The Interaction between Power Planning and Fish and Wildlife Program Development

BACKGROUND

The Columbia River Basin hydroelectric system is a limited resource that is unable to completely satisfy the demands of all users under all circumstances. Conflicts often arise that require policy makers to decide how to equitably allocate this resource. In particular, measures developed to aid fish and wildlife survival often diminish the generating capability of the hydroelectric system. Conversely, "optimizing[1]" the operation of the system to enhance power production has detrimental effects on fish survival.

As the years of 2000 and 2001 unfolded, analyses by the Council and others indicated that fully implementing the NOAA Fisheries' 2000 Biological Opinion (BiOp) mainstem hydroelectric operations in 2001 was very likely to compromise power system reliability. This was due to very dry conditions in that year and the basic state of power supply in the Northwest and the rest of the Western Interconnection. Allowances in the BiOp, however, permit the curtailment of fish and wildlife operations during emergencies. The Bonneville Power Administration (Bonneville) declared a power emergency in that year based on the water supply and the lack of available generation on the market. Decisions were made to severely reduce fish bypass spill during the spring and summer months in order to ensure adequate supplies of power and to manage the economic impact of the high market prices. [2]

The events of 2001 are just one example that there will always be significant financial incentives to deviate from prescribed fish and wildlife operations when power supplies become tight and prices soar. The solution is to develop a power plan that assures the region an adequate power supply and also minimizes the risk of emergency interruptions to fish and wildlife operations.

THE COUNCIL'S ROLE

The Council has dual responsibilities: to "protect, mitigate and enhance" fish and wildlife populations while assuring the region "an adequate, efficient, economical and reliable" power supply.[3] The interpretation of this mandate has led to great debate within the region. Some argue that fish and wildlife needs must be balanced or integrated with power planning activities. This implies that some sort of cost-effectiveness analysis be done, examining the tradeoff between biological benefits and power system costs. Others argue, however, that fish and wildlife operations should be viewed as firm environmental constraints similar to air and water quality standards. This implies that the power system would build adequate supplies to ensure that fish operations would never be compromised, regardless of cost. These two positions bracket the range of opinions regarding these often conflicting operations.

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[1] "Optimizing" here means that energy production is maximized limited by other than fish and wildlife constraints, such as flood control, irrigation, navigation, etc.
[2] See the Council's account of the events of 2000-01 in the main power plan document.
[3] See the Council's publication "Analysis of Adequacy, Efficiency, Economy and Reliability of the Power System"

Although developed at different times and under different processes, the Council has attempted to use an integrated approach in developing both its fish and wildlife program (program) and the power plan (plan). During the development of the program, physical and economic impacts of each fish and wildlife measure affecting the operation of the hydroelectric system were assessed and considered before final adoption of the program. The Council, in its program, has recommended that fish measures be examined for their cost-effectiveness. The program dictates that if the same biological objectives can be met at less cost, those less costly means should be pursued.

The analysis for this power plan assumes that all fish and wildlife operations pertaining to the hydroelectric system, as outlined in the NOAA Fisheries' biological opinion and in the Council's program, will be followed. However, the Council realizes that emergencies may occur in which fish and wildlife operations would be interrupted. Assuring the adequacy of resources for the power system minimizes not only the risk of electrical shortages and high prices but also minimizes the risk of emergency interruptions to fish and wildlife operations.

RECOMMENDATIONS

Federal agencies have formed several committees through the biological opinion process to deal with in-season operational issues affecting fish and power. The Technical Management Team (TMT) consists of technical staff from both federal and non-federal agencies that usually meet on a weekly basis to assess the operation of the hydroelectric system. Requests for variations to those operations can be made and discussed at TMT meetings. Conflicts that cannot be resolved at the technical meetings are passed on to the Implementation Team (IT), which consists of higher policy-level staff. Impasses not resolved by this group are forwarded to the Executive Committee (EC), made up of executive staff from the various participating organizations. The process of resolving conflicts in proposed hydroelectric operations can sometimes be lengthy and cumbersome.

While the existing committee structure is intended to solve in-season problems, no currently active process exists to address long-term planning issues. The Council recommended in its 2003 program that both in-season and annual decision-making forums be improved.[4] The program states "at present, this decision structure is insufficient to integrate fish and power considerations in a timely, objective and effective way." It goes on to recommend that the forums should broaden their focus by including "expertise in both biological and power system issues" and by directly addressing longer-term planning concerns, not just weekly and in-season issues.

