APPENDIX D

WYOMING WATER DEVELOPMENT COMMISSION BASIN PLAN TECHNICAL MEMORANDA

APPENDIX D-2

SURFACE WATER HYDROLOGY: NORTHEAST WYOMING BASINS PLAN

Subject: **Northeast Wyoming River Basins Plan**
Surface Water Hydrology
Tasks 3A and 3B

Date: February 2002

Prepared by: HKM Engineering Inc.

INTRODUCTION

Water availability models are to be developed to represent dry year, normal year, and wet year hydrologic conditions throughout the Northeast Wyoming River Basins planning area. Several key inputs are necessary to model the water availability including the current irrigated land base, crop water requirements, municipal and industrial surface water demands, and regulation by reservoir storage facilities. This information was developed through the Task 2 work effort. Schematic representations of the water availability models have been developed identifying the appropriate location of model nodes in relation to the various surface water demands, return flows, and storage regulation. Model nodes are located, to the extent possible, at historic streamflow gaging stations in order to take advantage of the historic records of streamflow at these locations. The Northeast Wyoming River Basins, however, are characterized by a scarcity of historic streamflow records. It is therefore necessary to locate model nodes at many locations with no record of streamflow, to appropriately simulate water use in the various drainages. This memorandum summarizes the methodology used to collect the historic records of streamflow, establish a study period for modeling, and to extend or fill-in the streamflow data where records are unavailable. The methodology used to estimate natural (virgin) streamflow at ungaged model nodes is also discussed in this memorandum.

HISTORIC STREAMFLOW RECORDS

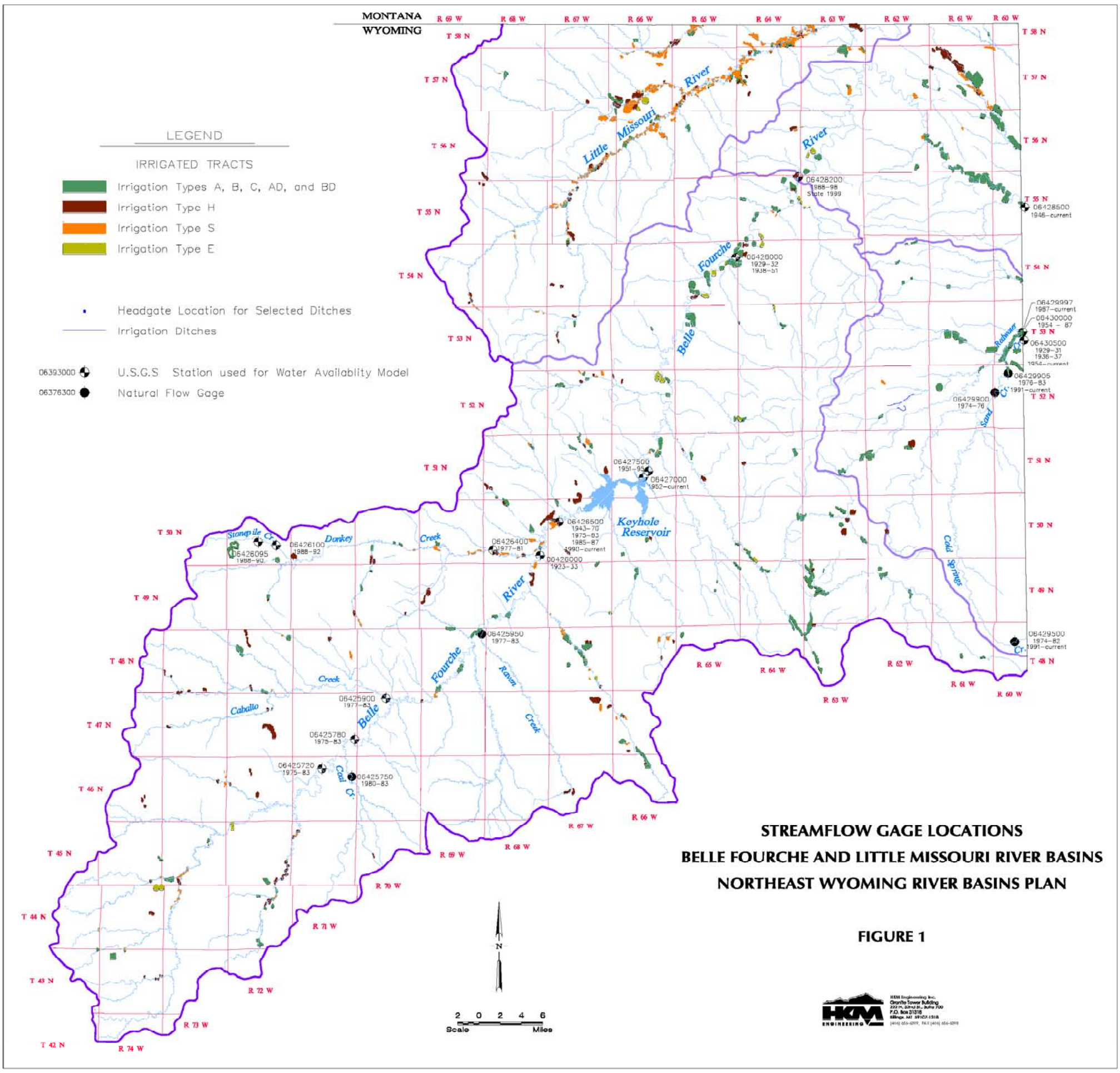
HKM inventoried the available records of streamflow in the Northeast Wyoming River Basins. Data from the following four sources were used for this study:

1. Wyoming USGS digital database in Cheyenne
2. USGS Water Resources Data Books for Wyoming
3. Records from State Engineers Office Hydrographers Annual Reports as compiled by HKM
4. Water Resources Data System (WRDS) database

The order of priority for use of data available from multiple sources was as numbered above.

The location of the various streamflow gaging stations are plotted in relation to the significant storage reservoirs and the irrigated lands mapped by HKM (Figures 1 and 2). The streamflow gages that are relatively free from the influence of depletions or storage regulations are characterized as natural flow stations. Where reasonably possible, those gages that are impacted by upstream depletions were adjusted to remove these effects. The list of streamflow gages inventoried for this study is provided in Table 1. Figure 3 illustrates the period of record for all of the streamflow stations available in the basins.

As shown in Figure 3, prior to 1970, there were only 13 streamflow gages in operation in the Northeast Wyoming River Basins. Beginning in the 1970s and 1980s, with the installation of an additional 18 streamflow gages, records for a total of 31 streamflow stations became available.

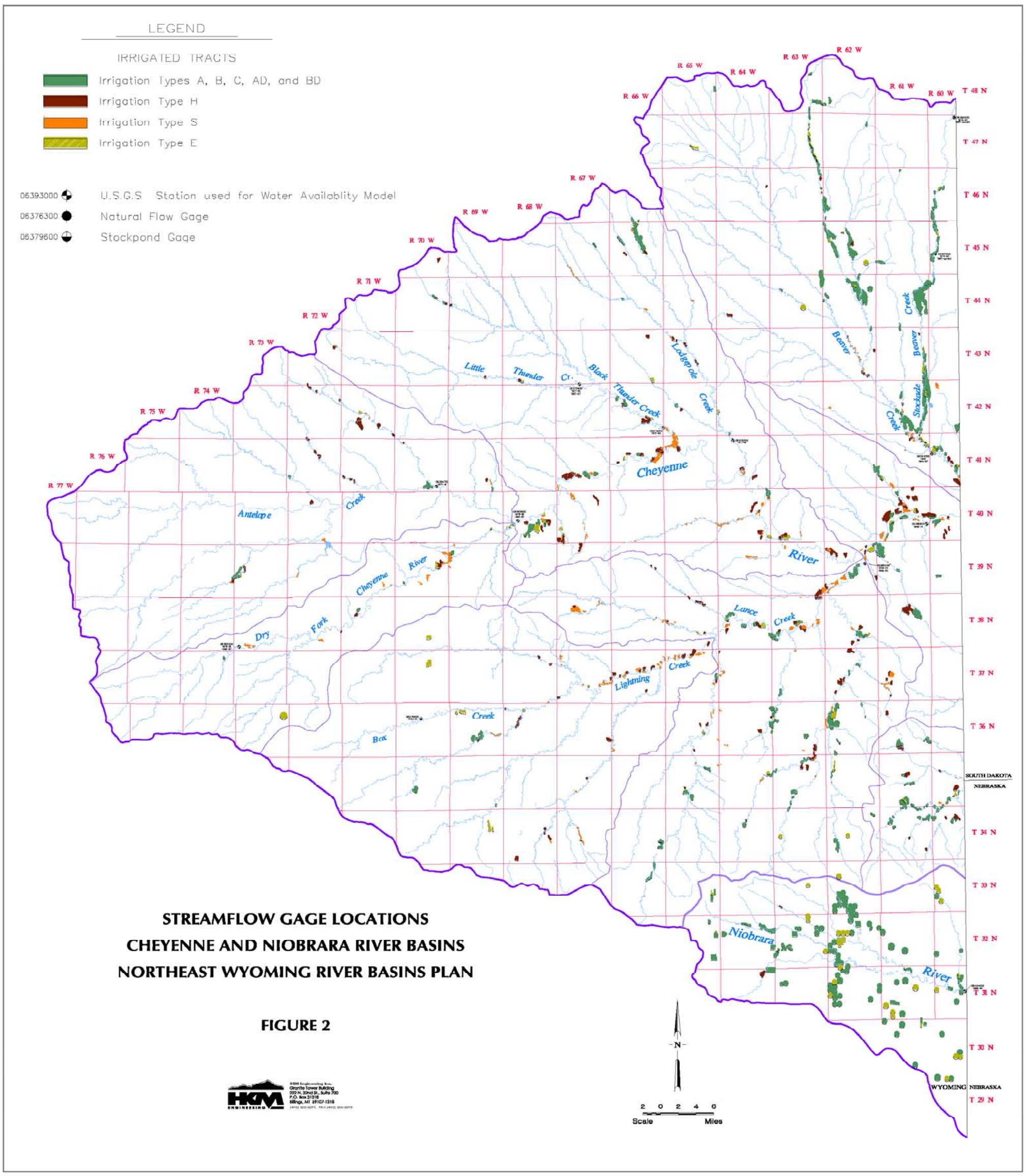


STREAMFLOW GAGE LOCATIONS

BELLE FOURCHE AND LITTLE MISSOURI RIVER BASINS

NORTHEAST WYOMING RIVER BASINS PLAN

FIGURE 1


LEGEND
IRRIGATED TRACTS
Irrigation Types A, B, C, AD, and BD
Irrigation Type H
Irrigation Type S
Irrigation Type E
06393000 U.S.G.S Station used for Water Availablity Model
06376300 Natural Flow Gage
06379600 Stockpond Gage
R 77 W
R 76 W
R 75 W
R 74 W
R 73 W
R 72 W
R 71 W
R 70 W
R 69 W
R 68 W
R 67 W
R 66 W
R 65 W
R 64 W
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T 48 N
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T 46 N
T 45 N
T 44 N
T 43 N
T 42 N
T 41 N
T 40 N
T 39 N
T 38 N
T 37 N
T 36 N
SOUTH DAKOTA
NEBRASKA
T 34 N
T 33 N
T 32 N
T 31 N
T 30 N
WYOMING
NEBRASKA
T 29 N
Little Thunder Cr.
Black Thunder Creek
Lodgepole Creek
Beaver Creek
Stockade Beaver Creek
Cheyenne River
Antelope Creek
Dry Fork Cheyenne River
Lance Creek
Lightning Creek
Box Creek
Niobrara River
N
2 0 2 4 6
Scale Miles
STREAMFLOW GAGE LOCATIONS
CHEYENNE AND NIOBRARA RIVER BASINS
NORTHEAST WYOMING RIVER BASINS PLAN
FIGURE 2
HKM ENGINEERING

