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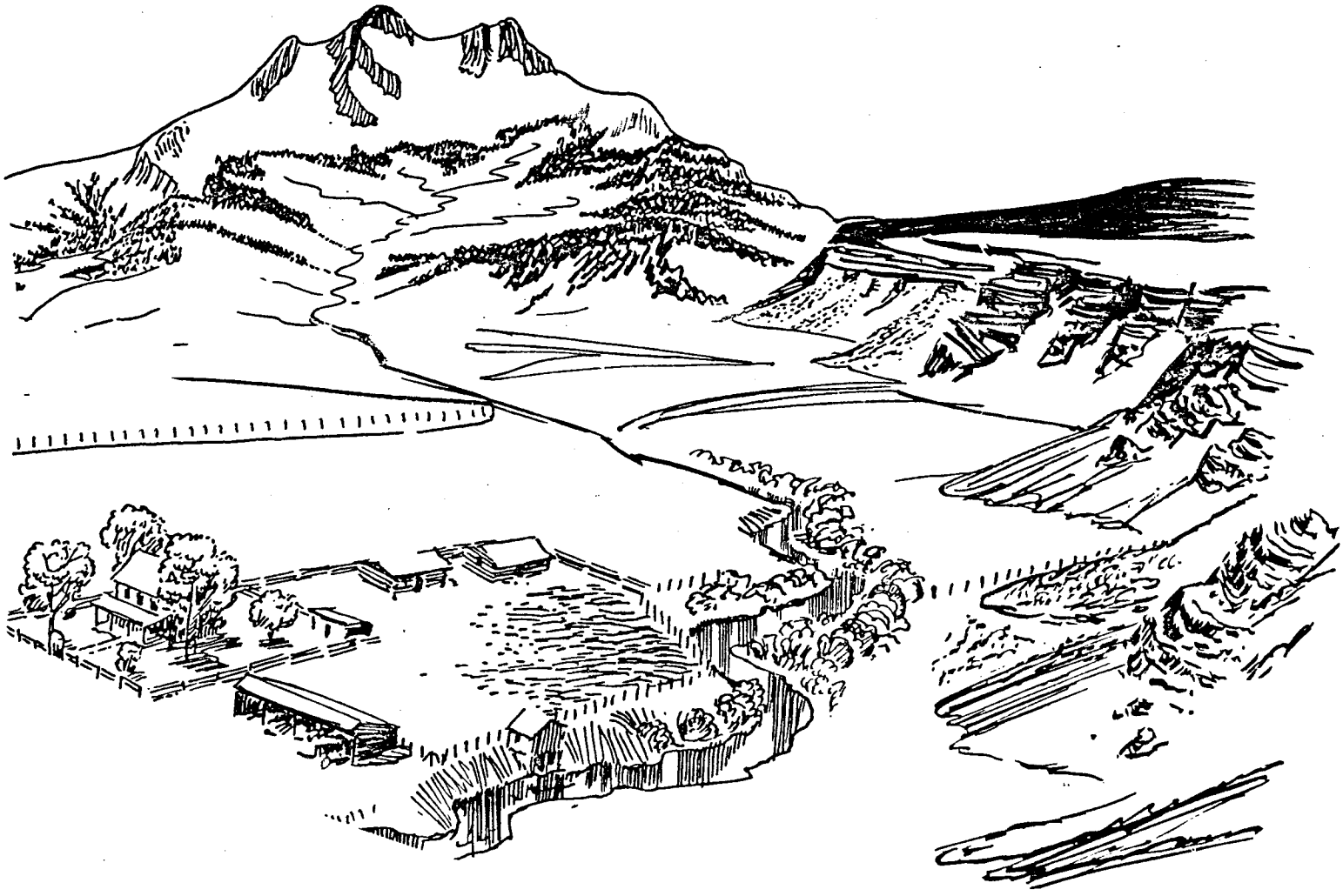
Irrigation Return Flow Study Duchesne River, Utah



Utah Division of Water Rights

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INTRODUCTION

As a result of meetings with the various water users and the Court in connection with the distribution of water on the Duchesne River System, the State Engineer at the request of the parties agreed to undertake an investigation of irrigation return flow on this System. The quantity of water returned to the River System ~~as a result of~~ from the diversion and use of water for irrigation purposes is one aspect of the broader question of duty of water which is a part of the statutory adjudication proceedings pending in this area. At the time this study was undertaken, the State Engineer advised the parties and the Court that because of budgetary and personnel limitations he would only be able to undertake a limited study of return flow on the Duchesne River System. It was further pointed out that ~~because of~~ due to the above limitations it would be necessary to conduct this study over several years rather than attempting to do a comprehensive evaluation of return flow in one irrigation season.

The results of the State Engineer's investigation are summarized below. However, the State Engineer realizes the rather technical nature of the data and the fact that some of the information obtained does not particularly lend itself to a narrative description, and thus is willing to meet with the parties and review the results of his investigation in detail.