It is in such a forum where the long-term physical, economic and biological impacts of a fish and wildlife operation can be openly discussed and debated. Actions identified in the program to benefit fish and wildlife "should also consider and minimize impacts to the Columbia basin hydropower system if at all possible." The program further says that the goal should be "to try to optimize both values to the greatest degree possible."

To this end, the Council reiterates its recommendation in the 2003 program to improve and broaden the focus of the forums created to address issues surrounding fish and wildlife operations, especially those related to long-term planning.

[4] "Fish and Wildlife Program," Northwest Power Planning Council, Council Document 2000-19, pp.28, and "Mainstem Amendments to the Columbia River Basin Fish and Wildlife Program," Northwest Power Planning Council, Council Document 2003-11, pp.28-29.

ACTION ITEM

In this power plan, the Council recommends (Action F&W-1 in the Action Plan) that it "will work with federal agencies, the states, tribes, and others to broaden the focus of the forums created to address issues surrounding fish and wildlife operations, especially those related to long-term planning." This action is intended to improve the interaction between power planning efforts and fish and wildlife program development. More specifically this may include the following:

NOAA Fisheries and other Federal Agencies

- Improve and broaden the focus of forums created to address issues surrounding fish and wildlife operations, especially those related to long-term planning.
- Allow region-wide participation in these forums.

Council, Bonneville Power Administration and Hydroelectric Facility Operators

- Analyze the physical impacts (river flows and reservoir elevations) and economic impacts (changes in energy production and cost) of alternative mainstem operations for fish and wildlife.
- Whenever appropriate, analyze physical and economic analysis of individual components or sets of components of a fish and wildlife operation.

Council

- Work with the Independent Economic Advisory Board (IEAB) to continue to develop and demonstrate methods to improve the cost effectiveness of the fish and wildlife operations.
- Work with fish and wildlife managers to develop a methodology to assess whether protective mainstem measures are being treated equitably. This may involve establishing some sort of a metric similar to those developed to assess power system reliability.

Fish Managers

- Work with power planners and agencies to develop a minimum impact curtailment plan for fish and wildlife operations in the event of a power emergency.
- Work with power planners to assure the region that the most cost-effective measures are taken to achieve biological objectives.

BENEFITS OF INTEGRATION

Power system planners can provide valuable information to fish and wildlife managers to aid their development of measures to improve survival. Similarly, fish and wildlife managers can provide data to power planners so that they can plan for resource mixes that minimize impacts to fish and wildlife, whenever possible.

Biologists developing a fish and wildlife program must be able to assess relationships between various physical parameters and survival. For example, river flows, water temperature, passage routes (turbines, bypass or barges), predation, ocean conditions and a host of other factors all affect survival and long-term population forecasts for salmon. Based on these relationships, biologists can make recommendations regarding those elements that can be controlled, such as the operation of the hydroelectric system. Any changes to the operation of that system will result in differences in reservoir elevations, river flows, energy production and cost.

Using sophisticated computer models that simulate the operation of the northwest power system, power planners can assess the impacts of any given set of fish and wildlife measures that change the operation of the hydroelectric system. For a fish and wildlife program and, in particular, for individual elements of that program, physical impacts (effects on reservoir elevations and on river flows) and economic impacts (changes in generation production and related cost) can be analyzed and provided to fish and wildlife managers.

Changes in reservoir elevations, river flows and spill are used, along with other data, by biologists to estimate fish passage survival through the system. Passage survival estimates are an important part of life-cycle models, which are used to forecast long-term fish populations. Long-term population estimates, along with their corresponding uncertainties, will determine whether certain species are well off, stable or declining. In this sense, physical analysis by power planners plays a very important role in the development of the fish and wildlife program.

In addition, physical and economic analysis of specific fish and wildlife measures can aid in the development of a fish and wildlife curtailment policy, in the event of a power emergency. It would be in the region's interest to have a policy in place prior to an emergency, in order to minimize the risk to fish and wildlife. The following section provides a description of the mainstem measures under the fish and wildlife program and an analysis of their cost.

COMPONENTS OF A FISH AND WILDLIFE OPERATION

The mainstem portion of the fish and wildlife program consists of two major types of actions to promote survival that will also affect the power supply; 1) flow augmentation and 2) bypass spill.[5]

Flow Augmentation

Monthly flow objectives are provided for both the Snake and Columbia rivers during the migration season (April through August). These flow objectives, however, cannot be achieved 100 percent of the time because our reservoir system simply cannot store enough water to make up the difference in dry years. The BiOp makes considerations for extremely dry years and for the large uncertainty in forecasting runoff volumes. Language in the BiOp directs spring refill curves at Grand Coulee to be developed using an 85 percent level of confidence (assuming that sufficient non-hydro resources are available for winter power needs). Refill curves at Libby, Hungry Horse and Dworshak are developed using a 75 percent level of confidence. Realistically, because of other higher priority constraints, these refill probabilities are not always achieved. In simulated operations, Grand Coulee refills 84 percent of the time and Libby, Horse and Dworshak refill 40 percent, 58 percent and 66 percent, respectively.

