CHAPTER 16: ANALYSIS OF COST EFFECTIVE RESERVES AND RELIABILITY

Contents

List of Figures and Tables

KEY FINDINGS

This analysis shows that the regional power system has sufficient capability to provide all required reserves. However, individual balancing authorities may be in a different position than the region as a whole. Further, the cost and availability of reserves varies depending on water conditions. To minimize the cost of providing reserves the region should continue to explore methods to better coordinate resource dispatch.

INTRODUCTION

This chapter focuses on the general category of reserves commonly referred to as balancing reserves.[1] While the term "balancing reserves" is most often associated with actions that are used to match generation and demand within an hour, the discussion in this chapter extends the definition to cover balancing across longer periods of time. Balancing reserves can be provided by generating resources or by demand side management measures.

For a resource to provide balancing reserves, it must be able to respond very quickly. For a generating resource this would correspond to being able to change its generation level very quickly. For a demand side management program this would correspond to being able to change load requirements from the grid within a short time frame. Balancing reserves that require additional generation or decreased load are referred to as incremental (INC) reserves and those that require reduced generation or increased load are referred to as decremental (DEC) reserves.

Within-hour balancing reserves are most commonly called upon to fill in the gaps due to short-term load variation or due to fluctuations in variable generation resources like wind or solar generation. For example, during peak load hours of the day, should expected wind generation not materialize, INC reserves are called upon to fill in the need. During light load hours, usually during the night, if wind generation exceeds expectations, DEC reserve resources will cut back their generation or alternatively, load is increased to absorb the additional and unexpected generation. Generally, some level of fast acting INC and DEC reserves must be held at all times to respond to forecast and scheduling error in the power system.

This chapter addresses the two main issues surrounding these reserves; 1) how much does the region's power system need and 2) what is the best and most cost-effective means of providing these reserves.

[1] For more information on reserves and ancillary services see Chapter 10.

RESERVES IN THE POWER ACT

The Power Act directs the Power Plan to include an analysis of reserve and reliability requirements and cost-effective methods of providing reserves designed to ensure adequate electric power at the lowest possible cost.[2] With the expansion of variable generation resources, the requirement for reserves to balance that generation has steadily increased. The operation of the system has evolved in such a manner that many different entities, called Balancing Authorities (BAs), have the responsibility to provide reserves for the region and the larger western electric grid.

While there are requirements[3] on how far each BA can deviate from its scheduled interchange of power with other BAs in an operational time-frame, there is no formal requirement on how a BA plans for future reserves. Further, there are limited and differing levels of detail available as public information on how each BA provides or plans for reserves. The Seventh Power Plan recommends that utilities and Bonneville provide more public information on how they plan for operating reserves as part of the Action Plan.[4] Given the current lack of public information, it is not possible to quantify the lowest possible cost for providing reserves in the models used for developing this plan. However, qualitative assessment is possible and actions that will help move toward more quantitative methods are proposed in this plan.

Reliability

Reliability is defined as having two distinct parts, adequacy and security. A power system is reliable if it is:

- Adequate - the electric system can supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
- Secure - the electric system can withstand sudden disturbances, such as electric short circuits or unanticipated loss of system elements.

“Adequacy” refers to having sufficient resources – generation, efficiency and transmission – to serve loads. To be adequate, the power supply must have sufficient energy across all months, sufficient capacity to protect against the coldest periods in winter and the hottest periods in summer, and sufficient flexibility to balance loads and resources within each hour. In determining adequacy, the Council uses a sophisticated computer model that simulates the operation of the power system over many different futures. Each future is simulated with a different set of uncertainties, such as varying water supply, temperature, wind generation and thermal resource performance. The adequacy standard used by the Council deems the power supply inadequate if the likelihood of curtailment five

[2] Northwest Power Act, §4(e)(3)(E), 94 Stat. 2706
[3] NERC Resource and Demand Balancing standards
[4] See Action Item REG-4

years in the future is higher than 5 percent.[5] The Council uses probabilistic analysis to assess that likelihood, most often referred to as the "loss of load probability."

"Security" of the regional power supply is achieved largely by having reserves that can be brought on line quickly in the event of a system disruption and through controls on the transmission system. These reserves can be in the form of generation or demand side curtailment that can take load off the system quickly. The North American Electric Reliability Corporation (NERC) and the Western Electricity Coordinating Council (WECC) establish reserve requirements, frequently expressed in terms of a percentage of load or largest single contingency. An additional resource requirement for the region is maintaining the reserves required for security and thus for a reliable power system.

