HyMet Streamflow Forecasting Model for the Pend Oreille River above Albeni Falls, Idaho

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Introduction

A new seasonal forecasting model has been developed to forecast natural inflow at Albeni Falls on the Pend Oreille River. Future plans include calibrating the forecasting model to forecast natural flow at Box Canyon and Boundary Dam. The Albeni model is a new addition to the Columbia River forecasting system that has been in operation since the 1999-2001 season (a detailed description of the Columbia model can be viewed at: www.hymet.com).

Input to the Albeni Falls model are daily precipitation and temperature observations collected at cooperative weather stations located in or near the basin, plus the natural inflow at the site. Figure 1 is a topographic map of the 24, 200 mi^2 (62,678 km^2) area basin, constructed from a 1 kilometer resolution DEM. The twenty-five weather stations that provide the daily

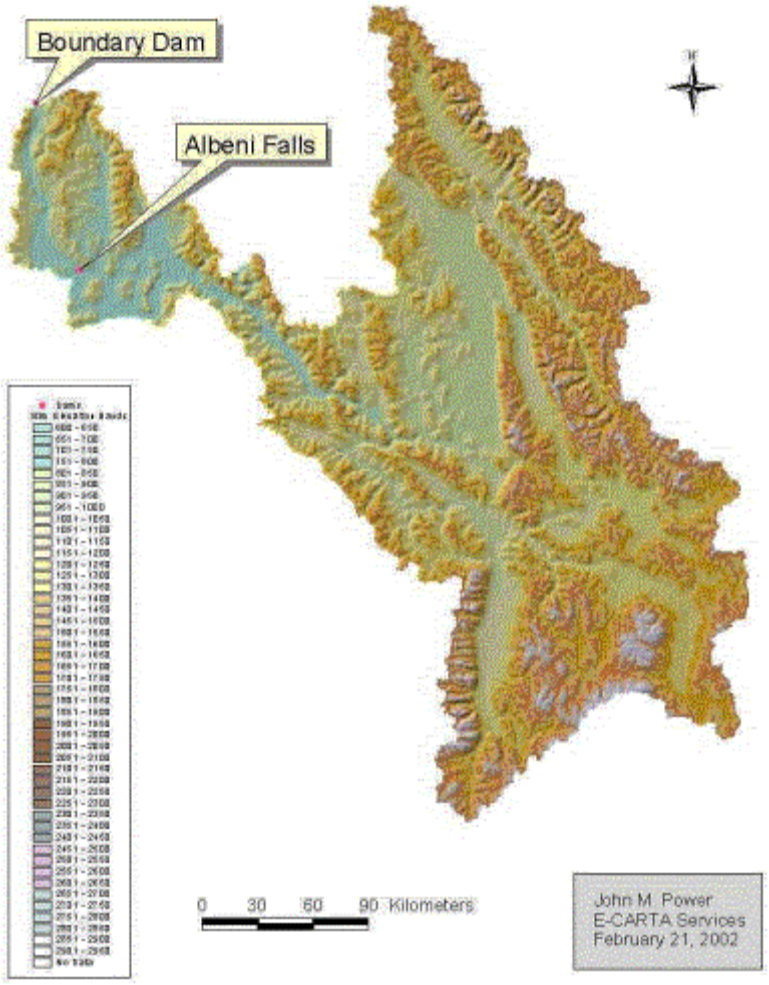

Figure 1. Topographic map of the Pend Oreille River basin.

weather observations are the same set used in the Columbia model but have a different distribution of weights. As with the Columbia model, precipitation station selection is based on split-sample testing of all twenty-five stations for the 1969-2001 period to determine which stations have the highest probability of producing the lowest forecast errors in the future. Consequently, some stations within the drainage divides have lower weights than others outside the basin. Two temperature stations, one high and one low-elevation to allow determination of the temperature lapse-rate, are selected by a similar technique. The distribution of watershed area as a function of elevation is also required for

optimum forecast accuracy. Figure 2 is a histogram of area for each of the 46 altitude increments, each of which spans 165 foot (50 m) of altitude. The record of reconstructed natural daily flow at Albeni Falls, required for model development and for operational forecasting, begins in 1969, and is calculated by the Bonneville Power Administration.

