AQU 3 Appendix 2

Merwin Flow Calculation Methodology

METHODOLOGY FOR FORECASTING THE REQUIRED MINIMUM FLOW BELOW MERWIN DAM

The present procedure for determining Lewis River variable energy content curves (VECC's) was established in 1965 using 28 years of rainfall and runoff data. July through June precipitation at Swift was correlated with August through July runoff at Merwin for the period 1932 through 1960. The last seven years of this data cannot currently be verified. The correlation coefficient was .9613. Swift rainfall measurements were not taken at a consistent location, there being at least five different locations represented in the data. The present rain gauge was installed in the Swift Plant switchyard in January 1960, which now provides a 22-year period of record with consistent data. Correlating the July through June precipitation at Swift with the August through July runoff at Merwin for the period 1960 through 1982 results in a correlation with a coefficient of .9748. The entire 50-year period of record was checked, and it showed a correlation coefficient of .9458. The 22-year period 1960-1982 was therefore chosen as most accurately representing the correlation of precipitation and runoff for the Lewis River.

The procedure for determining VECC's can also basically be used to determine the minimum discharge at Merwin during the March-April-May period as required by the stipulated flow regime for Merwin as agreed between Pacific, the J-0-A, and the Washington Departments of Fisheries and Game. The major difference is the modification of the confidence level from 95% for VECC's to 50% for Merwin minimum flow, which gives a forecast that is expected to be too high or too low half the time.

In addition, the forecast must be distributed by months for the March-May period, rather than from the forecast date through July as required by VECC. This also can be accomplished using the 22-year period of record as the basis.

The precipitation vs. runoff correlation is as follows:

17.417x annual inches precip. - 222.2 = Annual runoff in KSFD

Precipitation data is accumulated from July 1 through the forecast date and summed with the following precipitation values for the 50% confidence level for the forecast date through June 30:

Forecast Date

	March 1	April 1	May 1
Inches	27.10	15.40	7.70

The resulting total annual runoff forecast is then reduced by the actual runoff accumulated from August through the forecast date and the residual runoff distributed as follows:

Forecast Date

	March 1	April 1	May 1
March-May	74.4%	-	-
April-May	-	65.7%	-
May	-	-	48.8%

The following will illustrate the procedure for 1981:

July-Feb. Precip. (In.)		79.0;	Aug.-Feb. Runoff (KSFD)		1049
July-Mar.	"	87.6;	Aug.-Mar."	"	1150
July-Apr	"	96.9;	Aug. Apr. "	"	1337

March 1 Forecast for March-May

(17.417 (79.0 + 27.1) - 222 - 1049) .744 = 429 KSFD

March minimum flow from the stipulated agreement = 2260 cfs

April 1 Forecast for April-May

(17.417 (87.6 + 15.40) - 222 - 1150) .657 =277

April minimum flow = 1440 cfs

May 1 Forecast for May:

(17.417 (96.9 + 7.7) - 222 - 1337) .488 = 128

May minimum flow = 1650 cfs

The actual runoff for March-May, April-May, and May was 397, 294 and 109 KSFD respectively.

Consideration must be given to the fact that the minimum flow forecast is based upon single point precipitation data, single point runoff data, 50% probability, monthly data, correlations, an arbitrary relationship between forecast runoff and minimum flow, etc; and without relying on such factors as temperature, storm tracks, time or occurrence during the month, current conditions, etc. The minimum flow forecast may, therefore, not be realistic based on currently known conditions and should be modified, either increased or decreased, to reflect such conditions.

The entire fifty-year period of record was checked as to forecasted minimum flow values versus what would have been required had the actual runoff been known ahead of time. As to this criteria, it appeared that the forecasts should be modified to accommodate the following changes:

Number of Years

	March	April	May
Increase Forecast	10	12	10
Decrease Forecast	6	8	8

By examining historical patterns, however, not all of these indicated changes were desirable. Empirical relationships were therefore developed which nearly, (as much as possible) but not always, gave the desired changes. The forecasts were empirically overridden in the following number of years:

	March	April	May
Increased	7	8	10
Decreased	5	3	3

In a few instances some forecasts would have either an indicated or non-indicated change which undoubtedly would be overridden at the time by mutual consent of the parties based upon actual conditions of streamflow and storage.