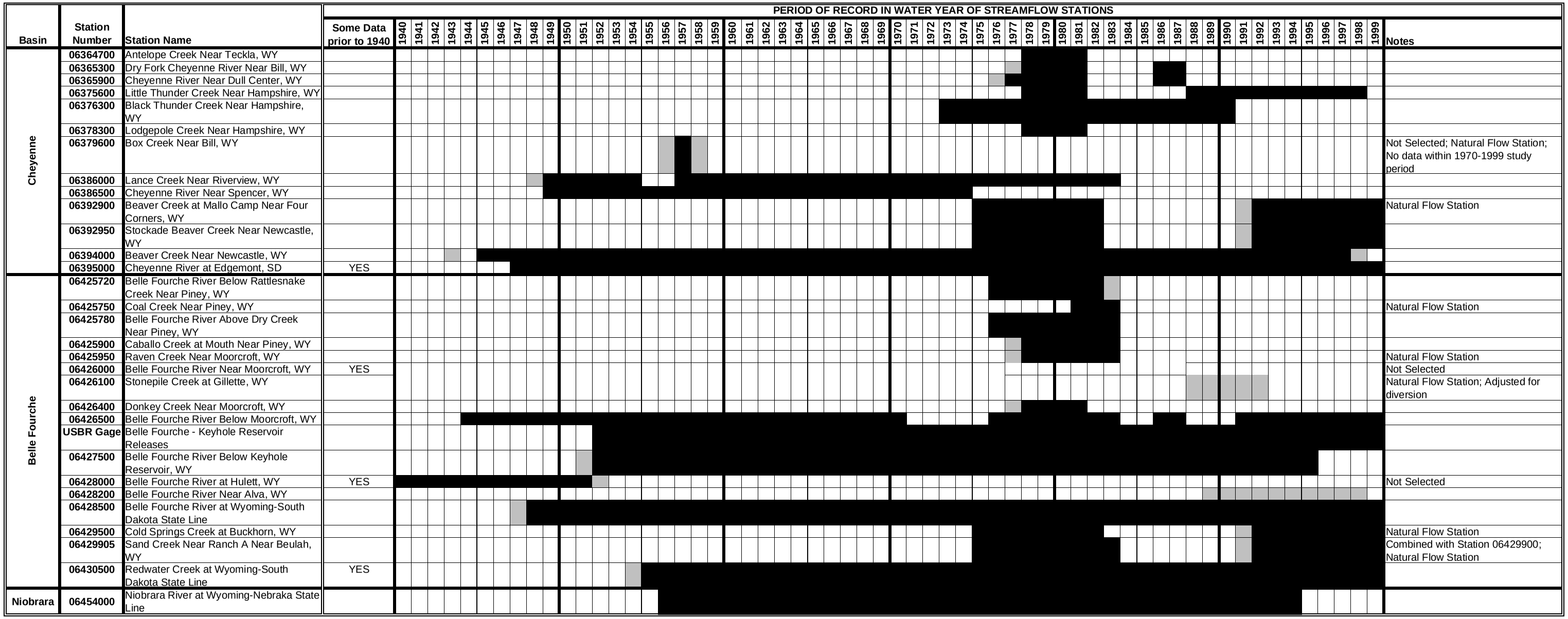
TABLE 1
STREAMFLOW STATIONS IN THE NORTHEAST WYOMING RIVER BASINS

Basin	Station Number	Station Name	Natural Flow	Period of Record in Water Years **	Note
Cheyenne	06364700	Antelope Creek Near Teckla, WY	NO	1978-1981	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO	1977-1981, 1986-1987	
	06365900	Cheyenne River Near Dull Center, WY	NO	1976-1981, 1986-1987	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	1978-1981, 1988-1998	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	1973-1990	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	1978-1981	
	06379600	Box Creek Near Bill, WY	YES	1956-1958	
	06386000	Lance Creek Near Riverview, WY	NO	1948-1954, 1956-1983	
	06386500	Cheyenne River Near Spencer, WY	NO	1949-1974	
	06392900	Beaver Creek at Mallo Camp, Near Four Corners, WY	YES	1975-1982, 1991-current	
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO	1975-1982, 1991-current	
	06394000	Beaver Creek Near Newcastle, WY	NO	1945-1998	
	06394500	Beaver Creek Near Burdock, SD	NO	1905-1907, 1929-1932	Abt. 2 mi. into SD
	06395000	Cheyenne River at Edgemont, SD	NO	1903-1907, 1928-1933, 1947-current	Several miles into SD; No winter records 1903-1906
Belle Fourche	06425720	Belle Fourche River Below Rattlesnake Creek, Near Piney, WY	NO	1976-1983	
	06425750	Coal Creek Near Piney, WY	YES	1981-1983	
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO	1976-1983	
	06425900	Caballo Creek at Mouth Near Piney, WY	NO	1977-1983	
	06425950	Raven Creek Near Moorcroft, WY	YES	1977-1983	
	06426000	Belle Fourche River Near Moorcroft, WY	NO	1923-1933	
	06426100	Stonepile Creek at Gillette, WY	YES	1988-1992	No winter records; Adjusted for diversions using Burlington Lake Ditch
	06426400	Donkey Creek Near Moorcroft, WY	NO	1977-1981	
	06426500	Belle Fourche River Below Moorcroft, WY	NO	1943-1970, 1976-1983, 1986-1987, 1991-current	
	USBR Gage	Inflow to Keyhole Reservoir	NO	USBR: 1952-current	Adjusted for evaporation
	USBR Gage	Belle Fourche - Keyhole Reservoir Releases	NO	USBR: 1952-current	
	06427500	Belle Fourche River Below Keyhole Reservoir, WY	NO	1951-1995	
	06428000	Belle Fourche River at Hulett, WY	NO	1929-1933, 1938-1952	
	06428200	Belle Fourche River Near Alva, WY	NO	1989-1998	No winter records
	06428500	Belle Fourche River at Wyoming-South Dakota State Line	NO	1947-current	
	06429500	Cold Springs Creek at Buckhorn, WY	YES	1975-1982, 1991-current	
	06429900	Sand Creek at Ranch A Near Beulah, WY	YES	1975-1976	Combined with Station 06429905
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES	1976-1983, 1991-current	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO	1929-1931, 1936-1937, 1954-current	Adjusted for diversions using Murrey Ditch
Niobrara	06454000	Niobrara River at Wyoming-Nebraka State Line	NO	1956-1994	

** Unless otherwise noted, records were obtained from the USGS.

FIGURE 3

STREAMFLOW STATIONS IN THE NORTHEAST WYOMING RIVER BASINS



STUDY PERIOD

It is important in any water availability evaluation to select a study period that is long enough to include a variety of hydrologic conditions including an extended period of dry years as well as wet years and normal years. At the same time, it is also important not to select a study period so long that many streamflows must be synthesized to fill-in missing data.

It is desirable in evaluating long-term hydrologic conditions to utilize streamflow records for a station that has a long period of continuous records and that reflects natural (virgin) flow, unaffected by upstream depletions or storage regulation. Unfortunately, no such streamflow gaging station exists in, or in near vicinity to, the Northeast Wyoming River Basins. The USGS has, however, maintained streamflow stations on Beaver Creek near Newcastle (#06394000) and the Cheyenne River at Edgemont, South Dakota (#06395000) since the mid 1940s (Table 1). The Beaver Creek gage was discontinued in 1998. The records for these gages are impacted by upstream irrigation depletions and storage, primarily in the form of stock ponds. The change in carryover storage from year to year is however expected to be relatively minor and the amount of irrigation depletion in relation to the total streamflow is not expected to vary greatly from year to year. The records for these stations although non-natural can therefore be used as a reasonable representation of annual hydrologic conditions. The USGS has also maintained a streamflow station on the Belle Fourche River below Moorcroft (#06426500) since 1944 with some gaps in the record in the 1970s and 1980s (Table 1). Similar to stations on Beaver Creek and the Cheyenne River, the streamflow at this gage is impacted by upstream irrigation depletion and stock pond storage. The record for this station can however be used to represent hydrologic conditions in the Belle Fourche drainage. The USBR maintains records of computed inflows into Keyhole Reservoir downstream from the Moorcroft gage (#06426500). HKM utilized this information to develop a regression relationship between streamflows at the upstream Moorcroft gage and inflows to Keyhole Reservoir to fill-in the missing records in the 1970s and 1980s. The relationship is shown below:

$$Q_{06426500} = 0.671 * Q_{\text{Keyhole Inflow}} - 386.2$$

Where: $Q_{06426500}$ is monthly streamflow at Gage #06426500 in acre-feet and
$Q_{\text{Keyhole Inflow}}$ is computed inflow to Keyhole Reservoir from USBR in acre-feet.

The coefficient of determination (R^2) for this relationship is 0.87. The coefficient of determination is defined as the proportion of variation in the independent variable that can be explained by variation in the dependent variable (DeVore, 1987). The higher the value of R^2, the stronger the relationship between the two variables. A perfect relationship would have an $R^2 = 1.0$. Regression of hydrologic data resulting in $R^2>0.7$ is typically considered strong enough for data estimating. The regression analysis and the resulting monthly streamflows for this station are provided in Appendix A.

The recorded and estimated streamflow records from the gages on Beaver Creek (#06394000), the Cheyenne River (#06395000), and the Belle Fourche River (#06426500) are selected as representative of the hydrologic conditions throughout the Northeast Wyoming River basins.

Figures 4, 5, and 6 are Cumulative Surplus/Deficit plots for Beaver Creek, the Cheyenne River, and the Belle Fourche River respectively for the longest concurrent period of record (1947 to 1997 or 1999). A Cumulative Surplus/Deficit plot represents a running total of the annual deviations from the long-term mean annual streamflow. Downward sloping lines (left to right) represent periods of time during which annual streamflow is less than the long-term mean (dry periods). Conversely, upward sloping lines represent years, which are wetter than average (wet periods). As can be seen from these plots, the hydrologic conditions can vary considerably throughout the Northeast Wyoming River Basins in any given period of years. By way of example, the period 1964 to 1970 is generally a wet period on Beaver Creek. Whereas, on the Cheyenne River, this same period is generally average, and on the Belle Fourche River, 1964 to 1970 is generally a dry period. Some similarities do however exist throughout the study area. The periods 1959 to 1961, 1979 to 1985, and 1988 to 1990 are generally dry periods at all locations. The years 1962 and 1978 are also extreme wet years at all locations.

FIGURE 4

CUMULATIVE SURPLUS/DEFICIT OF ANNUAL HISTORIC FLOWS

BEAVER CREEK NEAR NEWCASTLE, WY (Station 06394000)

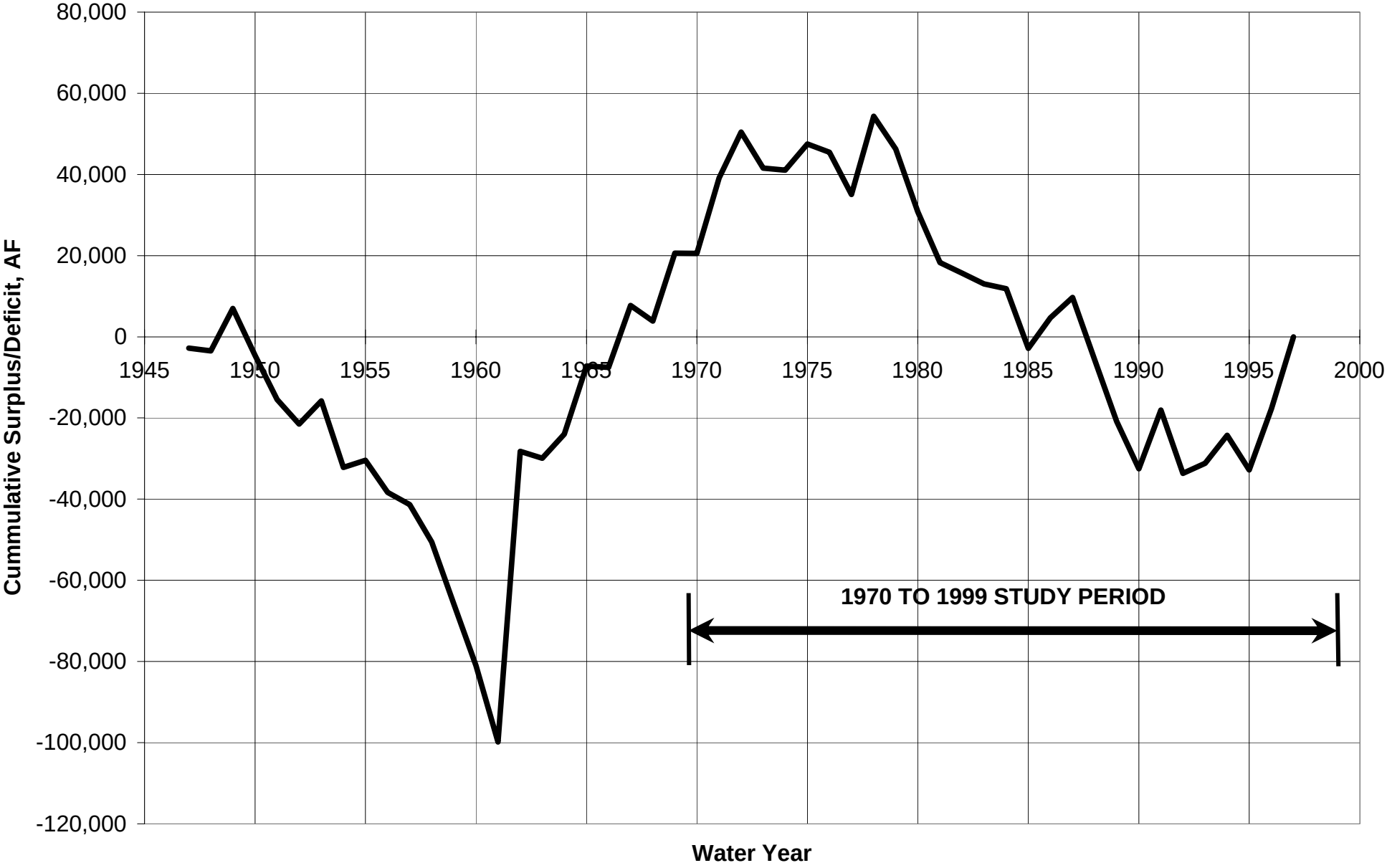


FIGURE 5

CUMULATIVE SURPLUS/DEFICIT OF ANNUAL HISTORIC FLOWS

CHEYENNE RIVER AT EDGEMONT, SD (Station 06395000)

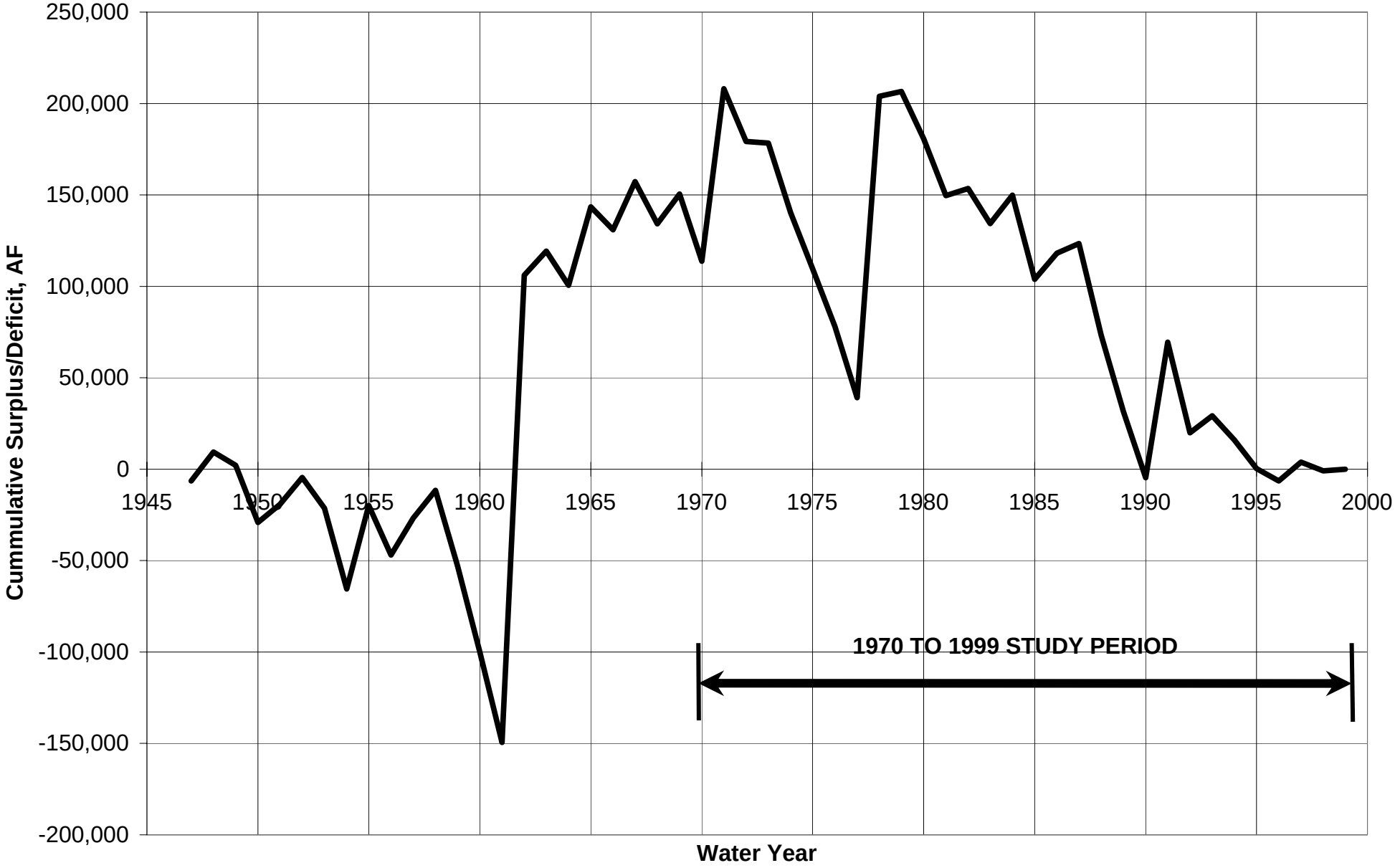


FIGURE 6

CUMULATIVE SURPLUS/DEFICIT OF ANNUAL HISTORIC FLOWS

BELLE FOURCHE RIVER BELOW MOORCROFT, WY (Station 06426500)

Based on an evaluation of the long-term hydrologic conditions at the three representative streamflow stations, together with the an understanding of the availability of historic streamflow records, the 30-year period 1970 through 1999 is selected as a candidate study period. The annual streamflows at each of these stations for the period 1947 to 1997 or 1999 are summarized in Table 2. The average annual flow for the period 1970 to 1999 ranges from 9% drier than the long-term period on the Cheyenne River to 12% wetter than the long-term period on the Belle Fourche River.

