

Appendix M: Integrating Fish & Wildlife and Power Planning

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SUMMARY OF KEY FINDINGS

The Columbia River Basin hydroelectric system is a limited resource that is unable to completely satisfy the demands of all users under all circumstances.¹ Conflicts often arise that require policy makers to decide how to equitably allocate this resource. The Council’s *Columbia River Basin Fish and Wildlife Program* and *Electric Power and Conservation Plan* must provide measures to “protect, mitigate, and enhance fish and wildlife affected by the development, operation, and management of [hydropower] facilities while assuring the Pacific Northwest an adequate, efficient, economical, and reliable power supply.”

The Council’s current assessment² indicates that the regional power supply can reliably provide actions specified to benefit fish and wildlife (and absorb the cost of those actions) while maintaining an adequate, efficient, economic and reliable energy supply. This is so even though the hydroelectric operations specified for fish and wildlife have a sizeable impact on power generation and cost. The power system has addressed this impact by acquiring conservation and generating resources, by developing resource adequacy standards, and by implementing strategies to minimize power system emergencies and events that might compromise fish operations.

¹ Some of the many uses of the Columbia River hydroelectric system include flood control, power generation, irrigation, recreation, navigation and protection for fish and wildlife.

² See <http://www.nwcouncil.org/energy/resource/Adequacy%20Assessment%20Final.doc>.

On average, hydroelectric generation is reduced by about 1,170 average megawatts, relative to an operation without any constraints for fish and wildlife.³ For perspective, this energy loss represents about 10 percent of the hydroelectric system's firm generating capability⁴. It is difficult to assess the cost of this loss because mitigation actions taken specifically for this loss cannot be identified. The region has acquired conservation and other resources since 1981 for many different reasons, fish and wildlife impacts being only one. However, the cost of fish and wildlife operations to the power system can be approximated. Using a long-term amortized replacement resource cost, the fish and wildlife program cost to the power system is on the order of \$300 million per year.

Sometimes, however, it becomes important to assess the cost of program measures using market prices. For example, Bonneville gets a credit for expenses made for non-power related operations. For this assessment, Bonneville appropriately uses market prices to determine its power purchase costs related to fish and wildlife operations. Using this approach, the annual average power system cost of the program is in the range of \$450 million. In addition to operational costs, fish and wildlife related capital expenses and other program costs, while variable, are expected to average \$287 million⁵ per year over the next 5 years. Bonneville estimates that replacing lost hydropower capability and funding direct fish and wildlife program expenditures have increased Bonneville's costs from \$750 to \$900 million per year. That amount represents about 20 percent of Bonneville's annual net revenue requirement.⁶ These impacts would definitely affect the adequacy, efficiency, economy and reliability of the power system, if they had been implemented over a short term. However, this has not been the case. Since 1981, the region has periodically amended fish and wildlife related hydroelectric system operations and, in each case, the power system has had time to adapt to these incremental changes.

Looking toward the future, there remain a number of uncertainties surrounding the operation of the hydroelectric system, which must be addressed in the development of the power plan. These uncertainties can have both positive and negative effects. For example, spillway weirs offer the potential to reduce bypass spill while providing the same or better passage survival. On the other hand, current bypass spill levels are under litigation and are likely to be increased. Climate change has the potential to alter river flows, which affect both power production and fish survival. The potential of dam removal or of operating reservoirs at lower elevations would further reduce power production. The Council recommends that the region continue to monitor fish and wildlife activities and to continue to develop better analytical methods to assess both power and biological impacts.

Outside of the Council's own power planning effort, there is no forum or process in the region to address long-term planning issues related to the integration of power planning and fish and wildlife operations. The Council would support the creation of an open forum where fish and wildlife managers and power planners could jointly explore strategies to improve both fish and

³ The comparison study, which includes no actions for fish and wildlife, is represented by hydroelectric operations prior to 1980.

⁴ Firm hydroelectric generating capability is about 11,900 average megawatts (2007 Bonneville White Book) and is based on the critical hydro year, which is currently defined to be the 1937 historical water year.

⁵ Taken from Bonneville's 2008 Integrated Program Review, the capital budget estimate for the next five years represents the maximum cost; actual expenditures may be less.

⁶ Bonneville's annual net revenue requirement is on the order of \$3.5 billion (Bonneville's 2007 Annual Report).

wildlife benefits and hydroelectric power operations. In such a forum, synergistic effects between fish and wildlife operations and power planning could be examined.

INTRODUCTION: INTEGRATING THE FISH AND WILDLIFE PROGRAM AND POWER PLANNING UNDER THE NORTHWEST POWER ACT

The many storage and hydroelectric facilities built in the Columbia River Basin provide a number of benefits to the citizens of the Pacific Northwest and Canada. This includes the fact that, on average, the US portion of the hydroelectric system provides nearly 75 percent of the electricity needs for the northwest.⁷ Development of the hydroelectric system, however, has also had adverse effects on salmon and steelhead and other native species of fish and wildlife in the basin. In the Northwest Power Act, Congress directed the Council to lead an on-going effort to find the best ways to operate the hydrosystem and further develop the region's power supply so as to improve the survival of fish and wildlife affected by the system while also meeting the region's growing electricity demands with the least-cost conservation and generating resources.⁸

The Northwest Power Act directs the Council to integrate planning for fish and wildlife and electric power resources in a recurring two-step process. The first step is to develop or amend the fish and wildlife program; the second is to include the fish and wildlife program in the power plan, developing a coordinated resource plan to accommodate the fish and wildlife requirements and meet any increasing demand for electricity. This is the Council's central fish and wildlife/power "integration" function under the Power Act, and yet it is largely ignored in the usual discussions of the relationship of the fish and wildlife program to the region's power system. Thus the first part of this appendix is devoted to explaining how the power planning process and the power system add least-cost resources over time to keep the electricity supply in balance while accommodating all the changes that affect that load/resource balance, including the effects of fish and wildlife operations.