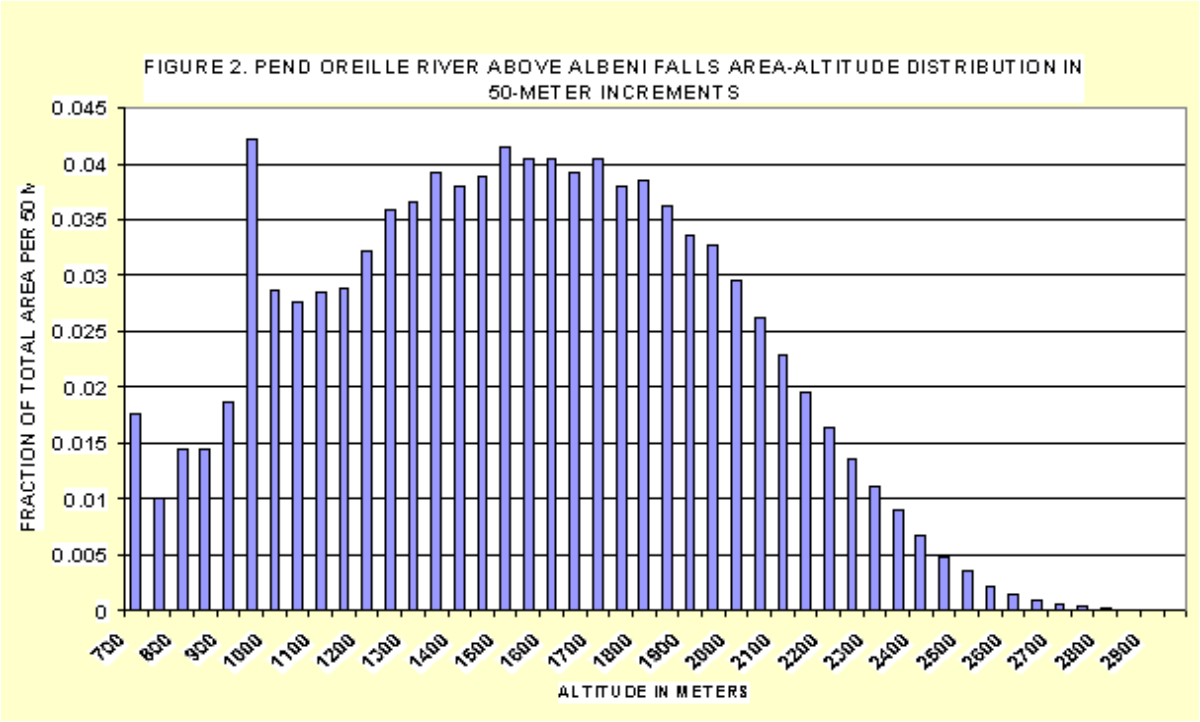

Figure 2

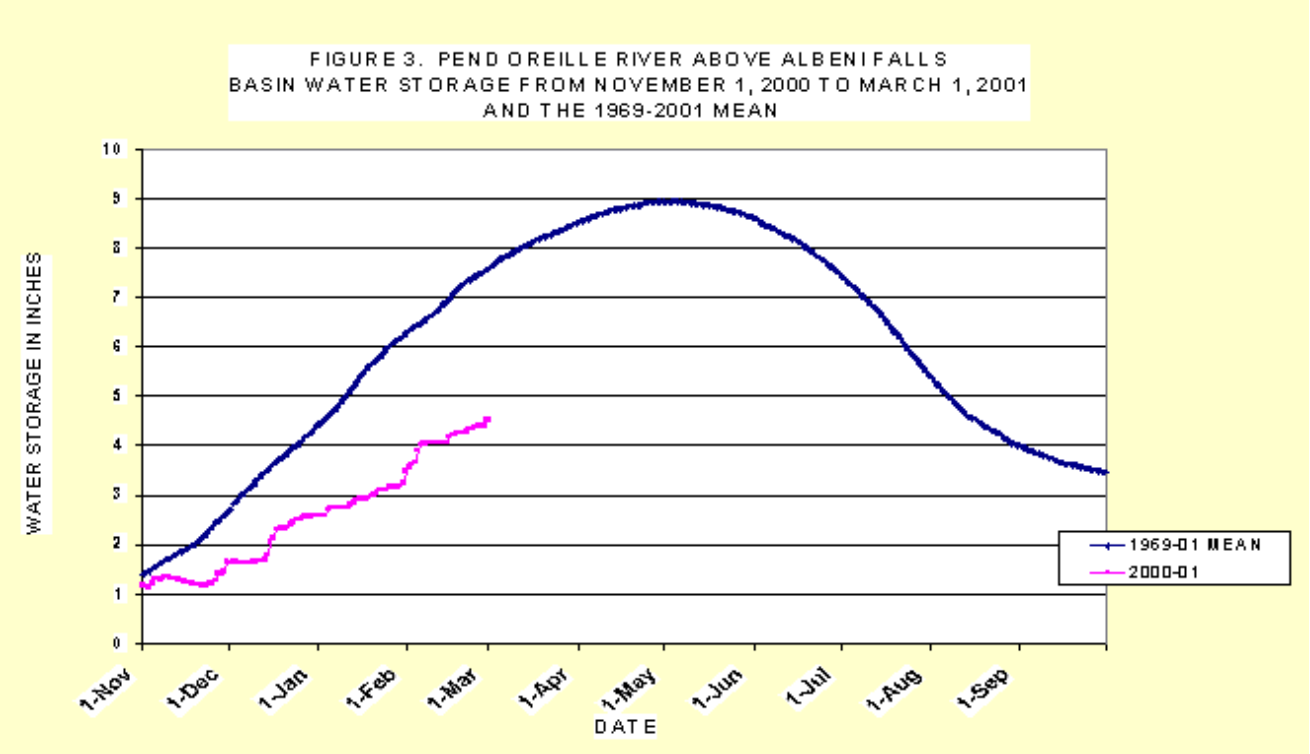

Figure 3

Model Structure

The model's computer program, written in Fortran 77, applies a set of algorithms that convert daily meteorological observations to such hydrologic variables as snow accumulation and melt, soil moisture, evapo-transpiration, groundwater inflow, outflow and storage. The seasonal forecast is based on the amount of water, both in the snowpack and as groundwater, which is stored in the basin on the day the forecast is made.The distribution of the snowpack as a function of elevation, which determines the time distribution of runoff as a forecast hydrograph, is calculated for each of the 46 altitude intervals. The basin water storage (the snowpack plus groundwater) averaged daily for the 1969-2001 period is shown in Figure 3. Also shown is the basin water storage for the 2000-2001 season, up to March 1, 2001. The distribution of the snowpack's water content versus elevation is demonstrated in Figure 4. Both the 1969-2001 mean and the snowpack on March 1, 2001 are shown, along with the elevation distribution of the percent of normal for the current snowpack.