On the Cheyenne River, the period 1970 to 1999 includes the extended dry periods 1972 to 1977, 1980 to 1983, and 1988 to 1990 as well as the wet period from 1978 to 1979. This period contains three out of six of the driest years of the 1947 – 1999 records including 1985, 1988, and 1992. The period also contains three out of six of the wettest years of record in 1971, 1978, and 1991. The extreme dry years and wet years (driest and wettest years) are defined here as those with exceedance or non-exceedance probabilities of less than approximately 10 percent.

The 1970 to 1999 period on the Belle Fourche River contains the dry periods from 1975 to 1977, 1979 to 1986 and 1990 to 1992 as well as the wet periods 1973 to 1974 and 1993 to 1997. This period also contains three of the six driest years of the 1947 – 1999 records in 1980, 1981, and 1990 and 4 of the six wettest years of record in 1973, 1974, 1978, and 1993.

On the Beaver Creek at Newcastle (#06394000), the period 1970 to 1999 includes the extended dry periods from 1979 through 1985 and 1988 through 1990 as well as the wet periods from 1971 to 1972, 1986 to 1987, and 1996 to 1997. This period also contains three out of six of the driest years of the 1947 – 1997 records including 1980, 1988, and 1992. The period also contains three out of six of the wettest years of record in 1971, 1978, and 1997.

In summary, the period 1970 through 1999 contains extended periods of dry years at all locations including some of the driest years of record as well as periods of normal and wet hydrologic conditions. This period also has the greatest abundance of recorded streamflow data and therefore requires less data synthesis. A study period of 1970 through 1999 is therefore appropriate for purposes of water availability modeling for the Northeast Wyoming River Basin Plan.

The remainder of this memorandum describes the methodologies used to determine the typical dry year, normal year, and wet year monthly flows required at each of the model nodes.

DATA EXTENSION

The spreadsheet modeling approach used for the Basin Plan utilizes model nodes located at historic streamflow gaging stations in order to take advantage of the historic records of streamflow at these locations. These records however contain many data gaps during the 1970 to 1999 study period (Figure 3). Monthly streamflows must therefore be estimated for those months, during the study period, with no recorded streamflow data.

The monthly record extension approach used in this study follows the procedure used by the USGS in recent studies in Montana (USGS WRI 89-4165, 1989: USGS WRI 89-4082, 1989). This mixed-station procedure uses the best base station from among all available base stations to fill in each month of missing data for a given gage. It is therefore possible that several different base stations may be used to fill in different months of missing data for a given station. The base station producing the smallest standard error of prediction is used for each particular month. The monthly record extension procedure also offers the option of using cyclic or noncyclic equations to fill in missing records. If the cyclic option is selected, an extension equation is computed for each month using only concurrent streamflows for the month. If the noncyclic option is selected, a single extension equation is computed using all concurrent streamflows. The smallest standard error criterion is used to select between the cyclic or noncyclic option for each month of missing record. For this study, the cyclic option is used only if the base station and the short record station have at least five concurrent monthly streamflows. The noncyclic option is used in all other cases. The technique used to estimate missing values in this study was developed by Hirsch and is referred to as MOVE.1 (Maintenance of Variance Extension, Type 1). This technique offers the

TABLE 2

LONG TERM AVERAGE ANNUAL FLOW COMPARISON TO 1970-1999 AVERAGE ANNUAL FLOW

	Annual Flow in Acre-Feet		
YEAR	Beaver Creek Near Newcastle, WY **06394000**	Cheyenne River at Edgemont, SD **06395000**	Belle Fourche River Below Moorcroft, WY **06426500**
1947	19,703	52,451	8,999
1948	21,855	74,782	26,989
1949	32,921	51,613	19,570
1950	10,925	27,659	7,965
1951	11,669	68,919	4,751
1952	16,476	73,500	7,726
1953	28,225	42,095	14,037
1954	6,100	14,868	2,288
1955	24,273	104,588	31,891
1956	14,573	31,719	9,290
1957	19,478	79,214	5,132
1958	13,292	74,108	5,868
1959	7,133	17,624	4,413
1960	7,443	11,881	9,097
1961	3,715	9,339	825
1962	94,071	314,408	75,153
1963	20,810	72,168	18,993
1964	28,424	40,155	40,060
1965	39,333	101,877	12,633
1966	22,155	46,363	6,120
1967	37,732	85,226	16,413
1968	18,708	35,927	6,549
1969	39,198	75,129	10,816
1970	22,458	22,264	10,842
1971	41,118	153,235	20,218
1972	33,801	30,052	14,051
1973	13,645	57,980	40,434
1974	21,996	20,970	44,264
1975	28,898	28,202	7,583
1976	20,510	27,407	7,543
1977	12,102	19,855	7,876
1978	41,784	223,740	98,331
1979	14,393	61,675	15,391
1980	7,085	32,972	3,712
1981	9,954	27,855	4,646
1982	19,917	62,767	20,283
1983	19,842	39,746	11,590
1984	21,339	74,519	18,478
1985	7,801	12,831	7,880
1986	30,004	73,186	14,496
1987	27,558	64,260	25,747
1988	7,171	8,725	15,069
1989	7,335	17,079	21,935
1990	10,762	22,894	4,576
1991	36,995	132,999	12,248
1992	6,889	9,408	4,994
1993	25,031	68,156	41,836
1994	29,359	45,633	23,223
1995	14,005	43,391	24,721
1996	37,581	52,131	20,135
1997	40,220	69,180	26,752
1998		54,230	11,136
1999		59,770	23,556
Avg 47-99	22,505	58,919	17,908
Avg 70-99	21,770	53,904	20,118

advantage over ordinary least-squares regression of preserving the variance of the unextended records (Alley and Burns, 1983). The MOVE.1 technique differs from ordinary least-squares regression in that ordinary regression minimizes the squared vertical deviations of the response variable from the regression line, whereas the MOVE.1 technique minimizes the areas of the right triangles formed by the horizontal and vertical deviations from the regression line (USGS WRI 89-4165, 1989). This procedure is carried out using a computer program developed by the USGS.

The USGS streamflow stations are divided into hydrologically similar groups with each group having at least one gage with sufficient data to develop relationships based on concurrent streamflow for the entire study period. The groupings also represent stations affected by similar reservoir operations. In particular, those stations below Keyhole Reservoir are grouped together because they all experience the same impacts from Keyhole operations. The monthly flow extension procedure is performed for each of these groupings of monthly streamflow data. There is a certain amount of overlap in hydrologic similarity among the various groupings. Some streamflow stations are therefore included in multiple groups. The station groupings and the resulting coefficients of determination (R^2) are provided in Table 3. Regression of hydrologic data resulting in $R^2>0.7$ is typically considered strong enough for data estimating. This criterion was used in evaluating the results of the regression analyses. The results of the MOVE.1 analyses are provided in Appendix B.

As shown in Table 3 in many instances no significant correlation ($R^2<0.7$) could be found using concurrent monthly streamflows between any base station and the short record station. Annual flow regression rather than monthly flow regression was performed in these instances to fill-in the missing streamflow data. The results of this analysis including the base station record used to fill-in the missing data at the short record station, the regression equation, and the resulting coefficient of determination (R^2) are summarized in Table 4. The supporting computations and graphic displays of the results of the annual flow regression analyses are provided in Appendix C. As noted in Table 4, in some cases, no significant correlation ($R^2<0.7$) could be found using the annual flow regression either. Three of these stations were dropped from the study. Four other stations on Beaver Creek and the Niobrara River were retained and the study periods for modeling were adjusted to utilize historic records only (Table 4). The monthly streamflows for the years of missing data were estimated by applying the average monthly distribution for the period of recorded streamflow to the estimated total annual flow. For those instances when records for some months are available, the recorded streamflows are used and subtracted from the estimated annual total. The remaining months of missing data are then filled-in using the average monthly distribution for these months applied to the total remaining streamflow for the partial year.

The average monthly and annual streamflows during the study period are summarized in Table 5, for the gaging stations selected for use in the water availability models. The recorded and extended monthly streamflows for each year of the study period are provided in Appendix D for each station.

NATURAL FLOW AT UNGAGED MODEL NODES

Records of streamflow from the limited number of gaging stations in planning area are used to the extent available to represent flow at model nodes. However, to fully represent water use in the various drainages, estimates of natural flow are also required at many model nodes where records from USGS or SEO streamflow stations are unavailable. HKM evaluated several alternatives for estimating natural flow at these locations including:

1. Use the streamflow records from a nearby gaging station on the same stream, adjusting for depletions and storage regulation to estimate natural flow at the location of interest.

2. Use the regression equations developed by the USGS in WRIR 88-4045 for relating drainage area and either average annual precipitation or mean basin elevation to estimate natural flow.

3. Use the recorded natural flow from a gaged stream with similar hydrologic characteristics, adjusting for the difference in drainage area at the location of interest.

TABLE 3
CORRELATION RESULTS BASED ON MONTHLY DATA

Basin	Station Number	Station Name	Natural Flow	USGS MOVE.1 EXTENSION GROUPINGS						Wtd. Avg. R^2 Value	Notes
				CHEANON7	CHECNON7	BLABNAT7	BELANON7	LBEBNON7	LBELNON7		
Cheyenne	06364700	Antelope Creek Near Teckla, WY	NO							0.74	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO							No Correlation	See Table 4
	06365900	Cheyenne River Near Dull Center, WY	NO							0.77	
	06375600	Little Thunder Creek Near Hampshire, WY	NO							No Correlation	See Table 4
	06376300	Black Thunder Creek Near Hampshire, WY	NO							No Correlation	See Table 4
	06378300	Lodgepole Creek Near Hampshire, WY	NO							No Correlation	See Table 4
	06386000	Lance Creek Near Riverview, WY	NO							No Correlation	See Table 4
	06386500	Cheyenne River Near Spencer, WY	NO							No Correlation	See Table 4
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES							No Correlation	See Table 4
	06392950	Stockade Beaver Creek Near Nearcastle, WY	NO							No Correlation	See Table 4
	06394000	Beaver Creek Near Newcastle, WY	NO							No Correlation	See Table 4
	06395000	Cheyenne River at Edgemont, SD	NO							N/A	Records available for entire study period
Belle Fourche	06425720	Belle Fourche River Below Rattlesnake Creek Near Piney, WY	NO							No Correlation	See Table 4
	06425750	Coal Creek Near Piney, WY	YES							No Correlation	See Table 4
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO							No Correlation	See Table 4
	06425900	Caballo Creek at Mouth Near Piney, WY	NO							No Correlation	See Table 4
	06425950	Raven Creek Near Moorcroft, WY	YES							No Correlation	See Table 4
	06426100	Stonepile Creek at Gillette, WY	YES							No Correlation	See Table 4
	06426400	Donkey Creek Near Moorcroft, WY	NO							No Correlation	See Table 4
	06426500	Belle Fourche River Below Moorcroft, WY	NO							N/A	Records available for entire study period
	USBR Gage	Belle Fourche - Keyhole Reservoir Releases	NO							N/A	Records available for entire study period
	06427500	Belle Fourche River Below Keyhole Reservoir, WY	NO							0.90	
	06428200	Belle Fourche River Near Alva, WY	NO							0.91	
	06428500	Belle Fourche River at Wyoming-South Dakota State Line	NO							N/A	Records available for entire study period
	06429500	Cold Springs Creek at Buckhorn, WY	YES							No Correlation	See Table 4
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES							0.82	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO							N/A	Records available for entire study period
Niobrara	06454000	Niobrara River at Wyoming-Nebraka State Line	NO							No Correlation	See Table 4

LEGEND	
	USGS MOVE.1 Group resulting in best R^2 value
	Station included in USGS MOVE.1 group

TABLE 4
STATIONS IN THE NORTHEAST WYOMING RIVER BASINS

Basin	Station Number	Station Name	Natural Flow	Station Used in Regression	R^2 Value	Regression Equation	Notes
Cheyenne	**06365300**	Dry Fork Cheyenne River Near Bill, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.97	Y= 0.012486X - 340.33	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.94	Y = 0.038268X - 779.37	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.93	Y = 0.12044X - 963.54	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.99	Y= 0.10146X - 98.335	
	06386000	Lance Creek Near Riverview, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.93	Y = 0.30488X - 820.91	
	06386500	Cheyenne River Near Spencer, WY	NO	Cheyenne River at Edgemont, SD (Station 06395000)	0.99	Y= 0.89571X - 8219.4	
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES		No Correlation		Study period modified to 1975-1982, 1992-1997
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO		No Correlation		Study period modified to 1975-1982, 1992-1997
	06394000	Beaver Creek Near Newcastle, WY	NO		No Correlation		Study period modified to 1975-1982, 1992-1997
Belle Fourche	**06425720**	Belle Fourche River Below Rattlesnake Creek, Near Piney, WY	NO	Belle Fourche River Below Moorcroft, WY (Station 06426500)	0.92	Y = 0.072446X + 192.57	
	06425750	Coal Creek Near Piney, WY	YES		No Correlation		Unable to find significant correlation with any available station
	06425780	Belle Fourche River Above Dry Creek, Near Piney, WY	NO	Belle Fourche River Below Moorcroft, WY (Station 06426500)	0.98	Y = 0.14088X + 176.13	
	06425900	Caballo Creek at Mouth, Near Piney, WY	NO	Belle Fourche River Below Moorcroft, WY (Station 06426500)	0.99	Y = 0.084892X - 297.37	
	06425950	Raven Creek Near Moorcroft, WY	YES	Belle Fourche River Below Moorcroft, WY (Station 06426500)	0.99	Y = 0.023728X - 126.42	
	06426100	Stonepile Creek at Gillette, WY	YES		No Correlation		Adjusted for diversions; Unable to find significant correlation with any available station
	06426400	Donkey Creek Near Moorcroft, WY	NO	Belle Fourche River Below Moorcroft, WY (Station 06426500)	0.99	Y = 0.27550X - 874.51	
	06429500	Cold Springs Creek at Buckhorn, WY	YES		No Correlation		Unable to find significant correlation with any available station
Niobrara	**06454000**	Niobrara River at Wyoming-Nebraska State Line	YES		No Correlation		Study period modified to 1970-1994