Another aspect associated with this problem is the loss of water from the major canals in this area. The State Engineer realized that because of staff limitations he would not be able to obtain all of the data which he desired on canal losses in the Duchesne River System. In an effort to develop additional data for the benefit of the parties, the State Engineer requested that the U.S. Geological Survey (USGS), as a part of its cooperative program with the State Engineer's Office, undertake a canal loss study on certain canals in this area. That study has been completed, covering the Rocky Point and Grey Mountain Canals and copies

(Seepage Study of the Rocky Point Canal and the Grey Mountain-Pleasant Valley Canal Systems, Duchesne County, Utah, Technical Publication No. 50

were made available to the parties at the Hearing on distribution held before the Court on August 9, 1978. Additional copies may be obtained from the State Engineer's Office. **The information developed in the $U_tS_AG_AS_A$ study should be read in conjunction with the information set forth** below.

STATE ENGINEER'S INVESTIGATION

The objective of the State Engineer's investigation regarding return flow to the Duchesne River System was to examine the current irrigation practice on the System and to determine what portion of the water diverted for irrigation purposes is not consumptively used and thus reappears in the River as return flow. In an attempt to answer this question the State Engineer's investigation was directed towards making field measurements of streamflow and canal diversions, to determine that portion of the irrigation diversions that is return flow to the River. A series of measurements were made during 1974 and 1977 and the results are presented in this report.

After analyzing these measurements, it was believed that they do in fact indicate that substantial quantities of the water diverted for irrigation purposes is return flow to the River. However, there were a number of unknown factors that could not be measured directly, such as ground-water inflow, ungaged surface runoff and losses to phreatophytes. Therefore, it was felt that perhaps a computer model of the river system would be helpful in determing these factors. The State Engineer developed a computer model for three various reaches of the river and the results of these models is presented in the following sections.

In this report a number of terms are used and the following is a definition of these terms.

Consumptive Use - Consumptive use, often called evapo-transpiration, is the amount of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil, and includes

effective precipitation used by the crops. Expressed as acre feet per acre or depth in feet.

Potential Return Flow - The quantity of water represented by the difference between the irrigation diversions minus the crop consumptive use. All or a portion of these may actually be return flow to the system.

Return Flow - That portion of the irrigation diversions that actually returns to the river system.

Streamflow and Canal Diversion Measurements

During 1974 and 1977 the State Engineer made a number of streamflow and canal diversion measurements on the Duchesne River in an attempt to determine irrigation return flow to the River. Table 1 presents a summary of these measurements and a complete listing is contained in Appendix A.

For the purpose of these measurements the River was divided into hydrologic reaches, (1) Hanna - Tabiona reach; (2) Tabiona - Utahn reach; and (3) Utahn - Myton reach. The measurements made in 1974 covered the area from Hanna to Myton and the 1977 measurements were made only in the Hanna - Tabiona area.

As can be seen from Table 1 there are substantial quantities of water that are either surface and ground water inflow or irrigation return flow to the Duchesne River. The largest gains are seen in the Hanna - Tabiona and Utahn - Myton reaches, with the Tabiona - Utahn reach showing the smallest gain. From these measurements it is apparent that a significant portion of the water diverted for irrigation purposes does get back to the river as return flow. However, in analyzing these field measurements it was not possible to determine what portion of the measured gain was the result of irrigation return flow or was ungaged surface water and/or ground water inflow. Therefore, it was felt that a computer model would be of great assistance in determining and identifying that portion of the gain(s) that is the result of irrigation return flow.

Table 1 - Summary of streamflow and canal diversion measurements, Duchesne River

REACH/DATE	(1) INFLOW	(2) DIVERSION	(3) OUTFLOW	(4) GAIN/LOSS (Col. 1-2-3)
Hanna-Tabiona				
July 17-18, 1974	112	206	102	196
August 28-29, 1974	65	117	66	118
Sept. 29-30, 1977	38	65	58	85
Oct. 6-7, 1977	57	74	62	79
Tabiona-Utahn				
July 17-18, 1974	260	66	193	-1
August 28-29, 1974	127	54	92	19
Utahn-Myton				
July 17-18, 1974	587	633	151	197
August 28-29, 1974	444	527	43	126

Duchesne River Model

The Duchesne River computer model was developed for the purpose of determining what portion of the water diverted for irrigation purposes is return flow to the River. The model used a water budget approach, on a monthly basis, and took into consideration the following items: (1) Surface and ground water inflow; (2) Canal diversions; (3) Consumptive Use; (4) Irrigation return flow; and (5) Surface water outflow.