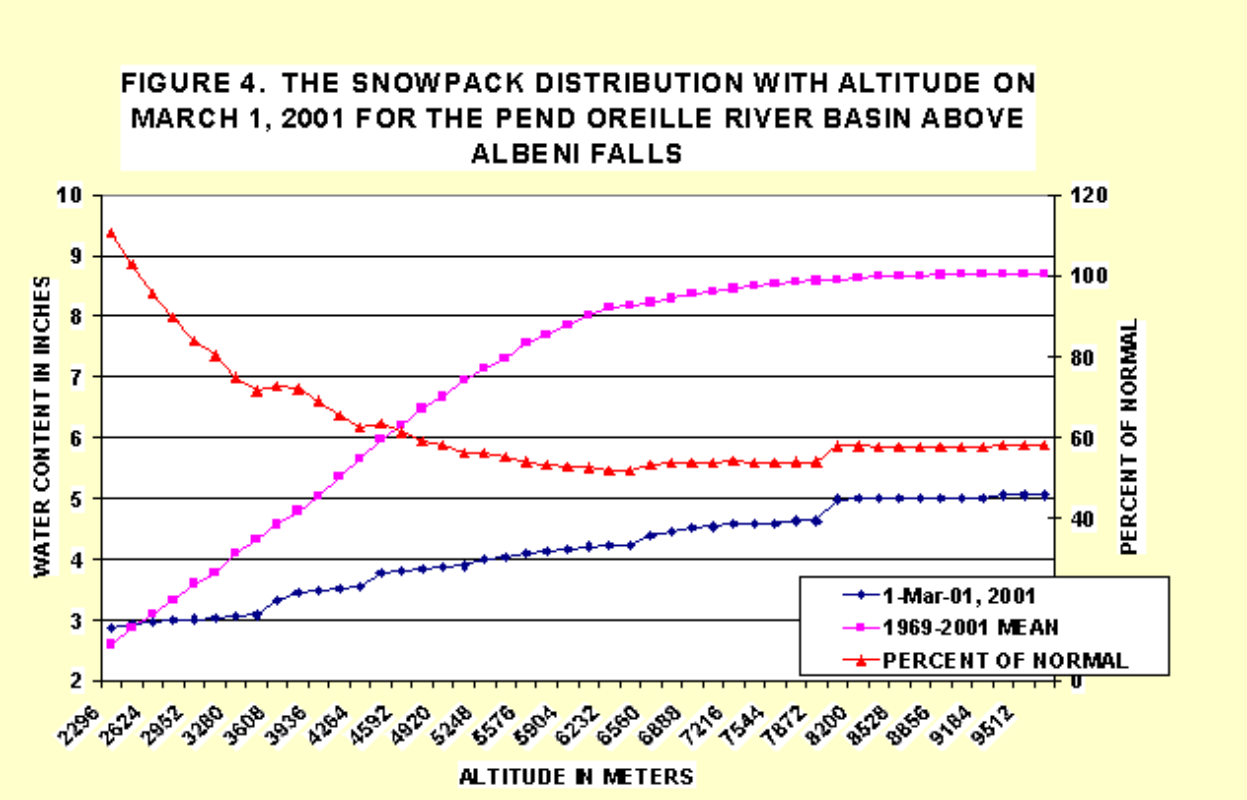

Figure 4

Forecast Accuracy

The expected forecast accuracy of the model, based on retrospective forecasts made each day from November 1 to July 1, for the 1969-2001 period, is shown in Figure 5. The R^2, a measure of model accuracy compared to using the historical mean runoff as a forecast, reaches nearly 0.90 by late February and remains at this value until the end of May. The mean error fraction, which is the root mean error divided by the average runoff for the forecast season, reaches a minimum of about 0.12 by late February. This forecast error is greater than HyMet's forecasts for the Columbia River at Grand Coulee, which has a minimum root mean error of about 0.065 in the early spring. The difference is likely because the Pend Oreille snowpack is a smaller component of seasonal runoff.