TABLE 5
SUMMARY OF AVERAGE MONTHLY AND ANNUAL FLOWS (1970 TO 1999 unless otherwise noted)
AT GAGED MODEL NODES

Basin	Station Number	Station Name	Natural Flow	AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET													Notes
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	
Cheyenne	06364700	Antelope Creek Near Teckla, WY	NO	97	64	18	22	159	545	291	1,520	1,005	361	148	93	**4,323**	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO	3	6	5	3	17	44	20	194	37	30	8	1	**366**	
	06365900	Cheyenne River Near Dull Center, WY	NO	176	101	26	36	407	798	633	3,475	2,247	854	425	66	**9,244**	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	3	4	5	5	48	86	11	824	131	135	100	2	**1,354**	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	307	16	0	51	272	846	308	1,788	671	549	405	498	**5,710**	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	1	2	1	1	2	45	33	223	91	32	34	1	**464**	
	06386000	Lance Creek Near Riverview, WY	NO	133	111	83	333	870	1,205	902	5,594	2,717	2,993	2,078	694	**17,713**	
	06386500	Cheyenne River Near Spencer, WY	NO	275	233	71	1,023	1,487	866	2,040	20,050	9,286	2,103	535	3,453	**41,423**	
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES	112	102	100	97	98	127	138	136	144	131	120	112	**1,415**	Study Period: 1975-1982, 1992-1997
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO	786	763	785	769	721	877	785	654	675	699	730	751	**8,996**	Study Period: 1975-1982, 1992-1997
	06394000	Beaver Creek Near Newcastle, WY	NO	876	804	796	881	2,381	5,716	2,353	3,250	2,339	1,106	797	497	**21,796**	Study Period: 1975-1982, 1992-1997
	06395000	Cheyenne River at Edgemont, SD	NO	1,910	1,416	684	800	3,106	8,847	4,275	14,156	10,524	4,720	3,269	1,700	**55,407**	
Belle Fourche	06425720	Belle Fourche River Below Rattlesnake Creek Near Piney, WY	NO	6	6	12	24	79	212	66	685	236	101	149	20	**1,596**	
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO	21	6	14	45	190	611	131	1,097	282	239	179	70	**2,887**	
	06425900	Caballo Creek at Mouth Near Piney, WY	NO	13	10	1	10	27	221	30	788	76	99	45	18	**1,339**	
	06425950	Raven Creek Near Moorcroft, WY	YES	6	0	0	2	54	169	3	78	2	7	13	0	**333**	
	06426400	Donkey Creek Near Moorcroft, WY	NO	34	18	33	20	37	1,707	145	2,309	104	17	5	4	**4,434**	
	06426500	Belle Fourche River Below Moorcroft, WY	NO	682	203	149	420	1,761	4,664	2,268	5,169	2,134	997	515	281	**19,243**	
	USBR Gage	Belle Fourche River - Total Keyhole Reservoir Discharge	NO	114	320	0	1	0	881	784	2,149	2,402	4,821	4,526	761	**16,759**	
	06427500	Belle Fourche River Below Keyhole Reservoir	NO	257	260	103	104	96	1,015	760	2,194	2,362	4,833	4,600	833	**17,417**	
	06428200	Belle Fourche River Near Alva, WY	NO	1,826	1,648	1,063	1,375	2,419	7,705	7,511	10,171	7,526	4,925	4,981	1,998	**53,148**	
	06428500	Belle Fourche River at Wyoming - South Dakota State Line	NO	2,307	2,082	1,272	1,741	3,233	10,987	10,552	15,575	12,134	6,507	5,402	2,336	**74,127**	
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES	1,312	1,307	1,285	1,237	1,092	1,231	1,288	1,881	1,776	1,499	1,480	1,334	**16,722**	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO	2,108	2,077	2,043	2,006	1,928	2,240	2,367	3,697	3,135	2,190	2,245	2,119	**28,155**	
Niobrara	06454000	Niobrara River at Wyoming-Nebraska State Line	NO	150	151	159	179	207	316	297	249	208	143	151	118	**2,328**	Study Period: 1970-1994

The downstream gaging stations are typically highly influenced by irrigation depletions and storage regulation. To develop natural flows using Alternative 1, the records for the downstream station would first need to be adjusted to remove these influences. Insufficient data is, typically, available to make these adjustments. It is therefore concluded that the first alternative does not yield reliable estimates of natural flow in most cases. The one exception is Donkey Creek, southeast of Gillette in the Belle Fourche River basin. Alternative 1 yielded the most reasonable estimates of natural flow for this location as evaluated during the calibration of the water availability models. The depletions (diversions minus return flows) used to make the adjustments to the downstream gage records are based on three representative hydrologic conditions (wet, normal, and dry years) and are taken from the water availability modeling work. The natural flow estimates for this location is therefore provided for these three representative hydrologic conditions only. This is in contrast to the estimates of natural flow at the other ungaged node locations for which natural flow estimates are provided for each month and each year within the study period. The selection of the years used to represent wet, normal, and dry conditions are discussed in the next section. The derivation of natural flow at this location is provided in Appendix E.

The USGS is currently updating the work originally developed by Lowham in the report "Streamflows in Wyoming" (USGS, 1988). Unfortunately, at the time of this writing, that work is several months away from completion. The 1988 USGS report presents regression equations, which rely on drainage area and either average annual precipitation or mean basin elevation to estimate mean annual flow. The equation for the plains region utilizes average annual precipitation and is applicable to the majority of the drainages within the planning area. According to personnel with the USGS in Cheyenne currently performing the updated work, the average annual precipitation data used in developing the equations in the 1988 report, for the plains region cannot be documented or verified. Data from the PRISM database will be used in developing the updated equations (www.ocs.orst.edu/prism/). Alternative 2 was dropped from further consideration due to the questionable validity of the original equations for the plains region.

Natural flow for the majority of the ungaged model nodes was estimated using the third alternative, which relies on measured natural flow at selected streamflow gages in the Northeast Wyoming River Basins. The natural flow gage in nearest proximity and with the most similar hydrologic conditions was used to estimate natural flow at the ungaged locations. The original selections were further evaluated and, in some cases modified, as part of the calibration of the water availability models. In addition to average annual natural flow at the ungaged model nodes, it is necessary to generate sequential monthly flows at these sites for all years of the study period. This is accomplished by selecting a natural flow gaging station having similar hydrologic characteristics and multiplying the sequential monthly flows at the gaged location by the ratio of the ungaged average annual natural flow to the gaged average annual natural flow. The time distribution of monthly flows at the ungaged sites is, therefore, represented by the streamflow at similar gaged sites. The streamflow gages used to estimate monthly and annual natural flow at the ungaged model nodes are summarized in Table 6. The average monthly and annual streamflows for the study period, for the ungaged model nodes are summarized in Table 7. The estimated monthly natural flows for each year of the study period are provided in Appendix F for each ungaged model node.

The locations of the ungaged model nodes are shown on Figure 7.

WET, DRY, AND NORMAL YEARS

Water availability models are to be developed to represent dry year, normal year, and wet year hydrologic conditions throughout the Northeast Wyoming River Basins. To this end, the annual streamflows for the study period developed through the surface water hydrology work are ranked and divided into these three hydrologic categories. Indicator gages are selected for this purpose, to represent hydrologic conditions for the entire geographic area of the Northeast Wyoming River Basins. The seven indicator gages are shown on Figure 8. The years with non-exceedance probabilities of 20 percent or less (the driest 20 percent) were selected as dry years. Similarly, the years with exceedance probabilities of 20 percent or less (the wettest 20 percent) were selected as wet years. The remaining 60 percent of the years represent normal years. The dry years, normal years, and wet years for the indicator gages are illustrated on Figure 9. As can be seen, the hydrologic conditions from year to year vary from location to location (i.e. dry

TABLE 6

STREAMFLOW GAGES USED TO ESTIMATED NATURAL FLOW AT UNGAGED MODEL NODES

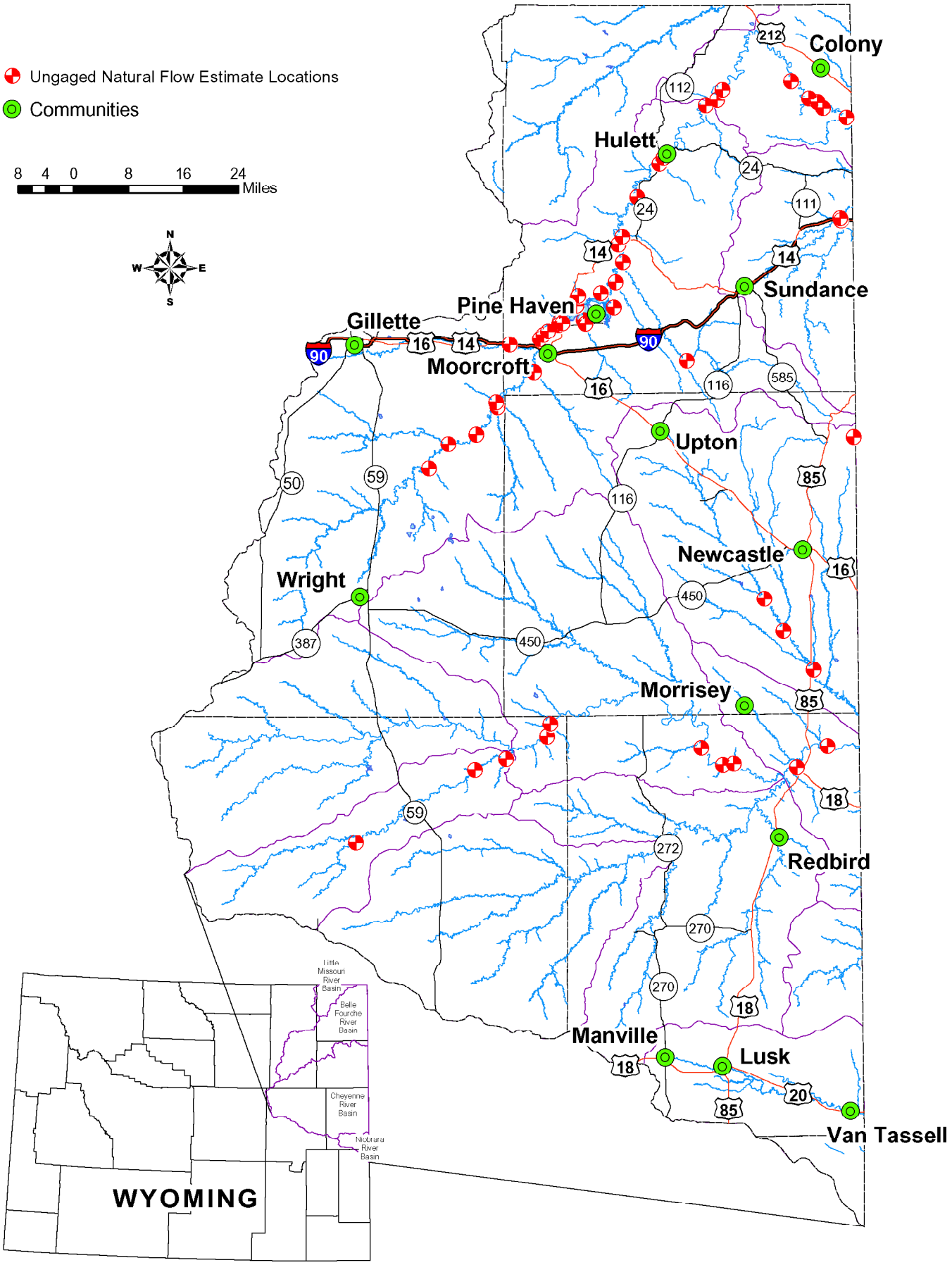
Basin	Site	Site Drainage Area (sq. mi.)	USGS Transfer Gage used to estimate annual flow	Gage Drainage Area (sq. mi.)	USGS Gage used for monthly distribution
Cheyenne	Willow Creek at Mouth in Section 28, T38N, R72W	107.1	Raven Creek Near Moorcroft (06425950)	76.0	Raven Creek Near Moorcroft (06425950)
	Woody Creek at Mouth in Section 5, T39N, R69W	14.0			
	Lake Creek at Mouth in Section 30, T40N, R68W	32.4			
	Sheep Creek at Mouth in Section 7, T40N, R67W	10.3			
	Wagonhound Creek at Mouth in Section 31, T41N, R67W	21.6			
	Snyder Creek at Mouth in Section 23, T40N, R64W	100.4			
	Boggy Creek at Mouth in Section 32, T40N, R63W	27.5			
	Sevenmile Creek at Mouth in Section 34, T40N, R63W	13.4			
	Mule Creek at Mouth in Section 6, T39N, R61W	43.2			
	Robbers' Roost Creek at Mouth in Section 23, T40N, R61W	61.2			
	Beaver Creek Just Below Mush Creek in Section 32, T44N, R62W	415.7	Raven Creek Near Moorcroft (06425950) using Wet, Dry, Normal averages		Raven Creek Near Moorcroft (06425950) using Wet, Dry, Normal averages
	Oil Creek at Mouth in Section 26, T43N, R62W	267.1	Sand Creek Near Ranch A Near Beulah (06429905)	267.0	Raven Creek Near Moorcroft (06425950)
	Blacktail Creek at Mouth in Section 2, T41N, R61W	40.9			Sand Creek Near Ranch A Near Beulah (06429905)
	Dry Beaver Creek Just Above Beaver Creek in Section 4, T47N, R60W	10.4	Beaver Creek at Mallo Camp Near Four Corners (06392900)	10.3	Beaver Creek at Mallo Camp Near Four Corners (06392900)
Belle Fourche	Dry Creek at Mouth in Section 29, T47N, R70W	19.5	Raven Creek Near Moorcroft (06425950)	76.0	Raven Creek Near Moorcroft (06425950)
	Yellow Hammer Creek at Mouth in Section 10, T47N, R70W	7.31			
	Whitetail Creek at Mouth in Section 32, T48N, R69W	10.8			
	Four Horse Creek at Mouth in Section 11, T48N, R69W	102.8			
	Timber Creek at Mouth in Section 2, T48N, R69W	26.9			
	Buffalo Creek at Mouth in Section 14, T49N, R68W	130.5			
	Donkey Creek Just Upstream of Gage in Sec. 30, T50N, R68W	14.6			
	Trail Creek at Mouth in Section 24, T50N, R68W	14.6			
	Dry Creek at Mouth in Section 24, T50N, R68W	20.4			
	Robinson Creek at Mouth in Section 18, T50N, R67W	6.24			
	Duck Creek at Mouth in Section 8, T50N, R67W	4.19	Sand Creek Near Ranch A Near Beulah (06429905)	267.0	
	Miller Creek at Mouth in Section 9, T50N, R67W	47.8			
	Smoke Creek at Mouth in Section 9, T50N, R67W	1.23			
	Berger Creek at Mouth in Section 12, T50N, R67W	2.02			
	Lone Tree Creek at Mouth in Section 26, T51N, R67W	4.39			
	Wind Creek at Mouth in Section 13, T50N, R67W	109.4			
	Deer Creek at Mouth in Section 23, T51N, R67W	23.1			
	Eggie Creek at Mouth in Section 21, T51N, R66W	3.20			
	Mule Creek at Mouth in Section 15, T50N, R66W	14.0			
	Cottonwood Creek at Mouth in Section 35, T51N, R66W	3.72			
	Arch Creek at Mouth in Section 11, T51N, R66W	88.0	Raven Creek Near Moorcroft (06425950)	76.0	
	Inyan Kara Creek at Mouth in Section 25, T52N, R66W	233.1[1]	Sand Creek Near Ranch A Near Beulah (06429905)	267.0	Sand Creek Near Ranch A Near Beulah (06429905)
		106.2[2]	Raven Creek Near Moorcroft (06425950)	76.0	Raven Creek Near Moorcroft (06425950)
	Cabin Creek at Mouth in Section 14, T52N, R66W	66.5			
	Miller Creek at Mouth in Section 12, T52N, R66W	55.0			
	Lytle Creek at Mouth in Section 8, T53N, R65W	38.0			
	Whitetail Creek at Mouth in Section 14, T54N, R65W	16.8	Sand Creek Near Ranch A Near Beulah (06429905)	267.0	Sand Creek Near Ranch A Near Beulah (06429905)
	Blacktail Creek at Mouth in Section 12, T54N, R65W	42.7			
	Beaver Creek at Mouth in Section 1, T55N, R64W	93.4			
	East Creek at Mouth in Section 32, T55N, R63W	9.72			
	Arnold Creek at Mouth in Section 28, T55N, R63W	4.52			
	Horse Creek at Mouth in Section 19, T56N, R61W	15.4			
	Pine Creek at Mouth in Section 33, T56N, R61W	35.0			
	Kilpatrick Creek at Mouth in Section 3, T55N, R61W	14.1			
	Kruger Creek at Mouth in Section 11, T55N, R61W	6.86			
	Oak Creek at Mouth in Section 20, T55N, R60W	43.9			
	South Redwater Creek Just Above Sand Creek in Section 31, T53N, R60W	115.0			
	Redwater Creek Just Above South Redwater Creek in Section 31, T53N, R60	58.4			

