THE YELLOWSTONE RIVER
INSTREAM
RESERVATION

SIXTH ANNUAL REPORT

December 16, 1983 - December 15, 1984

Compiled by:

Larry Peterman
and
Fred Nelson

Fisheries Division
Montana Department of Fish, Wildlife and Parks
1420 East Sixth Avenue
Helena, Montana 59620

January, 1985

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INTRODUCTION

The Order of the Board of Natural Resources and Conservation establishing water reservations for the Yellowstone basin was signed on December 15, 1978. As a result of that Order, the Department of Fish, Wildlife and Parks (MDFWP) was granted an instream reservation for the Yellowstone at Sidney of approximately 5.5 million acre-feet of water with varying amounts granted in upstream areas and tributaries.

The MDFWP applied for instream reservations on many streams and tributaries where little, if any, flow data were available. In granting an instream reservation for those waters, the Board frequently granted a percentile flow rather than a specific amount of water in acre-feet or cfs. In such areas, the department was directed by the Board through condition 116 to develop and submit to the Board within 5 years of December 15, 1978, a plan to convert the minimum flow instream reservation quantities into cubic feet of water per second and acre-feet of water per month.

Condition 117 states that the reservant shall submit to the Board an annual progress report setting forth accomplishments toward completion of such work as outlined in condition 116, a schedule of anticipated progress and other information as may be required. This report is designed to fulfill the requirement of the sixth-year annual progress report.

INSTREAM FLOW QUANTIFICATIONS

The first annual progress report outlined a tentative plan for accomplishing the objectives in condition 116. The tentative plan was then reviewed, commented on and revised. In the second annual report, a finalized plan to convert the minimum-flow instream reservations for those streams having little or no flow data into cubic feet of water per second and acre-feet of water per month using hydrologic modeling techniques was submitted to the Board. This was done pursuant to the Board's order, specifically condition 116(b). The Department of Natural Resources and Conservation (DNRC) concurred in the plan as presented and additionally suggested a provision for verifying the chosen methodology (Riggs' Method) using existing long-term gage stations in the area. The testing and verification of the Riggs' Method were performed by Systems Technology, Inc. and presented verbally to the Board. A write-up of the verification is contained in the third annual report. The findings in general were very good, and the report states that better results than those obtained during the verification can be achieved through a careful study of basin characteristics for all gaged streams in the Upper Yellowstone Basin and the omission of hydrologically different streams.

The finalized plan for quantifying the percentile flows was approved by the Board on June 5, 1981.

Plan and Schedule for Data Collection

The quantification of the granted percentile flows for those streams having insufficient flow records is being completed by the Helena office of the USGS through an extension of a cost-share, cooperative agreement with the MDFWP. The agreement specifies that the necessary field measurements will be completed by the USGS in two years and all data analyses and quantifications completed by the end of the third year.

The application of the Riggs' Method requires that monthly flow measurements be taken for one year on the streams to be analyzed. During the first year of the agreement (phase 1), the needed field data were collected for 22 stream sites within the Yellowstone River drainage upstream from Livingston, Montana. The preliminary instream flow quantifications that were derived by the USGS for these sites were presented in the fifth annual report.

During the second year of the agreement (phase 2), the needed flow data were collected for 19 stream sites in the Shields River drainage and the Yellowstone drainage downstream from Livingston. The preliminary flow quantifications for these sites were completed during this report period and are listed in Appendix A.

The USGS decided during the second year of the agreement to extend streamflow records at all gages used in the regression analyses (Riggs' Method) to a common 1934-82 base period. The purpose of the record extension is to eliminate any bias that might result from using a short-record gage that might not be truly representative of long-term hydrologic conditions.

The method chosen to extend streamflow records is a statistical regression procedure developed by the U.S. Army Corps of Engineers. This method is briefly described in Appendix B. All final quantifications, where possible, will reflect the 1934-82 base beriod.

The preliminary quantifications for the first year's work as presented in the fifth annual report were recalculated by the USGS to incorporate a common 1934-82 base period. These revised preliminary results are presented in Appendix C. The final results for both phases of the project will be documented by the USGS in a formal report. Until then, all quantifications are provisional and subject to revision.