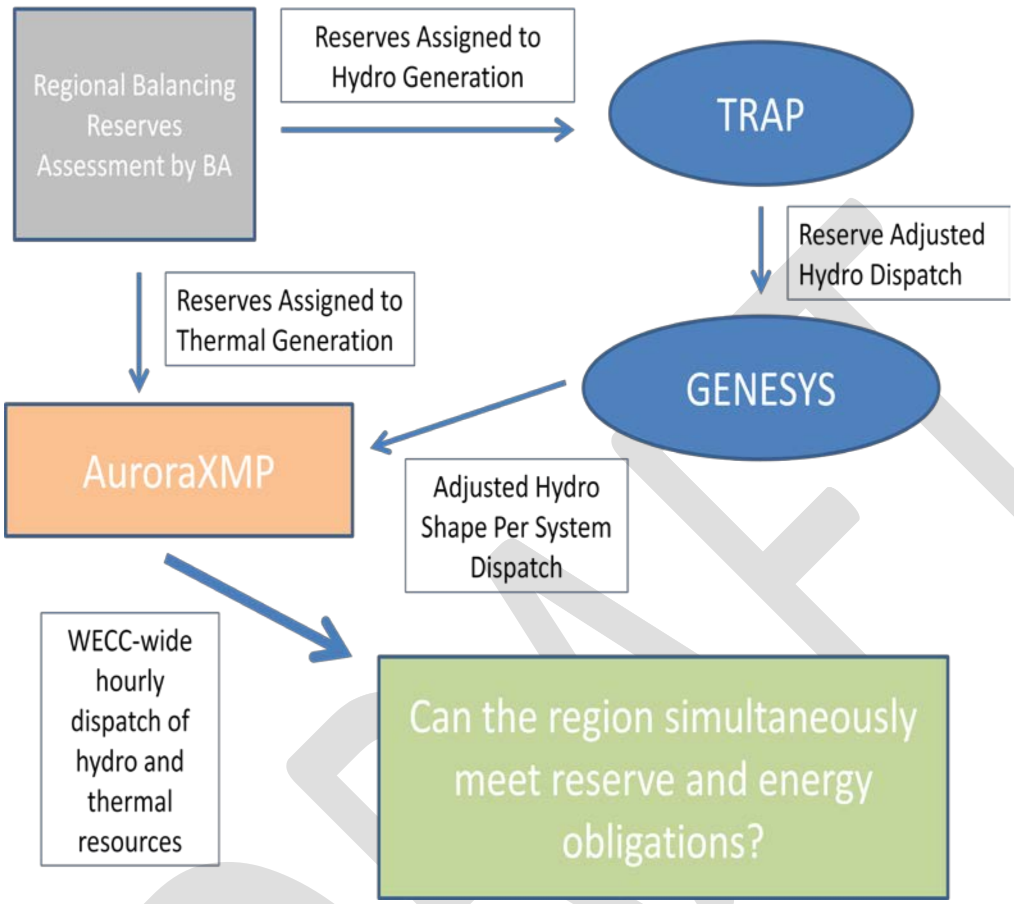
Provision of Cost-Effective Reserves

Determining how to allocate cost-effective reserves in an individual utility's portfolio, when the balancing authority requires it to self-supply its own reserves, is a challenging prospect that requires a systems operations model for each BA. Determining a methodology to assign cost-effective reserves for the region over the length of the plan period is even more problematic considering the uncertainty related to known market structures and transmission congestion. The future of market structures in the region (energy imbalance markets and Independent System Operators or ISOs) is currently in flux with issues including: geographic footprint, market participants, scheduling, and available products. These issues alone make modeling future regional reserve sufficiency challenging. Determining the most economic reserve assignment within the regional portfolio is virtually impossible. However, considering that difficulty, the Council has attempted to assign reserves to regional hydro and thermal generation resources to best determine if there are sufficient reserves, while simultaneously attempting to acknowledge some fundamental principles of power economics in the region.

[5] For information on the adequacy standard used by the Council see Chapter 11.

The Council's methodology is represented by the flow diagram in Figure 16 - , and summarized in more detail in the sections below.