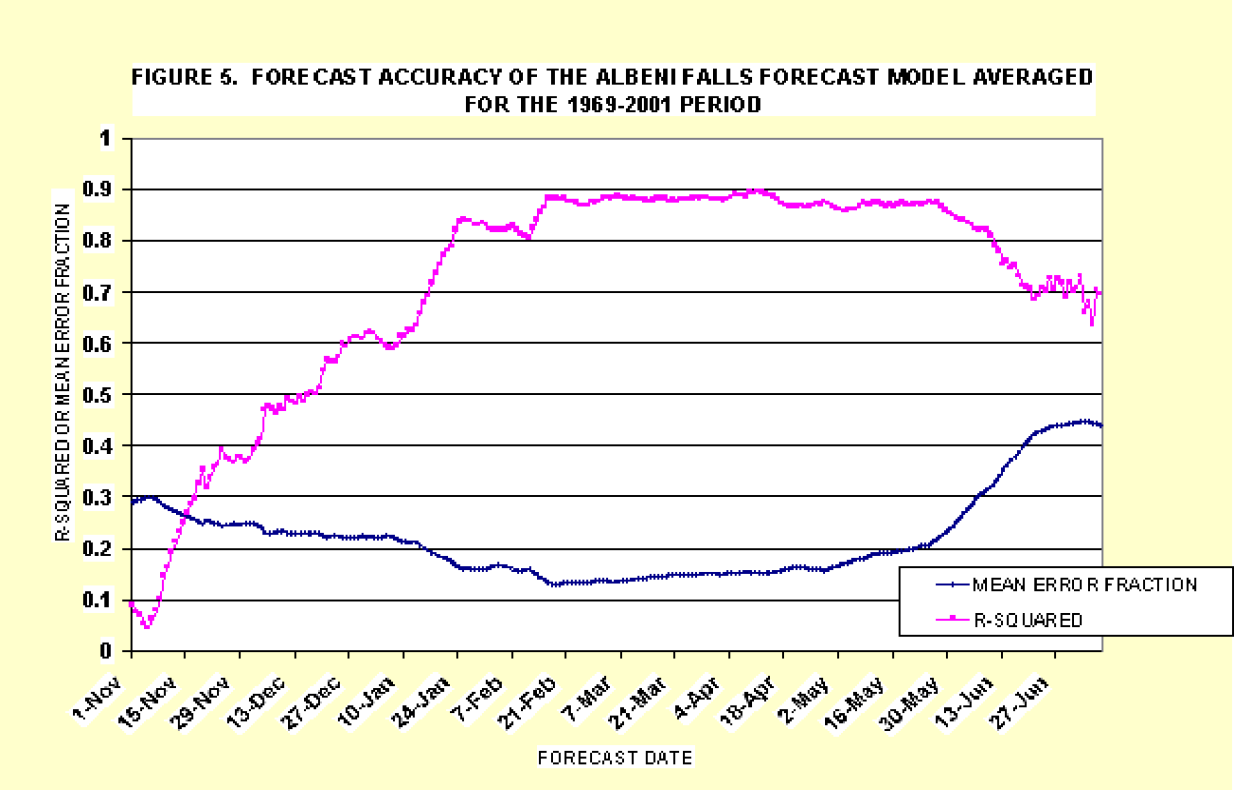

Figure 5

Hydrograph Forecast

The amount and altitude distribution of the snowpack determines the time-distribution of runoff. A low-elevation snowpack will melt rapidly early in the season and a heavy snowpack located at higher elevations will tend to produce high flows later in the season. By comparing the current year's snowpack with those of previous years, the time-distribution of runoff during the forecast season can be estimated. A forecast hydrograph for the March 1-July 31 2001 season is shown in Figure 6. The 2001 runoff season was one of the lowest on record and mean daily flows during the March-June period were a historic minimum, but were predicted with fair accuracy on March 1.