Remaining Quantifications

The quantification of the granted instream flows was originally scheduled to be completed for all Yellowstone tributaries in 1985. However, unforseen budget constraints of the MDFWP prevented the USGS from completing all scheduled tasks during the allotted contract period. The MDFWP is presently renegotiating our contract with the USGS and rescheduling the remaining tasks.

A number of the remaining quantifications will be completed in 1985 and included in the seventh annual Yellowstone report (December, 1985). These are discussed as follows:

A. Instantaneous flow measurements that have been collected in conjunction with other studies by the USGS and the MDFWP are sufficient for use in the Riggs' Method for defining the granted percentile flows for many of the stream reaches having an instream reservation. Short-term USGS gage records for many sites are also suitable for use in the Riggs' Method. The 10 stream reaches believed to have sufficient flow data and scheduled for quantification in 1985 are:

1. Castle Creek
   Mouth - 1,500 ft above Picket Pin Creek

2. East Rosebud Creek
   Custer National Forest boundary-West Rosebud Creek

3. Fishtail Creek
   Confluence of East and West Fishtail creeks-Mouth

4. Picket Pin Creek
   Mouth-Mouth of Swamp Creek

5. West Fork of Stillwater River
   Mouth-Castle Creek

6. West Fork of Stillwater River
   Castle Creek-Sweetgrass/Stillwater County Line

7. West Fork of Stillwater River
   Sweetgrass/Stillwater County Line-Tumble Creek

8. Butcher Creek
   West Butcher Creek-Mouth

9. Willow Creek
   Forest boundary-Cooney Reservoir

10. Red Lodge Creek
    Custer National Forest-Cooney Reservoir

B. At least 10 years of continuous daily flow records have been collected for four gage sites established by the USGS in the 1970s. The quantification of the granted flows will be completed for these sites using this existing record. These sites are:

1. Rosebud Creek (Cottonwood Creek-Yellowstone River) #06296003

2. Hanging Woman Creek (Mouth of East Fork-Tongue River) #06307600

3. Otter Creek (Mouth of Bear Creek-Tongue River) #06307740

4. Pumpkin Creek (Mouth of Deer Creek-Tongue River) #06308400

For three of the sites (Hanging Woman, Otter, and Pumpkin creeks), the Board granted the historic minimum monthly flows as the instream reservation rather than precentile flows. Since a reliable method for synthesizing the flows prior to the establishment of these three gages has not been established, the MDFWP requests that the historic period be limited to the period the gages were operated. These records include a severe drought year (1977).

C. The six flow quantifications listed on pages 3 and 4 of the fifth annual Yellowstone report will be recalculated to incompass the 1934-82 base flow period. These sites are:

1. Bluewater Creek (Mouth-Headwaters) #6-2078

2. Brackett Creek (Mouth-Sheep Creek) #6-1940

3. Rock Creek (Mouth-Custer National Forest) #6-2095

4. Sweet Grass Creek (Mouth-Forest Service boundary) #6-2005

5. Clarks Fork Yellowstone River #6-2075 (Near Belfry)

6. Clarks Fork Yellowstone River #6-2085 (At Edgar)

The other remaining quantifications require the collection of monthly flow measurements for use in the Riggs' Method. Due to present budget constraints, the MDFWP is unable to provide sufficient funding to the USGS to complete these streams. To lower costs, the MDFWP is proposing to the USGS that our personnel collect the needed monthly flow data after the measuring sites are established by the USGS. The data analyses and quantifications would be performed by the USGS. The field measurements would not be completed until the winter of 1986 at the earliest, with quantifications tentatively scheduled to be presented in the eighth annual report. These remaining sites are:

A. Yellowstone Spring Creeks

1. Armstrong Spring Creek (Mouth-origin)
2. Nelson Spring Creek (Mouth-origin)
3. McDonald Spring Creek (Mouth-northern boundary of Sec. 32)
4. Emigrant Spring Creek (Mouth-origin)