Figure 16 - 1: Methodology Testing Regional Balancing Reserve Capability



Were there a liquid reserve market, reserves would be assigned to the marginal unit within the system constraints. However, since there is neither a liquid reserve market nor even a price signal for those reserve products in the region, the Council assigns the reserves proportionally among reserve-providing units. The majority of reserves in the region have traditionally been provided by hydro generation resources with some sort of storage capability due to abundant, cheap and flexible fuel supply and the ramping capability of the hydro generation units. Thermal units have been used to provide reserves during periods when the hydroelectric system was heavily constrained or for utility portfolios that did not have enough hydroelectric capability to provide all reserves. Using similar reasoning, the Council's methodology assigns a majority of the regional reserve requirements to the hydroelectric system, and the remaining reserve requirements to capable thermal units.

Imbalance Markets

One possible method for reducing the need for or cost of reserves is to create new market structures that allow for the scheduled exchange of power to happen on a more frequent basis. A good example of this type of market is the California ISO and PacifiCorp Energy Imbalance Market. Several studies on the cost and benefits of these markets have been completed and have shown that it is likely the benefits of these types of markets exceed the cost. In concept, these markets are formed to solve for the least system cost for providing reserves, and thus should be considered as part of a lowest possible cost provision of reserves.

ASSESSING THE NEED FOR RESERVES

The first step in testing whether the region has sufficient balancing reserves is to determine the need for balancing reserves in the region. The need for reserves is driven by short-term uncertainty in load and variable generation levels. A recent study from the Pacific Northwest National Lab[6] estimated the need for reserves by Balancing Authority. One element of this study took the intra-hour load and variable generation imbalance and assumed that 95 percent of the deviations from a baseline schedule as a level for establishing reserve needs.[7] The maximum reserve level for each BA by month was extracted from these data, and assigned to thermal and hydro generation resources, per Table 16 - 1. These levels of reserves were used as inputs into the Council's study. The assumption is that if the maximum reserve level can be provided by regional resources, then the system has sufficient reserves.

Table 16 - 1: Maximum Within-Hour Reserve Requirement Assumptions for Regional BA's[8]

BA	Hydro Reserve Level (MW)[9]		Thermal Reserve Level (MW)	
	INC	DEC	INC	DEC
BPA[10]	900	1100	0	0
Avista	146	152	59	62
Idaho Power	188	229	79	96
Mid-Columbia	98	101	0	0
Northwestern	90	87	106	106
Pacificorp	91	100	193	212
Portland General	220	258	384	452
Puget Sound	167	207	262	323
Seattle City Light	148	156	0	0
Tacoma Power	66	72	0	0

[6] Analysis of Benefits of an Energy Imbalance Market in the NWPP
[7] Per the description of balancing reserves in Chapter 10, deviations from schedule are inevitable for load and generation due to forecast error and uncertainty. Thus, the balancing reserves held out by a BA ensure enough resources can be provided to the system to keep the system's Area Control Error within allowable limits. Note that the scenario using reserve requirements calculated to cover 95% deviations from the baseline schedule was used as the base case in the PNNL study.
[8] Note that there are other BA's in the region that were not part of the PNNL dataset. Since generally, their reserves are held on BPA's system, it is assumed for this study that BPA reserves assigned would be a proxy for the reserves on the rest of the BA's in the region.
[9] Reserves assigned to hydro resources are based on regulated hydro resources owned by a particular utility.
[10] BPA Reserve requirements used are per current status, not the PNNL study.

The reserves addressed in Table 16 - do not cover circumstances where a shortfall in peak capacity may also lead to a shortfall in reserves. Rather system needs, as described in Chapter 11, are met first and then the sufficiency of reserves is tested.

ESTIMATING RESERVES PROVIDED BY RESOURCES

The second step in testing whether the region has sufficient balancing reserves is to determine the supply for balancing reserves in the region. There are two primary types of resources that provide reserves: hydroelectric and thermal. Other types of resources such as demand response have also been used to provide reserves in some BAs but for the Council's analysis these have been excluded.

Hydro Resources

Providing INC reserves with hydroelectric resources requires decreasing their maximum allowed generation. Providing DEC reserves requires increasing their minimum allowed generation, leaving the remainder dedicated to providing reserves. The Council's hourly hydroelectric simulation model (TRAP) was used to calculate the maximum and minimum generation available from the hydroelectric system[11]. To analyze the effects of carrying reserves using the hydroelectric system, the maximum and minimum allowed generation was reduced on groups of hydro resources that correspond to balancing authority resources.