When analyses are done using the existing non-hydro resources in a probabilistic manner (i.e. simulating forced outages), reservoirs must sometimes be drafted below their operating rule curves during winter months to sustain electricity service. This use of hydro is often referred to as "hydro flexibility." Hydro flexibility is used to make up energy needs during cold snaps or periods when imports from out-of-region utilities are not available or during the outage of a major power system component. The additional water drafted to produce the extra energy is replaced as soon as possible,

[5] See the Council's 2003 Fish and Wildlife program and NOAA Fisheries' 2000 Biological Opinion.

even if energy must be imported. Most often reservoirs can recover and get back to the projected refill elevations by spring. In the event that hydro flexibility cannot be replaced by spring, then less water is available for flow augmentation through spring and summer.

Bypass Spill

During the summer, flow augmentation measures in the BiOp actually provide more generation from the hydroelectric system because they increase river flow. However, bypass spill, which diverts water around turbines, reduces generation and reactive support for the transmission system.[6] Bypass spill can be curtailed for two reasons; 1) due to summer power emergencies (which should be more rare than winter emergencies) or 2) to refill reservoirs to minimum end-of-summer elevations as specified in the BiOp or the Council's fish and wildlife program. Bypass spill could also be curtailed in order to store additional water in Canadian reservoirs as a safeguard for anticipated winter problems in an upcoming winter, as was the case in 2001.

Measuring the Success Rate of Providing Fish and Wildlife Operations

The BiOp allows for curtailment of fish and wildlife operations during power emergencies but it does not specify an upper bound for such actions. For a number of reasons (i.e. what occurred during the 1990s) it could happen that the region under builds its generation supply, which increases the likelihood of having to curtail fish and wildlife operations. Using curtailment of fish and wildlife operations as a "safety valve" for an inadequate power supply is not acceptable. Curtailment of fish and wildlife operations cannot be used in lieu of planning for and acquiring an adequate regional power supply.

As a possible method of quantitatively measuring the likelihood of curtailment to fish and wildlife operations, a probabilistic metric (similar to the loss of load probability) can be developed. The simulation models used to calculate the reliability of the power system can also readily provide an assessment of how often fish and wildlife operations would be curtailed. The model can count how often reservoirs do not reach the desired pre-migration elevations and also how often bypass spill would be curtailed to avoid power shortfalls.

Council staff has developed a prototype metric and has solicited comments from a wide range of agencies and organizations in the region. While there was significant interest and support for developing such a metric, it became clear that more regional analysis and debate would be required before such a metric could be implemented into the planning process. Problems yet to be resolved related to this metric are defining what a "significant" curtailment is and how often curtailments would be allowed (that is, setting a standard). Future discussion of this approach should be discussed in the long-term planning committee that the Council is recommending to be established.

COST OF INDIVIDUAL FISH AND WILDLIFE MEASURES

The analysis presented here estimates the cost of individual measures in the fish and wildlife program. This effort is not designed to be a cost-effectiveness analysis. Rather, it is to be used to help the Council identify the most costly elements of the fish and wildlife program, which should be re-examined for biological effectiveness. The Council specified, in its fish and wildlife program, that such measures, especially bypass spill, should be revisited in terms of assessing their biological

[6] See the February 24, 1998 memorandum from John Fazio to the Council members regarding the transmission impacts of drawing down John Day Dam (Council document 98-3).

benefits. During that process benefits to fish and wildlife from alternative main stem operations and their effects on the power system should also be examined.

Methodology

This analysis begins with a simulation of current river operations (BiOp). The simulation is performed with the GENESYS model.[7] Each subsequent study repeats the simulation but with one fish and wildlife measure removed. For each case study, the energy produced is compared to that in the base case and power system cost is calculated. This effectively determines the cost of each fish and wildlife measure analyzed. The measures are then ranked by cost.

It should be noted that fish and wildlife measures are not totally independent of each other. In other words, the cost of removing two measures will be different than the sum of the costs of removing each individually. Some measures, such as winter storage and flow augmentation are more dependent than others, such as bypass spill. However, performing the analysis as if each measure were independent provides a good first pass approximation. Once the data has been examined, the most expensive measures can be analyzed in more detail.