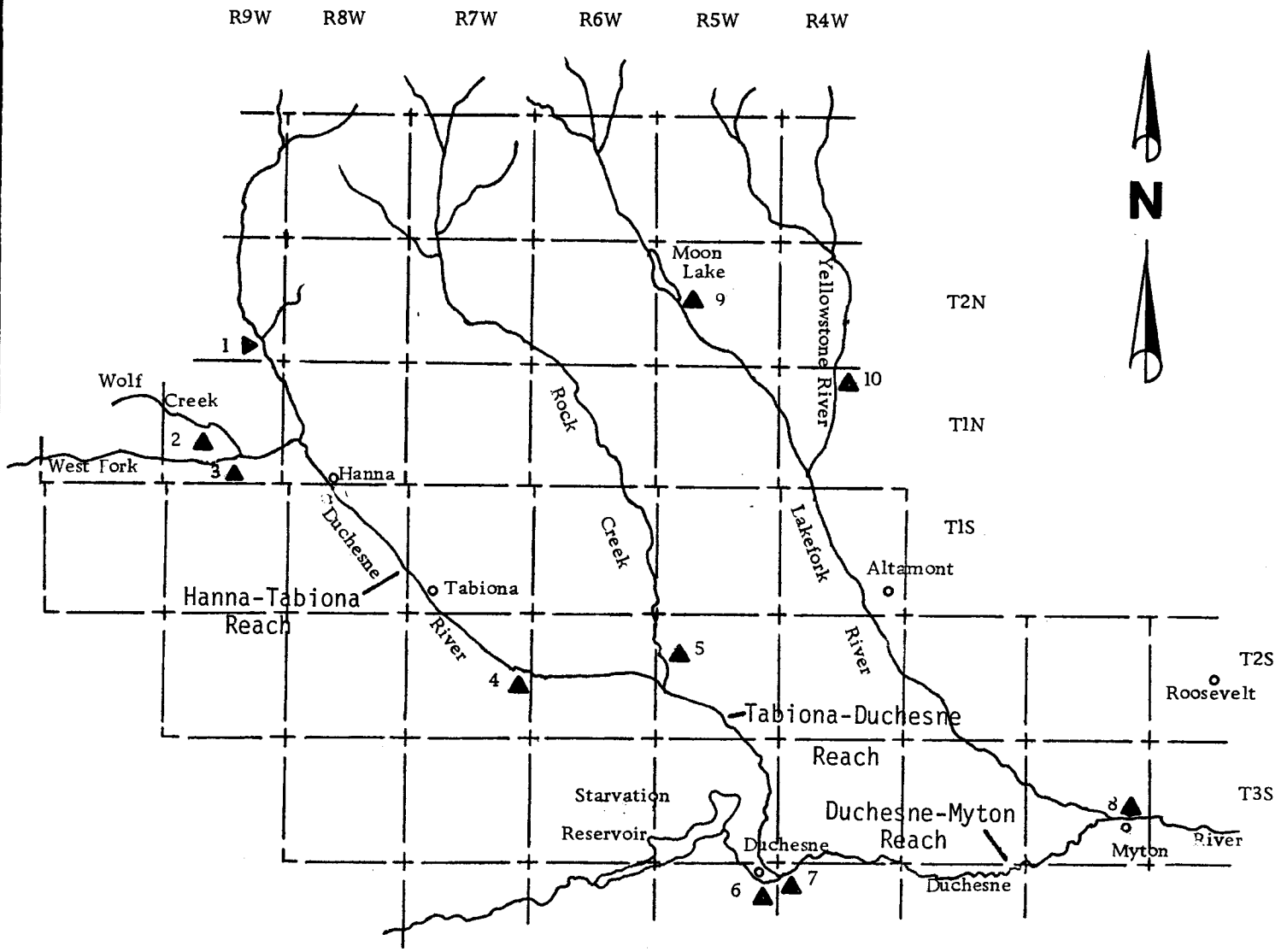
The Duchesne River was divided into three reaches as shown in figure 1, based upon hydrologic characteristics, location of stream gaging-stations, and canal diversions. The three reaches are described below.

Hanna - Tabiona Reach, Located from the Duchesne River near Hanna and West Fork Duchesne River near Hanna gaging-stations downstream to the Duchesne River near Tabiona gaging-station.

Tabiona - Duchesne Reach, Located from the Duchesne River near Tabiona gaging-station downstream to the Duchesne River at Duchesne gaging-station.

Duchesne - Myton Reach, Located from the Duchesne River at Duchesne gaging-station downstream to the Duchesne River at Myton gaging-station.

For each of the above three reaches a computer model was developed using a water budget approach. The measured stream inflow was taken from the U.S. Geological Survey (USGS) streamflow records and the ungaged surface and ground-water inflow was derived by the model. The canal diversions were obtained from the Duchesne River Commissioner's Reports. In the Commissioner's reports it lists daily and monthly diversions for some of the canals and yearly diversions for the others. To determine the monthly diversions for all of the canals and ditches in a reach, the percentage of each months diversion to the total annual diversion was computed for those canals which had monthly diversions recorded. These monthly percentages were then applied to the annual diversions of the other canals and ditches in that reach. The consumptive use figure for the irrigated acreage was calculated using the modi-



LEGEND	No.	Gaging-station	Period of Record
▲ USGS gaging-station	1	Duchesne River near Hanna	1946-1963
	2	Wolf Creek above Rhoades Canyon near Hanna	1945-present
	3	W. Fk. Duchesne River near Hanna	1945-present
	4	Duchesne River near Tabiona	1918-present
	5	Rock Creek near Talmage	1963-present
	6	Strawberry River at Duchesne	1914-69
	7	Duchesne River at Duchesne	1917-69
	8	Duchesne River at Myton	1911-present
	9	Lakefork River below Moon Lake	1942-present
	10	Yellowstone River near Altonah	1945-present

Figure 1 - Map of the Duchesne River System

fied Blaney-Criddle method and the consumptive use for phreatophytes was determined by the model. The outflow for each reach was obtained from USGS streamflow measurements.

The basic concept used in the development of the model(s) was to describe the hydrologic system using mathematical equations and using data, for a number of years, of the measured streamflow and canal diversions. With this data the model would calculate the outflow for the reach and then by comparing the calculated outflow to the actual measured outflow the model was calibrated. This calibration process determined which factors for such items as ground-water inflow, return flow and ungaged surface runoff ~~worked the best~~ best described the system. After a number of computer runs it was possible to determine which factors would result in the calculated outflow nearly equaling the measured outflow. The figures for return flow as determined by the model could be the result of conveyance losses in the canals, surface runoff from the fields and/or deep percolation below the root zone. No attempt was made to have the model identify which of these may have been the source of the return flow because of the many unknowns. A flow diagram showing the general concept of the model is shown in figure 2.