B. Stillwater River Tributaries

1. West Rosebud Creek
   Custer National Forest boundary-Fiddler Creek
2. West Rosebud Creek
   Fiddler Creek-Mouth
3. Butcher Creek
   Headwaters-West Butcher Creek
4. East Fishtail Creek
   West Fishtail Creek-its East Fork
5. Little Rocky Creek
   Mouth-Forest Service Road #1414
6. West Fishtail Creek
   East Fishtail Creek-Richmond/Kennedy Ditch

C. Clarks Fork Tributaries

1. Clear Creek
   Headwaters-Mouth
2. Dry Creek
   Headwaters-Mouth
3. Sage Creek
   Headwaters-Crow Reservation

WATER AVAILABILITY ABOVE BILLINGS

One question remained concerning the water availability situation above Billings. It has been pointed out that, while MDFWP agreed to allow unrestricted depletions from conservation district reservations to occur from May 1 through July 10, this may not be legally binding at some point in the future. To alleviate this concern, MDFWP offered to enter into a legally binding contract with the upper river conservation districts, whereby the MDFWP would stipulate that the instream reservation will not interfere with the utilization of the conservation district reservation for the period of May 1 through July 10, under any circumstances. These discussions are continuing.

APPENDIX A

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
Federal Building, Room 428
301 South Park Avenue, Drawer 10076
Helena, Montana 59626-0076

January 25, 1985

Mr. Fred Nelson
Montana Department of Fish,
Wildlife, and Parks
8695 Huffine Lane
Bozeman, Montana 59715

Dear Fred:

Enclosed is the revised table of percentile discharges for the streams in the second phase of our upper Yellowstone River study. The percentiles were incorrect in the original table for all streams. The only change in methodology required as a result of the change in percentiles was that the discharges for Cottonwood Creek (both sides) as well as for Rock Creek were based on a two-season mean discharge calculation. All other sites required three seasonal mean discharges.

Because the two Stillwater drainage sites are really not part of this past year's effort, we will re-do those discharge calculations at a later date. Please give me a call if you have any questions.

Sincerely,

Charles Parrett
Hydrologist

Enclosure

cc: Larry Peterman

Site Number	Stream	Mean annual discharge cubic feet per second	Percentile discharge for month indicated, in cubic feet per second											
			JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
21	Smith Creek	20.2	2.61	2.61	3.31	23.9	85.1	75.5	13.6	5.14	4.67	4.17	3.49	2.99
22	Flathead Cr. ab. Cache Cr.	13.1	4.20	4.20	5.24	12.9	43.8	33.1	13.4	5.07	4.61	6.74	5.69	4.86
23	Flathead Cr. ab. Muddy Cr.	37.3	13.4	13.4	16.1	31.1	112	107	35.2	13.3	11.4	21.7	18.8	15.8
24	Flathead Cr. at mouth	42.5	18.8	18.8	22.4	33.6	123	119	25.7	9.71	8.51	30.6	26.7	22.4
25	Cottonwood Cr. ab. Slippery Cr	27.6	5.44	5.44	5.69	15.1	74.8	105	41.4	13.7	12.4	9.40	8.18	6.43
26	Cottonwood Cr. blw. Little Cotton.	29.3	7.98	7.98	8.34	20.9	79.8	105	33.3	11.0	10.1	13.8	11.9	9.43
27	North Fork Brackett Cr.	[1] 7.74	[1] 1.60	[1] 1.60	[1] 2.18	[1] 12.6	[1] 25.9	[1] 16.1	[1] 10.6	[1] 3.96	[1] 4.55	[1] 2.49	[1] 1.97	[1] 1.57
28	Middle Fork Brackett Cr.	[1] 5.74	[1] 0.99	[1] 0.99	[1] 1.36	[1] 11.1	[1] 22.6	[1] 13.7	[1] 4.33	[1] 1.62	[1] 1.96	[1] 1.53	[1] 1.19	[1] 0.96
29	So. Fork Brackett Cr.	[1] 4.61	[1] 0.75	[1] 0.75	[1] 1.04	[1] 8.79	[1] 17.5	[1] 9.99	[1] 5.34	[1] 2.00	[1] 2.38	[1] 1.16	[1] 0.89	[1] 0.72
30	Brackett Cr. ab. Weasel	[1] 18.6	[1] 3.20	[1] 3.20	[1] 4.26	[1] 29.2	[1] 63.2	[1] 49.0	[1] 21.3	[1] 7.98	[1] 8.79	[1] 5.01	[1] 4.00	[1] 3.17
31	Brackett Cr. ab. Fox Cr.	[1] 27.9	[1] 5.77	[1] 5.77	[1] 7.55	[1] 40.4	[1] 89.6	[1] 75.6	[1] 29.6	[1] 11.1	[1] 11.9	[1] 9.08	[1] 7.31	[1] 5.79
32	Brackett Cr. at gage	[2] 29.2	[2] 7.00	[2] 7.00	[2] 9.00	[2] 42.0	[2] 93.0	[2] 79.0	[2] 27.0	[2] 10.0	[2] 11.0	[2] 11.0	[2] 9.00	[2] 7.00
33	Rock Cr. bel. Little Rock Cr.	30.8	5.77	5.77	6.03	15.9	68.0	132	48.6	16.2	14.5	9.96	8.66	6.81
34	Mission Cr. ab. Little Mission	20.7	4.80	4.80	5.97	17.3	78.6	62.7	21.8	7.54	6.40	7.71	6.54	5.56
35	Little Mission Cr	8.68	2.00	2.00	2.55	9.66	38.1	31.9	5.60	1.72	1.65	3.19	2.65	2.28
36	Mission Cr bel. Little Mission	29.2	6.79	6.79	8.36	24.6	122	94.6	27.4	9.68	8.05	11.0	9.35	7.93
37	Upper Deer Cr	28.1	3.06	3.06	3.08	13.3	64.6	130	7.17	2.25	2.11	4.23	4.85	3.57
38	Lower Deer Cr	24.7	3.09	3.09	3.12	10.4	51.9	101	13.7	4.55	4.03	4.28	4.90	3.61
39	Bridger Cr.	10.3	1.48	1.48	1.52	4.77	25.3	43.7	3.44	1.01	1.01	1.98	2.46	1.75