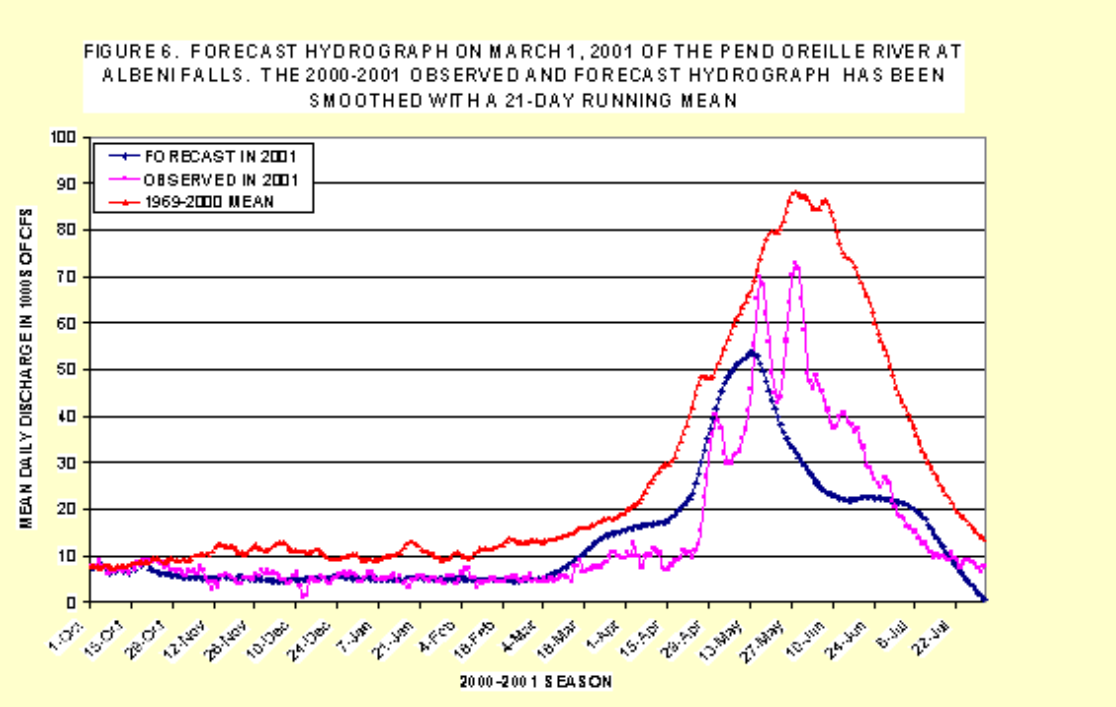

Figure 6

Forecast Example

A history of the forecasts that were made daily from November 1 through March 1, 2001 are shown graphically in Figure 7 as percent of normal inflow for seasons ending July 31.

An example of a real-time weekly forecast, made on March 1, 2001, is shown in Table 1. The March-July forecast inflow to Albeni Falls is 7.05 MAF, or 53.1 % of the mean flow for this season (13.29 MAF). The observed inflow for this season is 7.56 MAF (56.9 % of the mean), thus the forecast error is -0.51 MAF, or – 3.8 % of the mean. In addition to the forecast, Table 1 shows an alternative set of forecasts based on a range of precipitation and temperature scenarios, plus a statistical summary of weather and runoff conditions since the beginning of the water year and for the week previous to the forecast.