The key output parameter is annual-average regional power-system cost. That value is calculated by multiplying the difference in monthly hydroelectric energy production between the base case and a study case with the forecasted monthly market electricity price.[8] When the study case produces less energy, the difference is assumed to be purchased on the market and represents a cost. When the study case produces a surplus, the difference is sold on the market and represents revenue that offsets purchase costs. This calculation is performed for each month of the year, simulated over the 50-year historical water record.

The power system cost calculated for this analysis does not include costs of implementing fish and wildlife measures. It also does not include costs associated with loss of capacity or loss of transmission capability. Future analysis with the GENESYS model can shed some light on potential capacity problems associated with fish and wildlife measures. Those costs are not insignificant but it is believed, in most cases, that they are small compared to energy costs.

Results

Simulation results compare hydroelectric generation from the base case with that from the various scenarios analyzed. The monthly change in generation is multiplied by the wholesale electricity price (shown in Figure 1[9]) to compute the net gain or loss of revenue. Decreases in generation are assumed to be made up with purchases from the market and increases in generation are assumed to be sold into the market. By adding up the monthly purchases or sales over all water conditions, the average annual net cost or benefit of a particular scenario can be calculated for the region. Figure 2 below illustrates the range of annual costs for the entire BiOp. The average annual cost is $410 million. To put this in perspective, Bonneville's annual net revenue requirement is in the range of $3.5 billion. Thus, the BiOp cost is a little more than 10 percent of Bonneville's net revenue

[7] See http://www.nwcouncil.org/genesys.
[8] Electricity prices are forecast using the Aurora model, created and leased by EPIS.
[9] It should be noted that the long-term forecast electricity price drops from the 2006 average of about $43/megawatt-hour to about $30/megawatt-hour by the year 2010. The forecast price then rises gradually to a little over $35/megawatt-hour by 2025. This means that in real terms, the costs for fish and wildlife measures will be lower in future years relative to their cost for 2006.

requirement. Energy-wise, the BiOp has decreased average hydroelectric generation by about 1,100 average megawatts or about 10 percent of the firm hydro energy capability.

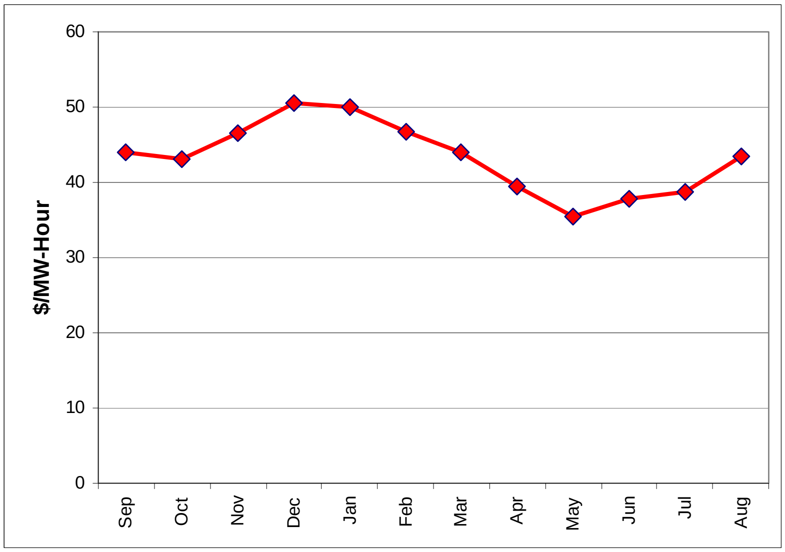

Figure O-1: Forecast Bulk Electricity Prices (at Mid-Columbia, 2006 operating year, 2004 dollars)