[1] Flows adjusted using record available at site 32

[2] Flows from record (extended to 1934-82 base period)

APPENDIX B

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
Federal Building, Room 428
301 South Park Avenue, Drawer 10076
Helena, Montana 59626-0076

January 8, 1985

Mr. Fred Nelson
Montana Department of Fish,
Wildlife, and Parks
8695 Huffine Lane
Bozeman, Montana 59715

Dear Fred:

Enclosed are tables showing the estimated mean annual discharge and 20th and 50th monthly percentile discharges for 21 measurement sites in the Yellowstone River area as required under the second phase of our cooperative program. Two of the sites (site 40, W.F. Stillwater River above Nye Creek and site 41, Fishtail Creek near Dean) are miscellaneous measurement sites used in previous U.S. Geological Survey projects. The remaining sites were measured specifically for the Department of Fish, Wildlife, and Parks during the 1984 water year. As discussed previously, the results for both phases of the project will be documented later in a formal USGS report. Until then, the tabular data must be considered provisional.

For this second phase of the project, the Riggs' correlation procedure was used to estimate a monthly mean discharge at each measurement site for the 1984 water year (flow measurements were available for the 1983 water year for sites 40 and 41; consequently the monthly mean estimates made for these sites is for water year 1983). The estimated monthly mean estimates were then summed to provide seasonal mean flow estimates for the year the measurements were made. At 3 sites (sites 33, 40, and 41) a seasonal mean for the non-irrigation months (October through May) and a seasonal mean for the irrigation months (June through September) were computed. For the remaining sites, it was determined that 3 seasonal mean flows rather than 2 would provide better estimates of monthly percentile discharge. Accordingly, the monthly mean estimates for these 18 sites were summed and averaged for the months October through March to provide a low-flow seasonal estimate. Similarly, the monthly mean estimates for April, May, and June were averaged to produce a high-flow seasonal estimate, and the monthly mean estimates for July, August, and September were averaged to produce an irrigation-season estimate. The various seasonal estimates for the measurement year (either 1983 or 1984) were converted to long-term seasonal estimates by using the following multipliers:

Non-irrigation season mean flow multiplier for site 33 = 0.91

Irrigation season mean flow mulitiplier for site 33 = 0.92

Non-irrigation season mean flow multiplier for sites 40 and 41 = 0.96

Irrigation season mean flow multiplier for sites 40 and 41 = 0.91

Low-flow season multiplier for all other sites = 0.77

High flow season multiplier for all other sites = 1.04

Irrigation season multiplier for all other sites = 0.97

The multipliers for site 33 were based on the average ratio of long-term seasonal mean discharge to 1984 seasonal mean discharge for the following four currently active stations: Big Creek near Emigrant (06191800), Yellowstone River at Corwin Springs (06191500), Yellowstone River at Livingston (06192500), and Boulder River at Big Timber (06200000). The multipliers for sites 40 and 41 were based on the ratio of long-term seasonal mean discharges to 1983 seasonal mean discharge for the Stillwater River near Absarokee (06205000). The seasonal multipliers for all other sites were based on the average ratio of long-term seasonal mean discharge to 1984 seasonal mean discharge for the same four current sites used to develop multipliers for site 33.

Regression equations relating long-term seasonal mean discharges to long-term monthly percentile discharges were then used to compute the monthly percentile discharges at the measurement sites. The regression equations were developed from record at ten gages in the Yellowstone River basin (06191500, 06191800, 06192500, 06193000, 06194000, 06197500, 06200500, 06294500, 06205000, and 06207500). For the Brackett Creek sites (sites 27-32), the monthly percentile estimates made using the 1984 measurements were adjusted in the following manner: For site 32, the actual gage record (adjusted to the 1934-82 base period) was used to determine the monthly percentile discharges. The percentage difference between the monthly percentile discharge computed from the record and the monthly percentile discharge computed from the appropriate regression equation was determined for each month. These percentage differences were then applied to the monthly percentile discharges computed from the regression equations for each of the other Brackett Creek measurement sites. Thus, for example, the monthly percentile discharge estimate for Brackett Creek (site 32) for October (using the regression equation) is 18.7 cfs. The actual value from the record is 13.0 cfs, and the percentage difference from the estimated value is -30.5. The October monthly percentile discharge thus computed from the regression equation for each of the other Brackett Creek sites was reduced by 30.5 percent to provide the final estimate reported in the table.

The difference between the regression estimates and the values from the record for Brackett Creek also provide some indication of the accuracy of the regression estimates for the other ungaged sites. The monthly differences for the Brackett Creek gage site ranged from a -28 percent for February (9.0 ft^3/s from the record, 11.5 ft^3/s for the regression estimate) to +85 percent for

June (79.0 ft^3/s from the record, 146 ft^3/s for the regression estimate). The average monthly percentile difference was +10 percent. The expected errors of regression estimates for the other measurements sites are probably larger, however, because the Brackett Creek gage record was used in the development of the regression equations.

As was the case with phase one of the project, a statistical correlation procedure was used to extend streamflow records at all gages used in the regression analysis to a common 1934-82 base period. The purpose of the record extension was to eliminate any bias that might result from using a short-record gage that might not be truly representative of long-term hydrologic conditions.

The method chosen to extend streamflow records was a statistical regression procedure developed by the U.S. Army Corps of Engineers. The regression procedure (HEC-4) uses monthly flow data from several streamflow gages in an area to estimate missing monthly flow values for each gage and for each year of record. The model also preserves the variance of the unadjusted short-term record by adding a random component to the estimated values. Starting with the first year of data, missing monthly streamflows are estimated at all stations for each month in sequence. Thus, whenever a missing flow is being estimated, there always exists a valid value for all stations already examined that month and for all remaining stations in either the current or preceding month. The equation for estimating missing flows has the following general form:

$$Q_{i,j} = B_1 Q_{i,1} + \ldots + B_{j-1} Q_{i,j-1} + B_j Q_{i-1,j} + B_{j+1} Q_{i,j+1} + \ldots + B_n Q_{i,n} + \sqrt{1 - R_{i,j}^2} \cdot (Z_{i,j})$$

where:

- $Q_{i,j}$ is the monthly flow logarithm, expressed as a standard normal deviate, for month i and station j,
- B_j is the beta coefficient for station j computed from a correlation matrix at all n stations,
- $R_{i,j}$ is the multiple correlation coefficient for month i, and station j, and
- $Z_{i,j}$ is a random number generated from a standard normal population.