Records for a number of the gaging-stations on the Duchesne River and its tributaries are available for a limited period of time and the time period selected for the model(s) was dependent upon the availability of records at several stations. This resulted in relatively short periods of time being examined and they may or may not represent long-term conditions. Figure 3 show the annual flow of the Duchesne River near Tabiona gaging-station for the period 1920 - 79, corrected for diversions through the Duchesne Tunnel since 1954. Also shown is the average annual flow for the period of record examined in the models. This provides an indication of how the period used in the models compares to the long-term conditions. It appears that the water supply in the years examined is generally ~~higher than~~ representative of the long-term average.

In a study of this nature, there are a number of assumptions that must be made in describing the physical characteristics of the river system. However, if

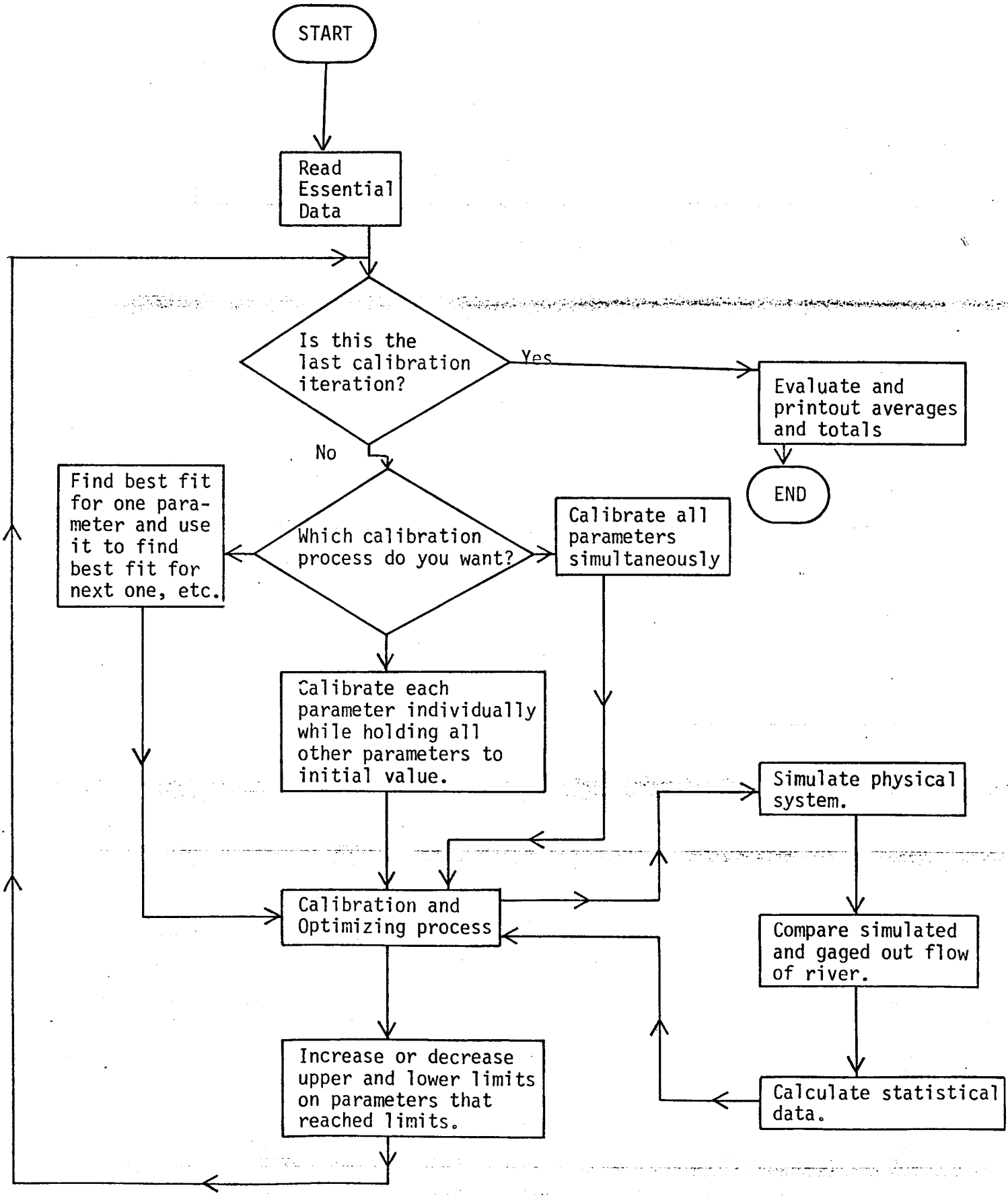


Figure 2 — Generalized flow diagram of the Duchesne River computer models

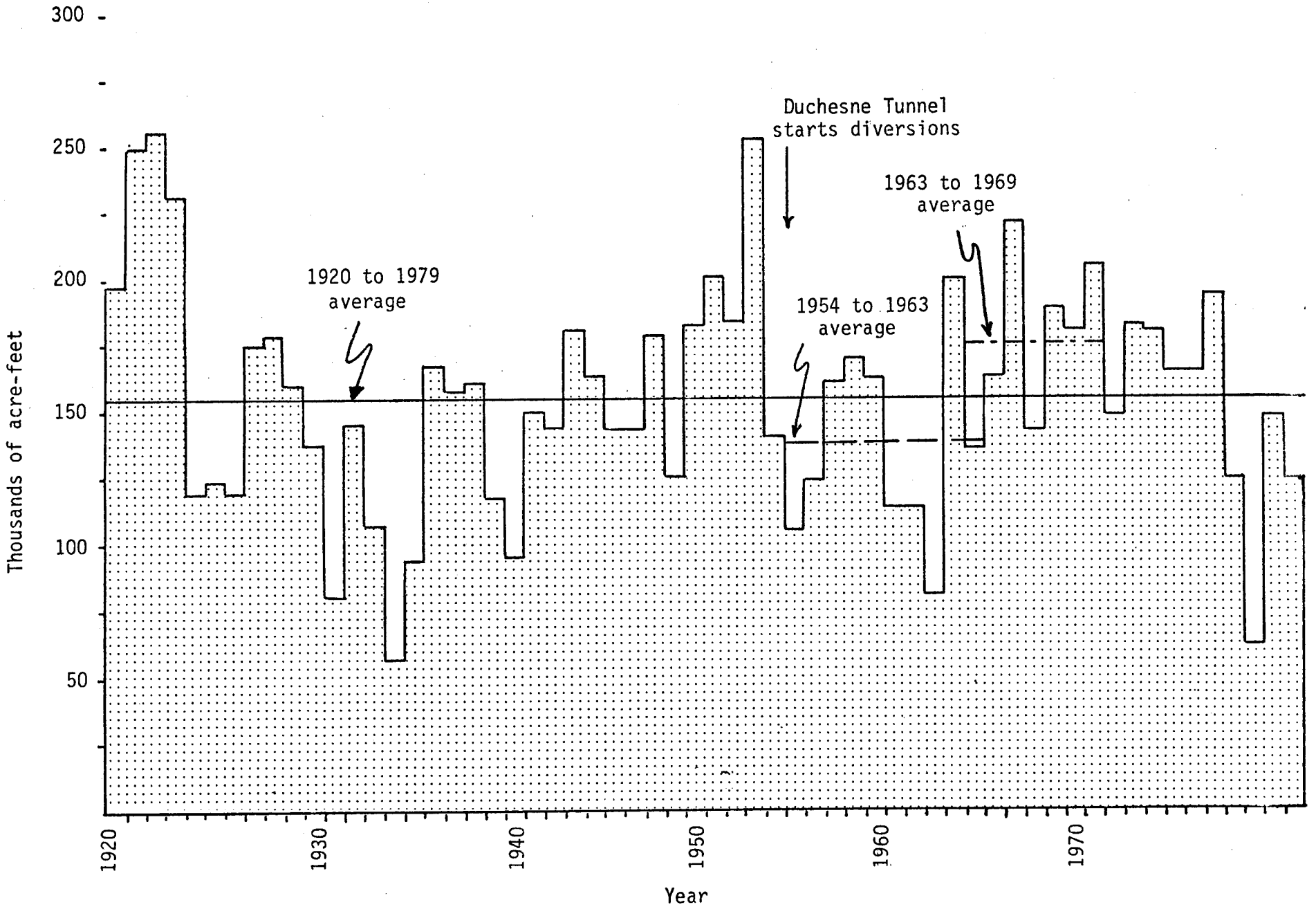


Figure 3 - Annual flow of Duchesne River near Tabiona

care is taken in developing the model(s) the results obtained from it are very representative of the system being examined. It is felt that the models developed for this study do accurately reflect the actual situation that exists on the Duchesne River, for the period of record used in the model(s).

A method used to determine the reliability of the model is to compute the coefficient of correlation which is a mathematical expression of the degree of association of two variables and in this case the two variables are the calculated and measured outflow. The coefficient of correlation of the annual measured and calculated outflow were computed for the models developed for the Duchesne River and are shown in Figure 9. The coefficient of correlation can range between 0 and 1.00, which 0 indicating no correlation and 1.00 indicating a perfect correlation. Generally in water resource related work a coefficient of correlation of at least 0.8 is recommended. As can be seen from the figures, the coefficient of correlation for the Duchesne River models range from .97 to 1.00 for annual values. Thus, indicating that the reliability of the models appears to be very good.

In the tables which present the results of the models the figures listed should be considered approximations of the various factors shown. Generally it is believed that average monthly or annual values indicated are within about a ten percent range.

The figures listed in tables 2 and 3 are the result of averaging the values over the period of record examined. Thus, although the computer shows the various values to the last decimal place it should be realized that they are relative values, i.e. 257 = 260, 25,483 = 25,500.

The following sections contain a discussion of the models for each of the three reaches and the results obtained from them, concerning irrigation return flow to the Duchesne River.