Notes: 1. Upper Portion of Inyan Kara Creek: Inyan Kara Creek Just Below Mason Creek in Section 9, T49N, R64W.
2. Lower Portion of Inyan Kara Creek: The remaining portion below the Upper Portion (Total Drainage Area = 339.3 sq. miles).

TABLE 7
SUMMARY OF AVERAGE MONTHLY AND ANNUAL FLOWS
AT UNGAGED NATURAL FLOW NODES

Basin	Station Name	ESTIMATED AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET												
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Cheyenne	Willow Creek at Mouth in Section 28, T38N, R72W	9	0	0	3	76	238	4	109	3	10	18	0	**470**
	Woody Creek at Mouth in Section 5, T39N, R69W	1	0	0	0	10	31	0	14	0	1	2	0	**59**
	Lake Creek at Mouth in Section 30, T40N, R68W	3	0	0	1	23	72	1	33	1	3	5	0	**142**
	Sheep Creek at Mouth in Section 7, T40N, R67W	1	0	0	0	7	23	0	11	0	1	2	0	**45**
	Wagonhound Creek at Mouth in Section 31, T41N, R67W	2	0	0	1	15	48	1	22	1	2	4	0	**96**
	Snyder Creek at Mouth in Section 23, T40N, R64W	8	0	0	3	71	223	3	103	3	10	17	0	**441**
	Boggy Creek at Mouth in Section 32, T40N, R63W	2	0	0	1	20	61	1	28	1	3	5	0	**122**
	Sevenmile Creek at Mouth in Section 34, T40N, R63W	1	0	0	0	10	30	0	14	0	1	2	0	**58**
	Mule Creek at Mouth in Section 6, T39N, R61W	4	0	0	1	31	96	1	44	1	4	7	0	**189**
	Robbers' Roost Creek at Mouth in Section 23, T40N, R61W	5	0	0	2	43	136	2	63	2	6	10	0	**269**
	Beaver Creek Just Below Mush Creek in Section 32, T44N, R62W	33	0	0	10	292	1,187	15	546	16	51	77	0	**2227[1]**
	Oil Creek at Mouth in Section 26, T43N, R62W	346	0	0	61	3,958	6,405	377	2,930	87	275	2,425	0	**16,864**
	Blacktail Creek at Mouth in Section 2, T41N, R61W	200	195	193	186	163	188	191	293	262	240	215	198	**2,524**
	Dry Beaver Creek Just Above Beaver Creek in Section 4, T47N, R60W	107	99	97	92	95	111	133	136	141	130	118	107	**1,366**
Belle Fourche	Dry Creek at Mouth in Section 29, T47N, R70W	2	0	0	1	14	43	1	20	1	2	3	0	**87**
	Yellow Hammer Creek at Mouth in Section 10, T47N, R70W	1	0	0	0	5	16	0	7	0	1	1	0	**31**
	Whitetail Creek at Mouth in Section 32, T48N, R69W	1	0	0	0	8	24	0	11	0	1	2	0	**47**
	Four Horse Creek at Mouth in Section 11, T48N, R69W	8	0	0	3	73	228	4	105	3	10	17	0	**451**
	Timber Creek at Mouth in Section 2, T48N, R69W	2	0	0	1	19	60	1	27	1	3	5	0	**119**
	Buffalo Creek at Mouth in Section 14, T49N, R68W	11	0	0	3	93	290	4	133	4	12	22	0	**572**
	Donkey Creek Just Upstream of Gage in Sec. 30, T50N, R68W	0	0	0	413	1,135	3,278	1,555	4,005	946	0	0	0	**11,332[1]**
	Trail Creek at Mouth in Section 24, T50N, R68W	1	0	0	0	10	32	0	15	0	1	2	0	**61**
	Dry Creek at Mouth in Section 24, T50N, R68W	2	0	0	1	14	45	1	21	1	2	3	0	**90**
	Robinson Creek at Mouth in Section 18, T50N, R67W	1	0	0	0	4	14	0	6	0	1	1	0	**27**
	Duck Creek at Mouth in Section 8, T50N, R67W	5	0	0	4	59	115	4	53	2	5	24	0	**271**
	Miller Creek at Mouth in Section 9, T50N, R67W	58	0	0	41	672	1,314	44	604	18	57	271	0	**3,079**
	Smoke Creek at Mouth in Section 9, T50N, R67W	1	0	0	1	17	34	1	16	0	1	7	0	**78**
	Berger Creek at Mouth in Section 12, T50N, R67W	2	0	0	2	28	56	2	26	1	2	11	0	**130**
	Lone Tree Creek at Mouth in Section 26, T51N, R67W	5	0	0	4	62	121	4	55	2	5	25	0	**283**
	Wind Creek at Mouth in Section 13, T50N, R67W	133	0	0	93	1,539	3,008	101	1,382	41	129	620	0	**7,046**
	Deer Creek at Mouth in Section 23, T51N, R67W	28	0	0	20	325	635	21	292	9	27	131	0	**1,488**
	Eggie Creek at Mouth in Section 21, T51N, R66W	4	0	0	3	45	88	3	40	1	4	18	0	**206**
	Mule Creek at Mouth in Section 15, T50N, R66W	17	0	0	12	197	385	13	177	5	17	79	0	**902**
	Cottonwood Creek at Mouth in Section 35, T51N, R66W	5	0	0	3	52	102	3	47	1	4	21	0	**238**
	Arch Creek at Mouth in Section 11, T51N, R66W	7	0	0	2	62	195	3	90	3	8	15	0	**385**
	Inyan Kara Creek at Mouth in Section 25, T52N, R66W	1,154	1,142	1,122	1,083	1,028	1,311	1,128	1,750	1,553	1,319	1,310	1,165	**15,065**
	Cabin Creek at Mouth in Section 14, T52N, R66W	5	0	0	2	47	148	2	68	2	6	11	0	**291**
	Miller Creek at Mouth in Section 12, T52N, R66W	5	0	0	1	39	122	2	56	2	5	9	0	**241**
	Lytle Creek at Mouth in Section 8, T53N, R65W	3	0	0	1	27	84	1	39	1	4	6	0	**166**
	Whitetail Creek at Mouth in Section 14, T54N, R65W	83	82	81	78	69	77	81	118	112	94	93	84	**1,052**
	Blacktail Creek at Mouth in Section 12, T54N, R65W	210	209	205	198	175	197	206	301	284	240	237	213	**2,675**
	Beaver Creek at Mouth in Section 1, T55N, R64W	459	457	449	433	382	431	451	658	621	524	518	467	**5,850**
	East Creek at Mouth in Section 32, T55N, R63W	48	48	47	45	40	45	47	68	65	55	54	49	**611**
	Arnold Creek at Mouth in Section 28, T55N, R63W	22	22	22	21	18	21	22	32	30	25	25	23	**283**
	Horse Creek at Mouth in Section 19, T56N, R61W	76	75	74	71	63	71	74	108	102	86	85	77	**962**
	Pine Creek at Mouth in Section 33, T56N, R61W	172	171	168	162	143	161	169	247	233	197	194	175	**2,192**
	Kilpatrick Creek at Mouth in Section 3, T55N, R61W	69	69	68	65	58	65	68	99	94	79	78	70	**882**
	Kruger Creek at Mouth in Section 11, T55N, R61W	34	34	33	32	28	32	33	48	46	39	38	34	**431**
	Oak Creek at Mouth in Section 20, T55N, R60W	216	215	211	203	179	202	212	309	292	247	243	219	**2,748**
	South Redwater Creek Just Above Sand Creek in Section 31, T53N, R60W	565	563	553	533	470	530	555	810	765	646	637	575	**7,202**
	Redwater Creek Just Above South Redwater Creek in Section 31, T53N, R60W	287	286	281	271	239	269	282	411	388	328	324	292	**3,658**

Note: 1. Monthly and Annual Flows are averaged from the Wet, Dry, and Normal Estimated Flows.



Ungaged Natural Flow Estimate Locations

HKM ENGINEERING

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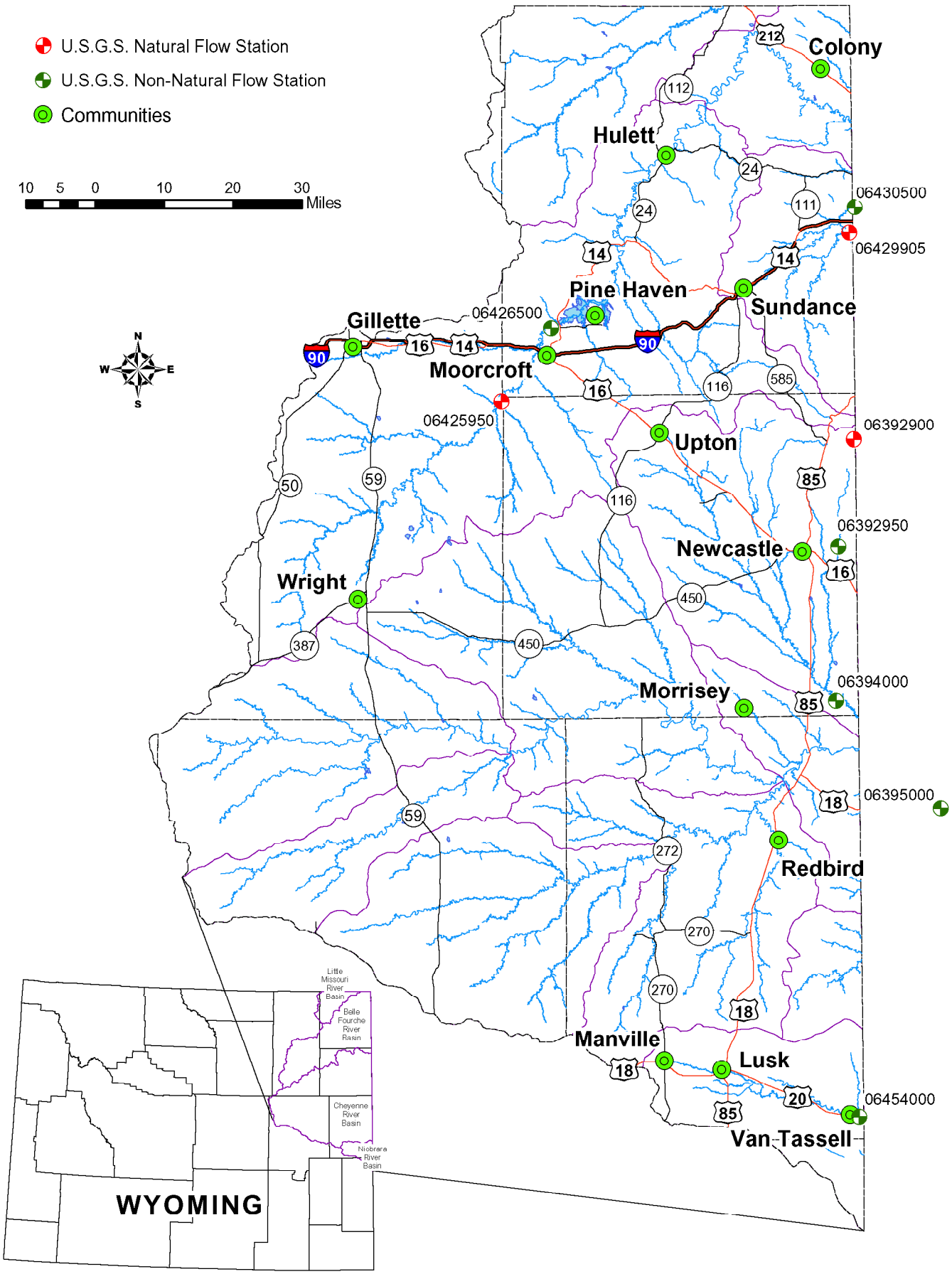
Figure 7