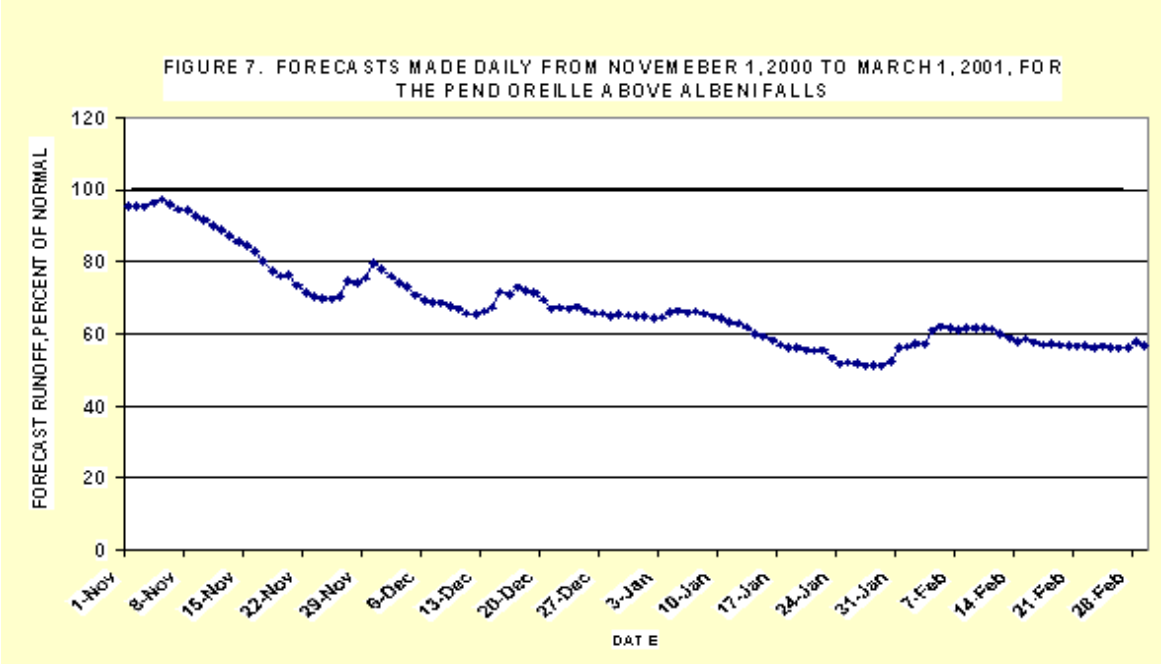

Figure 7

Table 1. Example of a Pend Oreille River at Albeni Falls forecast, made on March 1, 2001, for a season ending July 31.

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            HYMET FORECASTING MODEL - SEATTLE, WASHINGTON

                 PEND OREILLE RIVER AT ALBENI FALLS

                          FLOW FORECAST

                             SEASON
                        MAR  1 2001 TO JUL 31 2001
                          LENGTH: 153 DAYS

          TODAYS DATE  MAR  1 2002   TIME:14:11
FORECAST RUNOFF FOR: MAR  1 2001 TO JUL 31 2001 =   7.74 MAF
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 OR  57.3 % OF AN AVERAGE OF  13.50 MAF FORECAST MEAN DAILY DISCHARGE=   25499. CFS   AVERAGE DISCHARGE=   44497
 BASED ON BASIN WATER STORAGE THAT IS   4.53 INCHES OR   58.8 PERCENT OF MEAN
 GWS=   0.28 INCHES   60.2 % OF MEAN
 EXPECTED FORECAST ERROR: 10.77 % OR    1.45 MAF    RSQUARED=  0.864
   TEST-SEASON LENGTH=  2 DAYS
 JAN-JUL FORECAST RUNOFF IN MAF    8.322 MEAN=   17.460(  47.7 %)
 JAN 1- FC DAY, ADJ* =   0.584 % OF MEAN =   44.6
 JAN-JUL MEAN FORECAST ERROR   8.33 %
 J-J FORECAST WITHOUT T-SEASON  8.703 MAF    49.8 %, DIFF=  2.183 RSQ=  0.787
 SNOWPACK WATER CONTENT IN INCHES=  4.249  MEAN=  7.146  PERCENT  59.5