If any station being used to estimate a missing monthly flow is also missing a flow value for that particular month (i), then the flow for the preceding month (i-1) is used in the right side of equation 1. If, for example, the monthly flow at station 1 and month i were missing, the first term on the right side of equation 1 would be $B_1 Q_{i-1,1}$.

The HEC-4 program and its statistical properties are more completely described in the publication from the Corps of Engineers Hydrologic Engineering Center in Davis, California entitled HEC-4 Monthly Streamflow Simulation (1971).

To compute the various monthly percentile flows from the extended monthly streamflow record produced by HEC-4, a routine was added to the HEC-4 program presently being used in the Helena U.S. Geological Survey office. This routine uses the (M/N+1) plotting position formula to ascribe a plotting position or exceedance probability to each monthly discharge when they are arrayed from the largest to smallest. For example, if 9 years of monthly flow record are available and if 200 ft^3/s is the largest May monthly discharge that occurred in 9 years, then the monthly percentile for a May discharge of 200 ft^3/s is (1/9+1) 0.10 or 10 percent. Similarly, if the second largest May discharge is 140 ft^3/s, then 140 ft^3/s has a percentile of (2/9+1) 0.20 or 20 percent. This procedure is slightly different from the procedure used in the formal U.S. Geological Survey program for computing percentile discharges. Thus, the results obtained from the HEC-4 program will be slightly different from results you may previously have obtained, even when the record lengths are identical. Also, any results you previously obtained are based on the actual record only and not the extended, 1934-82 record. Accordingly, we are also enclosing percentile discharges as determined by the HEC-4 routine for the 1934-82 period for the following four gages: Boulder River at Big Timber (06200000), Clarks Fork near Belfry (06207500), Clarks Fork at Edgar (06208500), and Rock Creek (06209500). I believe that you now have HEC-4 results for all gages in the upper Yellowstone area; if not, give me a call.

Also, give me a call if you have any questions about the results or the procedure we used. I realize that the use of three seasonal flows for this second phase complicates matters a good deal, but I believe that the final estimates were substantially improved as a result. Our final results for this second phase, however, I would judge are not as reliable as for the first phase. The streams in the Shields River drainage behave more erratically than those in the Yellowstone River drainage above Livingston.

Sincerely,

Charles Parrett

Charles Parrett
Hydrologist

Enclosures

cc: Larry Peterman, Helena, MT

APPENDIX C

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
301 South Park Avenue, Room 428
Federal Building, Drawer 10076
Helena, Montana 59626-0076

May 10, 1984

Fred Nelson
Montana Department of Fish,
Wildlife and Parks
8695 Huffine Lane
Bozeman, Montana 59715

Dear Fred:

Enclosed are tables showing the estimated mean annual discharge and 20th and 50th monthly percentile discharges for the 19 measurement sites in the upper Yellowstone River area. As we discussed in our recent telephone conversation, we will be documenting the results in a formal U.S. Geological Survey report later on. The tabular data are thus provisional pending our report approval.

The percentile flow estimates were derived in a slightly different manner from the procedure used by Systems Technology, Inc. First, a monthly streamflow correlation program developed by the Corps of Engineers (HEC4) was used to develop a long-term record base for Big Creek near Emigrant and for Mill Creek near Pray. The record base used was the 49 year period from 1934-82. Thus, all estimates made at the ungaged sites for long-term mean annual discharge and for monthly percentile discharge are based on the 1934-82 period.

The Riggs' correlation procedure previously documented was used to estimate a monthly mean discharge at each measurement site for the November, 1982-October, 1983 measurement year. Big Creek near Emigrant or the Yellowstone River at Corwin Springs was used as the correlating gage site in each case. The estimated monthly mean discharges for 1982-83 were then summed to provide estimates for the non-irrigation season (October through May), the irrigation season (June-September) and for the year. The estimates for 1982-83 were converted to long-term (1934-82) estimates by using the following multipliers:

Non-irrigation season mean flow multiplier = 1.13
Irrigation season mean flow multiplier = 1.02
Mean annual flow multiplier = 1.06

In each case, the multipliers are the average of the ratios of the long-term values to the 1982-83 values for Big Creek near Emigrant and for the Yellowstone River at Corwin Springs.

