Importance of Water Supply Forecasts in Power Planning

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Introduction:

Hydroelectric systems reservoirs are operated within non-power constraints to both maximize the production of electric energy and to maintain a viable electric energy supply. There are a number of uncertainties in operating a hydroelectric system, the main ones being the uncertainty of future streamflows, the uncertainly of future electric energy loads, and the uncertainty of performance of electric generating units. Of these uncertainties, the one with the greatest variability, and thus the greatest effect on reservoir operation, is the uncertainty of future streamflows. This paper will address the importance of water supply forecasts in planning the power operation of the Federal Columbia River Power System (FCRPS) reservoirs.

Description of FCRPS

The FCRPS is the largest hydro electric energy system in the Pacific Northwest. Over eighty percent of the regions electric energy is hydro power and over one half of this is produced from the FCRPS. The key site measuring the hydro potential of the FCRPS is the Columbia River at The Dalles, Oregon, encompassing a drainage area of 237,000 square miles with a mean annual volume of runoff of about 131 million acre-feet (MAF). Normally over one-half of this runoff occurs in a relatively short period of time, about 3 months, as snowmelt runoff. Most of this runoff is controlled by the large reservoir storage system on the Columbia River and its tributaries. Storage for power production above The Dalles totals nearly 40 MAF. Managing the runoff and reservoir storage is essential to meet the region's electric power needs as well as controlling floods and meeting other non-power requirements.

Description of Operating Rule Curves

FCRPS reservoirs are operated to a variety of rule curves. The main rule curves governing the marketing condition of the FCRPS are the energy content curves. Energy content curves are defined as operating rule curves that maintain a 95 percent confidence of refill. Two basic energy content curves (ECC) exist, one is based on historic data and the other is based on water supply forecasts. The energy content curve that is based on historic data is called the base energy content curve (base ECC) and the one based on forecast water supply is called the variable energy content curve (VECC). During the period of active snowmelt runoff, reservoirs are generally operated to assured refill curves which are a refined development of the VECC.

Development of Operating Rule Curves

Base ECC

The base Energy Content Curve (base ECC) is defined to be a rule curve that maintains a 95 percent confidence of refill. It is determined from historic data. More specifically, the second lowest historic runoff year in the 40-year period from 1928 through 1968 is used to construct the base ECC. The shape of each reservoir's base ECC is adjusted to produce a maximum amount of electric energy while meeting forecast loads through the operating year. The base ECC thus is computed once for the entire year.

Variable ECC

Variable Energy Content Curves (VECC) again are defined and designed to maintain a 95 percent confidence of refill. The VECC's are constructed from the Water Supply Forecast and knowledge of the minimum amount of water that must be discharged to generate sufficient power to meet the FCRPS firm power requirements (called the minimum power discharge requirements). The 95 percent confidence of refill is achieved in design of the VECC's by lowering the probable water supply forecast to the 95 percent confidence runoff forecast. The 95 percent confidence runoff is then distributed according to a shape dictated by historical data, and the VECC is constructed. The VECC's are computed monthly beginning January 1.

Assured Refill Curve

Computation of the assured refill is essentially the same as that used for the VECC's. The principal difference is that one can begin to incorporate the actual distribution of the current year's runoff rather than using a historical distribution. Thus, a current day elevation is computed based on the 95 percent confidence residual runoff and the projected minimum power discharge requirement. Beginning about mid-April, the assured refill elevation is computed on almost a daily basis.

The FCRPS is operated on the base ECC from August 1 through December 31 provided additional reservoir drafting is not required to meet firm power load requirements. The lower of the base ECC, VECC, or assured refill curves are used as operating rule curves after December 31.

It is generally necessary to deviate from the operating rule curve toward the end of the refill period. This is because the headwater storage projects have limited turbine generating capacity and the fact that 95 percent of the time we should have more than sufficient water to refill. The result is an increasingly delicate operation to avoid spill on one hand and to achieve refill on the other as the end of the refill period is approached.

The 1979 operation of Libby reservoir in Montana provides an example of what can happen as we approach the end of the refill period. Table 1 shows that on June 1, Libby was 16,000 acre-feet above assured refill and the probable forecast showed 707,000 acre-feet in excess of refill requirements.

Table 1
1979 Libby January-July Water Supply Forecast
in 1000's Acre Feet

	Jan	Feb	Mar	Apr	May	June	July
Probable Forecast	6294	5368	5875	5512	5562	5460	
Standard Error	1058	722	659	597	500	420	
95% Confidence Hedge	1740	1188	1084	982	823	691	
95% Confidence Forecast	4554	4180	4794	4530	4739	4769	
Observed Runoff	4429	4429	4429	4429	4429	4429	4429

1979 Libby Refill Status
in 1000's Acre Feet

	Jan	Feb	Mar	Apr	May	June	July
Space to Fill + Min. Discharge		4366	4306	4174	3916	2543	1108
Probable Residual Runoff		5176	5519	4937	4717	3250	
Probable Excess to fill		810	1213	763	801	707	
95% Confidence Resid. Runoff		3988	4435	3955	3894	2559	
95% Confidence Excess to fill		-378	129	-219	-22	16	

The project owner (Corps of Engineers) and BPA began considering raising the discharge to reduce the risk of filling and spilling the project. Fortunately a warm spell that didn't produce a rise in streamflows along with a satellite picture of the snowpack indicated that there was less runoff available than forecast. As a result, minimum discharges were maintained and the reservoir still failed to refill by 420,000 acre feet. This example shows that the accuracy in water supply forecasts is critical to reservoir refill. Since the snowpack is directly related to the water supply forecast, it points out the necessity to be able to accurately appraise the basin snowpack.