The maximum and minimum hydroelectric generation limits from the TRAP model are then used in the Council's adequacy model (GENESYS) to determine the overall dispatch of the hydroelectric system under differing water conditions. When the hydroelectric system dispatches at a level that is not at either the minimum or maximum allowed generation, it has remaining upward or downward flexibility. This remaining flexibility is then added to the remaining upward or downward flexibility on the thermal resources described below.

Thermal Resources

Providing reserves by modifying the operating range of thermal resources, similarly to hydroelectric resources, requires decreasing their maximum allowed generation and increasing their minimum allowed generation. When allocating the reserve obligations, the maximum and minimum allowed generation was reduced on groups of thermal resources that correspond to specific balancing authority thermal resources. Using the modified thermal plant ranges and remaining hydro generation flexibility, the AuroraXMP model then can dispatch thermal resources within the new

[11] See Appendix K for more information on the TRAP model.

maximum and minimum generation levels. See Appendix K for additional information on the AuroraXMP model methodology.

RESULTS

Within-Hour Balancing Reserve Requirements

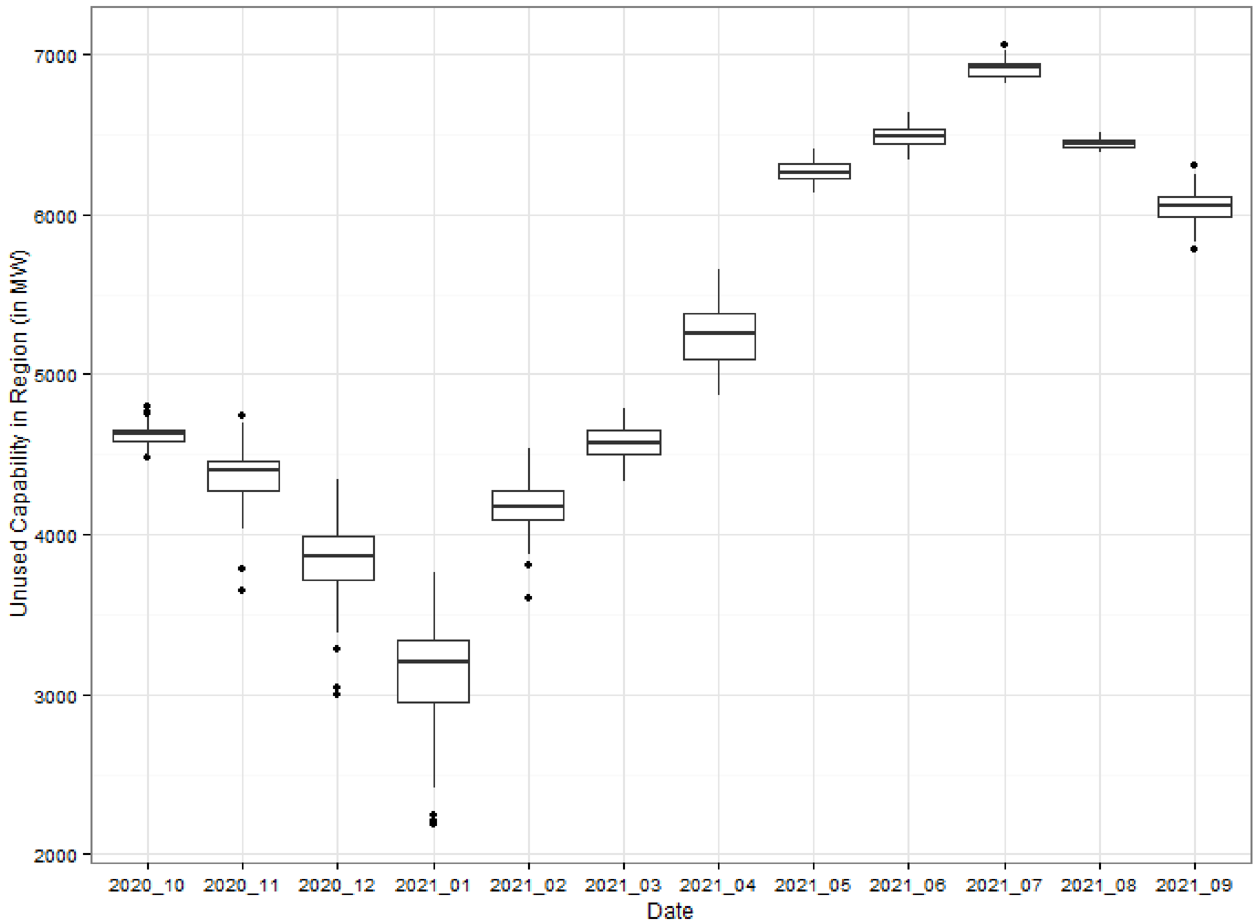
Based on the Council's methodology, the regional system was adequate in all hours for within-hour load following and regulation requirements in the test period (October 2020 through September 2021) for 80 water year conditions. In other words, the unused capability of the system was always greater than zero. Unused capability of the system in this context is defined as the difference between the capability of hydroelectric and thermal generation resources and the amount that those resources were dedicated to meeting system load, contingency reserve requirements, and within-hour balancing reserve requirements (load following and regulation).