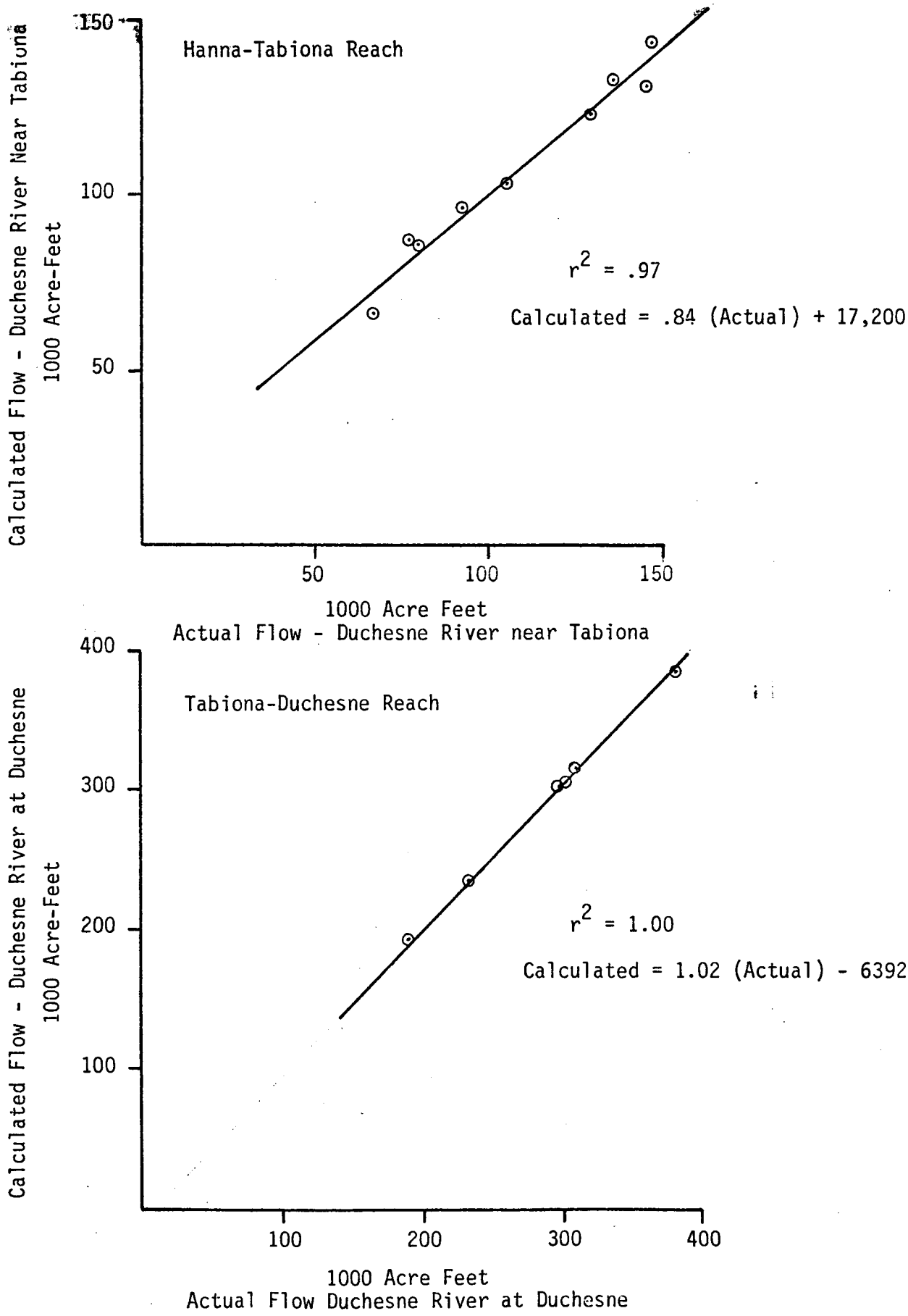


Figure 4—Comparison between the annual outflow for the calculated and actual measurement outflow.

Hanna-Tabiona Reach

The Hanna-Tabiona Reach covers the upper portion of the Duchesne River System. The measured inflow into the reach consists of the streamflow as measured at the Duchesne River near Hanna, West Fork Duchesne River near Hanna and Wolf Creek above Rhoades Canyon near Hanna gaging-stations. In addition, this reach also receives inflow from a number of small ungaged streams, ground-water inflow and several large springs. The measured streamflow at the Duchesne River near Tabiona gaging-station was used as outflow for this reach.

There are 25 canals or ditches which divert water for irrigation purposes within this reach, ~~and~~ the largest ~~canals~~ of which are Rhoades, Farm Creek, Jasper Pike and Tabby Canals. The canal diversions are generally typified by high diversion rates during the spring runoff months (May, June and early July) and then as the river flow decreases and the diversions are regulated by the Commissioner the canal diversion rates decrease significantly. Rhoades canal diverts water in the upper portion of the reach and it is reported to experience high conveyance losses. As a result, the diversions and potential return flow from Rhoades Canal ~~was~~ were examined separately from the other canals in the reach because it was felt that the high canal losses would greatly influence the return flow figures for this reach.

The period of record used for the model was from 1954 to 1963. This period was selected because of the availability of streamflow records at the desired locations. Diversions through the Duchesne Tunnel began in October, 1953 and thus if records were used prior to this time, it would require that the records be modified to reflect similar conditions.