Scenario of How Water Supply Forecasts Effected the 1978-79 Power Operations

Reservoirs were full in July 1978 and better than normal streamflows along with non-power reservoir drafts for flood control, produced energy in excess of firm power requirements. This excess energy was delivered to public agencies, industries and private utilities. Streamflows receded in early October, and reservoir drafts were picked up. Beginning October 15, BPA began reducing secondary energy deliveries as reservoirs began approaching their base ECC's. By October 24, only BPA's preference customers, the public agencies, were receiving secondary energy. As streamflows continued to recede into November and reservoirs reached rule curves, this last increment of secondary energy was curtailed on November 24. Continued low streamflows caused reservoirs to draft to about 2 MAF below their base ECC by the end of December.

Below normal fall precipitation resulted in a January-July water supply forecast at The Dalles of 80 percent of the 15-year average (88 MAF). Some individual reservoirs' water supply forecasts were sufficient to use the VECC instead of the base ECC's, but this did not produce sufficient energy to resume any significant secondary sales. They did produce enough energy that BPA was able to sell back to the industries the Hanford energy that had been withheld earlier in the year and to make small amounts of secondary energy available to the public agencies.

January 1979 precipitation continued to run below normal and the February 1 January-July water supply forecast at The Dalles dropped 9.4 MAF to 78.6 MAF. BPA was still able to make small amounts of secondary energy available to the public agencies.

February was much wetter than normal in contrast to preceding months. As a result, the March 1 January-July water supply forecast at The Dalles jumped 14.4 MAF to 93 MAF. The enhanced water supply forecast lowered VECC's sufficiently that BPA was able to restore secondary energy deliveries to the industries and private utilities. Conditions looked good enough from the forecast energy standpoint that industries sold a major portion of their Hanford energy to the Pacific Southwest and met their requirements with low cost hydro energy.

March precipitation was below normal, and The Dalles January-July water supply forecast on April 1 dropped 5.7 MAF to 87.3 MAF. Studies indicated that BPA could continue to deliver secondary energy and still refill reservoirs. The April 1 water supply forecast also indicated that the fisheries requested minimum discharge requirements could be met with the probable forecast and reservoirs would refill but if 95 percent confidence runoff were to occur, reservoirs would not refill.

The May 1 January-July water supply forecast at The Dalles rose 2.4 MAF to 89.7 MAF. This increase, along with the fact reservoirs were above VECC's by about 2 MAF indicated that BPA could continue to serve secondary energy. The fish flow operation that started in May produced secondary energy in excess of Pacific Northwest load requirements. Because this excess generation was not surplus to Pacific Northwest requirements for the balance of the operating year, efforts were made to store the excess. After all efforts to store the excess generation were made, some still remained which was sold to the Southwest.

There was no change in the June 1 water supply forecast from the May forecast at The Dalles. Reservoirs were still above VECC's on June 1, and BPA continued to supply secondary energy and store excess energy produced from the fish flow operation. Upon termination of the fish flow operation about mid-June and the likelihood of a much lower than forecasted runoff, BPA began restricting secondary energy deliveries. By July 1, only the public agencies were receiving secondary energy, and reservoirs were about 1 MAF below VECC's.

On July 6, the July 1 water supply forecast for the January-July period at The Dalles dropped from 89.7 MAF to 83.7 MAF. It became apparent reservoirs would not fill, and deliveries of secondary energy to the public agencies were curtailed. By the end of July, when normally reservoirs are filled, they were actually down about 4 MAF or 10 percent of the total reservoir storage available for meeting load requirements during the following year. The final January-July runoff at The Dalles amounted to 83.8 MAF.

Thus in review, the water supply forecasts were key ingredients in deciding to resume secondary energy deliveries; to meet fish flow requirements; to return Hanford energy to industries; for industries to sell Hanford energy to the Southwest; in deciding to store outside the region excess energy created from fish flow requirements, and in curtailments of secondary energy deliveries. Finally, it was primarily because of the over forecast water supply that the coordinated reservoir system failed to refill by 4 MAF.

Summary

During the majority of the power operating year the electric energy supply is directly related to the water supply which is the largest variable in planning the operation of FCRPS reservoirs. The water supply forecasts are used to determine the reservoir operating rule curves which in turn are used to measure the ability to meet various electric energy requirements. This paper touched only a small portion of how water supply forecasts are used in managing FCRPS reservoirs. These same forecasts are used in a multitude of reservoir operations for non-power purposes that may also effect power operations such as flood control, fish flow requirements and recreation. Managers of FCRPS reservoirs base most of their decisions on the availability of future water supplies. To conclude, the water supply forecasts are the main variables, with the largest uncertainties used in planning the operation of FCRPS reservoirs.