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Funding for WRDS and the creation of this electronic document was provided by the Wyoming Water Development Commission (http://wwdc.state.wy.us)

51.1245 (Little Bighorn River)

REPORT ON THE FEASIBILITY OF PROVIDING INSTREAM FLOW IN THE LITTLE BIGHORN RIVER FLOW SEGMENT NO. 1 TEMPORARY FILING NO. 26 5/339

July 1991

Prepared For:

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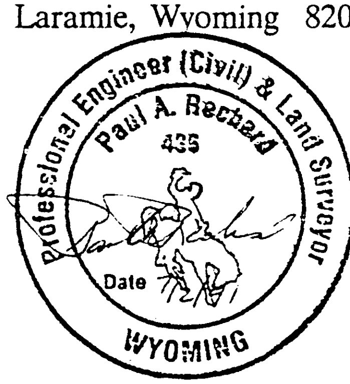

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Temporary Filing No. 26 5/339

Wyoming Water Development Commission
July 1991

I SUMMARY

The Wyoming Water Development Commission (WWDC) is required by W.S. 41-3-1004(a) to determine the feasibility of providing various amounts of unappropriated direct flow water for instream uses within stream segments as requested by the Wyoming Game and Fish Department (WGFD). For the Little Bighorn River, WWDC contracted with Western Water Consultants, Inc. (WWC) of Laramie, Wyoming to prepare the technical study. The WGFD has requested, under Temporary Filing No. 26 5/339, a direct flow water right for purposes of providing instream flow for fisheries in a segment of the Little Bighorn River upstream of Parkman, Wyoming. The amounts of flow requested by season are: 60 cubic feet per second (cfs) for the period October 1 - November 15; 50 cfs for the period November 16 - March 31; 60 cfs for the period April 1 to June 30; and 62 cfs for the period July 1 to September 30. The Little Bighorn River - Instream Flow Segment No. 1 is defined by an upstream point located at the confluence of the Little Bighorn River and Dry Fork Creek in the NE1/4 NW1/4 of Section 12, Township 57 North, Range 90 West and a downstream point located where the river crosses the north boundary line of the SW1/4 SW1/4 of Section 20, Township 58 North, Range 89 West, all in Sheridan County, Wyoming. The segment has a stream length of approximately 4.39 miles, and the location of the segment is shown on Figure 1.

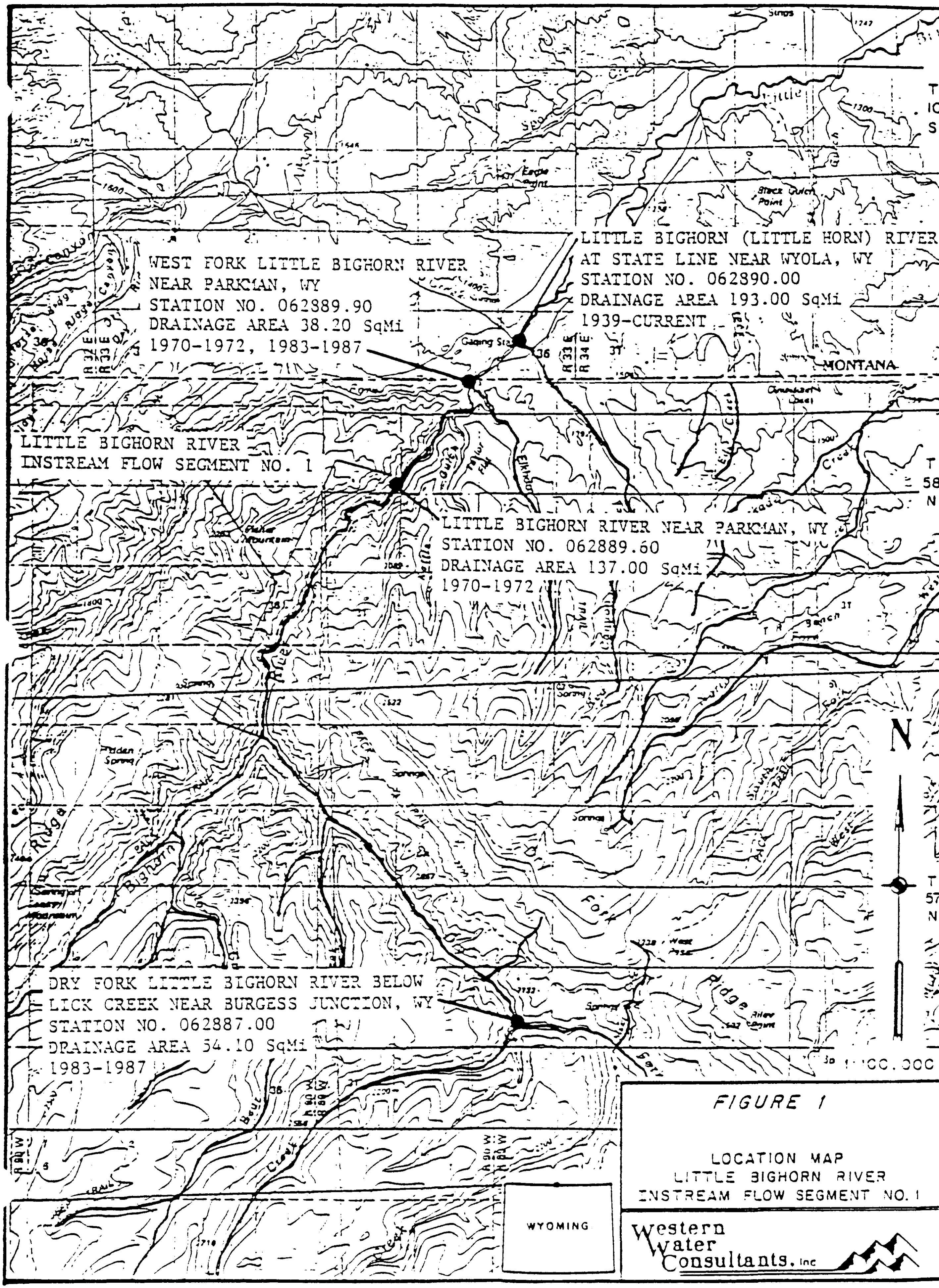


FIGURE 1

LOCATION MAP
LITTLE BIGHORN RIVER
INSTREAM FLOW SEGMENT NO. 1

Western Water Consultants, Inc

Mean monthly flow, dry year flow, and daily flow exceedence analyses were conducted for the Little Bighorn River at the lower end of the proposed Instream Flow Segment No. 1. The mean monthly flow analysis shows that on the average, the requested flows are available in their entirety except for slight shortages during the months of January, February, and March and by one cfs for the period of November 1-15. The following tabulation summarizes the estimated mean monthly discharge at the downstream end of the instream flow segment and the requested flows.

Month	Mean Discharge cfs	Requested Discharge cfs
October	66	60
November:	(57)	
Nov. 1-15	59	60
Nov. 16-30	55	50
December	52	50
January	47	50
February	42	50
March	45	50
April	61	60
May	261	60
June	463	60
July	181	62
August	99	62
September	72	62

During extremely dry years the requested flows are available only during the months of May, June, and July.

A daily flow-duration analysis was conducted for each of the four periods throughout the year. The flow of 60 cfs requested by the WGFD for the period October 1 through November 15 is available approximately 67% of the time, the requested flow of 50 cfs for the period November 16 to March 31 is available 48% of the time, and the flow of 60 cfs requested for the period of April 1 through June 30 is available 84% of the time. The mean discharge of 62 cfs requested for the critical period July 1 to September 30 is available 86% of the time. WGFD considers that if the requested flows are available at least 50% of the time during the period of July 1 through September 30, their criteria are satisfied. The WGFD has not developed exceedence criteria for other times of the year but has stated that during these periods the flow should equal natural flows up to the requested amounts.

II WATER RIGHTS

Current water rights and permits for diversion or use on the Little Bighorn River or its tributaries located upstream of the downstream end of the proposed Instream Flow Segment No. 1 are tabulated in Table 1. Both direct flow and storage rights are listed.

While there were several large water rights filed in the mid 1930's within and above Instream Flow Segment No. 1 there is no evidence that these rights have been developed. According to the USGS, there are diversions for only 163 acres above the State Line gage and those diversions are below the proposed Instream Flow Segment No. 1. Adjudicated direct flow water rights above and within the instream flow segment total to 0.11 cfs. Adjudicated storage rights for three stock reservoirs above and within the instream flow segment total 1.54 acre-feet.

Approximately 45,000 acre-feet per year has been appropriated in and by the State of Montana (EIS). Flows of the Little Bighorn River were not specifically allocated in the Yellowstone River Compact. No other interstate compact or court decree covers allocation of the waters of the Little Bighorn River.

A number of temporary filings are on file with the Wyoming State Engineer's Office for potential developments above or within the instream flow segment. These consist of large scale diversion and storage projects which, if constructed, would have a significant impact on the streamflows for this river. Temporary filings and permits for direct flow water rights above and within the instream flow segment total 1,532 cfs. Temporary filings and permits for storage rights that could potentially be developed to use flows above and within

Table 1
WYOMING WATER RIGHTS

From the Little Bighorn River and Tributaries
Upstream of the Downstream End of
Instream Flow Segment No. 1

Permit Number	Proof Number	Facility	Source	Priority Date M	Priority Date D	Priority Date Y	Amount CFS	Use*	Adj./ Unadj.	Diversion Location Sec.	Diversion Location Twn.	Diversion Location Rng.
DIRECT FLOW												
18584	----	Placer Ditch	S. Fk. Little Bighorn R.	4	1	1935	10.80	9	Unadj.	21	56	91
18658	----	Taylor Ditch	Dayton Gulch	5	27	1936	28.00	9	Unadj.	Unsur.	56	90
18656	----	James M. Taylor Ditch	Half Oz. Gulch	5	27	1936	8.90	9	Unadj.	23	56	91
18655	----	John Mathews Ditch	Half Oz. Gulch	5	27	1936	7.20	9	Unadj.	23	56	91
18941	----	Hawkes Ditch	Lick Creek	10	7	1936	28.00	9,SS	Unadj.	Unsur.	56	90
18827	----	Great Scott Ditch	Little Big Horn R.	12	10	1937	66.50	9	Unadj.	23	56	91
23955	----	Little Big Horn - East Twin Ck P.L.	Little Big Horn R.	8	25	1972	150.00	6	Unadj.	36	58	90
22 3/110	----	Beatty Gulch Enl. of Little Big Horn - East Twin Ck. P.L.	Little Big Horn R.	10	15	1975	300.00	6	Unadj.	36	58	90
22 5/157	----	Little Big Horn Tunnel & Canal Diversion	Little Big Horn R.	3	29	1976	1,000.00	6	Unadj.	36	58	90
27974	33242	Fitzgerald-Warner Pipeline	Fitzgerald Spring	1	22	1980	0.03	9	Adj.	30	58	89
23 1/258	----	Little Big Horn Pipeline	Little Big Horn R.	2	8	1980	82.00	6	Unadj.	30	58	89
27975	33243	Canyon Pipeline	Fitzgerald Spring	4	13	1981	0.056	9	Adj.	30	58	89
6723E	33244	Edington Enl. of Fitzgerald Warner P.L.	Fitzgerald Spring	6	22	1981	0.015	9	Adj.	30	58	89
26 5/339	----	Little Big Horn River Ins. Flow Seg #1	Little Big Horn R.	3	6	1989	62.00	11	Unadj.	20	58	89
RESERVOIRS												
7477R	----	Parkman Reservoir	Little Big Horn R.	8	25	1972	42,580 AF	10	Unadj.	34	58	87
22 1/110	----	Beatty Gulch Res.	Little Big Horn R.	10	15	1975	27,805 AF	10	Unadj.	7	57	83
23 5/258	----	Fuller No. 2 Res.	Drainage of Muir Draw - Little Bighorn R.	2	8	1980	1593.62 AF	1,8,10	Unadj.	22	58	89
23 4/258	----	Enl. Fuller Reservoir No. 1	Red Gulch Ck. - Little Bighorn R.	2	8	1980	22,829 AF	8,10	Unadj.	16	58	89
23 2/364	----	Dry Fork Reservoir	Dry Fork Creek	10	24	1980	30,671 AF	10	Unadj.	28	57	89
23 3/364	----	Half Ounce Reservoir	Little Big Horn R.	10	24	1980	34,224 AF	10	Unadj.	12	56	91
9030SR	----	Burnt Mtn. Stk. Res.	Bo Draw	6	30	1982	0.77 AF	3	Unadj.	3	56	91
9034SR	33435	Lake Creek Stk Res.	Lake Creek	6	30	1982	0.77 AF	3	Adj.	6	55	90
9061SR	33429	Cow Camp Stock Res.	Cow Creek	12	22	1982	0.77 AF	3	Adj.	3	57	90

* Use Description

1 = Irrigation
2 = Domestic
3 = Stock
4 = Highway Department
5 = Power
6 = Reservoir Conveyance
7 = BLM Water Use
8 = Municipal Use
9 = Miscellaneous Use
10 = Industrial
11 = Instream Flow
SS = Supplemental Supply

the instream flow segment are approximately 160,000 acre-feet. This compares with the calculated average annual discharge at the bottom of the instream flow segment of approximately 87,500 acre-feet. It is obvious that several of the storage rights are mutually exclusive with no chance of developing all of them. Parkman, Beatty Gulch and Fuller Reservoir facilities are located outside of the instream flow drainage area, and could be partially supplied from other sources.

III STREAMFLOW RECORDS

Two United States Geological Survey (USGS) streamflow gaging stations were used to estimate flow at the downstream end of the proposed instream flow segment. These gaging stations and the period for which records are available are:

1. Little Bighorn River near Parkman, Wyoming; Station Number 062889.60; 1970-1972.

2. Little Bighorn River at State Line near Wyola, Wyoming; Station Number 062890.00; 1939-Current.

The gaging station Little Bighorn River near Parkman, Wyoming (Station Number 062889.60) is approximately 700 feet upstream from the downstream end of the instream flow segment. As there are no tributaries in this 700 feet, flows at the Parkman station represent flows for the downstream end of the instream flow segment. The gaging station Little Bighorn River at State Line near Wyola, Wyoming (Station Number 062890.00) is approximately 4 miles downstream from the downstream end of the instream flow segment and has 50 years of record. The published mean monthly flow data for these two stations are presented in Tables 2 and 3, respectively.

