,905
March	965	161	1,735	1,899	218	2,393	2,451
April	780	149	1,382	1,483	155	1,801	1,842
May	614	253	2,148	2,107	29	2,355	2,363
June	445	316	1,436	1,381	235	1,862	2,301
July	445	242	1,102	1,049	25	1,181	1,327
August	445	143	920	892	191	1,138	1,196
September	445	229	901	859	211	1,098	1,151
October	445	206	813	782	219	1,020	1,072
November	445	199	761	763	208	971	1,030
December	445	211	816	824	218	1,041	1,047
Year: 1954							
January	445	180	743	733	214	973	981
February	445	190	757	734	189	928	911
March	445	161	812	771	218	1,032	1,067
April	445	149	697	656	115	869	851
May	445	253	693	652	29	869	851
June	851	252	2,940	3,430	235	5,434	5,407
July	445	242	1,337	1,442	25	1,697	1,670
August	445	143	939	890	191	2,778	2,755
September	445	229	865	814	211	1,263	1,239
October	445	206	845	881	219	1,312	1,294
November	445	199	799	822	208	1,046	1,027
December	445	211	781	772	218	989	971
Year: 1955							
January	445	180	778	739	214	990	973
February	1,088	190	1,423	1,510	189	2,582	2,646
March	841	161	1,317	1,483	218	2,071	2,331
April	550	149	1,208	1,389	115	1,781	1,774
May	445	253	979	1,200	29	1,411	1,891
June	445	252	748	727	235	1,304	1,277
July	445	242	1,167	1,272	25	1,713	2,362
August	445	143	743	733	191	1,053	1,113
September	445	229	811	757	211	1,000	973
October	445	206	1,149	1,148	219	1,723	1,706
November	445	199	725	711	208	945	927
December	445	211	726	686	218	943	925

Note: Results from MIT simulation model

Table C.2 Hydrograph (1980) con't.

Time	Release from Tuttle Creek (cfs)	Release From Milford (cfs)	Flow at Wamego (cfs)	Flow at Topeka (cfs)	Release from Perry (cfs)	Flow at Lecompton (cfs)	Flow at Bonner Springs (cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year: 1956							
January	445	180	692	653	214	869	851
February	445	190	692	653	189	869	851
March	445	161	692	651	218	869	934
April	445	149	692	688	115	927	978
May	445	253	759	805	29	1,037	1,267
June	445	252	692	636	235	878	851
July	445	242	692	639	25	1,445	1,420
August	445	143	692	636	191	878	851
September	445	229	692	638	211	869	877
October	445	206	692	651	219	869	864
November	445	199	692	651	208	869	935
December	445	211	692	653	218	869	941

Note: Results from MIT simulation model

Table C3. Reservoir Storage (2035 condition)

Time	Storage (a-ft)		
	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1952			
December	119,000	287,000	138,000
Year: 1953			
January	118,995	278,112	132,948
February	118,995	286,994	129,005
March	118,995	282,493	130,967
April	118,995	274,077	137,013
May	118,995	286,991	137,994
June	118,995	286,988	127,018
July	118,995	279,112	125,793
August	114,058	272,462	117,518
September	98,340	262,928	105,833
October	93,147	252,771	96,647
November	101,826	242,535	88,444
December	118,995	240,592	81,136
Year: 1954			
January	118,995	230,067	72,295
February	118,995	221,971	65,412
March	118,995	212,847	56,551
April	118,995	202,151	56,482
May	118,995	205,730	67,876
June	118,995	232,553	110,724
July	103,276	222,313	111,269
August	118,995	232,583	137,990
September	114,484	223,049	127,305
October	118,995	212,893	123,807
November	118,995	202,658	115,795
December	118,995	192,214	108,658
Year: 1955			
January	118,995	181,689	101,499
February	118,995	171,825	137,996
March	118,995	166,686	137,995
April	118,995	157,524	137,995
May	111,139	146,998	137,994
June	99,341	168,006	137,991
July	107,104	157,768	137,990
August	89,617	151,121	130,630
September	72,130	142,165	118,880
October	69,069	139,223	110,759

Note: Results from MIt simulation model

Table C3. Reservoir Storage (2035 condition) con't.