Since more generation is being dispatched during heavy load hours than during light load hours the Council tested whether heavy load hours and light load hours had significantly different unused capability.

Figure 16 - 2, Figure 16 - 3, and Figure 16 - 4 below show the average unused capability remaining on the system for each month of the study period for all hours, light load hours, and heavy load hours of the month, respectively.[12]

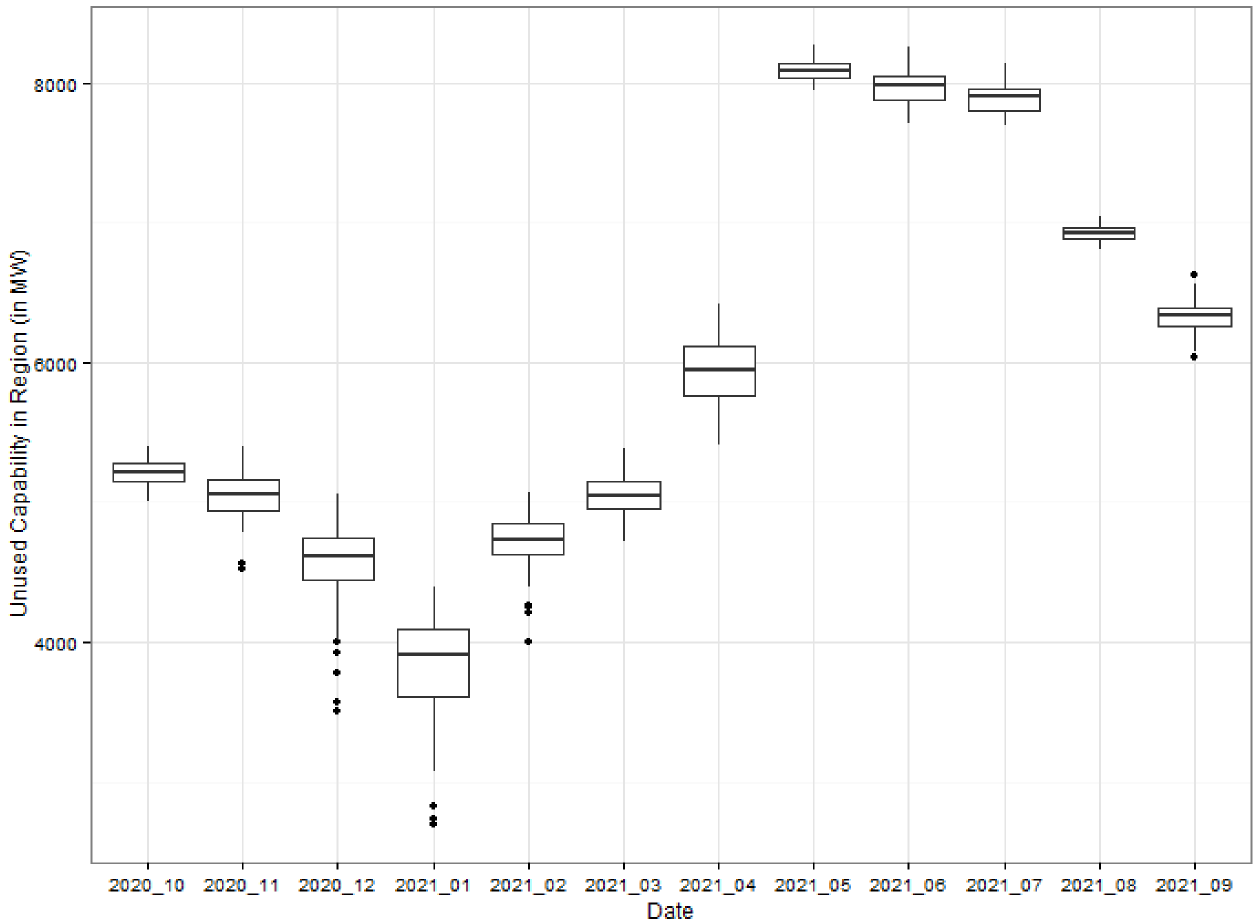
[12] In the Box and Whiskers plot style, the dark line inside the "box" indicates the median (2nd quartile), the vertical "box" boundaries are indicative of the 1st and 3rd quartiles (25th and 75th percentiles), the "whiskers" indicate 1.5 times the interquartile range of all the 80 simulations, and the dots are outliers which can contain the maximum or minimum values of the sampled data.