The empirical overrides to the forecasted minimum flows use the following data, which would have been known at the time of the forecast:

Item	March 1 Forecast	April 1 Forecast -	May 1 Forecast
1. Streamflow (Kcfs) on:	Feb. 28	Mar. 31	Apr. 30
2. Precipitation (In.):	Feb.	Mar	Apr.
3. Accum. Precip.(In.):	July thru Feb.	July thru March	July thru April
4. Product No. 1	-	-	-
5. Product No. 2	1 x 2 x 3	1 x 2 x 3	1 x 2 x 3

and are expressed as follows:

March 1:

Raise the forecasted minimum flow to 2700 cfs if product No. 2 is equal to or greater than 4200 or February precipitation is equal to or greater than 15 inches.

Lower the forecasted minimum flow to 1000 cfs if product No. 2 is equal to or less than 2300 and the accumulated precipitation through February is equal to or less than 81 inches.

April 1:

Raise the forecasted minimum flow to 2700 cfs if product No. 2 is equal to or greater than 4700 and March precipitation is equal to or greater than 12 inches. See Note.

Lower the forecasted minimum flow to 1300 cfs if product No. 2 is equal to or less than 3500 and-the accumulated precipitation through March is equal to or less than 89 inches. See Note.

May 1

Raise the forecasted minimum flow to 2700 *r-f* s if product No. 1 is equal to or greater than 46.0. See Note.

Lower the forecasted minimum flow to 1650 cfs if product No. 2 is equal to or less than 2500 and the streamflow on April 30 is equal to or less than 4.5 Kcfs. See Note.

Note: If the resulting forecast is significantly different from the previous month and current conditions so warrant, the flow should be changed gradually in 1/3 steps on the 1st, 10th, and 20th of the month within the limits of the stipulated agreement.

Again using 1981 as an example:

Item	March 1 Forecast	April 1 Forecast	May 1 Forecast
Streamflow			
(Kcfs) on	Feb. 28: 4.8	Mar. 31: 8.3	Apr. 30: 5.8 2
Precipitation (In):	Feb.: 18.7	Mar.: 8.7	Apr.: 9.3 3
Accum. Precip. (In):	Jul-Feb: 79.0	Jul-Mar: 87.6	Jul-Apr: 96.9 4
Product No. 1			53.9 5
Product No. 2	7091	6326	5227 6

Item	March 1 Forecast	April 1 Forecast	May 1 Forecast
Forecasted Min. Flow (cfs)	2260	1440	1650
7. Empirical Override (cfs)	Raise to 2700 cfs	None	Raise to 2700 in 3 Steps
8. Min. Flow reqm' t based on actual 1981 runoff	810	1780	1650

No matter what forecasting scheme or empirical over-ride is formulated, not all conditions can be accommodated. For this reason deviations must be allowed if current conditions and common sense so indicate.

DRAFT 1/18/83

ALTERNATIVES TO FORECASTING

The stipulated flow regime for Merwin uses forecasts to establish minimum flows in March, April and May. Such forecasts may or may not provide an accurate and reliable insight as to the pattern or volume of runoff. In addition, they introduce uncertainties to the planners and confusion to the operators (how can we determine our energy content curves if the minimum discharge used therein is based on one or more future forecasts?). Changing minimum flows to unusual numbers can be confusing to the operators, and also result in inefficient plant loadings.

If satisfactory results can be achieved, it would seem appropriate to try to develop a methodology of determining the springtime minimum flows by means other than forecasts. The attached paper describes the problems encountered in the forecasting technique, and contains proposals for otherwise determining the springtime minimum flows of the Lewis River.

ALTERNATIVES TO FORECASTING

<u>March</u>

In 50 years of record there is only one forecast: for a March minimum flow of less than 1500 cfs (1450 cfs, 1934), using the forecasting technique derived from that used for variable energy content curves. Based on foreknowledge of actual runoff, there would have been four occasions when the March minimum flow would have been less than 1500 cfs.: 1941 (1000), 1942 (1060), 1944 (1280) and 1973 (1170). The suggested technique of empirically overriding the forecast based upon current conditions would result in lowering the forecasted minimum flow to 1000 cfs in each of these latter years.

In 10 of the 50 years of record, the March minimum flow forecast, based upon foreknowledge of actual runoff, would have been less than 2700 cfs; and of these, five of the forecasts would have been for flows above 2400 cfs. Using the derived forecasting technique, 13 of the forecasts would be for March minimum flows below 2700 cfs; and of these, four would be empirically overridden to 2700 cfs.