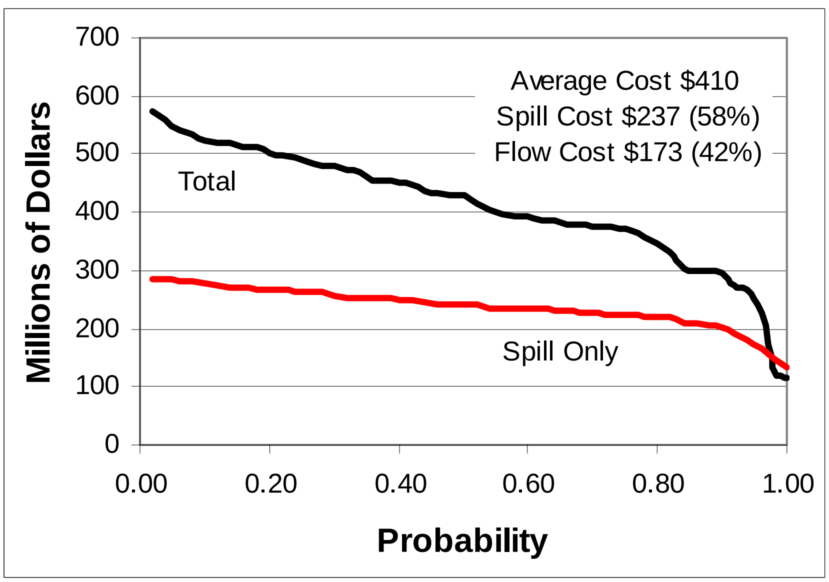

Figure O-2: Range of Annual Cost for Fish and Wildlife Operations (2006 operating year, 2004 dollars)

Annual BiOp costs range from a high of about $600 million to a low of about $100 million. In order to explain why some years have low costs, we must describe in more detail the two major components of fish and wildlife operations -- flow augmentation and bypass spill. Holding water back during winter months for release in spring and summer months effectively moves hydroelectric generation from months when the average price is about $50/MW-hour into spring months when the price can be as low as $35/MW-hour and into the summer months when the price can still be lower than the winter price. (There are also energy efficiencies to take into account but their impact is small relative to the shift in prices). Depending on how much water (energy) is moved into spring vs. summer, the range of economic impacts for flow augmentation is very large (Figure 2). There may be some situations when summer prices are higher than winter prices, in which case, flow augmentation actions could improve revenues. Unfortunately, the effects of bypass spill overwhelm any economic benefits derived from such situations.

Bypass spill is water that is routed around the turbines to enhance survival of migrating smolts. It always represents a loss of revenues for the region. At some projects, bypass spill is defined to be a fraction of outflow and at other projects it is defined as a flat amount. Both are subject to maximum spill levels that limit gas supersaturation to no more than 120 percent. The cost of spill varies with water conditions and prices. Figure 3 illustrates the annual breakdown of flow augmentation and bypass spill costs for the region. Overall, bypass spill costs represent about 58 percent of the total average cost of the BiOp. That percentage varies quite a bit as demonstrated in Figure 3.

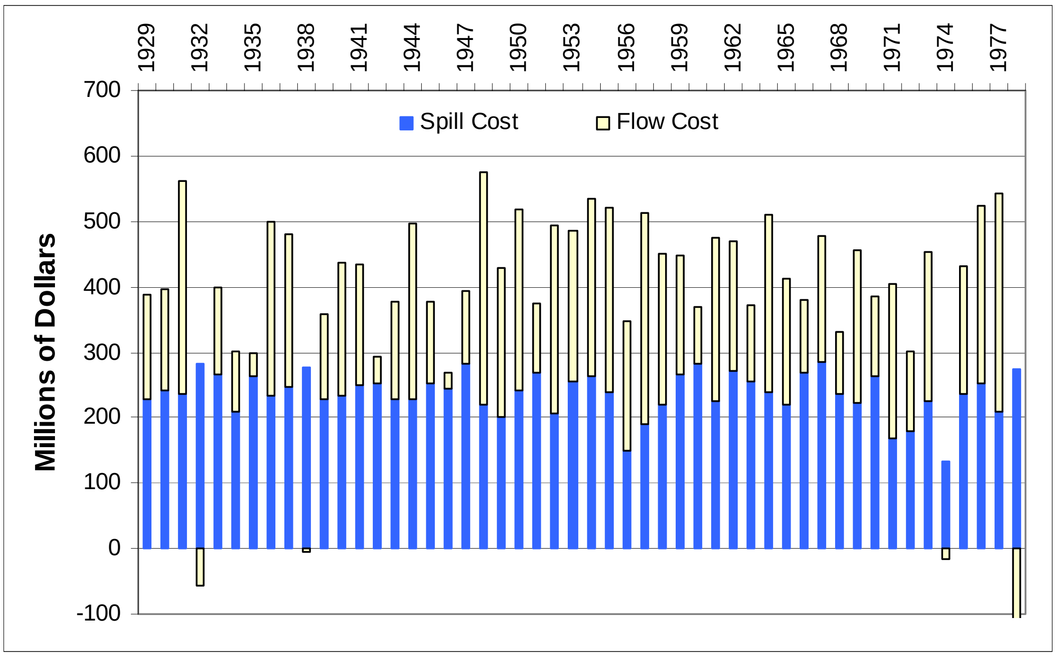

Figure O-3: Flow and Bypass Spill Cost by Water Condition (2006 operating year, 2004 dollars)

It is of interest to understand how fish and wildlife operation costs vary with water conditions. Figure 4 below plots the cost of both flow augmentation and bypass spill as a function of the January-to-July runoff volume as measured at The Dalles. The flow augmentation costs are represented by the square points in that figure and do not show any particular pattern, except that they may perhaps decrease slightly as runoff volume increases. This makes some intuitive sense since less water must be shifted from winter months into spring and summer months in wet years to attempt to achieve BiOp flow objectives.