TABLE 2
LITTLE BIGHORN RIVER NEAR PARKMAN, WYOMING
Station No. 062889.60
Average Monthly Flows (cfs)

YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	ANNUAL TOTAL (AF)
1970	72.13	63.20	57.48	52.74	50.71	48.58	52.40	338.19	822.80	280.10	136.71	101.93	125,345
1971	80.97	69.10	60.13	54.39	44.11	47.13	58.50	273.68	562.30	182.10	103.03	76.97	97,360
1972	70.94	66.53	53.94	49.35	51.45	53.19	57.37	226.58	492.17	155.48	104.23	75.80	88,014
MEAN	74.68	66.28	57.18	52.16	48.76	49.63	56.09	279.48	625.76	205.89	114.66	84.90	103,573
STD. DEV.	4.47	2.42	2.54	2.10	3.30	2.59	2.65	45.75	142.24	53.58	15.60	12.05	15,861
# RECORDS	3	3	3	3	3	3	3	3	3	3	3	3	3
MINIMUM	70.94	63.20	53.94	49.35	44.11	47.13	52.40	226.58	492.17	155.48	103.03	75.80	88,014
MAXIMUM	80.97	69.10	60.13	54.39	51.45	53.19	58.50	338.19	822.80	280.10	136.71	101.93	125,345

TABLE 3
LITTLE BIGHORN RIVER AT STATE LINE NEAR WYOLA, WYOMING
Station No. 06289000
Average Monthly Flows (cfs)

YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	ANNUAL TOTAL (AF)
1939							84.03	372.48	332.60	166.29	110.87	89.43	-----
1940	80.48	70.30	65.13	60.39	62.24	61.16	68.30	238.61	317.23	142.58	91.23	82.80	81,107
1941	77.55	60.83	58.65	59.87	53.07	52.00	69.20	319.97	289.47	135.39	99.55	109.97	83,827
1942	118.13	104.20	84.84	79.74	69.61	66.16	148.00	458.65	562.57	216.90	120.97	97.47	128,576
1943	84.55	81.93	70.84	60.26	61.21	59.06	131.80	257.68	651.53	282.71	138.65	105.30	119,797
1944	91.16	80.90	69.39	65.19	61.90	61.35	75.23	452.16	867.73	297.03	155.13	116.50	144,676
1945	103.55	87.93	81.81	74.26	67.32	75.48	72.53	276.26	525.80	307.48	157.13	121.27	117,951
1946	102.97	93.20	81.06	84.87	88.00	86.42	172.23	332.42	478.70	222.48	134.94	120.07	120,577
1947	105.97	90.63	80.87	79.19	73.18	69.87	91.10	419.45	595.40	278.26	164.19	135.63	132,030
1948	115.16	95.00	78.06	61.61	69.66	55.13	86.90	361.35	358.30	185.32	117.16	104.63	102,255
1949	84.58	68.20	59.61	57.35	64.07	67.90	85.57	327.45	383.37	161.45	98.61	84.50	93,242
1950	74.35	66.13	58.29	48.94	61.07	56.61	72.00	128.29	387.77	168.32	96.32	81.60	78,348
1951	76.55	70.07	62.71	60.90	50.14	54.13	66.37	303.10	367.47	230.87	132.84	93.30	94,958
1952	84.55	74.57	65.48	62.19	58.34	55.97	129.80	421.97	324.07	160.23	106.90	80.90	98,477
1953	70.26	58.87	61.35	60.35	54.46	59.23	60.13	126.55	619.10	179.45	104.87	82.43	92,560
1954	71.87	64.70	62.39	54.84	54.11	53.97	69.80	315.90	376.53	171.84	88.68	74.47	88,234
1955	69.77	60.83	54.90	50.55	56.36	53.87	69.67	326.10	491.17	202.74	105.71	80.70	98,029
1956	72.87	61.13	57.97	54.00	53.48	54.52	61.03	298.81	316.83	130.45	91.13	77.03	80,498
1957	67.26	60.47	57.52	49.55	52.50	52.65	59.13	228.42	724.50	284.77	153.77	115.27	114,970
1958	99.06	83.17	71.55	61.13	55.29	58.19	63.53	382.35	250.50	139.06	97.29	79.40	87,302
1959	70.23	66.00	60.65	56.48	57.89	57.23	65.90	182.06	686.70	218.55	118.13	89.57	104,191
1960	82.39	69.50	64.45	57.16	51.76	54.71	71.47	185.90	265.90	118.42	86.68	69.43	71,269
1961	63.97	57.20	52.29	50.45	52.32	48.65	50.73	211.71	256.30	101.32	69.84	67.90	65,404
1962	64.48	58.93	51.68	48.29	50.39	53.03	118.80	331.03	401.73	192.94	114.61	86.13	95,043
1963	72.06	68.00	56.52	43.65	60.50	57.13	69.70	406.55	787.77	242.06	128.45	99.20	126,216
1964	85.52	75.50	63.26	66.16	65.59	66.52	81.10	429.06	960.83	404.97	170.97	129.47	157,071
1965	107.74	91.77	85.65	74.74	66.75	61.42	85.90	313.55	926.83	337.39	149.23	122.40	146,178
1966	108.00	92.67	76.81	64.81	65.86	66.45	74.73	329.52	210.60	121.10	90.42	78.33	83,513
1967	73.10	61.30	61.19	61.42	59.54	58.68	67.60	284.55	883.37	315.42	153.94	128.33	133,176
1968	103.87	91.63	78.68	71.58	74.17	74.13	81.73	251.74	925.77	312.03	170.32	129.87	142,721
1969	108.13	95.17	83.00	69.45	70.21	70.77	127.30	428.35	405.27	255.97	134.45	106.07	118,284
1970	93.68	85.23	79.42	70.00	68.61	67.58	75.57	440.29	1017.30	354.74	162.71	129.53	159,614
1971	105.55	89.20	78.65	73.61	70.93	69.74	81.80	338.68	663.97	215.58	125.87	104.40	121,797
1972	95.10	84.17	71.87	67.00	70.90	80.61	88.83	275.03	575.17	200.74	131.90	102.67	111,415
1973	90.19	79.77	69.97	66.52	69.89	69.13	71.83	485.00	693.40	242.84	147.90	119.63	133,319
1974	98.87	89.17	83.26	75.06	69.18	68.52	127.43	379.87	667.80	252.94	143.00	109.40	130,709
1975	98.29	89.70	81.26	67.26	62.82	67.19	76.40	289.55	1125.33	689.29	228.26	151.33	182,871
1976	120.06	98.57	91.23	74.00	74.66	73.00	84.57	333.97	567.80	261.39	149.32	110.43	123,370
1977	95.48	81.53	78.42	69.42	73.00	69.39	130.43	533.35	401.57	174.90	116.19	91.20	115,912

TABLE 3 (continued)
LITTLE BIGHORN RIVER AT STATE LINE NEAR WYOLA, WYOMING
Station No. 062890.00
Average Monthly Flows (cfs)

YEAR	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	ANNUAL TOTAL (AF)
1978	85.23	76.13	67.00	65.81	70.50	67.52	85.17	487.61	1066.80	425.97	189.94	139.77	170,722
1979	114.16	94.53	79.81	73.23	72.54	73.97	81.07	267.87	339.37	152.32	107.29	89.30	93,397
1980	78.00	71.13	71.77	59.23	59.97	57.68	87.47	277.42	266.50	137.23	98.77	86.03	81,831
1981	79.52	73.47	67.52	63.90	60.71	59.52	88.20	341.97	371.20	173.61	108.39	91.30	95,509
1982	79.65	70.80	65.19	60.65	55.29	56.61	62.97	168.65	477.07	283.45	128.45	100.13	97,190
1983	95.74	80.70	73.71	69.94	60.93	59.65	71.40	216.61	593.10	226.03	126.03	96.70	106,835
1984	86.68	73.00	54.97	66.65	61.76	62.19	77.53	488.90	746.20	290.32	149.48	106.57	136,990
1985	94.16	77.63	69.42	67.74	64.18	65.58	86.57	249.97	169.40	102.65	78.00	70.77	72,360
1986	69.19	55.27	58.13	55.00	51.07	56.06	90.77	284.52	599.90	170.32	101.16	85.90	101,180
1987	76.55	65.50	60.87	60.26	55.82	54.26	131.40	282.90	206.03	118.42	85.77	75.47	77,009
1988	66.32	61.57	56.00	52.71	53.55	53.71	72.80	495.39	346.17	125.55	89.19	75.83	93,917
1989	68.19	61.17	56.42	54.39	49.21	52.84	71.43	229.13	199.97	125.94	86.06	70.13	68,076
MEAN	87.61	76.38	68.63	63.23	62.33	62.14	85.78	324.88	529.92	223.69	123.66	98.94	107,343
STD. DEV.	15.58	12.91	10.28	8.93	8.24	8.16	25.32	97.24	248.07	101.56	31.59	20.58	31,021
# RECORDS	50	50	50	50	50	50	51	51	51	51	51	51	50
MINIMUM	63.97	55.27	51.68	43.65	49.21	48.65	50.73	126.55	169.40	101.32	69.84	67.90	65,404
MAXIMUM	120.06	104.20	91.23	84.87	88.00	86.42	172.23	533.35	1125.33	689.29	228.26	151.33	182,871

IV HYDROLOGY

There are streamflow records for three years at the Parkman gage which represent the flows at the downstream end of the proposed instream flow segment. This period is not long enough to support conclusions about the availability of unappropriated streamflow to support the instream flow request. To estimate long term streamflow for the Parkman station regression analysis of records at Parkman with concurrent records at the State Line gage was used. Data (recorded or generated) for the Parkman gage include the effects of existing diversions above and within the proposed instream flow segment.

IV.1 Methodology:

Methods considered for estimating long-term flow at the Parkman gaging station (downstream end of Instream Flow Segment No. 1) include procedures recommended in the U.S. Bureau of Reclamation Hydrology Manual (1951) or the Lowham method (1988). These procedures include the following:

1. Regional-area elevation relationships (such as Lowham's);
2. Yield per square mile;
3. Regression of concurrent records at nearby station;
4. Regional altitude-runoff relationship; and
5. Regression with precipitation data and/or snow course data.

As recommended by the Bureau, the best procedure is regression analysis of concurrent records. When regressing streamflow data to estimate monthly flows, it is customary to regress data for each month. Another procedure is to regress the annual data and distribute the annual flow by percentages. A combination of these procedures is used herein. As shown in Table 2, there are only three (3) years of data from which to develop the regression equations. Statistically, this number of data points is not enough, but the results are better than would be obtained by the other methods.

For each month during the year the mean monthly flows recorded at the two stations were correlated using linear regression procedures. The State Line station was the independent variable and the Parkman station the dependent variable. Results of these linear regressions are presented below:

Y = Mean Monthly Flow at Parkman (second-foot-days)
X = Mean Monthly Flow at State Line (second-foot-days)

Month	R^2	Equation
October	0.95	Y = 0.83(X) - 195
November	0.48	N/A
December	0.74	Y = 0.64(X) + 241
January	0.94	Y = 0.75(X) - 17
February	0.09	N/A
March	0.86	Y = 0.42(X) + 593
April	0.55	N/A
May	1.00	Y = 0.67(X) + 1,349
June	1.00	Y = 0.74(X) + 1,967
July	0.99	Y = 0.77(X) + 270
August	0.99	Y = 0.96(X) - 616
September	1.00	Y = 0.98(X) - 757

As can be seen, the coefficients of determination, R^2, indicate a good correlation between the records at the two stations except for the months of November, February, and April. Because of the poor coefficient of determination for these months, an alternative regression analysis was used to generate flows for them.

<u>November:</u> Using the regression equation for the month of October alone and the October and November flows, November was solved by subtracting synthetic October flows from the estimated October-November flows.

<u>April:</u> Using regression equations for the months of May and June and the combination of April through June flows, April was solved for by subtracting the synthetic May and June flows from the estimated April through June flows.

<u>February:</u> Flows for February were calculated based on the average percent of annual total flows exhibited for February flows at the Parkman gage for the period of actual record. This average percentage was then applied to the annual totals generated by regressing annual flows at the Parkman station versus the State Line Station.

The linear regression equations developed for this procedure are:

Period	R^2	Equation
October and November	0.99	Y = 0.87(X) - 616
April, May, and June	1.00	Y = 0.73(X) + 2,917
Annual	1.00	Y = 0.765 x 1,699
February	NA	Y = 0.0271 (Annual)

Where:

Y = Mean Period Flow at Parkman (second-foot-days)
X = Mean Period Flow at State Line (second-foot-days)

In addition to the development of long-term monthly flows for the proposed instream flow segment, it was also necessary to develop flows for portions of the month of November, November 1-15, and November 16-30, because the WGFD requested different flow amounts for these two periods. This was accomplished by examining the three years of November data available for the Parkman gage. During these three years 51.8% of the total November flow occurred during the first half of the month and 48.2% during the latter period. The standard deviations in both cases were 0.03%, indicating that this proportionment is relatively constant.

Using the above equations and procedures, the estimated flows at the downstream end of the proposed instream flow segment were computed from the recorded flows of the Little Bighorn River at State Line gaging station. These flow estimates are presented in Table 4.

The means were calculated for all years in which flow records were available at the State Line gaging station (1939 - 1989). Along with the mean are the standard deviation, number of records, minimum and maximum monthly flow, and the flow requested by the WGFD.