The results of the Hanna-Tabiona Reach model is summarized in Table 2 and represent the average for the 1954 to 1963 period. In addition, table lists the distribution of return flow for the month the water was diverted and subsuequent months following the diversion. In effect, the model indicated that the return flow

from diversions in one month would occur over a three to four month period. This appears to be the result of the time required for the water to percolate down through the root zone or soil and flow back to the River. Therefore, the return flow, for example the month of August, is affected by the diversions of the proceeding months.

The model indicated that for the Rhoades Canal the return flow was approximately 85 percent of the diversions into the canal. Concerning the occurrence or timing of the return flow, about 81 percent of the monthly potential return flow occurred in the month it was diverted, 17 percent the following month, and 1 percent two months after it was diverted.

For the other canals in the reach, about 72 percent of the total canal diversions was estimated to be return flow to the River. Of the monthly potential return flow, about 55 percent occurred in the month it was diverted, 14 percent the following month, 14 percent two months after it was diverted and 12 percent returned three months later.

To help illustrate the occurrence of return flow, as predicted from the model, the following example concerning the other canals (excluding Rhoades Canal) is presented. For the month of July, the average return flow is shown to be about 3,820 acre-feet. This 3,820 acre-feet is the result of return flow from diversions in the months of April through July in the following quantities: April - 20 acre-feet; May - 910 acre-feet; June - 1,060 acre-feet; and July - 1,830 acre-feet.

The average annual streamflow at the Duchesne River near Tabiona gaging-station for 1954-63 was measured to be about 104,900 and the calculated flow from the model was about 104,700 acre-feet. Thus, indicating that the model does accurately describe the physical situation in this reach.

It should be noted that the average diversion of water per acre of land irrigated (duty of water) is relatively high and thus explains the high percentage of return flow. In the Duchesne River Commissioner's reports from 1954-63, the duty of water for the four largest canals in the reach (Rhoades, Farm Creek, Jasper, Pike

and Tabby combined) averaged about 6.7 acre-feet per acre. If the quantity of water was reduced, then the percentage of return flow would show a corresponding decrease, assuming that other factors remained basically the same.

Table 2

DUCHESNE RIVER COMPUTER MODEL - UPPER REACHES TO TABIONA - 1954 TO 1960

PRELIMINARY
SUBJECT TO REVISION

MON	WOLF CREEK	WEST FORK	NORTH FORK	UNGAGED INFLOW	DIV INTO RHODES CANAL	CONSUM-PTIVE USE	POT-RETURN FLOW	RETURN FLOW	DIV INTO OTHER CANALS	CONSUM-PTIVE USE	POT-RETURN FLOW	RETURN FLOW	PHREAT-OPHYTE LOSSES	USGS GAGE AT TABIONA	CALC-ULATED FLOW	PERCENT DIFF
1	188.	756.	450.	3913.	0.	0.	0.	0.	0.	0.	0.	251.	65.	5671.	5492.	.03
2	166.	702.	386.	3813.	0.	0.	0.	0.	0.	0.	0.	11.	51.	4981.	5027.	-.01
3	177.	839.	503.	4326.	0.	0.	0.	0.	0.	0.	0.	0.	119.	5716.	5726.	-.00
4	191.	2057.	1829.	4365.	239.	0.	239.	196.	459.	0.	459.	257.	274.	7664.	7923.	-.03
5	799.	9480.	9539.	5472.	2305.	180.	2125.	1781.	6803.	1076.	5728.	3269.	635.	20070.	20597.	-.03
6	533.	7235.	12472.	7230.	2772.	316.	2456.	2396.	9719.	1891.	7829.	5300.	1037.	22359.	22038.	.01
7	486.	2128.	2795.	5974.	1602.	403.	1199.	1425.	5965.	2417.	3548.	3991.	1338.	8069.	7895.	.02
8	353.	1268.	1424.	4577.	951.	293.	658.	755.	3949.	1752.	2196.	3467.	1033.	5653.	5910.	-.05
9	284.	1006.	1020.	4297.	733.	143.	591.	603.	3005.	864.	2141.	2904.	571.	5389.	5804.	-.08
10	261.	1016.	864.	4056.	585.	22.	563.	568.	2321.	135.	2186.	2276.	281.	6008.	5854.	.03
11	225.	906.	695.	3824.	0.	0.	0.	101.	0.	0.	0.	881.	92.	6657.	6540.	.02
12	204.	834.	592.	3898.	0.	0.	0.	0.	0.	0.	0.	546.	77.	6640.	5996.	.10
TOT	4267.	28225.	32568.	55744.	9187.	1356.	7830.	7826.	32222.	8135.	24088.	23153.	5573.	104877.	104802.	.00

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Table 3 , Listing of 1954-63 average monthly occurrence and distribution of return flow, Hanna - Tabiona reach

Month	Diversion	Consumptive Use	Potential Return Flow	RETURN FLOW					
				Month of Diversion	One Month Previous	Two Months Previous	Three Months Previous	Four Months Previous	Monthly Total
Jan.							240	11	251
Feb.								11	11
March									
April	459	0	459	257					257
May	6803	1076	5727	3200	69				3269
June	9719	1891	7828	4380	857	63			5300
July	5965	2417	3548	1985	1171	785	50		3991
Aug.	3949	1752	2197	1231	532	1072	630	2	3467
Sep.	3005	864	2141	1198	330	486	861	29	2904
Oct.	2321	135	2186	1225	321	301	390	39	2276
Nov.					328	293	242	18	881
Dec.						299	236	11	546
Total	32222	8135	24086	13476	3608	3299	2649	121	23153

Tabiona-Duchesne Reach

The Tabiona-Duchesne Reach covers approximately a 18 mile segment of the Duchesne River from the gaging-station near Tabiona downstream to the town of Duchesne. Rock Creek flows into the Duchesne River in this Reach. The period of record used for the model was October 1963 to December 1969 and was selected because of the availability of streamflow records at the desired gaging-stations.