Bypass spill costs however, behave in a very different manner. Figure 5 illustrates only the spill costs as a function of runoff volume. As runoff conditions increase, so do bypass spill costs but only up to a point. For more-or-less average water conditions spill costs seem to level off. For wet years, bypass spill costs actually decrease. This apparently unusual relationship between spill and costs can be explained fairly easily. At some projects, bypass spill is a percentage of outflow -- meaning that as the outflow increases (or as runoff volume increases) the absolute volume of spill also increases. However, this trend is limited by the gas supersaturation constraint. That is, once the absolute volume of spill reaches the gas limit, no more volume is spilled. In this case, the cost of bypass spill remains constant until the runoff volume increases to a point where the hydraulic capacity of the project is exceeded. In that case, the amount of bypass spill is reduced so that the total spill (bypass and forced) equals the desired amount. Because forced spill (flow exceeding hydraulic capacity) would occur anyway, there is no cost associated with it and the cost of the declining bypass spill decreases. This phenomenon is illustrated in Figure 6.

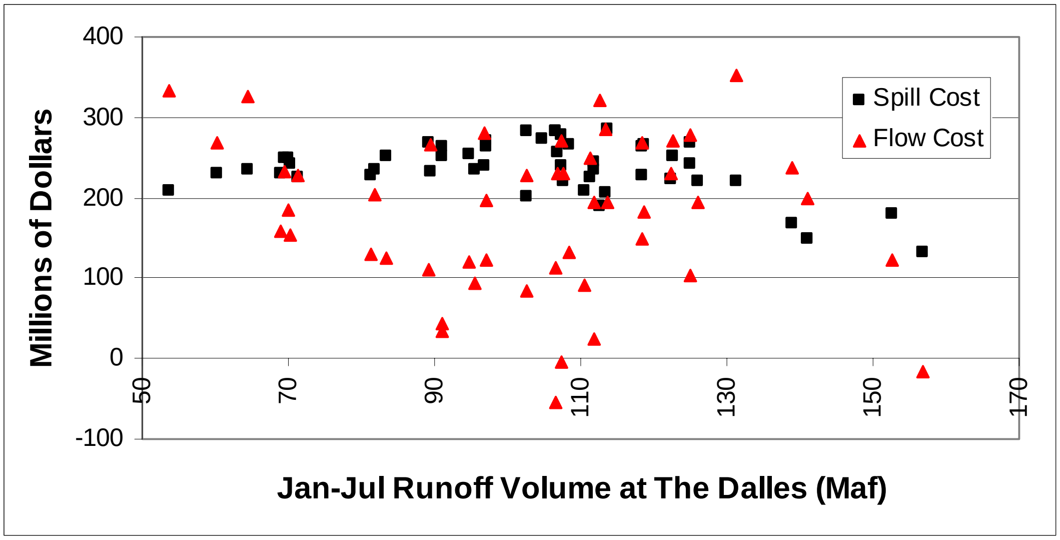

Figure O-4: Flow and Spill Cost as a function of Runoff Volume (2006 operating year, 2004 dollars)