IV. 2 Future Scenarios:

Currently the status of future development on the Little Bighorn River is being debated in Congress. The U.S. Forest Service (USFS) has recommended a Wild and Scenic Designation for the river above the forest boundary and extending upstream of Instream Flow Segment No. 1. The study entitled "Wild & Scenic Study Report and Final Environmental Impact Statement on the Little Bighorn River" (EIS) of June 1989 presents an evaluation of three alternatives for future management of the Little Bighorn River. The three alternatives presented are:

TABLE 4
LITTLE BIGHORN RIVER: GENERATED FLOWS AT
DOWNSTREAM END OF INSTREAM FLOW SEGMENT NO. 1

Average Monthly Flows (cfs)

YEAR	OCTOBER	NOVEMBER	NOV. 1-15	NOV 16-30	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	ANNUAL TOTAL (af)
1940	60.13	51.49	53.36	49.61	49.76	44.79	30.83	44.81	45.96	203.78	301.83	118.09	67.68	56.04	65,086
1941	57.71	43.06	44.63	41.49	45.58	44.40	32.95	40.97	51.91	258.42	281.15	112.57	75.67	82.71	68,196
1942	91.20	83.03	86.05	80.01	62.46	59.32	49.66	46.91	113.51	351.56	484.56	175.11	96.23	70.44	101,758
1943	63.49	61.86	64.11	59.61	53.44	44.69	46.38	43.93	88.31	216.58	550.82	225.60	113.20	78.13	95,725
1944	68.95	61.29	63.52	59.06	52.50	48.40	53.75	44.89	55.36	347.20	711.85	236.59	129.02	89.12	114,728
1945	79.17	68.07	70.55	65.59	60.51	55.20	45.69	50.83	48.11	229.06	457.17	244.61	130.94	93.80	94,520
1946	78.69	72.64	75.29	70.00	60.03	63.17	46.67	55.42	124.92	266.78	422.09	179.39	109.64	92.62	94,972
1947	81.16	70.55	73.12	67.98	59.91	58.91	50.95	48.47	69.15	325.24	509.01	222.19	137.72	107.90	105,256
1948	88.75	74.83	77.56	72.11	58.10	45.71	38.45	42.28	66.24	286.21	332.42	150.88	92.58	77.47	82,005
1949	63.52	49.86	51.67	48.04	46.20	42.52	36.46	47.64	62.86	263.44	351.09	132.57	74.77	57.71	74,294
1950	55.08	47.53	49.26	45.80	45.35	36.20	30.90	42.90	40.98	129.68	354.36	137.84	72.58	54.86	63,284
1951	56.89	51.08	52.94	49.22	48.20	45.18	37.10	41.86	47.64	247.09	339.24	185.83	107.63	66.35	77,119
1952	63.49	55.42	57.44	53.40	49.99	46.15	37.09	42.63	101.69	326.92	306.92	131.63	82.73	54.17	78,687
1953	51.70	40.97	42.46	39.48	47.33	44.77	36.21	44.00	28.68	128.51	526.66	146.38	80.78	55.68	74,223
1954	53.03	46.15	47.83	44.47	47.99	40.63	34.59	41.79	50.77	255.69	346.00	140.54	65.24	47.86	70,778
1955	51.30	42.67	44.22	41.11	43.17	37.41	38.25	41.75	49.53	262.53	431.38	164.25	81.59	53.98	78,425
1956	53.85	43.09	44.66	41.52	45.14	40.00	30.61	42.02	44.27	244.20	301.53	108.78	67.59	50.38	64,889
1957	49.22	42.22	43.76	40.68	44.85	36.66	44.57	41.24	32.43	196.93	605.17	227.19	127.72	87.91	92,663
1958	75.47	63.67	65.99	61.36	53.90	45.35	34.24	43.57	52.10	300.32	252.13	115.39	73.50	52.70	70,431
1959	51.67	47.21	48.93	45.49	46.87	41.86	40.55	43.16	35.18	165.80	577.01	176.37	93.51	62.68	83,294
1960	61.71	50.88	52.73	49.03	49.32	42.37	27.28	42.10	45.91	168.37	263.60	99.55	63.32	42.92	57,956
1961	46.51	39.20	40.62	37.77	41.48	37.33	26.07	39.56	32.47	185.71	256.45	86.43	47.15	41.41	53,207
1962	46.93	40.74	42.22	39.26	41.09	35.71	37.13	41.40	87.03	265.85	364.77	156.72	90.13	59.31	76,578
1963	53.19	49.05	50.83	47.26	44.21	32.22	48.77	43.12	49.82	316.57	652.29	194.42	103.42	72.14	100,098
1964	64.29	56.29	58.34	54.24	48.55	49.13	58.22	47.06	56.84	331.69	781.19	319.40	144.23	101.85	124,379
1965	82.63	71.63	74.24	69.02	62.98	55.57	56.23	44.92	53.95	254.11	755.87	267.55	123.36	94.91	116,013
1966	82.84	72.43	75.07	69.80	57.29	48.11	32.83	47.03	57.72	264.83	222.41	101.61	66.91	51.65	66,987
1967	54.04	43.24	44.82	41.67	47.22	45.57	51.37	43.77	39.53	234.63	723.49	250.70	127.88	100.74	106,248
1968	79.43	71.32	73.92	68.72	58.49	53.19	53.04	50.26	47.23	212.59	755.07	248.10	143.61	102.24	113,118
1969	82.95	74.62	77.34	71.91	61.28	51.60	45.81	48.85	99.00	331.21	367.40	205.08	109.18	78.88	94,164
* 1970	72.13	63.20	64.54	60.93	57.48	52.74	50.71	48.58	52.40	338.19	822.80	280.10	136.71	101.93	125,343
* 1971	80.97	69.10	71.67	66.53	60.13	54.39	44.11	47.13	58.50	273.68	562.30	182.10	103.03	76.97	97,359
* 1972	70.94	66.53	68.93	64.13	53.94	49.35	51.45	53.19	57.37	226.58	492.17	155.48	104.23	75.80	88,013
1973	68.15	60.25	62.45	58.06	52.88	49.39	51.43	48.16	57.52	369.26	582.00	195.01	122.09	92.20	105,624
1974	75.31	68.91	71.42	66.40	61.45	55.81	50.45	47.90	92.18	298.65	562.93	202.76	117.38	82.15	103,606
1975	74.83	69.35	71.87	66.82	60.16	49.95	69.93	47.35	42.55	237.99	903.71	537.55	199.22	123.32	145,872
1976	92.80	78.20	81.05	75.35	66.58	55.01	46.07	49.78	59.70	267.82	488.45	209.24	123.45	83.17	98,036
1977	72.51	62.07	64.32	59.81	58.33	51.57	44.93	48.27	107.62	401.74	364.64	142.89	91.65	64.29	91,422

* Note: Shading indicates actual recorded flow data

TABLE 4 (continued)
LITTLE BIGHORN RIVER: GENERATED FLOWS AT
DOWNSTREAM END OF INSTREAM FLOW SEGMENT NO. 1

Average Monthly Flows (cfs)

YEAR	OCTOBER	NOVEMBER	NOV. 1-15	NOV 16-30	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	ANNUAL TOTAL (af)
1978	64.05	56.83	58.89	54.76	50.97	48.86	65.39	47.48	61.68	371.01	860.11	335.52	162.43	111.96	134,952
1979	87.92	74.38	77.08	71.67	59.22	54.43	36.52	50.19	56.69	223.43	318.31	125.56	83.10	62.42	74,531
1980	58.09	52.09	53.98	50.19	54.04	43.92	31.09	43.35	63.04	229.84	264.04	113.98	74.93	59.21	65,882
1981	59.34	54.20	56.18	52.23	51.30	47.43	37.31	44.12	65.83	273.19	342.02	141.90	84.16	64.38	76,527
1982	59.44	51.88	53.77	49.99	49.80	44.99	37.94	42.90	35.44	156.78	420.87	226.17	103.42	73.05	78,721
1983	72.73	61.35	63.58	59.12	55.29	51.96	41.54	44.18	42.69	189.00	507.30	182.12	101.09	69.68	85,648
1984	65.25	54.16	56.13	52.19	43.21	49.49	50.98	45.25	61.10	371.88	621.33	231.44	123.60	79.37	108,676
1985	71.42	58.59	60.72	56.46	52.53	50.31	28.66	46.67	62.23	211.40	191.72	87.45	54.99	44.23	58,162
1986	50.82	37.77	39.15	36.40	45.25	40.75	39.43	42.67	60.77	234.61	512.36	139.37	77.22	59.08	80,836
1987	56.89	47.09	48.80	45.38	47.02	44.69	30.40	41.91	96.34	233.52	219.01	99.55	62.45	48.84	62,195
1988	48.45	43.13	44.70	41.56	43.88	39.03	35.45	41.68	64.16	376.24	323.38	105.02	65.73	49.20	74,866
1989	49.99	42.88	44.44	41.32	44.15	40.29	27.06	41.32	49.47	197.41	214.49	105.32	62.73	43.60	55,633
MEAN	66.02	57.16	59.22	55.08	52.02	46.93	42.46	45.22	60.53	261.07	463.18	181.20	99.06	72.07	87,420
STD DEV	12.86	12.06	12.49	11.62	6.64	6.70	9.90	3.44	21.72	65.80	185.42	78.46	30.58	20.36	21,237
# RECORD	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
MINIMUM	46.51	37.77	39.15	36.40	41.09	32.22	26.07	39.56	28.68	128.51	191.72	86.43	47.15	41.41	53,207
MAXIMUM	92.80	83.03	86.05	80.01	66.58	63.17	69.93	55.42	124.92	401.74	903.71	537.55	199.22	123.32	145,872
REQUEST	60		60	50	50	50	50	50	60	60	60	62	62	62	

1) (No Action), Unsuitable for Designation;

2) Designation of 19.2 miles into the Wild and Scenic Rivers System; and

3) Designation of 16.9 miles into the Wild and Scenic Rivers System.

The EIS presents Alternative No. 2 as the preferred alternative however in the draft EIS, Alternative No. 3 was the preferred alternative. Alternative No. 3 would exclude from Wild and Scenic Designation that portion of Dry Creek on which the proposed Dry Fork Reservoir is to be located thus possibly allowing this development to occur. For the purposes of this report, these were the three scenarios evaluated.

Scenario No. 1: No Designation

If the river is not designated Wild & Scenic, the proposed developments for which water right applications have been filed could be accomplished. All of the proposed developments above the instream flow segment would be higher in priority and the size of the proposed diversions structures and reservoirs are such that these structures could potentially dry-up the river. This, however, is not likely to occur because of limitations on the proposed development that would be set by the USFS.

It is stated in the Environmental Impact Statement for the Wild & Scenic designation that under the "No Designation" Scenario, the U.S. Forest Service would require the proposed developments to maintain instream flows as a condition of use. Assumed instream flow requirements are presented in the EIS (Table IV-1) for Dry Fork Creek below Lick

Creek, and the Little Bighorn River below Dayton Gulch. This table is presented below:

Stream	Hydrologic Period	Approximate Dates	Average Streamflow (cfs)	Average Minimum Instream Flow Reqm't (cfs)	Percent of Total Normal Flow (cfs)
Dry Fork below Lick Creek	Rise	5/11-6/1	89	80	90
	Bank Full	6/2-6/7	245	219	89
	Recede	6/8-6/28	164	86	52
	Base Flow	6/29-5/10	30	30	100
Little BigHorn River below Dayton Gulch	Rise	5/25-6/9	94	74	79
	Bank Full	6/10-6/12	200	158	79
	Recede	6/13-6/21	118	80	68
	Base Flow	6/22-5/24	11	8	73

These instream flow requirements are, however, presently being revised due to an update in the methodology used to determine these requirements. Instream flow requirements that may be required of other projects on the Little Bighorn River have not yet been set.

The above instream flows that might be required by the USFS would be comparable to the flows requested by the WGFD. Thus, while the possibility would exist for significantly lower streamflows throughout the Little Bighorn Instream Flow Segment No. 1 should this scenario come to pass, this is unlikely. The streamflow that would occur will largely be a function of bypass flow levels set by the USFS. These flows would probably be comparable to those requested by the WG&F. A more accurate assessment of the streamflows that would exist under this scenario cannot be developed until these requirements are set by the USFS.

Scenario No. 2: Designation of all 19.2 miles

If the larger reach of river is designated Wild & Scenic then the proposed, unadjudicated water development projects will not be allowed to be constructed. The streamflows will remain at their current levels to the Forest boundary. For the area between the Forest boundary and the downstream end of Instream Flow Segment No. 1, no proposed development has yet been filed, and thus the Instream Flow water right would have seniority. Streamflows throughout Instream Flow Segment No. 1 would continue as they have in the past.

Scenario No. 3: Designation of 16.2 miles

This scenario is similar to Scenario No. 2, with the exception that the section of Dry Fork Creek would be excluded from Wild & Scenic designation to permit development of the proposed Dry Fork Reservoir. However, it may be assumed that the USFS in granting a permit would require the bypass of flows much as those presented in Table IV-1 of the

EIS. An analysis of the data from Table IV-I to indicate storage potential is presented below:

Hydrologic Period, Dates (# days)		Average Streamflow (cfs)	Assumed USFS Instream Flow Requirements (cfs)	Average Flow Available for Storage (cfs)	(af)
5/11-6/1	(22)	89	80	9	392
6/2-6/7	(6)	245	219	26	309
6/8-6/28	(21)	164	86	78	3,243
6/29-5/10	(316)	30	30	0	0
			Total Available for Storage (af/yr)		3,944

The average flows available for storage in Dry Fork Creek above Instream Flow Segment No. 1 are the flows remaining after the assumed USFS instream flow requirements are subtracted from the average streamflow. The WG&F instream flow request for the months of May and June is 60 cfs. Average discharges for these months at the downstream end of the Instream Flow Segment No. 1 are 216 and 463 cfs respectively, therefore depletions between 9 and 78 cfs will not reduce flows in the Instream Flow Segment No. 1 below the requested amounts.