Time	Storage (a-ft)		
	Tuttle Creek Reservoir	Milford Reservoir	Perry Reservoir
(1)	(2)	(3)	(4)
Year: 1955 con't.			
November	61,042	128,999	102,407
December	57,682	118,556	94,609
Year: 1956			
January	57,242	108,031	85,831
February	58,591	97,443	78,885
March	63,754	87,702	69,789
April	64,677	78,286	70,061
May	51,196	67,761	72,357
June	67,630	75,262	60,722
July	67,573	95,836	69,174
August	55,733	89,192	61,028
September	38,693	79,662	49,302
October	28,153	69,509	39,883
November	19,168	59,276	31,425
December	14,039	48,833	23,436

Note: Results from MIt simulation model

Table C.4 Hydrograph (2035)

Time	Release from Tuttle Creek (cfs)	Release From Milford (cfs)	Flow at Wamego (cfs)	Flow at Topeka (cfs)	Release from Perry (cfs)	Flow at Lecompton (cfs)	Flow at Bonner Springs (cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year: 1953							
January	735	174	1,202	1,218	150	1,477	1,481
February	820	192	1,333	1,293	125	1,584	1,596
March	966	174	1,643	1,689	158	2,121	2,150
April	780	177	1,305	1,287	25	1,513	1,527
May	615	202	1,991	1,832	174	2,224	2,203
June	387	331	1,285	1,052	226	1,522	1,921
July	297	169	772	541	25	672	780
August	289	110	623	417	139	611	632
September	289	157	566	357	197	580	597
October	289	168	515	367	157	544	569
November	289	169	471	355	144	497	529
December	358	173	584	478	135	611	591
Year: 1954							
January	326	174	513	388	150	563	546
February	539	175	730	591	125	720	676
March	406	174	680	521	158	721	728
April	518	177	690	531	25	653	606
May	504	174	660	501	25	713	666
June	1,697	179	3,510	3,818	226	5,814	5,746
July	289	169	999	925	25	1,179	1,112
August	548	110	902	674	590	2,960	2,895
September	289	157	543	325	197	760	703
October	447	168	701	619	157	987	942
November	317	169	549	453	144	613	567
December	342	173	568	444	135	577	535
Year: 1955							
January	382	174	614	459	150	647	604
February	1,586	175	1,821	1,792	177	2,852	2,891
March	842	174	1,223	1,270	286	1,926	2,158
April	550	177	1,058	1,121	255	1,653	1,618
May	289	174	638	575	111	867	1,320
June	289	179	449	249	258	848	781
July	289	169	790	716	101	1,233	1,843
August	289	110	447	260	139	528	550
September	289	157	477	256	197	483	421
October	289	168	849	730	157	1,244	1,200
November	289	169	447	317	144	485	439
December	289	173	448	293	135	466	423

Note: Results from MIT simulation model

Table C.4 Hydrograph (2035) con't.

Time	Release from Tuttle Creek (cfs)	Release From Milford (cfs)	Flow at Wamego (cfs)	Flow at Topeka (cfs)	Release from Perry (cfs)	Flow at Lecompton (cfs)	Flow at Bonner Springs (cfs)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Year: 1956							
January	289	174	447	292	150	444	400
February	289	175	448	293	125	444	400
March	289	174	447	288	158	444	482
April	289	177	447	324	25	471	494
May	289	174	447	375	25	601	803
June	289	179	447	211	226	444	376
July	289	169	448	216	25	1,022	957
August	289	110	487	254	139	444	378
September	289	157	450	228	197	444	424
October	289	168	448	288	157	444	413
November	289	169	450	291	144	444	483
December	289	173	466	311	135	444	490

Note: Results from MIT simulation model