Indicator Gages for Selection of Dry, Normal, & Wet Years

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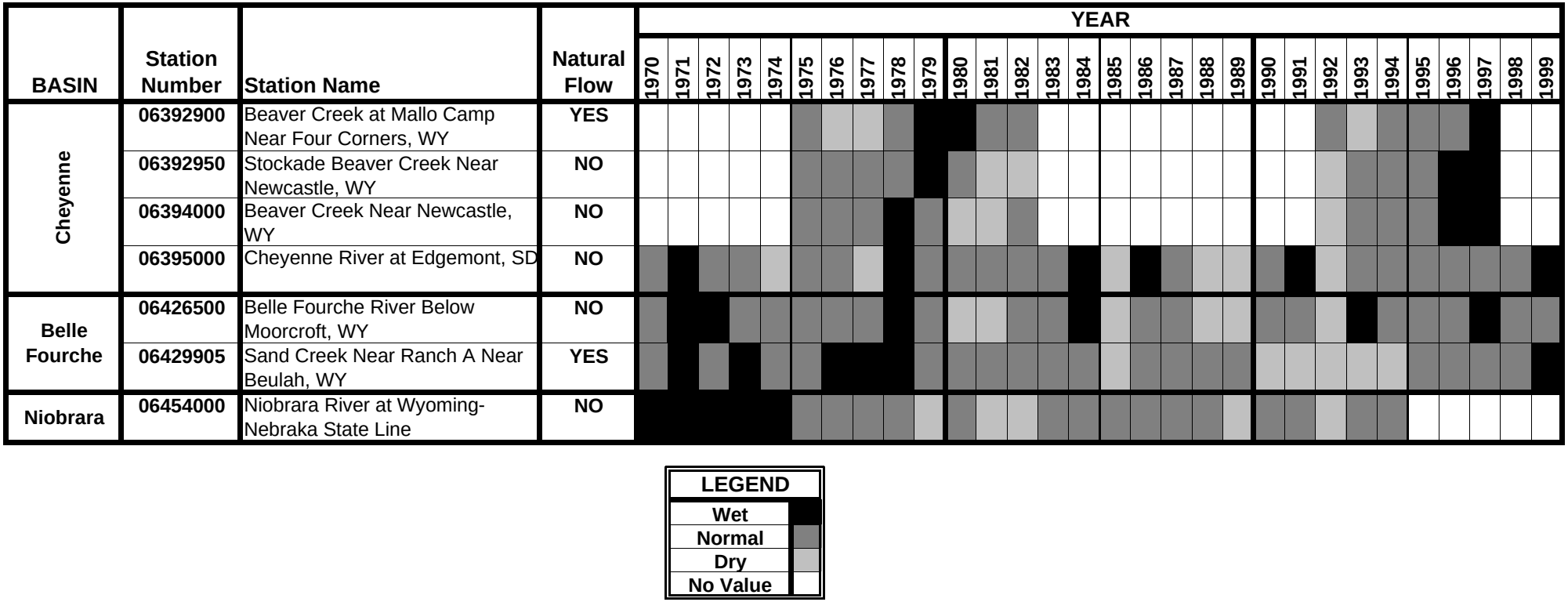
Figure 8

FIGURE 9

WET, DRY AND AVERAGE YEARS FOR INDICATOR STATIONS IN THE NORTHEAST WYOMING RIVER BASINS



LEGEND	
Wet	
Normal	
Dry	
No Value	

years, wet years, and normal years do not occur at all locations simultaneously). The dry, normal, and wet years selected to represent each drainage are, therefore unique to each geographic location. The years selected to represent dry, wet, and normal hydrologic conditions are summarized on Figure 10. According to the streamflow records for the Beaver Creek drainage, the hydrologic conditions vary significantly from location to location within the drainage. The wet years, dry years, and normal years for the Beaver Creek drainage are therefore, selected to best represent all locations concurrently.

The average monthly and annual streamflow for dry years, normal years, and wet years at the gaged model nodes are provided in Tables 8, 9, and 10 respectively.

The average monthly and annual streamflow for dry years, normal years, and wet years at the ungaged model nodes are provided in Tables 11, 12, and 13 respectively.

FIGURE 10
SELECTION OF WET, DRY, AND NORMAL YEARS FOR MODELING
INDICATOR STATIONS FOR THE NORTHEAST WYOMING RIVER BASINS

		Cheyenne River	
		Cheyenne River at Edgemont, SD	
Rank	Weibull Plotting Position	Year	06395000
1	3.23%	1988	8,725
2	6.45%	1992	9,408
3	9.68%	1985	12,831
4	12.90%	1989	17,079
5	16.13%	1977	19,855
6	19.35%	1974	20,970
7	22.58%	1970	22,264
8	25.81%	1990	22,894
9	29.03%	1976	27,407
10	32.26%	1981	27,855
11	35.48%	1975	28,202
12	38.71%	1972	30,052
13	41.94%	1980	32,972
14	45.16%	1983	39,746
15	48.39%	1995	43,391
16	51.61%	1994	45,633
17	54.84%	1996	52,131
18	58.06%	1998	54,230
19	61.29%	1973	57,980
20	64.52%	1979	61,675
21	67.74%	1982	62,767
22	70.97%	1987	64,260
23	74.19%	1993	68,156
24	77.42%	1997	69,180
25	80.65%	1986	73,186
26	83.87%	1984	74,519
27	87.10%	1999	104,860
28	90.32%	1991	132,999
29	93.55%	1971	153,235
30	96.77%	1978	223,740

		Belle Fourche	
		Belle Fourche River Below Moorcroft, WY	
Rank	Weibull Plotting Position	Year	06426500
1	3.23%	1985	2,434
2	6.45%	1980	3,712
3	9.68%	1988	4,576
4	12.90%	1981	4,646
5	16.13%	1992	4,994
6	19.35%	1989	6,739
7	22.58%	1976	7,543
8	25.81%	1973	7,583
9	29.03%	1977	7,876
10	32.26%	1990	8,601
11	35.48%	1974	9,163
12	38.71%	1970	10,842
13	41.94%	1998	11,136
14	45.16%	1983	11,590
15	48.39%	1991	12,248
16	51.61%	1986	14,496
17	54.84%	1979	15,391
18	58.06%	1975	16,936
19	61.29%	1996	20,135
20	64.52%	1982	20,283
21	67.74%	1994	23,223
22	70.97%	1999	23,556
23	74.19%	1995	24,721
24	77.42%	1987	25,747
25	80.65%	1997	26,752
26	83.87%	1984	27,498
27	87.10%	1971	40,434
28	90.32%	1993	41,836
29	93.55%	1972	44,264
30	96.77%	1978	98,331

		Redwater Creek	
		Sand Creek Near Ranch A Near Beulah, WY	
Rank	Weibull Plotting Position	Year	06429905
1	3.23%	1992	11,406
2	6.45%	1985	11,846
3	9.68%	1993	11,881
4	12.90%	1990	12,271
5	16.13%	1991	12,284
6	19.35%	1994	12,471
7	22.58%	1989	13,096
8	25.81%	1981	13,222
9	29.03%	1986	14,049
10	32.26%	1988	14,131
11	35.48%	1980	15,800
12	38.71%	1987	15,995
13	41.94%	1982	16,047
14	45.16%	1995	16,881
15	48.39%	1984	17,203
16	51.61%	1975	17,520
17	54.84%	1996	17,630
18	58.06%	1979	17,750
19	61.29%	1983	17,790
20	64.52%	1998	17,810
21	67.74%	1997	18,530
22	70.97%	1970	19,333
23	74.19%	1974	19,464
24	77.42%	1971	19,640
25	80.65%	1976	19,700
26	83.87%	1977	20,380
27	87.10%	1972	20,911
28	90.32%	1978	21,330
29	93.55%	1999	22,060
30	96.77%	1973	23,215

		Niobrara River	
		Niobrara River at Wyoming-Nebraka State Line	
Rank	Weibull Plotting Position	Year	06454000
1	3.85%	1982	1,549
2	7.69%	1992	1,725
3	11.54%	1989	1,751
4	15.38%	1979	1,760
5	19.23%	1981	1,794
6	23.08%	1976	1,860
7	26.92%	1990	1,882
8	30.77%	1978	1,897
9	34.62%	1975	1,917
10	38.46%	1985	1,963
11	42.31%	1984	2,054
12	46.15%	1988	2,078
13	50.00%	1983	2,120
14	53.85%	1994	2,165
15	57.69%	1980	2,434
16	61.54%	1986	2,491
17	65.38%	1987	2,503
18	69.23%	1991	2,556
19	73.08%	1977	2,606
20	76.92%	1993	2,625
21	80.77%	1970	2,859
22	84.62%	1971	3,069
23	88.46%	1973	3,173
24	92.31%	1972	3,283
25	96.15%	1974	4,081

LEGEND	
	WET
	DRY

		Beaver Creek					
		Beaver Creek at Mallo Camp Near Four Corners, WY		Stockade Beaver Creek Near Newcastle, WY		Beaver Creek Near Newcastle, WY	
Rank	Weibull Plotting Position	Year	06392900	Year	06392950	Year	06394000
1	6.67%	1977	682	1992	7,114	1992	6,889
2	13.33%	1993	834	1982	7,378	1980	7,085
3	20.00%	1976	957	1981	7,412	1981	9,954
4	26.67%	1992	1,066	1993	7,505	1977	12,102
5	33.33%	1994	1,261	1994	7,531	1995	14,005
6	40.00%	1995	1,392	1980	8,271	1979	14,393
7	46.67%	1996	1,423	1995	8,807	1982	19,917
8	53.33%	1978	1,466	1977	9,017	1976	20,510
9	60.00%	1981	1,476	1976	9,222	1993	25,031
10	66.67%	1975	1,479	1978	9,277	1975	28,898
11	73.33%	1982	1,548	1975	9,298	1994	29,359
12	80.00%	1997	1,667	1979	9,393	1996	37,581
13	86.67%	1980	1,789	1996	9,736	1997	40,220
14	93.33%	1979	1,874	1997	10,351	1978	41,784

SELECTION OF WET, DRY AND NORMAL YEARS					
Hydrologic Condition	Model Area				
	Beaver Creek	Cheyenne River	Belle Fourche River	Redwater Creek	Niobrara River
WET	1979, 1996, 1997	1971, 1978, 1984, 1986, 1991, 1999	1971, 1972, 1978, 1984, 1993, 1997	1972, 1973, 1976, 1977, 1978, 1999	1970, 1971, 1972, 1973, 1974
DRY	1977, 1992, 1993	1974, 1977, 1985, 1988, 1989, 1992	1980, 1981, 1985, 1988, 1989, 1992	1985, 1990, 1991, 1992, 1993, 1994	1979, 1981, 1982, 1989, 1992
NORMAL	All Other Yrs Between 1975 & 1982 and 1992 & 1997	All Other Yrs Between 1970 and 1999	All Other Yrs Between 1970 and 1999	All Other Yrs Between 1970 and 1999	All Other Yrs Between 1970 and 1994

TABLE 8
SUMMARY OF DRY YEAR MONTHLY AND ANNUAL FLOWS (1970 TO 1999 unless otherwise noted)
AT GAGED MODEL NODES

Basin	Station Number	Station Name	Natural Flow	AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET													Notes
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	
Cheyenne	06364700	Antelope Creek Near Teckla, WY	NO	22	24	9	18	38	161	69	39	8	153	27	130	**698**	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO	0	1	1	0	2	5	6	4	0	11	0	0	**30**	
	06365900	Cheyenne River Near Dull Center, WY	NO	33	13	14	30	73	324	128	114	82	447	217	103	**1,577**	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	0	0	0	0	0	3	0	3	1	10	1	0	**19**	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	122	9	0	60	9	70	114	169	176	308	145	92	**1,272**	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	0	0	0	0	0	5	4	26	11	4	4	0	**54**	
	06386000	Lance Creek Near Riverview, WY	NO	104	99	41	683	240	273	347	1,008	466	545	511	230	**4,547**	
	06386500	Cheyenne River Near Spencer, WY	NO	259	216	67	953	430	283	473	1,734	762	187	51	280	**5,695**	
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES	65	61	54	50	62	66	70	72	108	91	81	81	**861**	Study Period: 1975-1982, 1992-1997
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO	722	758	744	759	675	759	648	419	506	668	557	664	**7,879**	Study Period: 1975-1982, 1992-1997
	06394000	Beaver Creek Near Newcastle, WY	NO	363	762	740	741	756	3,202	1,906	1,411	1,744	1,459	1,187	404	**14,674**	Study Period: 1975-1982, 1992-1997
	06395000	Cheyenne River at Edgemont, SD	NO	743	893	430	632	1,264	4,005	1,571	1,081	664	1,148	511	1,871	**14,811**	
Belle Fourche	06425720	Belle Fourche River Below Rattlesnake Creek Near Piney, WY	NO	1	3	7	12	24	53	16	155	55	36	71	5	**438**	
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO	5	2	6	13	51	128	29	284	56	146	69	13	**802**	
	06425900	Caballo Creek at Mouth Near Piney, WY	NO	1	12	0	1	7	17	4	50	6	70	7	1	**175**	
	06425950	Raven Creek Near Moorcroft, WY	YES	0	0	0	0	7	3	0	1	0	0	8	0	**20**	
	06426400	Donkey Creek Near Moorcroft, WY	NO	4	12	23	17	31	156	29	186	15	3	3	3	**481**	
	06426500	Belle Fourche River Below Moorcroft, WY	NO	26	70	61	41	464	1,460	299	443	212	1,189	183	71	**4,517**	
	USBR Gage	Belle Fourche River - Total Keyhole Reservoir Discharge	NO	0	0	0	4	2	0	1,272	4,445	4,782	8,563	7,857	995	**27,919**	
	06427500	Belle Fourche River Below Keyhole Reservoir	NO	106	99	101	105	96	100	1,362	4,476	4,872	8,172	7,803	1,102	**28,394**	
	06428200	Belle Fourche River Near Alva, WY	NO	763	990	748	372	565	3,225	2,160	4,088	3,941	5,745	6,394	2,123	**31,114**	
	06428500	Belle Fourche River at Wyoming - South Dakota State	NO	870	1,170	863	409	640	4,244	3,332	5,742	4,923	7,172	6,845	2,458	**38,668**	
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES	927	1,071	1,063	1,036	906	987	1,028	1,085	996	982	968	979	**12,026**	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO	1,465	1,615	1,582	1,543	1,398	1,642	1,665	1,700	1,671	1,441	1,538	1,577	**18,836**	
Niobrara	06454000	Niobrara River at Wyoming-Nebraska State Line	NO	118	130	134	131	138	210	180	185	142	115	115	117	**1,716**	Study Period: 1970-1994

TABLE 9
SUMMARY OF NORMAL YEAR MONTHLY AND ANNUAL FLOWS (1970 TO 1999 unless otherwise noted)
AT GAGED MODEL NODES