Figure 16 - 2: Average Unused Capability All Hours



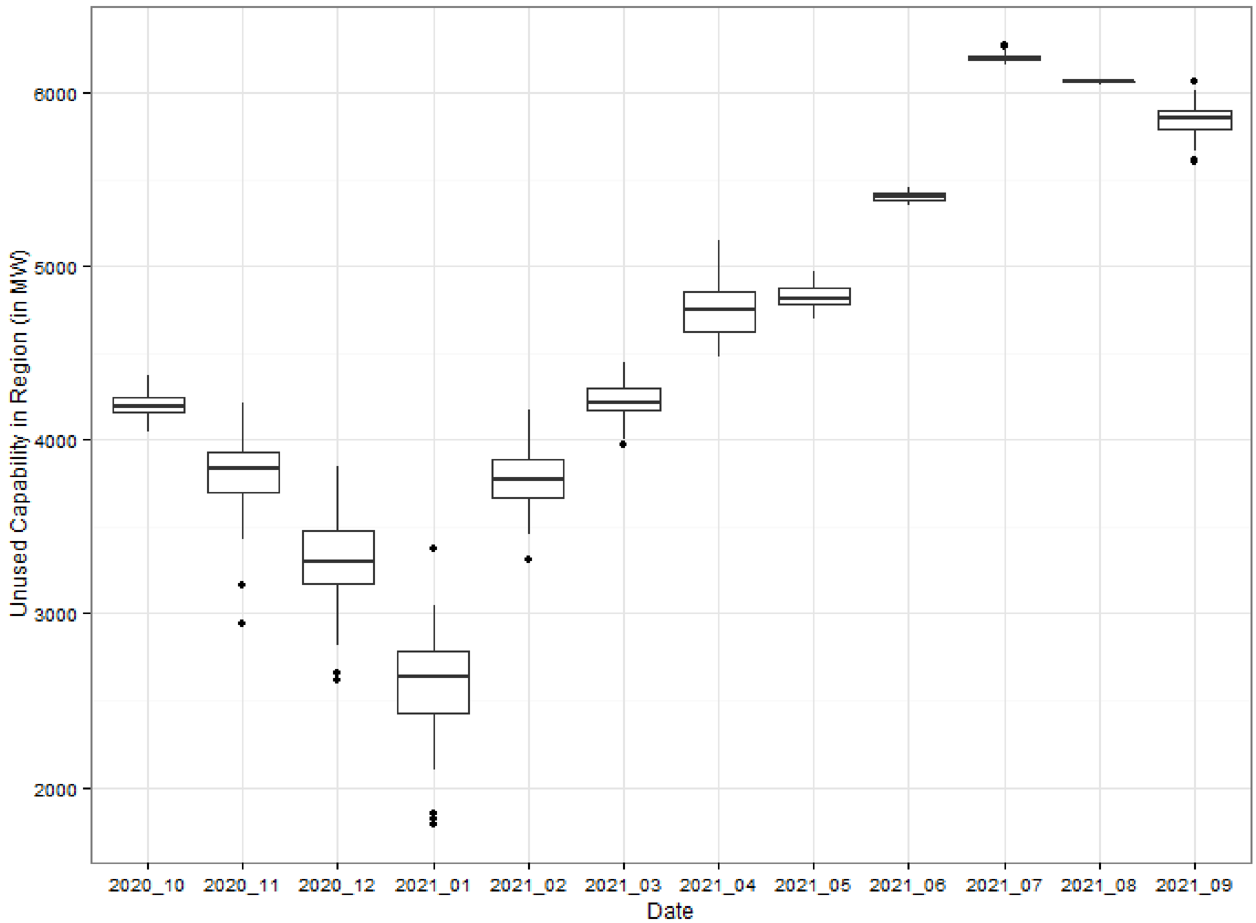
In Figure 16 - 2, the minimum unused capability of the system varies between 2,188 megawatts in January to 6,814 megawatts in May, with the average unused capability varying between 3,125 megawatts in January to 6,913 megawatts in July. In general, this shows the system having more unused capability on average during summer, spring and early fall months, and the unused capability during those months that are is less dependent on water conditions. During winter and late fall months, the unused capability varies significantly more with water conditions, and the unused capability is lower on average.