PEND OREILLE RIVER AT ALBENI FALLS
MAR  1 2001 TO JUL 31 2001
LENGTH: 153 DAYS
ALTERNATIVE FORECASTS BASED ON
PERCENT OF NORMAL SEASONAL PRECIPITATION
AND TEMPERATURE DEPARTURES
IN MILLIONS OF ACRE=FEET(MAF) AND PERCENT
                            PERCENT PRECIPITATION
               80     85     90     95    100    105    110    115    120
 -2.0 DEG      6.6    7.0    7.3    7.6    8.0    8.3    8.7    9.0    9.3
 % OF MEAN     49.    52.    54.    57.    59.    62.    64.    67.    69.
 -1.5 DEG      6.6    6.9    7.3    7.6    7.9    8.3    8.6    8.9    9.3
 % OF MEAN     49.    51.    54.    56.    59.    61.    64.    66.    69.
 -1.0 DEG      6.5    6.9    7.2    7.5    7.9    8.2    8.5    8.9    9.2
 % OF MEAN     48.    51.    53.    56.    58.    61.    63.    66.    68.
 -0.5 DEG      6.5    6.8    7.1    7.5    7.8    8.1    8.5    8.8    9.1
 % OF MEAN     48.    50.    53.    55.    58.    60.    63.    65.    68.
  0.0 DEG      6.4    6.7    7.1    7.4    7.7    8.1    8.4    8.7    9.1
 % OF MEAN     47.    50.    52.    55.    57.    60.    62.    65.    67.
  0.5 DEG      6.3    6.7    7.0    7.3    7.7    8.0    8.3    8.7    9.0
 % OF MEAN     47.    49.    52.    54.    57.    59.    62.    64.    67.
  1.0 DEG      6.3    6.6    6.9    7.3    7.6    7.9    8.3    8.6    9.0
 % OF MEAN     46.    49.    51.    54.    56.    59.    61.    64.    66.
  1.5 DEG      6.2    6.5    6.9    7.2    7.6    7.9    8.2    8.6    8.9
 % OF MEAN     46.    48.    51.    53.    56.    58.    61.    63.    66.
  2.0 DEG      6.2    6.5    6.8    7.2    7.5    7.8    8.2    8.5    8.8
 % OF MEAN     46.    48.    51.    53.    55.    58.    60.    63.    65.
Table 1 (continued)
WEATHER CONDITIONS FROM OCT 1 2000 TO MAR  1 200
MEAN FOR PERIOD: 1969 - 2000
   CUMULATIVE PRECIPITATION FOR PERIOD(INCHES)
     MEAN   CURRENT  PERCENT   STATION      NAME
    16.65     9.45     56.8   P1B25D     25 STA AVERAGE FOR GRAND COULEE
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15.34	8.90	58.0	P2B25D	25 STA AVERAGE FOR THE DALLES
10.70	6.86	64.1	P3B25D	25 STA AVERAGE FOR LOWER GRANITE
17.11	9.77	57.1	P4B25D	25 STA AVERAGE FOR ALBENI FALLS
4.19	3.75	89.4	P0412D	BAKER OR PRECIP
8.78	5.64	64.2	P4622D	LA GRANDE OR PRECIP
6.95	6.36	91.6	P6546D	PENDELTON OR PRECIP
5.91	5.03	85.2	P8746D	UNION OR PRECIP
6.20	5.80	93.5	P1022D	BOISE ID PRECIP
4.72	3.34	70.7	P1303D	BURLEY ID PRECIP
12.96	7.76	59.8	P1514D	CASCADE ID PRECIP
14.93	9.22	61.7	P4442D	IDAHO CITY PRECIP
6.13	5.90	96.3	P3732D	GRACE ID PRECIP
5.53	4.14	74.9	P5241D	LEWISTON ID PRECIP
5.39	4.02	74.6	P7211D	POCATELLO ID PRECIP
19.50	14.26	73.1	P8137D	SANDPOINT ID PRECIP
22.99	18.59	80.8	P9498D	WALLACE ID PRECIP
5.64	3.14	55.6	P1767D	COULEE DAM WA PRECIP
11.92	6.41	53.8	P6789D	PULLMAN WA PRECIP
53.27	27.14	50.9	P6894D	LONGMIRE WA PRECIP
19.21	9.03	47.0	P4084D	HERON MT PRECIP
6.87	2.91	42.3	P4558D	KALISPELL MT PRECIP
13.29	6.48	48.7	P5020D	LIBBY MT PRECIP
4.84	4.82	99.6	P5745D	MISSOULA MT PRECIP
10.74	8.26	76.9	P7448D	SEELEY LAKE MT PRECIP
11.92	6.34	53.2	P8211D	THOMPSON FALLS MT PRECIP
14.21	5.92	41.7	P8809D	WEST GLACIER MT PRECIP
5.80	2.41	41.5	P2102D	CRANBROOK BC
19.96	11.07	55.4	P6751D	REVELSTOKE, BC PRECIP

MEAN TEMPERATURE FOR PERIOD(F)

MEAN	CURRENT	DEVIATION	STATION	NAME
42.1	38.8	-3.31	TX1767D	GRAND COULEE MAX TEMP (F)
28.6	25.7	-2.89	TN1767D	GRAND COULEE MIN TEMP
37.3	36.0	-1.26	TX5020D	LIBBY MAX TEMP
18.4	13.2	-5.13	TN5020D	LIBBY MIN TEMP
47.6	43.2	-4.47	TX6546D	PENDLETON MAX TEMP
32.0	32.3	0.24	TN6546D	PENDLETON MIN TEMP
42.5	37.9	-4.59	TX7211D	POCATELLO MAX TEMP
22.2	17.8	-4.39	TN7211D	POCATELLO MIN TEMP

RECONSTRUCTED (NATURAL) INFLOW FOR PERIOD(MAF)

MEAN	CURRENT	PERCENT	STATION	NAME
13.67	8.84	64.7	R4365D	GRAND COULEE RUNOFF (MAF)
29.54	18.66	63.2	R1057D	THE DALLES RUNOFF (MAF)
10.31	6.18	59.9	R3530D	LOWER GRANITE RUNOFF (MAF)
3.11	1.68	54.1	33900D	PEND PREILLE RUNOFF (MAF)