Basin	Station Number	Station Name	Natural Flow	AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET													Notes
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	
Cheyenne	**06364700**	Antelope Creek Near Teckla, WY	NO	69	27	19	21	199	658	302	516	531	268	179	94	**2,882**	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO	2	5	5	2	14	30	16	93	20	14	8	0	**209**	
	06365900	Cheyenne River Near Dull Center, WY	NO	203	20	23	35	516	816	582	908	1,120	730	491	50	**5,494**	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	3	5	6	5	55	61	12	395	120	124	100	2	**890**	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	317	17	0	27	200	647	286	1,051	699	370	378	335	**4,326**	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	1	2	1	1	2	40	26	150	79	21	34	1	**358**	
	06386000	Lance Creek Near Riverview, WY	NO	115	110	93	201	1,040	956	754	2,998	2,471	2,988	2,280	802	**14,809**	
	06386500	Cheyenne River Near Spencer, WY	NO	186	159	48	695	1,196	748	1,534	14,793	6,889	1,938	511	3,325	**32,023**	
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES	114	102	106	95	95	113	142	154	141	129	122	111	**1,421**	Study Period: 1975-1982, 1992-1997
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO	723	713	762	723	694	827	746	600	642	628	658	686	**8,400**	Study Period: 1975-1982, 1992-1997
	06394000	Beaver Creek Near Newcastle, WY	NO	520	763	846	815	1,610	5,867	1,840	4,151	2,177	1,597	850	403	**21,439**	Study Period: 1975-1982, 1992-1997
	06395000	Cheyenne River at Edgemont, SD	NO	1,744	1,023	741	836	3,785	9,936	4,071	5,678	7,006	4,720	3,922	1,584	**45,044**	
Belle Fourche	**06425720**	Belle Fourche River Below Rattlesnake Creek Near Piney, WY	NO	7	6	11	24	86	179	61	449	246	93	150	22	**1,334**	
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO	21	6	14	48	203	484	130	690	292	174	179	68	**2,310**	
	06425900	Caballo Creek at Mouth Near Piney, WY	NO	13	7	1	11	27	183	30	487	58	81	40	13	**951**	
	06425950	Raven Creek Near Moorcroft, WY	YES	6	0	0	2	55	96	2	44	1	4	11	0	**223**	
	06426400	Donkey Creek Near Moorcroft, WY	NO	24	13	24	15	27	1,302	128	1,616	74	14	4	3	**3,245**	
	06426500	Belle Fourche River Below Moorcroft, WY	NO	846	276	205	494	1,513	3,406	2,128	2,920	1,675	804	418	376	**15,059**	
	USBR Gage	Belle Fourche River - Total Keyhole Reservoir Discharge	NO	191	533	0	0	0	8	629	380	1,340	4,723	4,080	623	**12,507**	
	06427500	Belle Fourche River Below Keyhole Reservoir	NO	359	371	108	107	98	186	557	374	1,233	4,867	4,192	695	**13,147**	
	06428200	Belle Fourche River Near Alva, WY	NO	2,083	1,922	1,197	1,347	2,606	6,675	7,476	9,812	6,582	4,667	4,803	1,918	**51,086**	
	06428500	Belle Fourche River at Wyoming - South Dakota State Line	NO	2,652	2,471	1,445	1,656	3,488	9,328	10,601	15,628	10,124	5,983	5,235	2,267	**70,878**	
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES	1,343	1,290	1,274	1,227	1,096	1,236	1,266	1,998	1,772	1,494	1,445	1,329	**16,772**	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO	2,143	2,068	2,038	1,996	1,976	2,280	2,386	4,025	3,077	2,135	2,167	2,096	**28,387**	
Niobrara	**06454000**	Niobrara River at Wyoming-Nebraska State Line	NO	149	144	148	142	157	299	275	257	214	147	172	105	**2,210**	Study Period: 1970-1994

TABLE 10
SUMMARY OF WET YEAR MONTHLY AND ANNUAL FLOWS (1970 TO 1999 unless otherwise noted)
AT GAGED MODEL NODES

Basin	Station Number	Station Name	Natural Flow	AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET													Notes
				OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL	
Cheyenne	06364700	Antelope Creek Near Teckla, WY	NO	258	217	28	28	162	588	482	6,013	3,421	848	176	52	**12,273**	
	06365300	Dry Fork Cheyenne River Near Bill, WY	NO	7	13	11	7	43	126	44	687	124	97	14	1	**1,174**	
	06365900	Cheyenne River Near Dull Center, WY	NO	237	434	46	46	414	1,221	1,289	14,535	7,795	1,635	436	77	**28,165**	
	06375600	Little Thunder Creek Near Hampshire, WY	NO	8	7	8	7	74	245	17	2,930	295	291	200	3	**4,084**	
	06376300	Black Thunder Creek Near Hampshire, WY	NO	464	20	0	115	752	2,218	569	5,615	1,081	1,324	748	1,391	**14,298**	
	06378300	Lodgepole Creek Near Hampshire, WY	NO	1	3	2	1	4	100	81	638	206	93	61	4	**1,193**	
	06386000	Lance Creek Near Riverview, WY	NO	215	128	97	379	990	2,883	1,898	17,967	5,708	5,456	3,037	835	**39,593**	
	06386500	Cheyenne River Near Spencer, WY	NO	559	474	144	2,078	3,418	1,800	5,123	54,135	25,000	4,514	1,091	7,012	**105,348**	
	06392900	Beaver Creek at Mallo Camp Near Four Corners, WY	YES	126	122	114	120	123	147	166	148	167	166	138	117	**1,655**	Study Period: 1975-1982, 1992-1997
	06392950	Stockade Beaver Creek Near Newcastle, WY	NO	789	770	771	780	739	1,075	918	787	689	760	884	865	**9,827**	Study Period: 1975-1982, 1992-1997
	06394000	Beaver Creek Near Newcastle, WY	NO	715	924	829	972	5,219	8,927	3,837	4,062	2,113	1,339	1,321	474	**30,731**	Study Period: 1975-1982, 1992-1997
	06395000	Cheyenne River at Edgemont, SD	NO	3,573	3,117	768	859	2,914	10,422	7,592	52,665	30,940	8,293	4,069	1,879	**127,090**	
Belle Fourche	06425720	Belle Fourche River Below Rattlesnake Creek Near Piney, WY	NO	9	9	17	34	115	470	130	1,926	386	189	224	30	**3,540**	
	06425780	Belle Fourche River Above Dry Creek Near Piney, WY	NO	39	10	22	70	290	1,476	237	3,132	477	531	290	130	**6,705**	
	06425900	Caballo Creek at Mouth Near Piney, WY	NO	26	18	1	17	47	538	55	2,429	204	182	100	51	**3,667**	
	06425950	Raven Creek Near Moorcroft, WY	YES	12	0	0	4	99	552	5	254	7	24	23	0	**979**	
	06426400	Donkey Creek Near Moorcroft, WY	NO	93	38	70	40	74	4,474	310	6,512	282	40	11	8	**11,952**	
	06426500	Belle Fourche River Below Moorcroft, WY	NO	850	118	70	577	3,802	11,643	4,656	16,641	5,432	1,384	1,138	208	**46,519**	
	USBR Gage	Belle Fourche River - Total Keyhole Reservoir Discharge	NO	0	0	0	0	0	4,378	759	5,162	3,206	1,374	2,531	943	**18,353**	
	06427500	Belle Fourche River Below Keyhole Reservoir	NO	105	90	91	93	87	4,416	766	5,372	3,239	1,391	2,620	979	**19,248**	
	06428200	Belle Fourche River Near Alva, WY	NO	2,121	1,487	977	2,462	3,715	15,275	12,966	17,333	13,942	4,878	4,102	2,114	**81,370**	
	06428500	Belle Fourche River at Wyoming - South Dakota State Line	NO	2,709	1,827	1,162	3,329	5,058	22,710	17,625	25,247	25,372	7,413	4,458	2,423	**119,333**	
	06429905	Sand Creek Near Ranch A Near Beulah, WY	YES	1,602	1,597	1,539	1,468	1,263	1,460	1,617	2,326	2,566	2,031	2,094	1,704	**21,266**	
	06430500	Redwater Creek at Wyoming-South Dakota State Line	NO	2,646	2,567	2,517	2,498	2,317	2,718	3,012	4,712	4,772	3,104	3,185	2,730	**36,778**	
Niobrara	06454000	Niobrara River at Wyoming-Nebraska State Line	NO	189	191	218	337	427	471	478	286	254	158	125	159	**3,293**	Study Period: 1970-1994

TABLE 11
SUMMARY OF DRY YEAR MONTHLY AND ANNUAL FLOWS
AT UNGAGED NATURAL FLOW NODES

Basin	Station Name	ESTIMATED AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET												
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Cheyenne	Willow Creek at Mouth in Section 28, T38N, R72W	1	0	0	0	7	22	0	10	0	1	2	0	**43**
	Woody Creek at Mouth in Section 5, T39N, R69W	0	0	0	0	1	3	0	1	0	0	0	0	**5**
	Lake Creek at Mouth in Section 30, T40N, R68W	0	0	0	0	2	7	0	3	0	0	1	0	**13**
	Sheep Creek at Mouth in Section 7, T40N, R67W	0	0	0	0	1	2	0	1	0	0	0	0	**4**
	Wagonhound Creek at Mouth in Section 31, T41N, R67W	0	0	0	0	1	4	0	2	0	0	0	0	**7**
	Snyder Creek at Mouth in Section 23, T40N, R64W	1	0	0	0	7	21	0	9	0	1	2	0	**41**
	Boggy Creek at Mouth in Section 32, T40N, R63W	0	0	0	0	2	6	0	3	0	0	0	0	**11**
	Sevenmile Creek at Mouth in Section 34, T40N, R63W	0	0	0	0	1	3	0	1	0	0	0	0	**5**
	Mule Creek at Mouth in Section 6, T39N, R61W	0	0	0	0	3	9	0	4	0	0	1	0	**17**
	Robbers' Roost Creek at Mouth in Section 23, T40N, R61W	0	0	0	0	4	13	0	6	0	1	1	0	**25**
	Beaver Creek Just Below Mush Creek in Section 32, T44N, R62W	1	0	0	0	39	16	0	7	0	1	44	0	**108**
	Oil Creek at Mouth in Section 26, T43N, R62W	201	0	0	63	1,739	5,441	84	2,507	73	235	414	0	**10,757**
	Blacktail Creek at Mouth in Section 2, T41N, R61W	182	177	181	181	162	174	183	218	207	198	186	181	**2,230**
	Dry Beaver Creek Just Above Beaver Creek in Section 4, T47N, R60W	65	62	54	51	62	67	71	73	109	92	81	82	**869**
Belle Fourche	Dry Creek at Mouth in Section 29, T47N, R70W	0	0	0	0	2	1	0	0	0	0	2	0	**5**
	Yellow Hammer Creek at Mouth in Section 10, T47N, R70W	0	0	0	0	1	0	0	0	0	0	1	0	**2**
	Whitetail Creek at Mouth in Section 32, T48N, R69W	0	0	0	0	1	0	0	0	0	0	1	0	**2**
	Four Horse Creek at Mouth in Section 11, T48N, R69W	0	0	0	0	10	4	0	2	0	0	11	0	**27**
	Timber Creek at Mouth in Section 2, T48N, R69W	0	0	0	0	3	1	0	0	0	0	3	0	**7**
	Buffalo Creek at Mouth in Section 14, T49N, R68W	0	0	0	0	12	5	0	2	0	0	14	0	**33**
	Donkey Creek Just Upstream of Gage in Sec. 30, T50N, R68W	0	0	0	902	1,400	1,658	1,367	1,176	676	0	0	0	**7,179**
	Trail Creek at Mouth in Section 24, T50N, R68W	0	0	0	0	1	1	0	0	0	0	2	0	**4**
	Dry Creek at Mouth in Section 24, T50N, R68W	0	0	0	0	2	1	0	0	0	0	2	0	**5**
	Robinson Creek at Mouth in Section 18, T50N, R67W	0	0	0	0	1	0	0	0	0	0	1	0	**2**
	Duck Creek at Mouth in Section 8, T50N, R67W	1	0	0	0	47	18	0	8	0	1	36	0	**111**
	Miller Creek at Mouth in Section 9, T50N, R67W	7	0	0	2	532	200	3	91	3	9	409	0	**1,256**
	Smoke Creek at Mouth in Section 9, T50N, R67W	0	0	0	0	14	5	0	2	0	0	11	0	**32**
	Berger Creek at Mouth in Section 12, T50N, R67W	0	0	0	0	22	8	0	4	0	0	17	0	**51**
	Lone Tree Creek at Mouth in Section 26, T51N, R67W	1	0	0	0	49	18	0	8	0	1	38	0	**115**
	Wind Creek at Mouth in Section 13, T50N, R67W	17	0	0	5	1,218	458	7	208	6	21	935	0	**2,875**
	Deer Creek at Mouth in Section 23, T51N, R67W	4	0	0	1	257	97	1	44	1	5	198	0	**608**
	Eggie Creek at Mouth in Section 21, T51N, R66W	0	0	0	0	36	13	0	6	0	1	27	0	**83**
	Mule Creek at Mouth in Section 15, T50N, R66W	2	0	0	1	156	59	1	27	1	3	120	0	**370**
	Cottonwood Creek at Mouth in Section 35, T51N, R66W	1	0	0	0	41	16	0	7	0	1	32	0	**98**
	Arch Creek at Mouth in Section 11, T51N, R66W	0	0	0	0	8	3	0	2	0	0	9	0	**22**
	Inyan Kara Creek at Mouth in Section 25, T52N, R66W	919	1,051	1,068	1,017	884	960	963	1,061	939	894	896	943	**11,595**
	Cabin Creek at Mouth in Section 14, T52N, R66W	0	0	0	0	6	2	0	1	0	0	7	0	**16**
	Miller Creek at Mouth in Section 12, T52N, R66W	0	0	0	0	5	2	0	1	0	0	6	0	**14**
	Lytle Creek at Mouth in Section 8, T53N, R65W	0	0	0	0	4	1	0	1	0	0	4	0	**10**
	Whitetail Creek at Mouth in Section 14, T54N, R65W	66	76	77	73	63	69	69	76	68	64	64	68	**833**
	Blacktail Creek at Mouth in Section 12, T54N, R65W	168	193	196	186	160	175	176	194	172	164	162	173	**2,119**
	Beaver Creek at Mouth in Section 1, T55N, R64W	368	421	428	407	350	383	386	424	376	358	354	378	**4,633**
	East Creek at Mouth in Section 32, T55N, R63W	38	44	45	42	36	40	40	44	39	37	37	39	**481**
	Arnold Creek at Mouth in Section 28, T55N, R63W	18	20	21	20	17	19	19	21	18	17	17	18	**225**
	Horse Creek at Mouth in Section 19, T56N, R61W	61	69	71	67	58	63	64	70	62	59	58	62	**764**
	Pine Creek at Mouth in Section 33, T56N, R61W	138	158	160	153	131	143	145	159	141	134	133	142	**1,737**
	Kilpatrick Creek at Mouth in Section 3, T55N, R61W	56	64	65	61	53	58	58	64	57	54	54	57	**701**
	Kruger Creek at Mouth in Section 11, T55N, R61W	27	31	31	30	26	28	28	31	28	26	26	28	**340**
	Oak Creek at Mouth in Section 20, T55N, R60W	173	198	201	191	165	180	181	199	177	168	167	178	**2,178**
	South Redwater Creek Just Above Sand Creek in Section 31, T53N, R60W	399	461	458	446	390	425	443	467	429	423	417	422	**5,180**
	Redwater Creek Just Above South Redwater Creek in Section 31, T53N, R60W	203	234	232	227	198	216	225	237	218	215	212	214	**2,631**