Figure 16 - 3: Average Light Load Hours Unused Capability



In Figure 16 - 3 the minimum unused capability of the system during light load hours varies between 2,697 megawatts in January to 7,938 megawatts in May, with the average unused capability varying between 3,800 megawatts in January to 8,091 megawatts in May. In general, this again shows the system having more unused capability on average during summer and spring months, during light load hours, and that capability is less dependent on the water conditions. Whereas, during the winter and late fall months, the unused capability varies significantly more with water conditions and the unused capability is lower on average.

Figure 16 - 4: Average Heavy Load Hours Unused Capability



In Figure 16 - 4, the minimum unused capability of the system during heavy load hours varies between 1,786 megawatts in January to 6,166 megawatts in July, with the average unused capability varying between 2,592 megawatts in January to 6,208 megawatts in July. In general, this again shows the system having more unused capability on average during summer and spring months, during heavy load hours, and that capability is less dependent on the water conditions. Whereas, during the winter and late fall months, the unused capability varies significantly more with water conditions and the unused capability is also lower on average.

Notice that the overall shape of different unused capabilities between heavy and light load hours is similar, but there is approximately 1,500 megawatts less unused capability on average during heavy load hours. In spring, especially in May and June, the unused capability shrinks by almost 3,000 megawatts between light load hours and heavy load hours.

This result shows that the capability of the hydroelectric system is being used more in heavy load hours and less in light load hours. This, in general, corresponds to the traditional operation of hydroelectric plants by shifting generation with limited fuel into the higher priced heavy load hours. This operation can be seen more clearly in Table 16 - 2 and Table 16 - 3 below, by comparing the monthly unused hydro capability over 80 water conditions.

Table 16 - 2: Unused Hydropower Capability (MW) in Light Load Hours

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average	185	222	54	17	56	511	1,252	3,763	2,492	1,263	359	162
Min	134	60	10	0	19	310	961	3,626	2,252	1,069	261	113
Max	257	359	158	60	114	708	1,432	3,901	2,766	1,488	477	219

Table 16 - 3: Unused Hydropower Capability (MW) in Heavy Load Hours

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Average	2	4	0	0	3	12	73	544	184	60	7	3
Min	0	0	0	0	0	4	39	481	157	35	6	3
Max	12	20	1	0	22	28	119	608	218	91	11	4

It is also worth noting that for a large part of the year, there is not much unused capability on the hydroelectric system. That is, during summer, fall and winter, thermal resources must be used if there is a need for additional shaping during the heavy load hours. However, as can be seen in Figure 16 - 4: Average Heavy Load Hours Unused Capability, the regional thermal resources still have the capability to provide these services.

Inter-hour Balancing Reserve Requirements

While regional inter-hour balancing reserve requirements were not considered explicitly in the Council's analysis, some conclusions can be drawn from the data about inter-hour ramping requirements. Operationally, sometimes ramping requirements between multiple hours in conjunction with within-hour reserve requirements can be problematic, due to uncertainty in load and variable generation forecasts. For this analysis, during all hours, the inter-hour operating constraints were adhered to for both hydroelectric and thermal resources, since the multi-hour sustained peaking requirements of TRAP and GENESYS, and operating constraints of AuroraXMP were met. Since there were no constraint violations and from inspection of the major ramping hours between light and heavy load hours, the analysis did not yield any concerning inter-hour ramping events. Further analysis of different load and variable generation combinations in conjunction with the 80 water conditions might yield different results, thus this could be an area for further study.