The percentile discharges for each month were determined from regression equations relating the 20th or 50th percentile discharge to either the non-irrigation season discharge (October through May) or to the irrigation season discharge (June through September). The 12 regression equations were derived from gaged data at 9 sites in or near the upper Yellowstone area. The HEC4 program was used on all gages to develop a common 1934-82 record. The coefficients of determination (r^2) for the regression equations ranged from 0.91 to 0.99.

Data from the old Mill Creek gage site was used to check the regression equation estimates for the non-irrigation season. The estimates from the equations varied from the percentile discharges determined from the record by an average of +3.1 percent. The month of May had the largest difference between the estimated and recorded percentile discharges (268 ft^3/s versus 388 ft^3/s; -30.9 percent). Conversely, the month of November showed almost no difference between estimated and recorded values (57 ft^3/s versus 58 ft^3/s; -1.7 percent). We feel that the estimated percentile discharges for the other measurement sites have a comparable accuracy.

Also enclosed for your use are monthly flow-duration tables (monthly percentile discharges) for various streams in the Yellowstone area based on the 1934-82 base period. As we discussed, we now have the capability of determining the monthly flow-duration values for any record length greater than 9 years. Using the HEC4 correlation option, we can thus effectively develop a flow-duration table for any specified base period.

Please give us a call if you have any questions about the data or the methodology.

Sincerely,

Chuck Parrett

Chuck Parrett

cc: Larry Peterman, Dept. of Fish, Wildlife, and Parks, Helena

United States Department of the Interior

GEOLOGICAL SURVEY
Water Resources Division
301 South Park Avenue, Room 428
Federal Building, Drawer 10076
Helena, Montana 59626-0076

May 31, 1984

Fred Nelson
Montana Dept. of Fish, Wildlife,
and Parks
8695 Huffine Lane
Bozeman, Montana 59715

Dear Fred:

In response to your recent call, I am sending a computer sheet showing the percentile flows for Bear Creek below North Fork Bear Creek and for Mol Heron Creek below Cinnabar Creek.

Give me a call if you have any questions.