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 NO. OF P-STATIONS   28
 MAXIMUM   99.6 %  STATION  P5745D
 MINIMUM   41.5 %  STATION  P2102D
 AVERAGE  66.49 %
 STD DEV  17.24 %

WEATHER CONDITIONS FROM FEB 23 2001 TO MAR  1 200:
MEAN FOR PERIOD: 1969 - 2000
   CUMULATIVE PRECIPITATION FOR PERIOD(INCHES)
     MEAN   CURRENT  PERCENT   STATION      NAME
     0.58     0.34     58.1   P1B25D     25 STA AVERAGE FOR GRAND COU
     0.54     0.31     56.8   P2B25D     25 STA AVERAGE FOR THE DALLE
     0.40     0.15     38.7   P3B25D     25 STA AVERAGE FOR LOWER GRA
     0.61     0.35     58.0   P4B25D     25 STA AVERAGE FOR ALBENI FALLS
     0.14     0.04     28.1   P0412D     BAKER OR PRECIP
     0.41     0.00      0.0   P4622D     LA GRANDE OR PRECIP
     0.34     0.02      5.8   P6546D     PENDELTON OR PRECIP
     0.26     0.00      0.0   P8746D     UNION OR PRECIP
     0.25     0.00      0.0   P1022D     BOISE ID PRECIP
     0.15     0.01      6.7   P1303D     BURLEY ID PRECIP
     0.50     0.04      8.1   P1514D     CASCADE ID PRECIP
     0.54     0.00      0.0   P4442D     IDAHO CITY PRECIP
     0.28     0.85    306.2   P3732D     GRACE ID PRECIP
     0.26     0.00      0.0   P5241D     LEWISTON ID PRECIP
     0.21     0.09     43.3   P7211D     POCATELLO ID PRECIP
     0.67     1.40    207.9   P8137D     SANDPOINT ID PRECIP
     0.85     2.08    245.7   P9498D     WALLACE ID PRECIP
     0.22     0.02     11.4   P1767D     COULEE DAM WA PRECIP
     0.46     0.01      2.2   P6789D     PULLMAN WA PRECIP
     1.75     0.27     15.4   P6894D     LONGMIRE WA PRECIP
     0.61     0.10     16.5   P4084D     HERON MT PRECIP
     0.29     0.12     41.6   P4558D     KALISPELL MT PRECIP
     0.47     0.12     25.4   P5020D     LIBBY MT PRECIP
     0.21     0.05     23.5   P5745D     MISSOULA MT PRECIP
     0.41     0.10     23.8   P7448D     SEELEY LAKE MT PRECIP
     0.45     0.03      6.7   P8211D     THOMPSON FALLS MT PRECIP
     0.43     0.21     50.1   P8809D     WEST GLACIER MT PRECIP
     0.20     0.02      8.0   P2102D     CRANBROOK BC
     0.68     0.51     75.7   P6751D     REVELSTOKE, BC PRECIP
   MEAN TEMPERATURE FOR PERIOD(F)
     MEAN   CURRENT  DEVIATION STATION      NAME
     44.4     39.9    -4.51   TX1767D    GRAND COULEE MAX TEMP (F)
     28.3     20.0    -8.28   TN1767D    GRAND COULEE MIN TEMP
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    39.0     39.0    -0.04   TX5020D    LIBBY MAX TEMP
    17.8      4.3   -13.50   TN5020D    LIBBY MIN TEMP
    49.2     47.0    -2.25   TX6546D    PENDLETON MAX TEMP
    32.5     29.9    -2.65   TN6546D    PENDLETON MIN TEMP
    43.4     32.3   -11.08   TX7211D    POCATELLO MAX TEMP
    23.4     15.1    -8.30   TN7211D    POCATELLO MIN TEMP
  RECONSTRUCTED (NATURAL) INFLOW FOR PERIOD(MAF)
    MEAN   CURRENT  PERCENT   STATION      NAME
    0.68     0.30     43.5   R4365D     GRAND COULEE RUNOFF (MAF)
    1.81     0.73     40.4   R1057D     THE DALLES RUNOFF (MAF)
    0.72     0.29     40.8   R3530D     LOWER GRANITE RUNOFF (MAF)
    0.15     0.07     43.0   R3955D     ALBENI FALLS (MAF)
NO. OF P-STATIONS   28
MAXIMUM  306.2 %  STATION  P3732D
MINIMUM    0.0 %  STATION  P4622D
AVERAGE  46.63 %
STD DEV  75.55 %
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