There are 12 canals/ditches which divert water for irrigation purposes in this reach and the largest ~~canals~~ of which are the Pioneer, Murray-White and Rocky Point Canals. The Rocky Point Canal serves land located within and below this reach and an estimate of the water diverted to those lands located below the reach was made.

The average annual irrigation diversions for the period of record examined was about 17,900 acre-feet and the model indicated that about 9,200 acre-feet or 51 percent, was return flow to the River. Tables 4 and 5 presents a summary of the results of the Tabiona-Duchesne Reach model. The monthly and annual calculated outflow compared to the measured flow is generally very good, except for the month of November which has a 12 percent difference. This is perhaps the result of diversions being made during early November of some years but were not reported by the Commissioner.

The monthly occurrence of return flow as indicated by the model is somewhat different than that for the Hanna-Tabiona reach. For this reach approximately 30 percent of the potential return flow was return flow in the month it was diverted, 50 percent the following month, 6 percent two months later and 5 percent three months later. Table shows the quantity of monthly return flow and its occurrence.

Table 4- DUCHESNE RIVER COMPUTER MODEL - TABIONA TO DUCHESNE - 1963 TO 1969

MONTHLY AVERAGES AND TOTALS

MONTH	USGS GAGE AT TABIONA	USGS GAGE AT ROCK CREEK	UNGAGED INFLOW	DIVERSIONS INTO CANALS	CONSUM-PTIVE USE	POTENTIAL RETURN FLOW	RETURN FLOW	ROCKY PT. CANAL DIV. PAST GAGE	PHREAT-OPHYTE LOSSES	USGS GAGE AT DUCHESNE	CALC-ULATED FLOW	PERCENT DIFFER-ENCE
1	7147.	3682.	116.	0.	0.	0.	48.	0.	45.	11563.	10948.	.05
2	5833.	3067.	574.	0.	0.	0.	12.	0.	44.	9587.	9441.	.02
3	6632.	3520.	857.	0.	0.	0.	0.	0.	167.	10705.	10842.	-.01
4	9887.	5317.	426.	382.	0.	382.	97.	441.	400.	14432.	14503.	-.00
5	29122.	28075.	805.	3990.	1062.	2928.	961.	2420.	866.	51045.	51686.	-.01
6	44973.	51435.	1619.	3551.	1426.	2125.	2189.	2290.	1116.	93068.	93261.	-.00
7	15902.	25512.	2387.	3929.	2372.	1557.	1657.	2292.	1820.	37872.	37416.	.01
8	8198.	10108.	1303.	2736.	1779.	957.	1250.	1754.	1480.	14965.	14940.	.00
9	7353.	6228.	899.	2421.	968.	1454.	1031.	1481.	824.	11033.	10785.	.02
10	7105.	5155.	216.	1360.	221.	1139.	1192.	885.	416.	11278.	11007.	.02
11	7633.	4220.	189.	0.	0.	0.	711.	0.	117.	11422.	12637.	-.11
12	7842.	4048.	99.	0.	0.	0.	76.	0.	51.	11992.	12014.	-.00
TOTALS	157627.	150367.	9491.	18369.	7827.	10542.	9224.	11562.	7296.	288962.	289480.	-.00

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Table 5 , Listing of 1963-69 average monthly occurrence and distribution of return flow, Tabiona-Duchesne reach

Month	Diversion	Consumptive Use	Potential Return Flow	RETURN FLOW					
				Month of Diversion	Previous Month	2 Months Previous	3 Months Previous	4 Months Previous	Monthly Total
Jan.							34	15	49
Feb.								11	11
March									
April	382	0	382	97					97
May	3990	1062	2928	747	214				961
June	3551	1426	2125	542	1640	8			2190
July	3929	2372	1557	397	1190	59	11		1657
Aug.	2736	1779	957	244	872	43	88	4	1251
Sep.	2421	968	1454	371	536	31	64	29	1031
Oct.	1360	221	1139	290	814	19	47	21	1191
Nov.					638	29	29	16	712
Dec.						23	44	10	77
Total	18369	7828	10542	2688	5904	212	317	106	9227

Table 6 - Listing of the monthly occurrence of return flow as a percentage of the potential return flow for the Duchesne River System

REACH	OCCURRENCE OF RETURN FLOW [1] Month of Diversion	1st Month After Div.,	2nd Month After Div.,	3rd Month After Div.,	4th Month After Div.,	Total [2]
Hanna-Tabiona						
Rhoades Canal	82%	18%	0	0	0	100%
Other Canals	56	15	13.7%	11%	.5%	96.2%
Tabiona-Duchesne	25	56	2	3	1	87
Duchesne-Myton						

[1] The percentages listed are of the potential return flow as a result of irrigation diversions.

[2] The total percentage is return flow divided by potential return flow and does not equal 100 percent as a result of the accuracy of the model, perhaps losses to phreatophytes, or ungaged flow past gage.