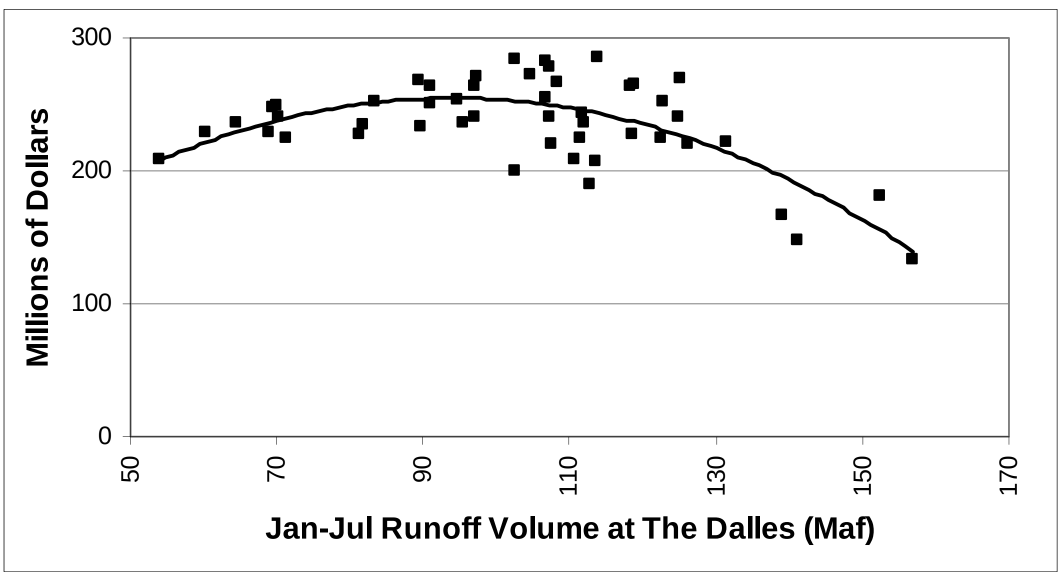

Figure O-5: Bypass Spill Cost as a function of Runoff Volume (2006 operating year, 2004 dollars)

It is of no great surprise that bypass spill shows the greatest cost to the power system in most years. Not only does the region lose energy when providing spill but it also limits the peaking capability of the project and in some cases may reduce reactive support for the transmission system. The later impact effectively reduces the transfer capability of nearby transmission lines.[10]

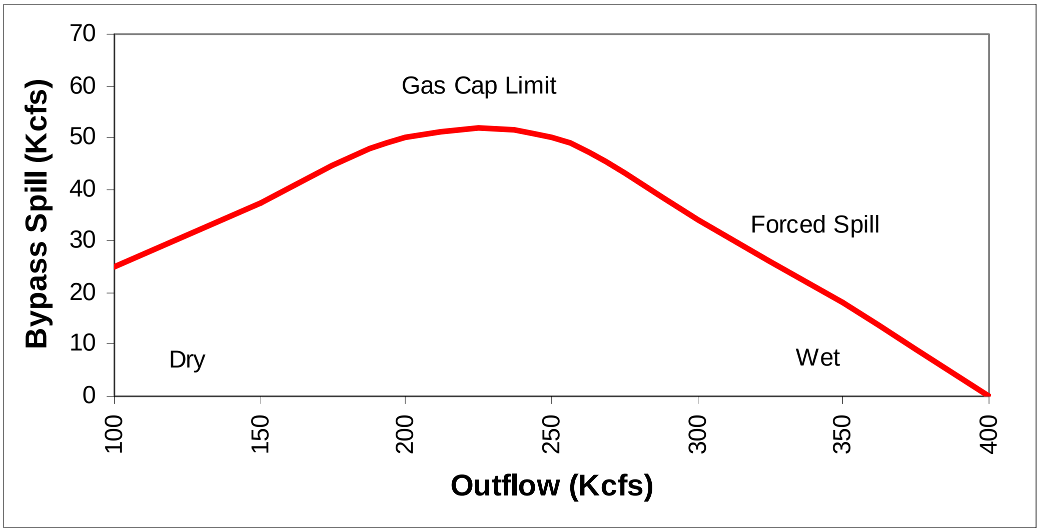

Figure O-6: Illustration of Bypass Spill Flow as a function of Outflow

Because of the Council's commitment to re-examine bypass spill, the remaining analysis focuses on that operation. Table 1 below identifies the energy loss and associated costs of providing bypass spill at the eight lower river dams for both spring and summer periods. From Table O-1, it is clear that bypass spill at The Dalles and John Day is the most costly. In fact, bypass spill costs at those two projects make up almost half of the total spill cost. If any research money is to be spent, it should focus on these two projects and perhaps Ice Harbor.

Figures 7 and 8 illustrate the cost of bypass spill in graphic form. Figure 7 shows the average cost for bypass spill at each of the eight lower river dams. Figure 8 breaks those costs down into spring and summer periods, just like the data in Table 1. Using this information helps direct money and research efforts to the right projects.

[10] See Council document number 98-3.