V MEAN MONTHLY FLOW ANALYSIS

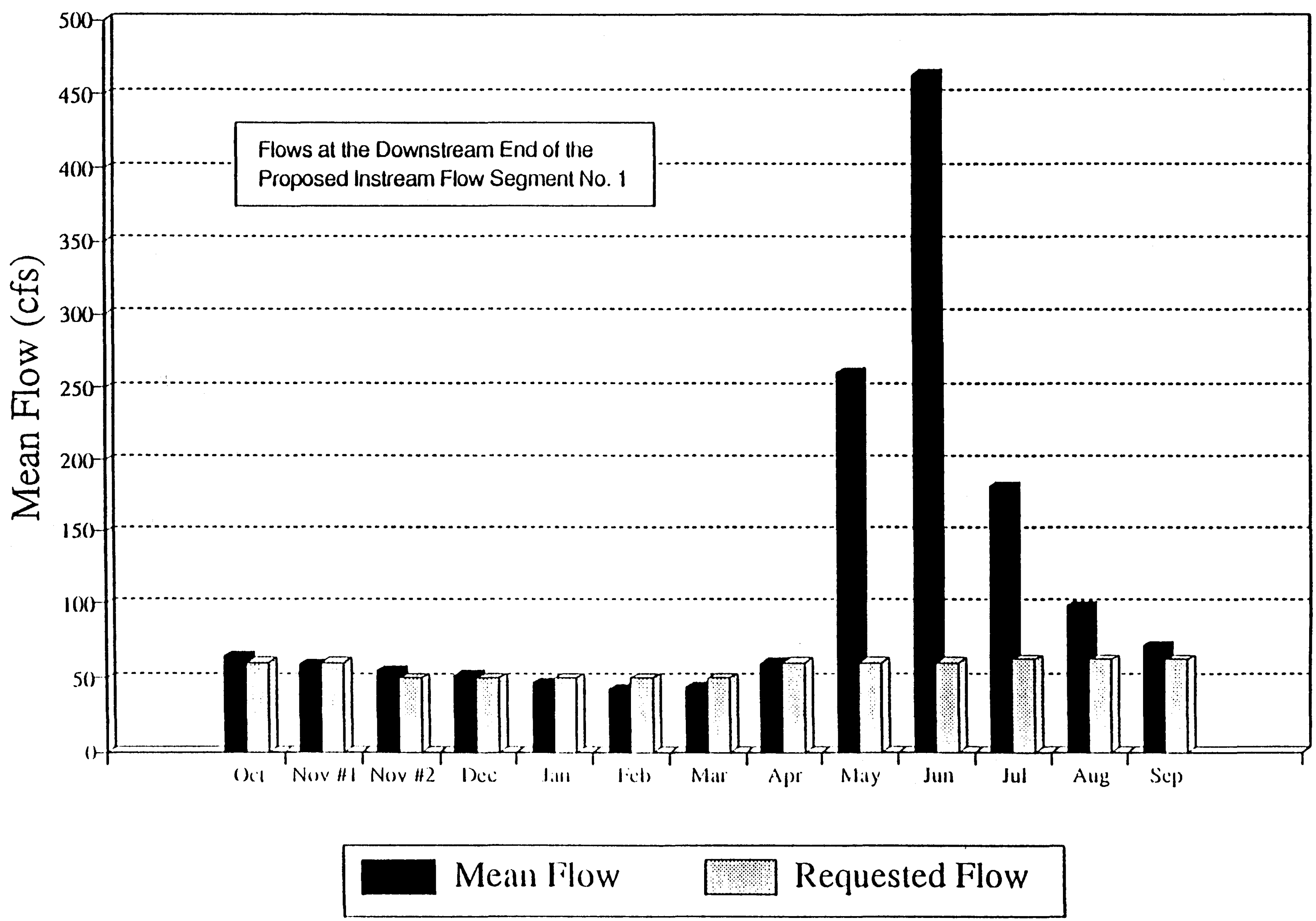
The mean of the monthly flows (which are a mean of the daily flow readings for that month) for the downstream end of the instream flow segment from Table 4 (page 16) are presented in the following summary:

Month	Mean Discharge (cfs)	Requested Discharge (cfs)
October	66	60
November:	(57)	
Nov. 1-15	59	60
Nov. 16-30	55	50
December	52	50
January	47	50
February	42	50
March	45	50
April	61	60
May	261	60
June	463	60
July	181	62
August	99	62
September	72	62

Figure 2 graphically compares the mean monthly flows to the requested flows.

As can be seen, the requested flow is not available in the average year during the months of January, February and March and by one cfs for the period November 1-15. For all other months the average flow exceeds the requested flow.

FIGURE 2: LITTLE BIGHORN RIVER
Avg Monthly & Requested Flow Comparison



VI DRY YEAR FLOW ANALYSIS

The ability of the Little Bighorn River to meet the requested instream flows was evaluated for dry years using two methods. First, the requested flows are compared to those available in the driest year on record determined by total annual flow. Second, the requested flows are compared to the flow during the average of the lowest three years by period. This second procedure was utilized because the lowest flow during a period may not correspond to the lowest flow by annual total.

The ranking of estimated monthly flow of the Little Bighorn River at the downstream end of the Instream Flow Segment No. 1 in ascending order is presented in Table 5. The table presents the average flows for each instream flow period in cubic-feet per second and annual flows in acre-feet. The driest year on record for the Little Bighorn River is 1961. A comparison of the recorded monthly flows for 1961 versus the flows requested by the WG&F is presented in Table 6. Shortage occurred in all months except May, June, and July. A bar graph comparing 1961 monthly flows to the requested flows is presented on Figure 3.

TABLE 5
'ANKING OF FLOWS IN ASCENDING ORDER
Downstream End of Instream Flow Segment No. 1
Little Bighorn River

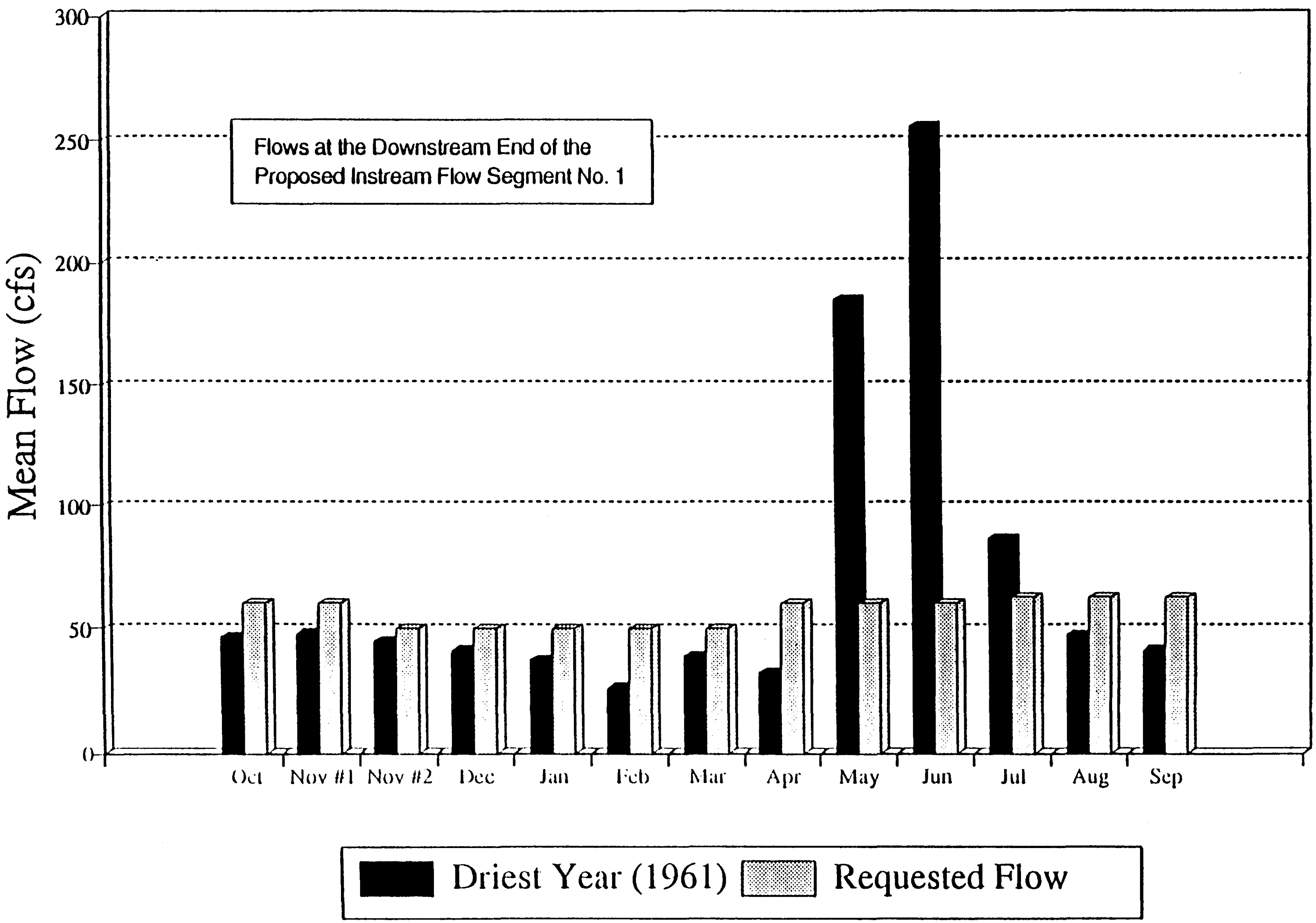
Average Discharge (cfs)

YEAR	Oct. 1 to Nov. 15	YEAR	Nov. 16 to Mar. 31	YEAR	Apr. 1 to Jun. 31	YEAR	Jul. 1 to Sep. 30	YEAR	Total Annual (af)
1961	44.59	1961	36.51	1989	154.27	1961	58.52	1961	53,207
1962	45.40	1989	38.79	1985	155.74	1985	62.42	1989	55,633
1986	47.01	1962	38.92	1961	158.51	1960	68.87	1960	57,956
Ave.	45.67	Ave.	38.07	Ave.	156.17	Ave.	63.27	Ave.	55,598
1988	47.23	1950	39.78	1960	159.39	1987	70.51	1985	58,162
1957	47.44	1956	39.87	1950	174.51	1989	70.84	1987	62,195
1989	48.18	1988	40.28	1966	182.57	1988	73.58	1950	63,284
1953	48.69	1955	40.29	1987	183.51	1966	73.63	1956	64,889
1955	48.99	1941	41.21	1940	184.07	1956	75.86	1940	65,086
1959	50.78	1986	41.46	1980	186.13	1958	80.83	1980	65,882
1956	50.85	1960	41.52	1956	197.19	1940	80.87	1966	66,987
1967	51.03	1957	41.64	1941	197.83	1980	82.96	1941	68,196
1954	51.33	1987	41.72	1979	199.74	1954	84.94	1958	70,431
1963	52.42	1954	41.75	1958	202.60	1949	88.68	1954	70,778
1950	53.18	1963	42.51	1982	203.84	1950	88.79	1953	74,223
1941	53.45	1953	42.83	1951	211.72	1952	89.90	1949	74,294
1987	54.25	1959	43.43	1954	217.90	1941	90.40	1979	74,531
1951	55.60	1949	43.89	1949	226.21	1979	90.67	1988	74,866
1980	56.75	1951	43.89	1953	226.86	1986	92.25	1981	76,527
1982	57.59	1940	43.90	1981	227.52	1953	94.70	1962	76,578
1940	57.93	1980	44.15	1948	228.93	1981	97.17	1951	77,119
1981	58.31	1982	44.71	1962	239.51	1977	99.99	1955	78,425
1960	58.78	1952	45.16	1945	244.61	1955	100.44	1952	78,687
1949	59.65	1981	46.00	1983	245.70	1962	102.52	1982	78,721
1952	61.52	1985	46.21	1952	246.07	1948	107.30	1986	80,836
1984	62.27	1967	46.30	1955	247.97	1959	111.38	1948	82,005
1964	62.35	1958	46.37	1988	255.93	1972	112.23	1959	83,294
1978	62.37	1984	47.69	1959	258.30	1942	114.40	1983	85,648
1943	63.69	1943	48.51	1972	258.35	1983	118.15	1972	88,013
1973	66.29	1948	49.17	1969	266.59	1951	120.52	1977	91,422
1944	67.18	1966	49.20	1986	268.87	1971	121.17	1957	92,663
1985	67.93	1983	49.59	1946	271.21	1963	123.88	1969	94,164
1983	69.74	1944	50.81	1976	271.94	1946	127.59	1945	94,520
1977	69.84	1964	50.96	1957	277.28	1969	131.61	1946	94,972
1970	69.97	1973	51.28	1943	284.48	1974	134.66	1943	95,725
1972	70.29	1977	51.90	1977	292.55	1982	134.88	1971	97,359
1958	72.38	1979	52.77	1971	297.89	1973	136.91	1976	98,036
1975	73.86	1978	53.08	1947	301.40	1976	139.22	1963	100,098
1974	74.04	1971	53.27	1942	316.93	1943	139.64	1942	101,758
1945	76.36	1972	53.33	1974	317.71	1984	145.52	1974	103,606
1946	77.58	1970	53.36	1967	331.48	1957	148.26	1947	105,256
1968	77.63	1969	54.23	1973	336.62	1944	152.26	1973	105,624
1971	77.92	1945	54.60	1968	336.92	1947	156.46	1967	106,248
1947	78.54	1974	55.36	1963	339.31	1945	157.13	1984	108,676
1965	79.89	1968	55.41	1984	351.66	1967	160.41	1968	113,118
1966	80.31	1947	56.12	1965	353.54	1965	162.67	1944	114,728
1969	81.12	1965	56.45	1944	371.21	1968	165.33	1965	116,013
1979	84.39	1976	56.86	1964	389.27	1970	173.68	1964	124,379
1948	85.10	1942	57.50	1975	393.03	1964	189.44	1970	125,343
1976	88.96	1975	57.66	1970	403.74	1978	204.30	1978	134,952
1942	89.52	1946	58.04	1978	430.28	1975	288.47	1975	145,872

Table 6
Comparison of Monthly Flows During Driest Year on Record (1961) and Requested Flow

Month	1961 Mean Monthly Flow (cfs)	Requested Flow (cfs)	Shortfall (cfs)	Volume of Shortfall (AF)
Oct.	46.5	60	13.5	829
Nov.	(39.2)			
Nov. 1-15	40.6	60	19.4	576
Nov. 16-30	37.8	50	12.2	362
Dec.	41.5	50	8.5	522
Jan.	37.3	50	12.7	780
Feb.	26.1	50	23.9	1,337
Mar.	39.6	50	10.4	638
Apr.	32.5	60	27.5	1,634
May	185.7	60	---	----
June	256.5	60	---	---
July	86.4	62	---	---
Aug.	47.2	62	14.8	908
Sept.	41.4	62	20.6	1,224
			TOTAL	8,810
			TOTAL (July-Sept.)	2,132

FIGURE 3: LITTLE BIGHORN RIVER
Driest Year & Requested Flow Comparison



Using the average of the three lowest years for each instream flow period helps minimize the influence of data from one extremely dry year which may not be representative of typical low flow years. By period, the three driest years are:

October - November 15	1961, 1962, 1986
November 16 - March 30	1961, 1989, 1962
April 1 to June 30	1989, 1985, 1961
July 1 to September 30	1961, 1985, 1960

Averaging the monthly flows for the three driest years by period yields the information shown in Table 7. This analysis shows that there are shortfalls for the requested flows for all months except May, June, and July (the same months as for the driest year). Figure 4 is a bar graph relating the three lowest year average, by period, to the requested flow. The shortfall for the 12 months is 6,780 acre-feet versus 8,800 acre-feet for 1961, the driest year on record.