TABLE 12
SUMMARY OF NORMAL YEAR MONTHLY AND ANNUAL FLOWS
AT UNGAGED NATURAL FLOW NODES

Basin	Station Name	ESTIMATED AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET												
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Cheyenne	Willow Creek at Mouth in Section 28, T38N, R72W	11	0	0	4	97	188	4	87	3	8	23	0	**425**
	Woody Creek at Mouth in Section 5, T39N, R69W	1	0	0	0	13	25	1	11	0	1	3	0	**55**
	Lake Creek at Mouth in Section 30, T40N, R68W	3	0	0	1	29	57	1	26	1	2	7	0	**127**
	Sheep Creek at Mouth in Section 7, T40N, R67W	1	0	0	0	9	18	0	8	0	1	2	0	**39**
	Wagonhound Creek at Mouth in Section 31, T41N, R67W	2	0	0	1	20	38	1	18	1	2	5	0	**88**
	Snyder Creek at Mouth in Section 23, T40N, R64W	10	0	0	3	91	177	4	82	2	8	22	0	**399**
	Boggy Creek at Mouth in Section 32, T40N, R63W	3	0	0	1	25	48	1	22	1	2	6	0	**109**
	Sevenmile Creek at Mouth in Section 34, T40N, R63W	1	0	0	0	12	24	1	11	0	1	3	0	**53**
	Mule Creek at Mouth in Section 6, T39N, R61W	4	0	0	1	39	76	2	35	1	3	9	0	**170**
	Robbers' Roost Creek at Mouth in Section 23, T40N, R61W	6	0	0	2	55	108	2	50	1	5	13	0	**242**
	Beaver Creek Just Below Mush Creek in Section 32, T44N, R62W	35	0	0	11	299	526	14	243	7	23	60	0	**1,218**
	Oil Creek at Mouth in Section 26, T43N, R62W	402	0	0	49	5,048	5,977	70	2,767	83	261	1,971	0	**16,628**
	Blacktail Creek at Mouth in Section 2, T41N, R61W	199	196	190	180	156	179	187	324	274	244	218	200	**2,547**
	Dry Beaver Creek Just Above Beaver Creek in Section 4, T47N, R60W	115	103	107	96	96	114	143	155	142	130	124	112	**1,437**
Belle Fourche	Dry Creek at Mouth in Section 29, T47N, R70W	2	0	0	1	14	25	1	11	0	1	3	0	**58**
	Yellow Hammer Creek at Mouth in Section 10, T47N, R70W	1	0	0	0	5	9	0	4	0	0	1	0	**20**
	Whitetail Creek at Mouth in Section 32, T48N, R69W	1	0	0	0	8	14	0	6	0	1	2	0	**32**
	Four Horse Creek at Mouth in Section 11, T48N, R69W	9	0	0	3	74	130	3	60	2	6	15	0	**302**
	Timber Creek at Mouth in Section 2, T48N, R69W	2	0	0	1	19	34	1	16	0	1	4	0	**78**
	Buffalo Creek at Mouth in Section 14, T49N, R68W	11	0	0	4	94	165	4	76	2	7	19	0	**382**
	Donkey Creek Just Upstream of Gage in Sec. 30, T50N, R68W	0	0	0	235	1,126	2,518	1,451	2,883	886	0	0	0	**9,100**
	Trail Creek at Mouth in Section 24, T50N, R68W	1	0	0	0	10	18	0	9	0	1	2	0	**41**
	Dry Creek at Mouth in Section 24, T50N, R68W	2	0	0	1	15	26	1	12	0	1	3	0	**61**
	Robinson Creek at Mouth in Section 18, T50N, R67W	1	0	0	0	4	8	0	4	0	0	1	0	**18**
	Duck Creek at Mouth in Section 8, T50N, R67W	6	0	0	5	60	116	5	53	2	5	21	0	**273**
	Miller Creek at Mouth in Section 9, T50N, R67W	68	0	0	55	689	1,322	58	607	18	57	236	0	**3,110**
	Smoke Creek at Mouth in Section 9, T50N, R67W	2	0	0	1	18	34	1	16	0	1	6	0	**79**
	Berger Creek at Mouth in Section 12, T50N, R67W	3	0	0	2	29	56	2	26	1	2	10	0	**131**
	Lone Tree Creek at Mouth in Section 26, T51N, R67W	6	0	0	5	63	121	5	56	2	5	22	0	**285**
	Wind Creek at Mouth in Section 13, T50N, R67W	156	0	0	126	1,578	3,025	133	1,389	41	130	540	0	**7,118**
	Deer Creek at Mouth in Section 23, T51N, R67W	33	0	0	27	333	639	28	293	9	27	114	0	**1,503**
	Eggie Creek at Mouth in Section 21, T51N, R66W	5	0	0	4	46	88	4	41	1	4	16	0	**209**
	Mule Creek at Mouth in Section 15, T50N, R66W	20	0	0	16	202	387	17	178	5	17	69	0	**911**
	Cottonwood Creek at Mouth in Section 35, T51N, R66W	5	0	0	4	54	103	5	47	1	4	18	0	**241**
	Arch Creek at Mouth in Section 11, T51N, R66W	8	0	0	2	63	111	3	51	2	5	13	0	**258**
	Inyan Kara Creek at Mouth in Section 25, T52N, R66W	1,199	1,143	1,138	1,116	1,037	1,231	1,146	1,820	1,641	1,397	1,401	1,207	**15,476**
	Cabin Creek at Mouth in Section 14, T52N, R66W	6	0	0	2	48	84	2	39	1	4	10	0	**196**
	Miller Creek at Mouth in Section 12, T52N, R66W	5	0	0	1	40	70	2	32	1	3	8	0	**162**
	Lytle Creek at Mouth in Section 8, T53N, R65W	3	0	0	1	27	48	1	22	1	2	5	0	**110**
	Whitetail Creek at Mouth in Section 14, T54N, R65W	86	82	82	80	69	79	82	127	118	100	100	87	**1,092**
	Blacktail Creek at Mouth in Section 12, T54N, R65W	218	209	208	204	176	201	209	322	300	255	254	221	**2,777**
	Beaver Creek at Mouth in Section 1, T55N, R64W	477	458	456	446	385	439	458	704	657	557	555	483	**6,075**
	East Creek at Mouth in Section 32, T55N, R63W	50	48	47	46	40	46	48	73	68	58	58	50	**632**
	Arnold Creek at Mouth in Section 28, T55N, R63W	23	22	22	22	19	21	22	34	32	27	27	23	**294**
	Horse Creek at Mouth in Section 19, T56N, R61W	79	76	75	74	63	72	75	116	108	92	92	80	**1,002**
	Pine Creek at Mouth in Section 33, T56N, R61W	179	172	171	167	144	165	172	264	246	209	208	181	**2,278**
	Kilpatrick Creek at Mouth in Section 3, T55N, R61W	72	69	69	67	58	66	69	106	99	84	84	73	**916**
	Kruger Creek at Mouth in Section 11, T55N, R61W	35	34	33	33	28	32	34	52	48	41	41	36	**447**
	Oak Creek at Mouth in Section 20, T55N, R60W	224	215	214	210	181	207	215	331	309	262	261	227	**2,856**
	South Redwater Creek Just Above Sand Creek in Section 31, T53N, R60W	579	556	549	529	472	533	545	860	763	644	623	572	**7,225**
	Redwater Creek Just Above South Redwater Creek in Section 31, T53N, R60W	294	282	279	268	240	270	277	437	388	327	316	291	**3,669**

TABLE 13
SUMMARY OF WET YEAR MONTHLY AND ANNUAL FLOWS
AT UNGAGED NATURAL FLOW NODES

Basin	Station Name	ESTIMATED AVERAGE STREAMFLOW FOR 1970-1999 IN ACRE-FEET												
		OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	ANNUAL
Cheyenne	Willow Creek at Mouth in Section 28, T38N, R72W	10	0	0	3	83	601	5	276	8	26	20	0	**1,032**
	Woody Creek at Mouth in Section 5, T39N, R69W	1	0	0	0	11	79	1	36	1	3	3	0	**135**
	Lake Creek at Mouth in Section 30, T40N, R68W	3	0	0	1	25	182	2	84	2	8	6	0	**313**
	Sheep Creek at Mouth in Section 7, T40N, R67W	1	0	0	0	8	58	0	27	1	2	2	0	**99**
	Wagonhound Creek at Mouth in Section 31, T41N, R67W	2	0	0	1	17	121	1	56	2	5	4	0	**209**
	Snyder Creek at Mouth in Section 23, T40N, R64W	9	0	0	3	77	563	5	259	7	24	18	0	**965**
	Boggy Creek at Mouth in Section 32, T40N, R63W	3	0	0	1	21	154	1	71	2	7	5	0	**265**
	Sevenmile Creek at Mouth in Section 34, T40N, R63W	1	0	0	0	10	75	1	35	1	3	2	0	**128**
	Mule Creek at Mouth in Section 6, T39N, R61W	4	0	0	1	33	242	2	111	3	10	8	0	**414**
	Robbers' Roost Creek at Mouth in Section 23, T40N, R61W	6	0	0	2	47	343	3	158	5	15	11	0	**590**
	Beaver Creek Just Below Mush Creek in Section 32, T44N, R62W	63	0	0	20	539	3,018	30	1,388	40	130	128	0	**5,356**
	Oil Creek at Mouth in Section 26, T43N, R62W	225	0	0	71	1,950	6,374	1,364	2,810	82	263	4,838	0	**17,977**
	Blacktail Creek at Mouth in Section 2, T41N, R61W	220	211	211	204	182	226	210	283	282	272	239	211	**2,751**
	Dry Beaver Creek Just Above Beaver Creek in Section 4, T47N, R60W	127	124	115	122	125	148	168	149	169	168	139	118	**1,672**
Belle Fourche	Dry Creek at Mouth in Section 29, T47N, R70W	3	0	0	1	25	142	1	65	2	6	6	0	**251**
	Yellow Hammer Creek at Mouth in Section 10, T47N, R70W	1	0	0	0	9	53	1	24	1	2	2	0	**93**
	Whitetail Creek at Mouth in Section 32, T48N, R69W	2	0	0	1	14	78	1	36	1	3	3	0	**139**
	Four Horse Creek at Mouth in Section 11, T48N, R69W	16	0	0	5	133	746	7	343	10	32	32	0	**1,324**
	Timber Creek at Mouth in Section 2, T48N, R69W	4	0	0	1	35	195	2	90	3	8	8	0	**346**
	Buffalo Creek at Mouth in Section 14, T49N, R68W	20	0	0	6	169	947	9	436	13	41	40	0	**1,681**
	Donkey Creek Just Upstream of Gage in Sec. 30, T50N, R68W	0	0	0	102	879	5,657	1,848	7,956	1,275	0	0	0	**17,717**
	Trail Creek at Mouth in Section 24, T50N, R68W	2	0	0	1	19	106	1	49	1	5	5	0	**189**
	Dry Creek at Mouth in Section 24, T50N, R68W	3	0	0	1	26	148	1	68	2	6	6	0	**261**
	Robinson Creek at Mouth in Section 18, T50N, R67W	1	0	0	0	8	45	0	21	1	2	2	0	**80**
	Duck Creek at Mouth in Section 8, T50N, R67W	4	0	0	1	37	153	2	71	2	7	9	0	**286**
	Miller Creek at Mouth in Section 9, T50N, R67W	49	0	0	15	425	1,750	22	805	23	75	101	0	**3,265**
	Smoke Creek at Mouth in Section 9, T50N, R67W	1	0	0	0	11	45	1	21	1	2	3	0	**85**
	Berger Creek at Mouth in Section 12, T50N, R67W	2	0	0	1	18	74	1	34	1	3	4	0	**138**
	Lone Tree Creek at Mouth in Section 26, T51N, R67W	5	0	0	1	39	161	2	74	2	7	9	0	**300**
	Wind Creek at Mouth in Section 13, T50N, R67W	113	0	0	35	973	4,004	50	1,843	53	173	232	0	**7,476**
	Deer Creek at Mouth in Section 23, T51N, R67W	24	0	0	7	206	846	11	389	11	36	49	0	**1,579**
	Eggie Creek at Mouth in Section 21, T51N, R66W	3	0	0	1	28	117	1	54	2	5	7	0	**218**
	Mule Creek at Mouth in Section 15, T50N, R66W	14	0	0	5	125	512	6	236	7	22	30	0	**957**
	Cottonwood Creek at Mouth in Section 35, T51N, R66W	4	0	0	1	33	136	2	63	2	6	8	0	**255**
	Arch Creek at Mouth in Section 11, T51N, R66W	13	0	0	4	114	639	6	294	8	28	27	0	**1,133**
	Inyan Kara Creek at Mouth in Section 25, T52N, R66W	1,255	1,227	1,126	1,049	1,145	1,900	1,242	2,233	1,905	1,511	1,448	1,259	**17,300**
	Cabin Creek at Mouth in Section 14, T52N, R66W	10	0	0	3	86	483	5	222	6	21	21	0	**857**
	Miller Creek at Mouth in Section 12, T52N, R66W	8	0	0	3	71	399	4	184	5	17	17	0	**708**
	Lytle Creek at Mouth in Section 8, T53N, R65W	6	0	0	2	49	276	3	127	4	12	12	0	**491**
	Whitetail Creek at Mouth in Section 14, T54N, R65W	89	88	81	75	73	81	89	135	137	107	102	91	**1,148**
	Blacktail Creek at Mouth in Section 12, T54N, R65W	227	225	206	191	185	207	226	344	347	271	259	231	**2,919**
	Beaver Creek at Mouth in Section 1, T55N, R64W	496	491	451	418	404	452	495	753	759	592	567	505	**6,383**
	East Creek at Mouth in Section 32, T55N, R63W	52	51	47	44	42	47	51	78	79	62	59	53	**665**
	Arnold Creek at Mouth in Section 28, T55N, R63W	24	24	22	20	20	22	24	36	37	29	27	24	**309**
	Horse Creek at Mouth in Section 19, T56N, R61W	82	81	74	69	67	75	82	124	125	98	94	83	**1,054**
	Pine Creek at Mouth in Section 33, T56N, R61W	186	184	169	157	151	169	185	282	285	222	213	189	**2,392**
	Kilpatrick Creek at Mouth in Section 3, T55N, R61W	75	74	68	63	61	68	75	114	115	89	86	76	**964**
	Kruger Creek at Mouth in Section 11, T55N, R61W	36	36	33	31	30	33	36	55	56	43	42	37	**468**
	Oak Creek at Mouth in Section 20, T55N, R60W	233	231	212	197	190	213	232	354	357	278	267	237	**3,001**
	South Redwater Creek Just Above Sand Creek in Section 31, T53N, R60W	690	688	663	632	544	629	697	1,002	1,105	875	902	734	**9,161**
	Redwater Creek Just Above South Redwater Creek in Section 31, T53N, R60W	350	349	337	321	276	319	354	509	561	444	458	373	**4,651**

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