Table O-1: Annual Average Cost and Energy Loss of Bypass Spill (2006 operating year, 2004 dollars)

Project/Season	**Cost** (Millions $)	**Energy Loss** (MW-Hours)
John Day/Summer	31.1	766,810
John Day/Spring	29.6	791,895
Ice Harbor/Spring	28.6	742,361
The Dalles/Spring	27.5	735,028
The Dalles/Summer	25.6	625,399
Bonneville/Summer	23.3	560,671
Bonneville/Spring	20.7	542,524
McNary/Summer	12.2	306,571
Ice Harbor/Summer	11.8	292,441
McNary/Spring	10.6	276,784
Lower Monumental/Spring	8.8	233,917
Little Goose/Spring	4.1	109,644
Lower Granite/Spring	3.3	87,504
Total (energy loss in average megawatts)	**237**	**693**

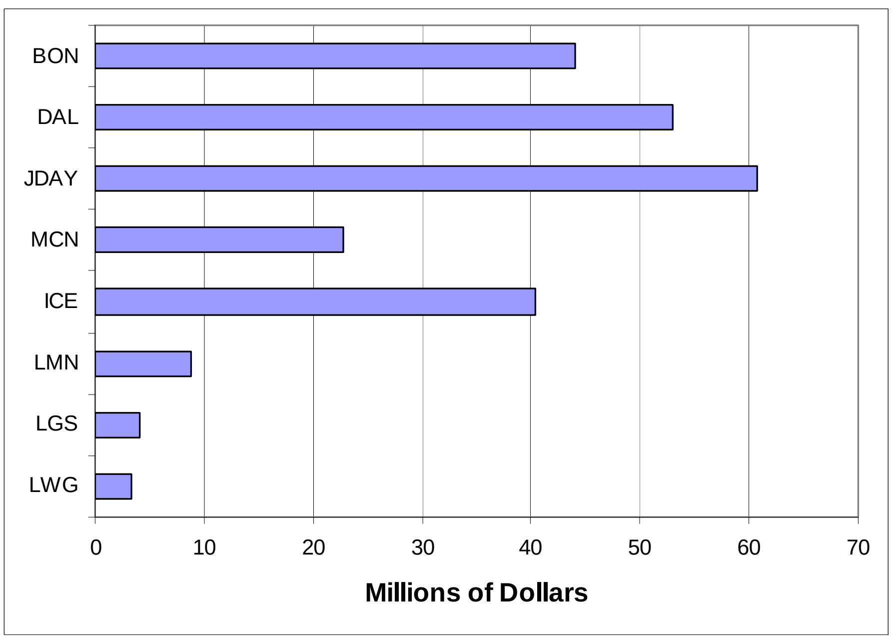

Figure O-7: Bypass Spill Cost by Project (2006 operating year, 2004 dollars)

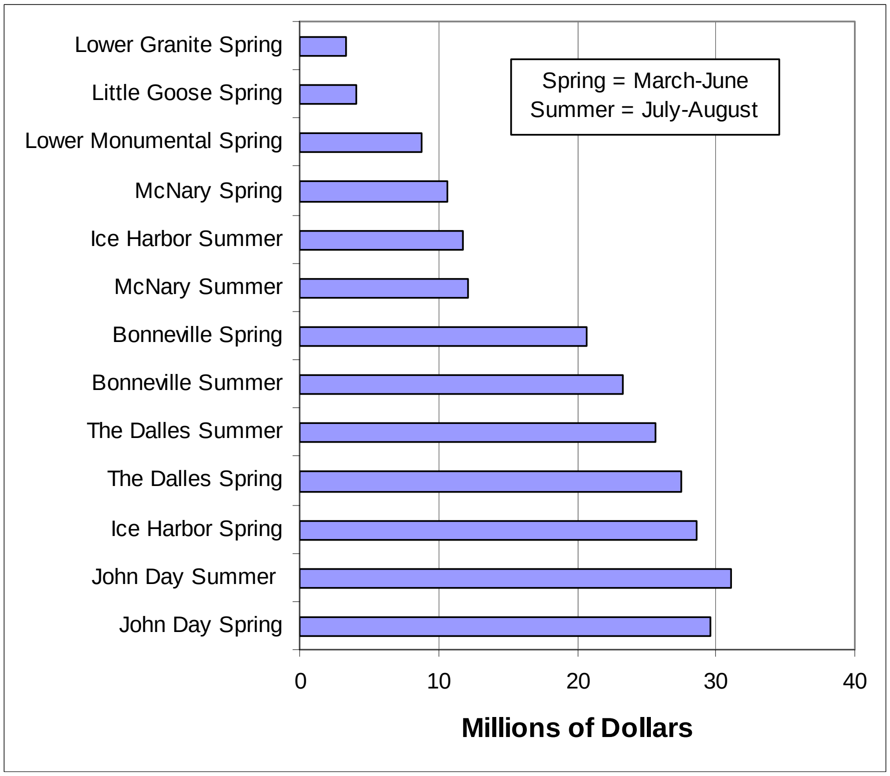

Figure O-8: Bypass Spill Cost by Project and by Season (2006 operating year, 2004 dollars)