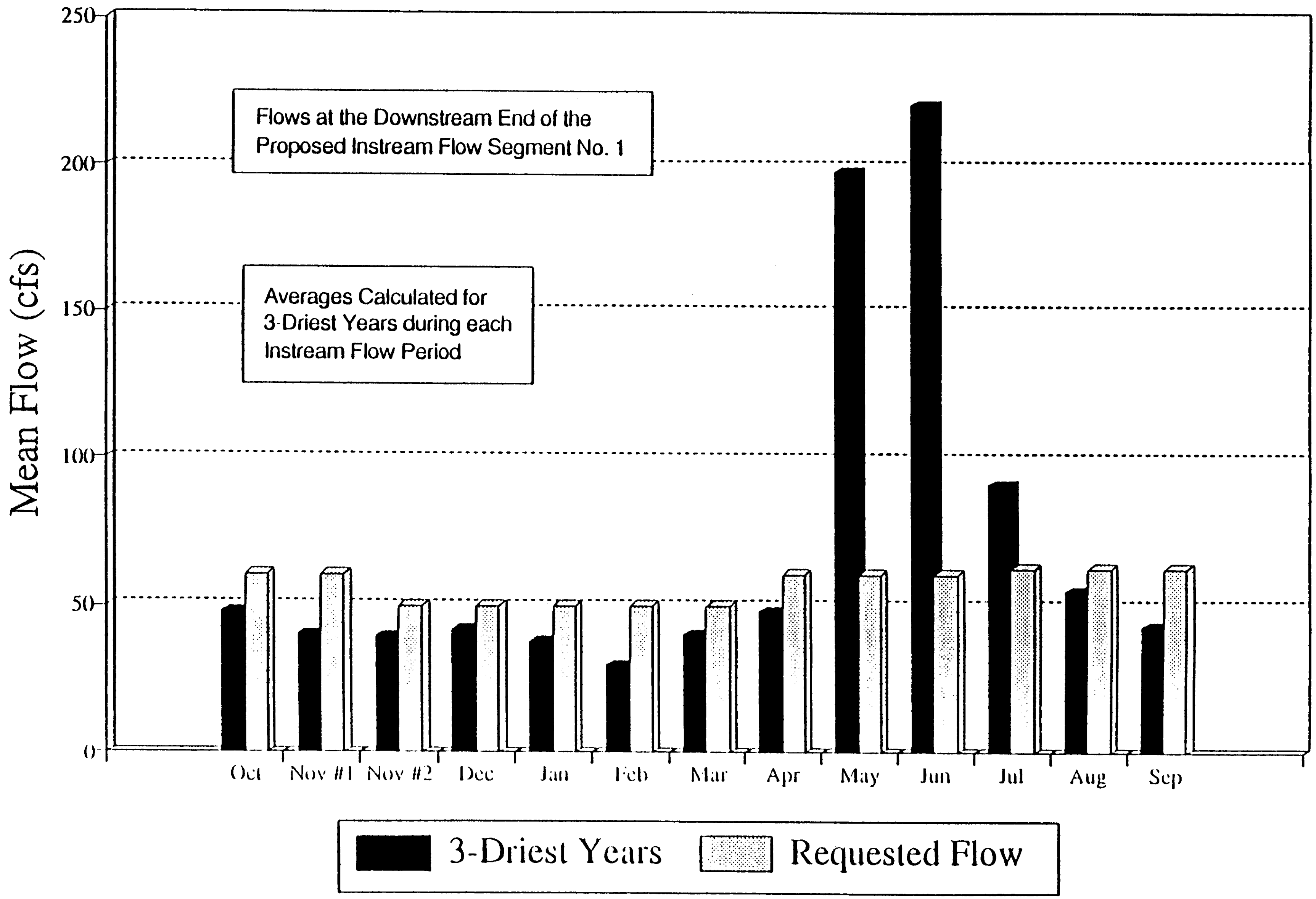
Table 7

Comparison of Monthly Flows During the Average of 3 Driest Years by Period and Requested Flows

Period	3-Year Mean Monthly Flow (cfs)	Requested Flow (cfs)	Average Shortfall (cfs)	Average Volume Shortfall (AF)
Oct.	48.1	60	11.9	730
Nov.				
Nov. 1-15	40.7	60	19.3	573
Nov. 16-30	39.5	50	10.5	312
Dec.	42.2	50	7.8	479
Jan.	37.8	50	12.2	749
Feb.	30.1	50	19.9	1,113
March	40.8	50	9.2	565
April	48.1	60	11.9	707
May	198.2	60	----	---
June	220.9	60	----	---
July	91.1	62	----	---
Aug.	55.2	62	6.8	417
Sept.	42.9	62	19.1	1,135
			TOTAL	6,780
			TOTAL (July-Sept.)	1,552

FIGURE 4: LITTLE BIGHORN RIVER

3-Driest Yr. Avg. & Request Comparison



VII RESERVOIR OPERATION STUDY

The Little Bighorn River basin has experienced little water development to date. However, large water development projects involving diversion and storage of water have been proposed and temporary filings made to the State Engineer's Office. The current developments regarding designation of the river as Wild and Scenic may curtail all future development projects.

Because the requested flows for instream flow are not available during dry years, an assessment was made to estimate whether storage above the segment could regulate flow to provide supplemental water during shortages. To assess reservoir feasibility, a balance of flows at the instream flow segment was performed. Two scenarios were examined; first provide additional water to meet the instream flow request for the entire year and second provide water to meet the request only for the period April to September. The WGFD has stated that if natural winter flows are not sufficient to satisfy the requested flow, it is their intent that the request would be only to maintain natural flows. Table 8 presents a summary of annual flow shortages and excesses for the proposed instream flow segment.

A reservoir could physically be constructed on the Little Bighorn River or its tributaries above the proposed instream flow segment. However, before water could be stored in such a reservoir, prior downstream storage rights would have to be filled, or negotiated agreements to store water out of priority would have to be arranged. Because of these institutional constraints to a new storage facility, such a proposal must be studied as part of a much larger planning study.

Table 8

Summary of Annual Flow Shortages and Excesses
Little Bighorn River at Proposed Instream Flow Segment

	Average Year (AF)	Lowest Year, 1961 (AF)	Lowest 3-Years by Period (AF)
Shortfall for Entire Year	988	8,810	6,780
Shortfall for July - September	0	2,132	1,552
Excess Flow	47,155	20,885	19,826

As can be seen, the amount of storage necessary to satisfy the instream flow request for July through September depends on the criterion used. The flow in the river, if regulated by a reservoir with approximately 2,100 acre-feet of yield, could meet the instream flow request for the July through September period even in the driest year recorded. The July through September request can be supplied during an average year so, on the average no storage is required.

VIII DAILY FLOW EXCEEDENCE ANALYSIS

The Wyoming Game and Fish Department considers that an instream flow request is "feasible" if during the period of July 1 through September 30 the requested flow is available at least 50% of the time. Therefore, a daily flow duration analysis was conducted and for completeness, the analysis was done for all four instream flow periods. Daily flow-duration data were obtained by periods from the Wyoming Water Research Center WRD System for both the State Line and the Parkman gaging stations on the Little Bighorn River. The curves for the Parkman gaging station were then adjusted using procedures detailed by Searcy (1951) to create duration curves for the downstream end of the instream flow segment based on the long term relationships exhibited between the two gages. The duration curves for the end of the instream flow segment are presented in Figures 5 through 8.

The WG&F requested flow, their exceedence criteria and actual exceedence data are summarized below:

Table 9
Daily Flow Exceedence Summary
Little Bighorn River

Period	Requested Instream Flow (cfs)	WG&F Exceedence Criteria % Time	Exceedence Value % Time
October 1 - November 15	60 cfs	N/A	67%
November 15 - March 31	50 cfs	N/A	48%
April 1 - June 30	60 cfs	N/A	84%
July 1 - September 30	62 cfs	50%	86%

This indicates that the flow of 62 cfs during the critical period July to September is available 86% of the time which exceeds the WG&F exceedence criterion of 50%.

FIGURE 5: LITTLE BIGHORN RIVER
Daily Duration Curve, Oct 1-Nov 15

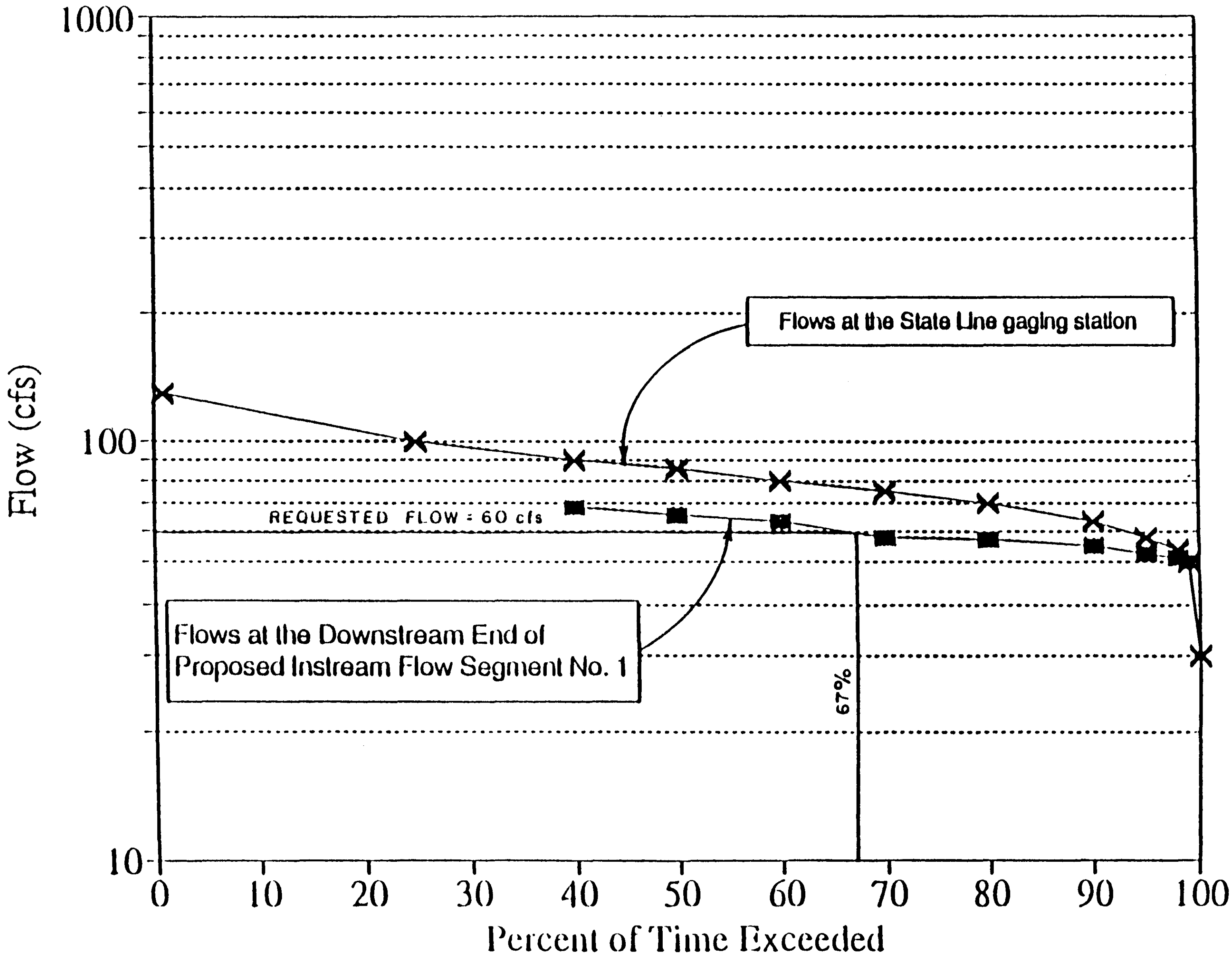
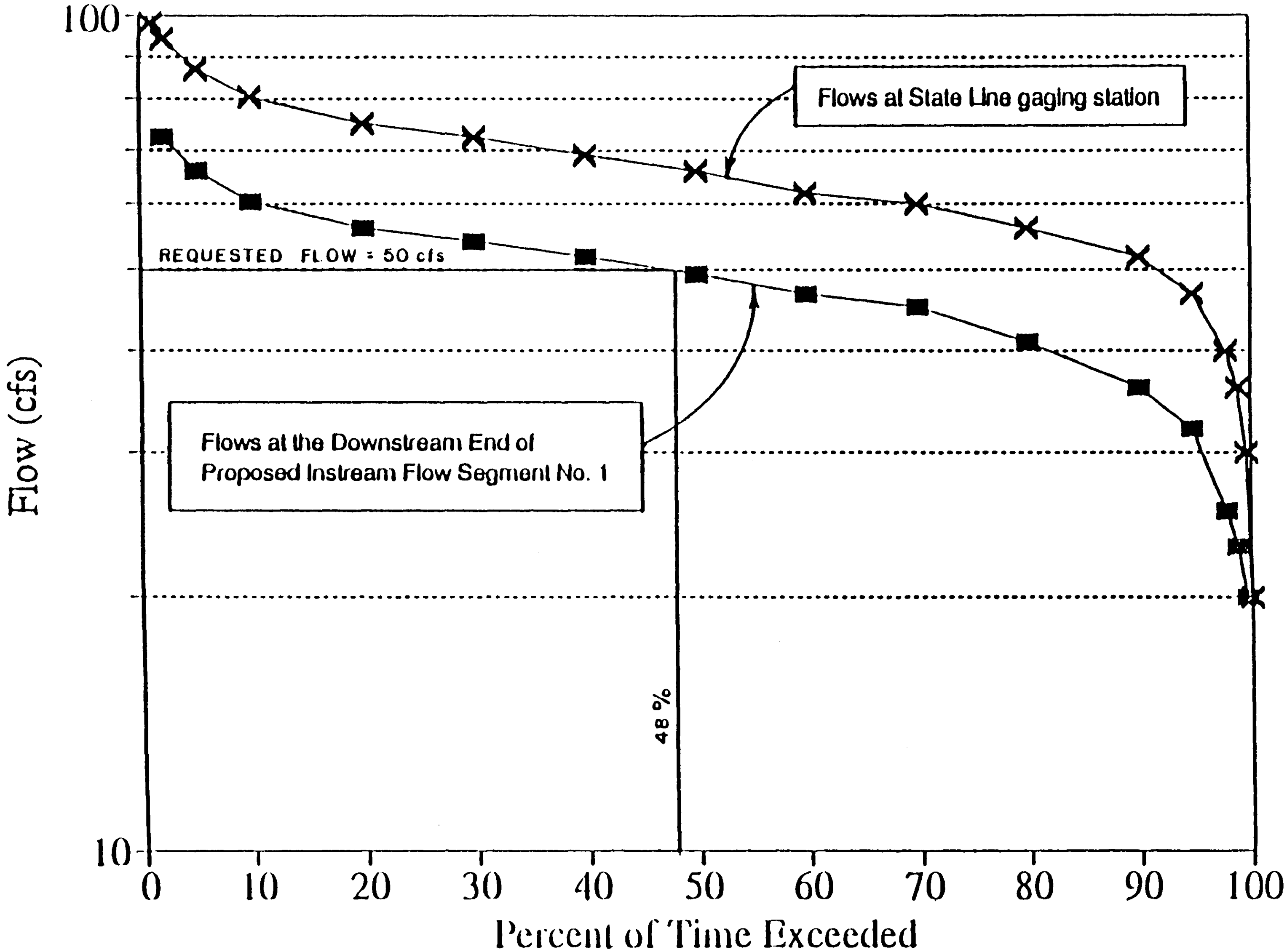