Sincerely,

Chuck Parrett

Enclosure

```
OK, BASICV PCT


OK, BASICV PCT
INPUT NO OF STATIONS
!2
INPUT STREAM NAME
!BEAR CR BELOW NF BEAR CR
INPUT MEAN DISCHARGE FOR NON-IRRIGATION SEASON
!24.6
INPUT MEAN DISCHARGE FOR IRRIGATION SEASON
!129

************************************************************

*********  PERCENTILE DISCHARGES *****************

 ** BEAR CR BELOW NF BEAR CR **    Q (NON-IRRIG) = 24.6  Q (IRRIG) = 129

JAN                     Q = 10.1
FEB                     Q = 9.63
MAR                     Q = 10.8
APR                     Q = 32.3
MAY                     Q = 91.1
JUN                     Q = 290
JUL                     Q = 120
AUG                     Q = 41.2
SEP                     Q = 34.5
OCT                     Q = 18.2
NOV                     Q = 16.5
DEC                     Q = 12.5

**********************************************************
INPUT STREAM NAME
!MOL HERON CR BELOW CINNABAR CR
INPUT MEAN DISCHARGE FOR NON-IRRIGATION SEASON
!29.4
INPUT MEAN DISCHARGE FOR IRRIGATION SEASON
!54.8

************************************************************

*********  PERCENTILE DISCHARGES *****************

 ** MOL HERON CR BELOW CINNABAR CR **    Q (NON-IRRIG) = 29.4  Q (IRRIG) = 54.

JAN                     Q = 12.4
FEB                     Q = 11.8
MAR                     Q = 13.2
APR                     Q = 38.2
MAY                     Q = 108
JUN                     Q = 129
JUL                     Q = 47.1
AUG                     Q = 15.7
SEP                     Q = 14.1
OCT                     Q = 22.2
NOV                     Q = 20
DEC                     Q = 15.1

************************************ **********************
OK, COMO END
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Site No.	Stream	Mean annual discharge, cubic ft per second	20th Percentile discharge for month indicated, in cubic feet per second											
			JAN	FEB	MAR	APR	MAY [1]	JUN [1]	JUL [1]	AUG [1]	SEP [1]	OCT	NOV	DEC
1	Bear Cr. above N. Fork	37.2	5.68	5.35	6.15	19.9	56.2	186	71.9	24.3	21.1	10.3	9.48	7.11
2	Mol Heron Creek (Ab Cinnabar Cr)	24.4	6.91	6.53	7.46	23.4	66.2	92.7	32.4	10.6	9.78	12.5	11.4	8.60
3	Cinnabar Cr. ab. Cottonwood	10.7	3.35	3.13	3.67	12.8	36.1	35.7	10.8	3.41	3.41	6.09	5.70	4.26
4	Cinnabar Cr. at mouth	12.7	4.29	4.21	4.88	16.3	46.1	38.8	11.9	3.76	3.73	8.13	7.54	5.65
5	Cedar Creek	9.16	3.02	2.81	3.30	11.7	33.0	28.7	8.43	2.63	2.68	5.48	5.15	3.84
6	Tom Miner Cr. ab Canyon	63.0	22.0	21.3	23.3	62.0	175	211	83.2	26.3	24.3	39.4	35.0	26.6
7	Tom Miner Cr. at mouth	57.2	20.7	19.9	21.9	58.8	166	188	72.7	24.6	21.3	37.0	33.0	25.0
8	Rock Creek	23.3	436	4.09	4.74	15.9	45.0	109	39.1	12.9	11.8	7.90	7.34	5.50
9	Sixmile Creek	34.0	6.60	6.23	7.13	22.6	63.7	157	59.1	19.8	17.5	11.9	10.9	8.23
10	Fridley Cr. ab. Miller Cr.	19.8	6.12	5.77	6.62	21.2	59.8	69.6	23.3	7.55	7.13	11.1	10.2	7.64
11	Fridley Cr. at mouth	7.02	1.58	1.46	1.76	6.81	19.2	29.7	8.76	2.74	2.78	2.90	2.77	2.05
12	Eightmile Creek	24.9	10.5	9.99	11.2	33.3	93.9	63.2	20.8	6.72	6.40	18.9	17.1	12.9
13	Mill Cr. ab. diversions	160	33.0 [2]	34.0 [2]	33.0 [2]	80.0 [2]	388 [2]	75.7 [2]	323	115	89.7	51.0 [2]	58.0 [2]	47.0 [2]

[1] 50th percentile discharge during irrigation season
[2] Determined from record

Site No.	Stream	Mean annual discharge, cubic ft per second	20th Percentile discharge for month indicated, in cubic feet per second											
			JAN	FEB	MAR	APR	MAY [1]	JUN [1]	JUL [1]	AUG [1]	SEP [1]	OCT	NOV	DEC
14	Trail Creek	20.7	7.93	7.52	8.54	263	74.3	59.0	19.3	6.20	5.93	14.3	13.1	9.84
15	Suce Creek	6.36	0.83	0.76	0.93	3.96	11.2	34.5	10.4	3.27	3.28	1.53	1.48	1.09
16	Coke Cr Billman Cr. ab. Miner Cr.	11.2	5.25	4.94	5.70	18.6	52.6	21.6	6.10	1.88	1.96	9.50	8.78	6.59
17	Coke Cr. Miner Cr.	8.32	4.02	3.77	4.38	14.9	42.0	13.2	3.46	1.05	1.14	7.30	6.79	5.08
18	Billman Cr. at mouth	18.1	9.66	9.18	10.4	31.0	87.7	27.8	8.11	2.53	2.58	17.4	15.8	11.9
19	Fleshman Cr. at mouth	5.47	2.72	2.53	2.99	10.7	30.3	6.57	1.55	0.46	0.52	4.95	4.66	3.48

[1] 50th percentile discharge during irrigation season