February is still too early in the year to definitely establish runoff patterns, but based on the 50 years of record, the following approach provided consistent results, uniform flows and no anomalies:

Proposal: If February runoff is equal to or less than 90 KSFD; or if the product of February end-of-month Kcfs and February precipitation is equal to or less than 31.0, and February runoff is equal to or less than 150 KSFD (5357-cfs average), March minimum flow shall be 1500 cfs. In all other instances the minimum flow shall be 2700 cfs.

Nine years would thus have a minimum flow in arch of 1500 cfs: 1934, 1937, 1941, 1942, 1944, 1962, 1969, 1973 and 1977. The snow pack in 1969 would probably suggest that a higher minimum flow would be indicated. In the other eight years, 1500 cfs is appropriate based upon the conditions, as they would have been known at the time.

April

Based upon the derived forecasting procedure, 15 Aprils would have minimum discharges equal to less than 1500 cfs, 10 of which would be under 1400 cfs. Of these, 6 would be empirically raised and 6 would be raised based on current conditions. Of the forecasts greater than 1500 cfs, 3 would be empirically lowered to 1300 cfs. Thus 6 years would have a minimum flow of less than 1500 cfs: 1941, 1942, 1944, 1973, 1977 and 1981.

Based on foreknowledge of actual runoff, there would have been 10 Aprils with a minimum discharge of less than 1500 cfs.

At the other end of the scale, 20 Aprils would have minimum flows forecasted to be less than 2700 cfs. Of these, 8 would have been raised empirically or, based on current conditions, to 2700 cfs, leaving 12 years below--2700 cfs of which the aforementioned 6 years would be below 1500 cfs. Based on foreknowledge, 19 Aprils would be below 2700 cfs.

By the end of March a more definite pattern of springtime runoff begins to emerge, and again, based on the 50 years of record, the following approach provides consistent and uniform results with no anomalies:

Proposal: If the February-March runoff is equal to or less than 275 KSFD and the March end-of-month Kcfs is equal to or less than 6.0, April minimum flow shall be 1500 cfs. In all other instances the minimum flow shall be 2700 cfs.

Of the nine years wherein the required March minimum flow was 1500 cfs, only five emerge as requiring a minimum flow in April of 1500 cfs, and no years require less minimum flow in April than in March:

Year	March	April

1934	1500	2700
1937	1500	2700
1941	1500	1500
1942	1500	1500
1944	1500	1500
1962	1500	2700
1969	1500	2700
1973	1500	1500
1977	1500	1500

May

Based upon the derived forecasting procedure, 21 of the 50 years of record would have forecasted minimum flows below 2700, of which 15 would have been at the 1650 cfs level. Of these 15, seven would have been empirically raised to 2700 cfs, and two to lesser amounts. In the other direction, there was one year wherein the May forecast would have been empirically overridden from a higher flow to 1650 cfs. Thus there would be 7 years with minimum flows of 1650 cfs: 1934, 1941, 1947, 1968, 1970, 1977, and 1981 (1942 would have been 1820 cfs). Based on foreknowledge of actual runoff there would have been 13 years at the 1650-cfs level.

Continuing the approach proposed for determining April minimum flow to the determination of May minimum flow also provides consistent, uniform and non-anomalous results:

Proposal: If the February-April runoff is equal to or less than 430 KSFD and the April end-of-month Kcfs is equal to or less than 5.0, May minimum flow shall be 1650 cfs. In all other instances the minimum flow shall be 2700 cfs.

The same five years as before thereby have an indicated minimum flow in May of 1650 cfs, and again, no years require less minimum flow in May than in April:

Year	March	April	May

1941	1500	1500	1650
1942	1500	1500	1650
1944	1500	1500	1650
1973	1500	1500	1650
1977	1500	1500	1650

Through such an empirical alter-native to forecasting, the same few years keep appearing as requiring absolute minimum flows; and anomalous situations which occur as a result of a subjective forecast are avoided:

Year	March	April	May
1934	1500	1937	1500
1941	1500	1500	1650
1942	1500	1500	1650
1944	1500	1500	1650
1962	1500	1969	1500
1973	1500	1500	1650
1977	1500	1500	1650

*denotes 2700. Minimum flow in all other years during March-May is 2700 cfs.

Though no anomalies were encountered in reviewing the 50 years of record it doesn't mean it can't happen; therefore, the option to over ride, based upon current conditions, must be maintained.