FIGURE 6: LITTLE BIGHORN RIVER
Daily Duration Curve, Nov 16-Mar 31



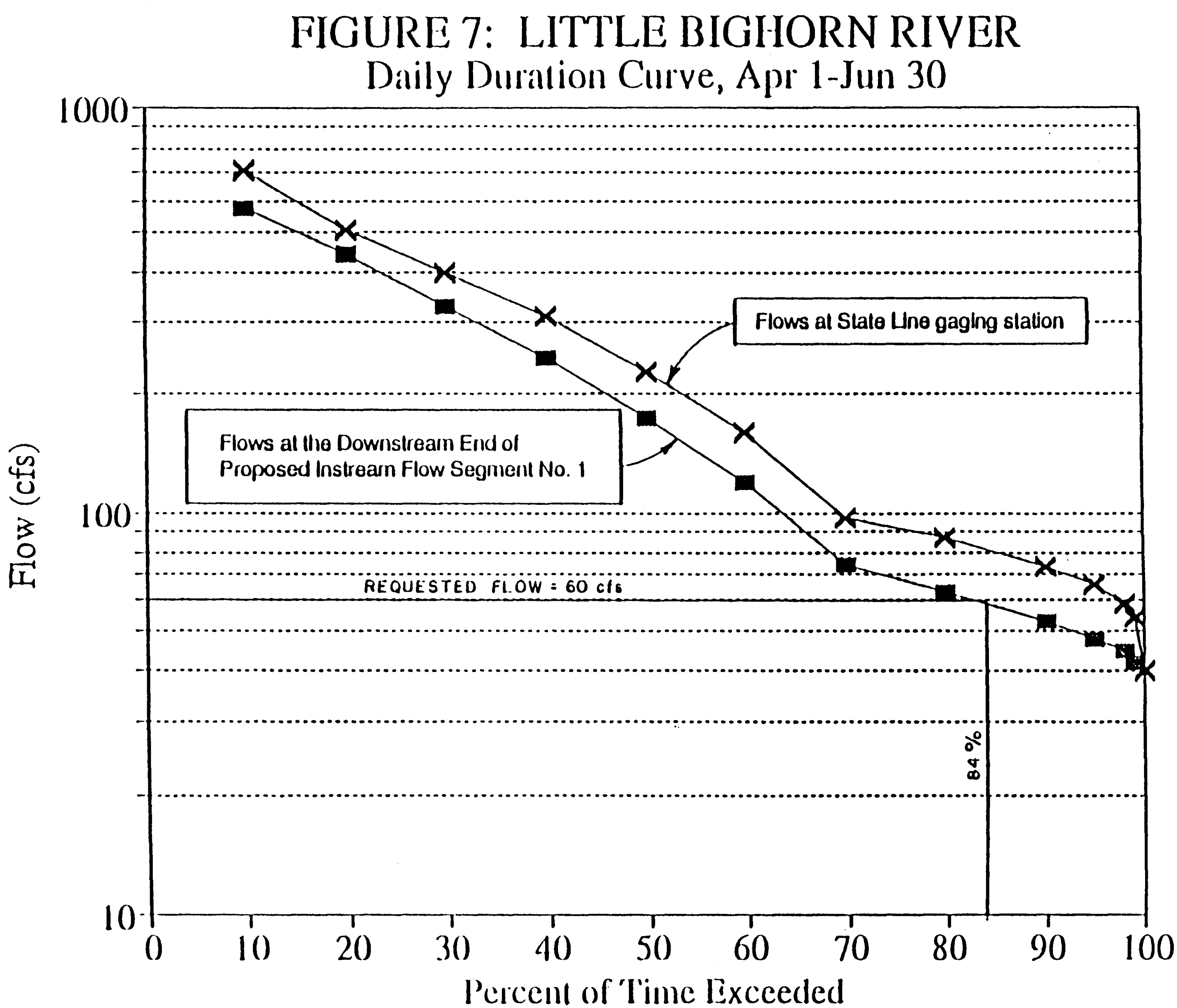
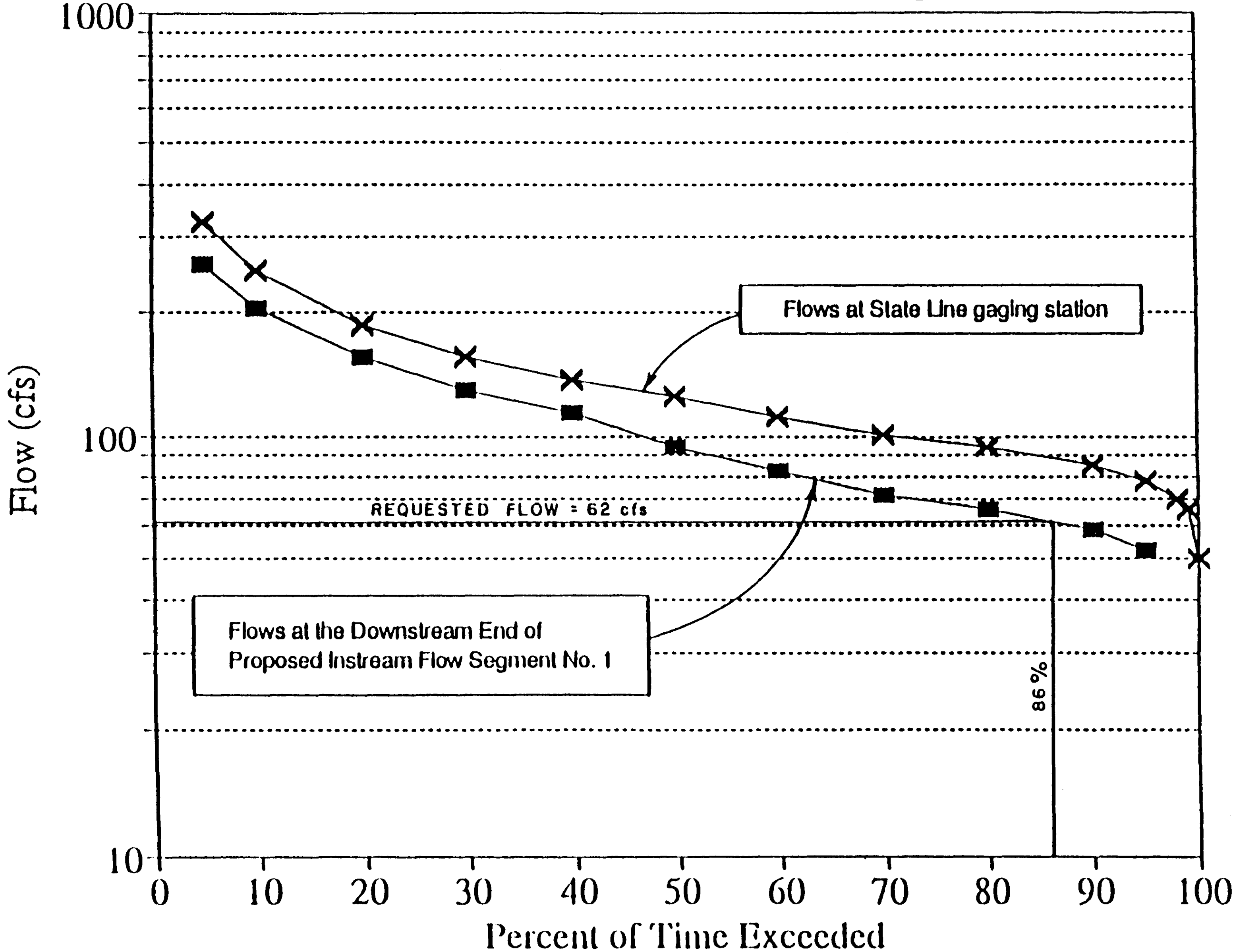


FIGURE 7: LITTLE BIGHORN RIVER
Daily Duration Curve, Apr 1-Jun 30
1000
100
10
Flow (cfs)
0
10
20
30
40
50
60
70
80
90
100
Percent of Time Exceeded
Flows at State Line gaging station
Flows at the Downstream End of
Proposed Instream Flow Segment No. 1
REQUESTED FLOW = 60 cfs
84 %

FIGURE 8: LITTLE BIGHORN RIVER

Daily Duration Curve, Jul 1-Sep 30



IX CONCLUSIONS

The mean monthly flow analysis indicates that on the average for the Little Bighorn River Instream Flow Segment No. 1, the WG&F instream flow request can be met by direct flow except during the winter months, January through March, and the November 1 to 15 period. During dry years the requested flow is only met during spring runoff, May - June. Dry year shortages could be met if storage were provided, but this is a complex issue in which other users in the basin must be considered and is not required by the exceedence criteria established by the WG&F. Their exceedence criterion of flows equalling or exceeding 62 cfs for 50% of the time during July through September can be met with direct flows.

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Searcy, J.K., Flow Duration Curves, Manual of Hydrology: Part 2. Low Flow Techniques, USGS Water-Supply Paper 1542-A, USGPO, 1959.

U.S. Bureau of Reclamation Manual, Volume IV, Water Studies, January 1951.

U.S. Department of Agriculture, Forest Service, Wild and Scenic River Study Report and Final Environmental Impact Statement on the Little Bighorn River, June 1989

APPENDIX I

WYOMING GAME AND FISH DEPARTMENT REPORT

AND

APPLICATION TO WYOMING STATE ENGINEER

T F NO. 26 5/339

WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: Little Bighorn River Instream Flow Report

PROJECT: IF-3088-07-8703

AUTHOR: Gerald F. Vogt, Jr.

DATE: February 1989

INTRODUCTION

Data were collected during the 1988 field season to conduct instream flow analyses for a segment of the Little Bighorn River located in the Bighorn National Forest. The study was designed to provide results which could be used to determine instream flow needs for trout as well as to evaluate potential flow related impacts of possible future water development activities. This study does not address recommendations for flushing flows for channel maintenance.

METHODS

Study Area

The Little Bighorn River is considered a Class 2 stream by the Wyoming Game and Fish Department (WGFD). Stream classifications throughout Wyoming range from Class 1 (highest rating) to Class 5 (lowest rating). Class 2 streams are generally considered important trout fisheries on a statewide basis. Less than 6% of all streams in the state are Class 2 streams.

The Little Bighorn River contains naturally reproducing populations of rainbow trout, brown trout, and mountain whitefish. Brook and cutthroat trout occur incidentally. The stream below the mouth of Dry Fork Creek is primarily managed as a wild fishery for rainbow trout and secondarily for brown trout; therefore no fish are stocked in this section by the WGFD. The entire study reach is located within National Forest land and is accessible to the public. Because this section of the Little Bighorn River supports an important trout fishery and has public access, this segment was identified as a critical reach.

Data Collection

All of the field data used in this study were collected from a 519 foot long study site located in the southeast quarter of Section 25, Township 58 North, Range 90 West. This site is located approximately 3.5 miles upstream from the

T. F. NO. 26 5/339

Wyoming-Montana border (Figure 1). This site contained a combination of pool and riffle habitat for trout that was representative of trout habitat features found throughout this portion of the stream. Results and recommendations were applied to a portion of the stream extending from the north boundary of the SW1/4 SW1/4 of Section 20, Township 58 North, Range 89 West to the mouth of Dry Fork Creek at the east boundary of the NW1/4 NW1/4 of Section 12, Township 57 North, Range 90 West. This is a distance of approximately 4.4 stream miles.

In accordance with the 1986 Instream Flow legislation, the goal of this study was to determine instream flows necessary to maintain or improve the existing trout fishery in the above segment of the Little Bighorn River. The specific objectives of this study were to determine instream flows necessary to 1) maintain or improve physical habitat for rainbow trout spawning and incubation during the spring, 2) maintain or improve physical habitat for brown trout spawning and incubation during the fall, 3) maintain or improve hydraulic characteristics in the winter that are important for survival of trout, fish passage and aquatic insect production and, 4) maintain or improve adult trout production during the late summer months. Three habitat models were used to make these determinations.

Models

A physical habitat simulation model (PHABSIM) developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) was used to quantify incremental changes in the amount of physical habitat available for rainbow and brown trout spawning and incubation at various discharge rates. The amount of physical habitat available at a given discharge is expressed in terms of weighted usable area (WUA) and reflects the composite suitability of depth, velocity and substrate at a given flow. Depth, velocity and substrate data were collected at eight transects as described in Bovee and Milhous (1978). Dates and discharge rates when data were collected are given in Table 1. The WUA for various life stages of rainbow and brown trout was simulated for flows ranging from 10 to 300 cubic feet per second (cfs) using calibration and modeling techniques outlined in Milhous et al. (1984).

Table 1. Dates and discharges when instream flow data were collected.

Date	Discharge (cfs)
06-17-88	230
07-16-88	111
09-13-88	68

A Habitat Retention method (Nehring 1979, Annear and Conder 1984) was used to identify a maintenance flow. A maintenance flow is defined as a continuous flow that is needed to maintain minimum hydraulic criteria at riffle areas in a stream segment. These criteria are needed to provide passage for all life stages of trout between different habitat types and maintain existing survival rates of trout and aquatic macroinvertebrates.

Data from single transects placed across three riffles within the study area were analyzed with the IFG-1 computer program (Milhous 1978). Flow data were collected

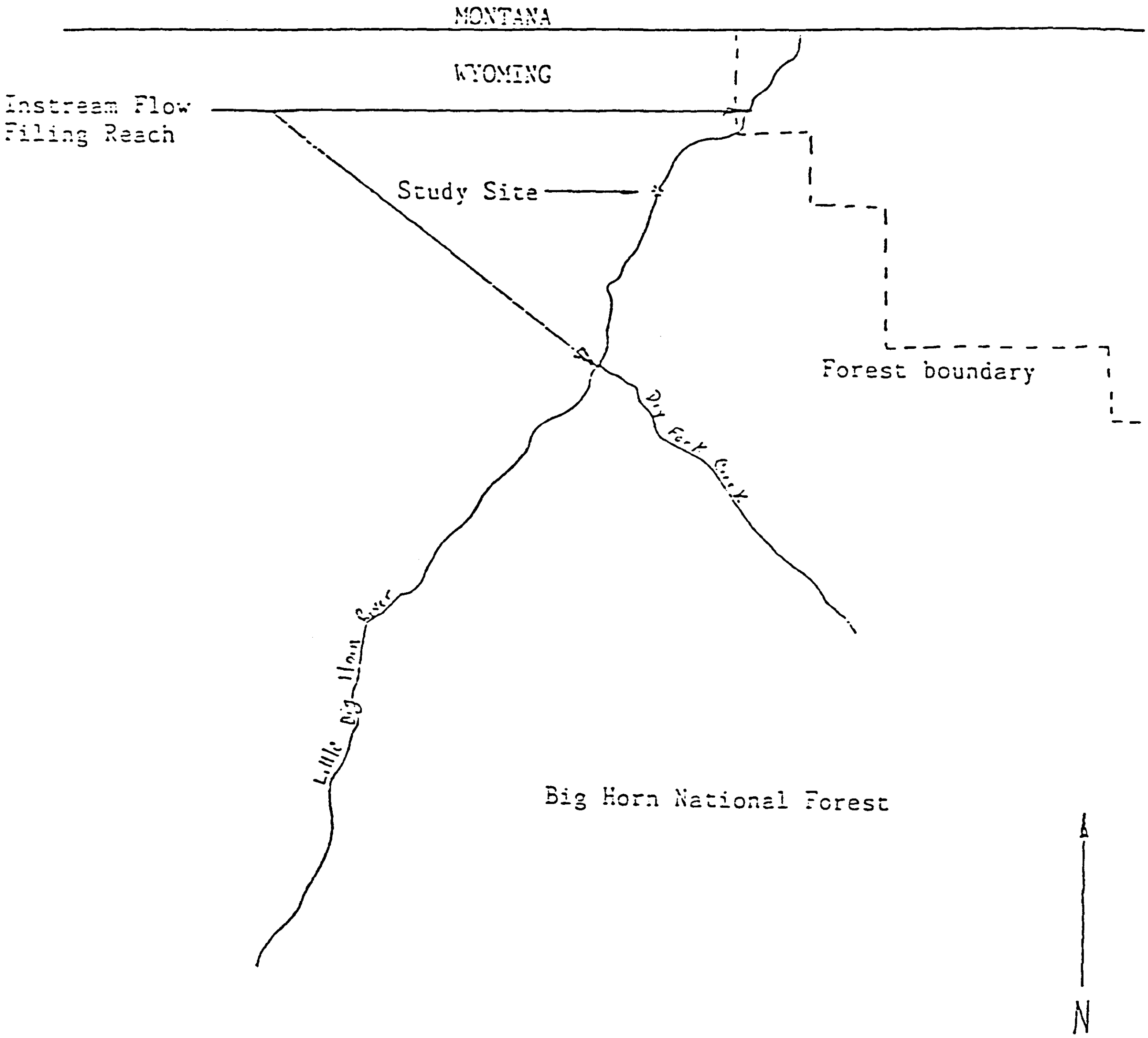

Figure 1. Map of study area on the Little Bighorn River.

during three different flow events (Table 1). The maintenance flow is identified as the discharge at which two of the three criteria in Table 2 are met for all riffles in the study area.

Table 2. Hydraulic criteria used to obtain an instream flow recommendation using the Habitat Retention method.

Category	Criteria
Average Depth (ft)	Top width[1] x 0.01
Average Velocity (ft per sec)	1.00
Wetted Perimeter (percent)[2]	60

1 - At average daily flow
2 - Compared to wetted perimeter at bank full conditions

The Habitat Quality Index (HQI) developed by the Wyoming Game and Fish Department (Binns and Eiserman 1979) was used to estimate potential changes in trout standing crops over a range of late summer flow conditions. This model incorporates seven attributes that address chemical, physical and biological components of trout habitat. Results are expressed in habitat units (HU). One HU is defined as the amount of habitat quality which will support one pound of trout. Analyses obtained from this method apply to the time of year that governs trout production. On the Little Bighorn River, this time period is between July 1 and September 30.

By measuring habitat attributes at various flow events as if associated habitat features were typical of late summer flow conditions, HU estimates can be made for a range of theoretical summer flows. Habitat attributes on the Little Bighorn River were measured on the same dates and flow levels that data were collected for the PHABSIM and Habitat Retention models (Table 1). To better define the potential impact of other late summer flow levels on trout production, some attributes were derived mathematically or obtained from existing gage data. Gage data were obtained from a U.S. Geological Survey gage located on the Little Bighorn River near the Wyoming-Montana border for the period 1939 to 1986. A regression equation was developed to relate the discharges at the U.S.G.S. gage with discharges measured at the study site. This relationship was used to determine the annual stream flow variation and critical period stream flow, two variables of the HQI, at the study site.

Results from the PHABSIM analysis were used to evaluate the relationship between discharge and physical habitat for rainbow trout spawning and incubation. Rainbow trout generally spawn in April and May and their eggs incubate in the stream gravels until late June. Results from this model were applied to the stream for the period between April 1 and June 30.

PHABSIM results were also used to identify stream flows necessary to maintain or improve physical habitat for brown trout. This species normally spawns in October and November and the eggs incubate until late March. Spawning and incubation results were subsequently used to address the relationship between these life stages and discharge from October 1 to March 31. Results from the Habitat Retention model were combined with the results of the PHABSIM model for brown trout to identify a flow from October 1 to March 31 which would meet the dual objectives of maintaining trout survival and passage and aquatic insect survival as well as maintaining brown trout reproductive success.

Results from the HQI model were used to identify the flow needed to maintain existing levels of trout production between July 1 and September 30.

RESULTS

An analysis of gage records indicated that existing flow conditions at the study site approximate 60 cfs during the month of April. Results of the PHABSIM analysis indicate that at this discharge, physical habitat for rainbow trout spawning is approximately 80% of the maximum amount available, which occurs at a discharge of 90 cfs (Figure 2). Reductions in existing physical habitat for spawning occur at flows lower than 60 cfs, while flows between 70 and 125 cfs result in relatively large increases in physical habitat for spawning.

Gage records indicate that existing flows during May and June approximate 300 cfs. PHABSIM results indicate that a flow of 300 cfs provides approximately 40% of the maximum amount of physical habitat for incubation, which occurs at a discharge of 20 cfs. Flows between 20 and 300 cfs will therefore maintain or improve the existing physical habitat for rainbow trout incubation. However, flows less than 60 cfs will reduce the existing amount of physical habitat for trout that may still be spawning during May and June. Such reductions would also dewater some rainbow trout eggs that were deposited at this flow level and consequently cause a reduction in spawning success.

To maintain or improve physical habitat available to rainbow trout for both spawning and incubation, an instream flow of 60 cfs is recommended for the period of April 1 to June 30. This discharge will maintain the existing amount of physical habitat for spawning during the period April 1 to April 30. In addition this discharge will improve existing physical habitat for incubation between May 1 and June 30 while also maintaining physical habitat for late spawning fish during these months.

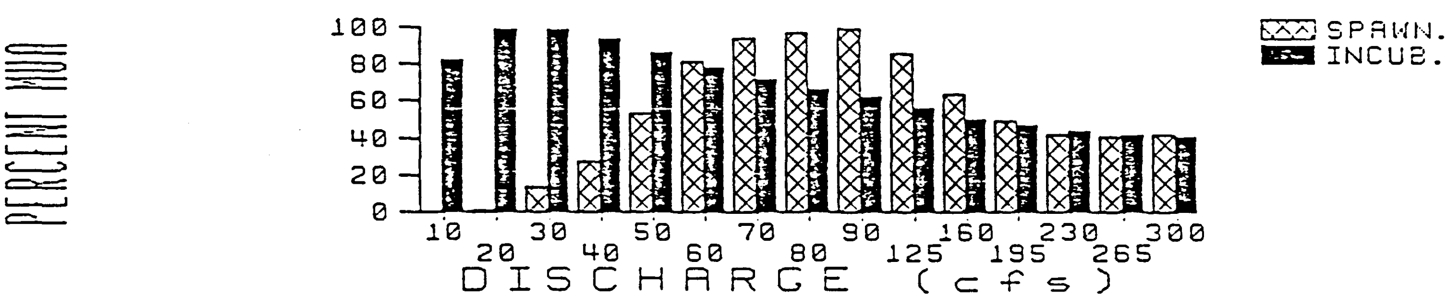

Figure 2. Percent of maximum usable area (MUA) for spawning and incubation life stages of rainbow trout.

PHABSIM results for brown trout spawning and incubation were nearly identical to those for rainbow trout. Results of the PHABSIM analysis indicate that under existing average flow conditions during the month of October (approximately 60 cfs), physical habitat for brown trout spawning is approximately 80% of the maximum amount available, which occurs at a discharge of 90 cfs (Figure 3). Reductions in existing physical habitat for spawning occur at flows lower than 60 cfs, while flows between 70 and 125 cfs result in relatively large increases in physical habitat for spawning.

The hydrologic analysis showed that existing average flows during the brown trout incubation period (November through March) approximate 50 cfs. A discharge of 50 cfs provides about 85% of the maximum usable area for incubation, which occurs at a discharge of 20 cfs. Flows of between 20 and 50 cfs will maintain or improve the existing physical habitat for brown trout incubation. However, flows less than 60 cfs will reduce physical habitat for trout that may still be spawning in early November. In addition, reductions in flows below 50 cfs from late November to March 31 would also dewater some brown trout eggs that were deposited during October and early November and consequently cause a reduction in spawning success.

To maintain or improve physical habitat available to brown trout for spawning, an instream flow of 60 cfs is recommended for the period of October 1 to November 15. A discharge of 50 cfs during the period November 16 to March 31 is the minimum flow that will maintain existing physical habitat for incubation while preventing the dewatering of eggs that were deposited at higher discharges in October and early November.

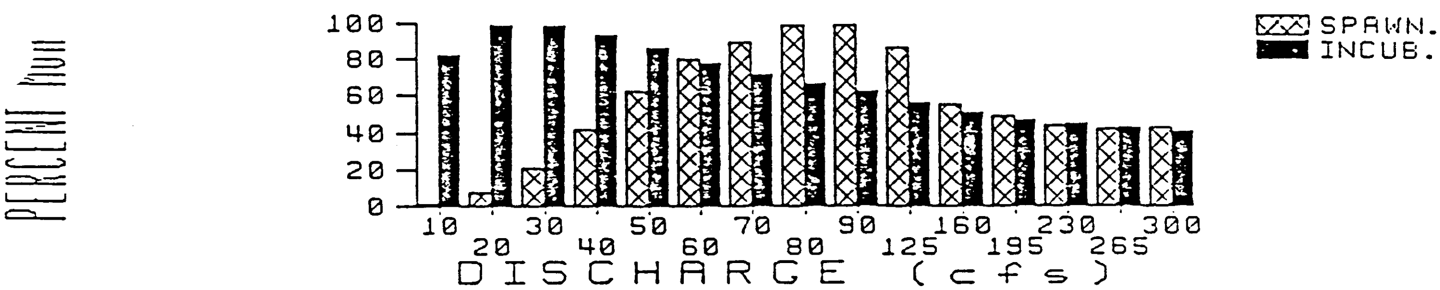

Figure 3. Percent of maximum usable area (MUA) for spawning and incubation life stages of brown trout.

Results from the Habitat Retention model showed that the hydraulic criteria in Table 2 are met at flows of 8.8, 14.0 and 15.9 cfs for riffles 1, 2, and 3, respectively (Table 3). The maintenance flow derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site which in this case is 15.9 cfs.

Table 3. Simulated hydraulic criteria for three riffles on the Little Bighorn River. Average daily flow = 110 cfs. Bank full discharge = 712.0 cfs.

Riffle 1

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
2.49	5.84	50.3	712.0
2.42	5.49	49.5	636.9
2.23	4.77	48.0	497.4
2.04	4.11	46.8	380.7
1.84	3.49	45.5	284.5
1.34	2.06	40.4	110.0
1.08	1.52 [1]	38.7	61.9
0.81	1.00	34.7 [1]	28.3 [2]
0.51 [1]	0.57	30.2	8.8
0.39	0.46	28.2	5.4

Riffle 2

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
1.95	7.12	52.4	712.0
1.85	6.63	51.8	619.1
1.71	5.65	48.5	458.8
1.53	4.72	46.5	328.8
1.31	3.87	45.2	226.0
0.96	2.67	42.7	110.0
0.68 [1]	1.84	39.8	48.8
0.42	1.16	33.1 [1]	17.1 [2]
0.39	1.07 [1]	31.5	14.0
0.36	1.00	30.3	11.7

Riffle 3

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
2.80	5.05	53.6	712.0
2.53	4.69	52.5	583.1
2.26	4.14	47.8	416.3
1.85	3.58	45.6	281.7
1.42	3.06	43.5	177.1
1.10	2.66	39.8	110.0
0.93	2.37	34.2 [1]	70.6
0.81 [1]	2.22	32.2	55.5 [2]
0.37	1.84 [1]	24.1	15.9
0.12	1.00	3.5	0.0

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

Based on the results of the Habitat Retention method, an instream flow of 15.9 cfs was identified as the flow that would maintain minimum hydraulic criteria at riffles to provide passage for all life stages of trout between different habitat types and maintain existing survival rates of trout and aquatic macroinvertebrates. However, a flow of 15.9 cfs during the fall and winter would result in significant reductions in physical habitat for brown trout spawning. The results of the PHABSIM analysis indicate that physical habitat for brown trout spawning would be reduced to approximately 5 percent of the maximum amount available. As a result, the recommended instream flow for the period October 1 to November 15 is 60 cfs and for the period November 16 to March 31 the recommended flow is 50 cfs. These recommendations will maintain the existing levels of spawning and incubation for brown trout and also meet or exceed the hydraulic criteria used in the Habitat Retention method for providing fish passage, and maintaining survival rates of trout and aquatic macroinvertebrates.

Results from the HQI analyses (Figure 4) indicate that trout HU's in this portion of the Little Bighorn River would be maximized at an average late summer flow of approximately 85 cfs. Under existing conditions, the stream presently supports 248 HUs which is equal to the maximum potential indicated by the HQI model. A flow of 62 cfs is the minimum flow that will maintain the existing number of habitat units. At lower average late summer flows, the model indicates that reductions in the fishery would occur. These reductions would largely be the result of lower velocities, lower critical period flow and higher annual flow variation. Significant increases in stream flow above 85 cfs would result in increasingly rapid reductions in trout HUs, as would small reductions in discharge below 62 cfs (Figure 4).

Figure 4. Number of potential trout habitat units at several late summer flow levels in the Little Bighorn River.

Based on the results from the HQI analysis, an instream flow of 62 cfs is recommended to maintain existing levels of trout production between July 1 and September 30.

CONCLUSIONS

Based on the analyses and results contained in this report, the instream flow recommendations in Table 4 will maintain or improve the existing fishery of the Little Bighorn River. These recommendations apply to a 4.4 mile segment of the river extending from the north boundary of the SW1/4 SW1/4 of Section 20, Township 58 North, Range 89 West to the mouth of Dry Fork Creek at the east boundary of the NW1/4 NW1/4 of Section 12, Township 57 North, Range 90 West.

Table 4. Summary of instream flow recommendations to maintain the existing trout fishery in the Little Bighorn River.

Time Period	Instream Flow Recommendation (cfs)
April 1 to June 30	60 [1]
July 1 to September 30	62 [2]
October 1 to November 15	60 [2]
November 16 to March 31	50

1 - Feasibility determined by availability at the 50% exceedence level during the specified time period

2 - To maintain the existing natural flows up to the specified amount

REFERENCES

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Form S.W. 1
Rev. 5-73

NOTE: Do not fold this form. Use typewriter or print neatly with black ink.

STATE OF WYOMING

OFFICE OF THE STATE ENGINEER

APPLICATION FOR PERMIT TO APPROPRIATE SURFACE WATER

THIS SECTION IS NOT TO BE FILLED IN BY APPLICANT

Filing/Priority Date

THE STATE OF WYOMING, } SS.
STATE ENGINEER'S OFFICE }

This instrument was received and filed for record on the 6th day of March, A.D. 19 89, at 3:50 o'clock P. M.

Frank J Trelease
FRANK J. TRELEASE, for State Engineer

Recorded in Book ______ of Ditch Permits, on Page ______.

Fee Paid $ ______. Map Filed E.

WATER DIVISION NO. 2

DISTRICT NO. 6 Temp. Filing No. 26 5/339

PERMIT NO. ______

NAME OF FACILITY Little Bighorn River - Instream Flow Segment No. 1

1. The name(s) and complete mailing address(es) of the applicant(s) is/are Wyoming Water Development Commission, Herschler Building, Cheyenne, WY 82002

(If more than one applicant, designate one to act as Agent for the others)

2. Name & address of agent to receive correspondence and notices Francis Petera, Wyoming Game and Fish Department, 5400 Bishop Blvd., Cheyenne, WY; Michael Purcell, W.W.D.C. Herschler Building, Cheyenne, WY

3. (a) The use to which the water is to be applied is Instream Flow

(b) If more than one beneficial use of water is applied for, the location and ownership of the point of use must be shown in item 10 of the application and the details of the facilities used to divert and convey the appropriation must be shown on the map in sufficient detail to allow the State Engineer to establish the amount of appropriation. In multiple use applications, stock and domestic purposes are limited to 0.056 cubic feet per second.

4. The source of the proposed appropriation is Little Bighorn River

5. The instream flow segment extends from ~~point of diversion of the proposed works is located~~ the confluence of the Little Bighorn River and ~~feet dis-~~ Dry Fork Creek in the NE¼NW¼ ~~tant from the~~ ~~corner~~ of section 12 T. 57 N., R. 90 W., and downstream ~~is in the~~ to the point of ending on the ~~of Section ______ T. ______ N., R. ______ W.~~ north boundary line of the SW¼SW¼ of Sec. 20, T. 58 N., R. 89 W.

6. Are any of the lands crossed by the proposed facility owned by the State or Federal Government? If so, describe lands and indicate whether State or Federally owned.
The land crossed by this stream segment in Section 20, T. 58 N., R. 89 W. is owned by the State of Wyoming. All other lands crossed by this stream segment are Federally owned lands within the Bighorn National Forest.

7. The carrying capacity of the ditch, canal, pipeline or other facility at the/downstream ~~point of diversion is~~ the reach is (see Remarks) ~~cubic~~ feet per second.

8. The accompanying map is prepared in accordance with the State Engineer's Manual of Regulations and Instructions for filing applications and is hereby declared a part of this application. The State Engineer may require the filing of detailed construction plans.

9. The estimated time required for commencement of work is 30 days, for completion of construction is 30 days, and to complete the application of water to the beneficial uses stated in this application is 30 days.

Permit No. ______

Page No. ______
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10. The land to be irrigated under this permit is described in the following tabulation: (Give irrigable acreage in each 40-acre subdivision. Designate ownership of land, federal, State or private. If private, list names of owners and land owned separately.) If application is for stock, domestic, or for purposes other than irrigation, indicate point of use by 40-acre subdivision and owner.

Town-ship	Range	Sec.	NE¼				NW¼				SW¼				SE¼				TOTALS
			NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	NE¼	NW¼	SW¼	SE¼	
58	89	20											X						
58	89	19																Lot 4	
58	89	30	X	X			X		Lot 2	X		Lot 3							
58	90	25																X	
58	90	36	X		X	X								X		X	X		
57	90	1					X	X		X	X			X					
57	90	12					X												

The length of the stream segment is 4.40 miles.

Location of instream flow control gage is not identified. If one is needed, a gage will be installed near the North boundary of the SW¼SW¼ of Section 20, T. 58 N., R. 89 W.

Number of acres to receive original supply ______

Number of acres to receive supplemental supply ______

Total Number of acres to be irrigated ______

REMARKS

MONTHLY INSTREAM FLOW REQUESTED

MONTH	FLOW (cfs)
October	60
November 1-15	60
Nov. 16 - 30	50
December	50
January	50
February	50
March	50
April	60
May	60
June	60
July	62
August	62
September	62

Based on the results of a study conducted in 1988 by the Wyoming Game and Fish Department (attached), a flow right of 60 cfs is requested from October 1 to November 15 to maintain Hydraulic conditions for existing levels of trout survival and to maintain existing levels of brown trout spawning.

A flow of 50 cfs is requested from November 16 to March 31 to maintain existing levels of brown trout incubation.

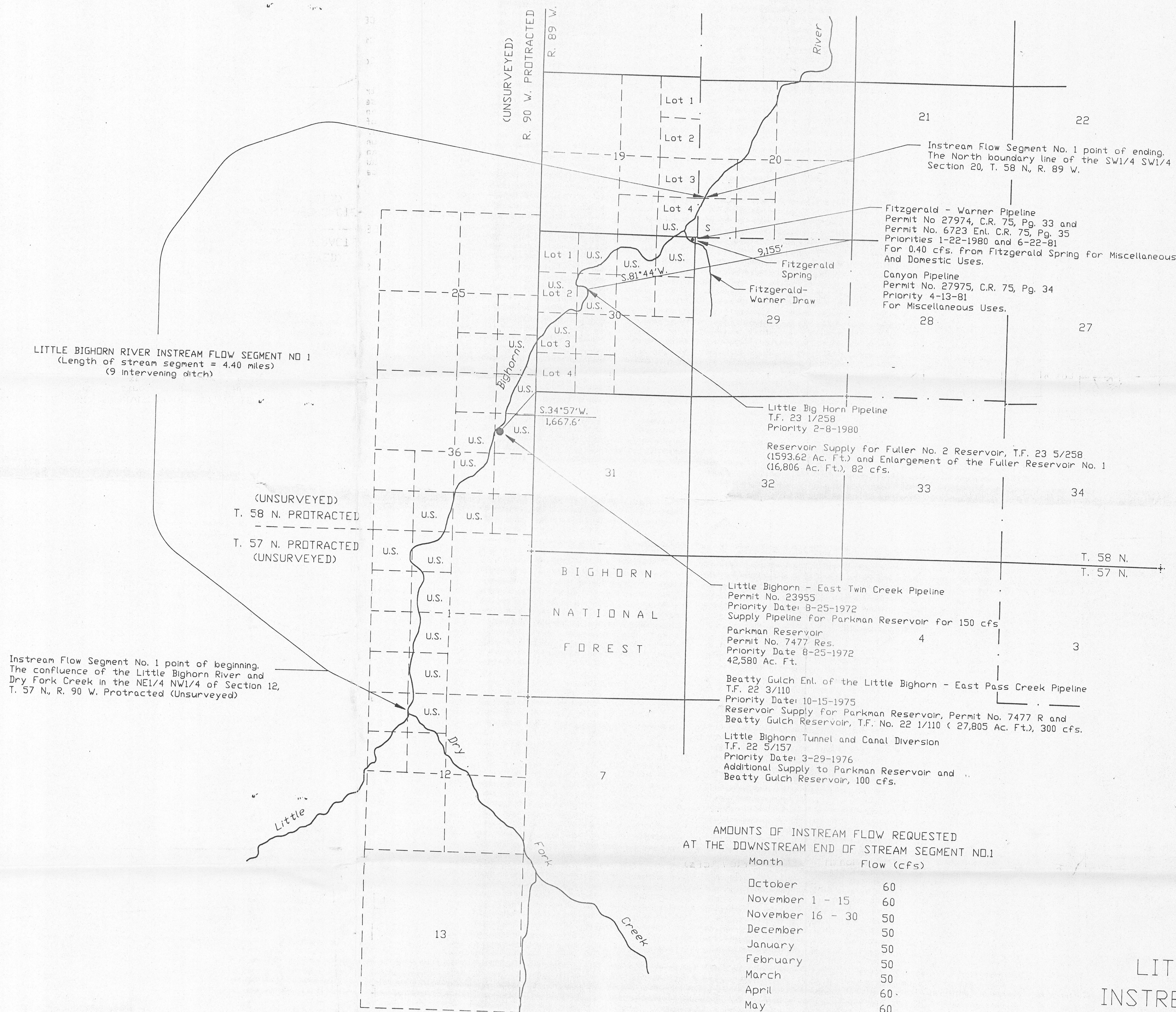
A flow of 60 cfs is requested from April 9 to June 30 to maintain existing levels of rainbow trout spawning and incubation. A flow of 62 cfs is requested from July 1 to September 30 to maintain the existing level of adult trout production.

Intervening ditches - Little Bighorn - East Twin Creek pipeline, Permit No. 23955, Priority Date 8/25/1972, supply pipeline for Parkman Reservoir for 150 cfs.

Under penalties of perjury, I declare that I have examined this application and to the best of my knowledge and belief it is true, correct and complete.

Michael A. Russell
Signature of Applicant or Agent

5/6/92
Date



CERTIFICATE OF ENGINEER

State of Wyoming)
) ss
County of Laramie)

I Jon S. Ogden of Cheyenne, Wyoming do hereby certify that this map was made from U.S. Geological Survey Maps (7.5 min. series) dated 1964; Bull Elk Park, Wyoming; West Pass, Wyoming and from U.S. Department of the Interior General Land Office Plat of T. 58 N., R. 89 W. dated May 12,1903 the Plats of Fractional T. 58 N., R. 89 W. dated May 7, 1903 and April 1, 1913 and the undated Plat of T. 56-58 N., R. 90-93 W. Protracted (Unsurveyed) and that it correctly represents the Little Bighorn River and the land through which it flows to the best of my knowledge and belief.

Jon S. Ogden
11/29/89

LEGEND

S - State land
U.S. - Federal land, Bighorn National Forest

—N—

SCALE: 1" = 2000'

Location Of Instream Flow Control Gage:
1. A specific site has not been identified.
2. If the State Engineer orders a gage to be installed, it will be on State land near the downstream end of the stream segment in Section 20, T58N, R89W.

AMOUNTS OF INSTREAM FLOW REQUESTED
AT THE DOWNSTREAM END OF STREAM SEGMENT NO.1

Month	Flow (cfs)
October	60
November 1 - 15	60
November 16 - 30	50
December	50
January	50
February	50
March	50
April	60
May	60
June	60
July	62
August	62
September	62

MAP
TO ACCOMPANY
APPLICATION FOR
LITTLE BIGHORN RIVER -
INSTREAM FLOW SEGMENT NO. 1

APPLICANT
WYOMING WATER DEVELOPMENT COMMISSION
HERSCHLER BUILDING
CHEYENNE, WYOMING 82002

Approved ____________________

Gorden W. Fassett State Engineer

T.F. No. 26 5/339

Computer Generated, Corrected, and Redrawn 10-24-89