The second part of this appendix discusses the costs of the fish/power integration, from a number of different viewpoints. For too long the integration of the fish and wildlife program and the power plan have been talked of *only* in terms of cost, and *only* in terms of the difference between current operations and operations without consideration for fish and wildlife, priced at current wholesale market electricity prices. This may be interesting information to know, as a theoretical opportunity cost and for understanding total effects on Bonneville revenues over time. It does not necessarily reflect actual costs to Bonneville and the region over time, which should take into account instead the costs of the resources actually added over time to replace the hydropower generation, which is the first set of costs addressed in this part. Identifying the cost of individual fish and wildlife program measures allows the Council to assess their power system value relative to their biological benefits. This helps the Council include in its fish and wildlife program cost-effective measures to achieve its biological goals. Also, the Bonneville Power

⁷ Hydroelectric generation in the Pacific Northwest averages about 16,000 average megawatts and annual demand is about 21,000 average megawatts.

⁸ The development and operation of the hydroelectric system also affects flood control, irrigation, navigation, recreation, water for municipal and industrial uses, Native American cultural resources, and water quality. All of these effects must be taken into account as the relevant agencies plan and operate the system. But the Power Act has a particular focus on the relationship between fish and wildlife and electrical energy, and so that is the focus here.

Administration receives a credit from the US Treasury for part of its expenses related to non-power operations, which includes fish and wildlife costs and is another important aspect of cost assessment. Finally, it is important to assess how the fish and wildlife program has affected Bonneville's revenue sources and electricity rates.

Finally, the third part of this appendix discusses future uncertainties that would affect the fish and wildlife program and the power supply. These include uncertainties and risks related to (1) possible future changes in the fish and wildlife program; (2) an evolving power system that must integrate different kinds of generating resources, which will put more stress on the hydroelectric system; (3) possible modifications in Columbia River Treaty operations; and (4) climate change effects on the amount and timing of runoff and on electricity demands that would pose problems for both fish and wildlife and power generation.

PART 1: POWER RESOURCE PLANNING TO ACCOMMODATE THE POWER SYSTEM EFFECTS OF THE FISH AND WILDLIFE PROGRAM

This part of the appendix is devoted to explaining how the power planning process and the power system add least-cost resources over time to keep the power supply in balance while accommodating all the changes that affect the load/resource balance, including the effects of the fish and wildlife operations.

Prior to the development of the first power plan, the Power Act directed the Council to call for recommendations and adopt the *Columbia River Basin Fish and Wildlife Program*. Prior to each five-year review of the regional power plan, the Council must first call for recommendations and amend the fish and wildlife program. Leading into the Sixth Power Plan, for example, the Council recently completed amendments to the fish and wildlife program, resulting in the *2009 Columbia River Basin Fish and Wildlife Program* (www.nwcouncil.org/fw/program).

In this first stage in the planning sequence, the Power Act requires the Council to adopt fish and wildlife program measures that will “protect, mitigate, and enhance fish and wildlife” affected by the development and operation of the basin's hydroelectric facilities, and to do so while also assuring the region an “adequate, efficient, economical, and reliable power supply.” To this end the Council's fish and wildlife program contains, among other measures, mainstem flow and passage measures (such as bypass spill) that affect hydroelectric system operations. These flow and passage measures have evolved over time, differing with each new version of the program. The changing flow and passage measures alter power generation at the mainstem dams, shifting flows and generation from winter to spring and summer as reservoir storage operations have changed to benefit fish and wildlife, and reducing potential generation in spring and summer by increasing bypass spill at run-of-the-river dams to improve fish passage survival.

Each time the Council considers and adopts a revised fish and wildlife program, it must also assess how the revised program measures will affect the region's power supply, and then evaluate, albeit in a preliminary way, if it will be possible to accommodate these changes and still assure the region an adequate, efficient, economical, and reliable power supply. The power system evaluation at this stage is necessarily preliminary. This is because what will follow immediately will be a comprehensive power planning effort that will include, among many other

tasks, assessing whether and how to adapt the power system and add resources to accommodate the effects on power supply of the revised fish and wildlife program.

The power plan process is then the second step in the integration of fish and wildlife program measures and power system expansion under the Northwest Power Act. As the Northwest Power Act describes the power planning process, the Council projects a range of electricity demand scenarios over the next 20 years, and then evaluates whether current electric power resources will be adequate to meet increasing demand under different future conditions. If not, the Council includes a plan for adding the lowest-cost new resources, including (as a first priority) cost-effective conservation. What's important here is that the Power Act makes the just-amended fish and wildlife program one element of the power plan. In part, this is because knowing the latest flow and passage operations of the fish and wildlife program is an important part of assessing the current generating capability of the hydroelectric system, and the amount of hydroelectric generation available is then one contributor to knowing the total generating capability of current regional power resources. The current resource capability is then compared to current and projected load demands, and the differences are noted. In that sense, a change in hydroelectric generation due to a change in operations for fish and wildlife is functionally the same, for the Council's power planning purposes, as an increase in electricity demand, altering the load-resource balance in ways Congress expected the Council to be concerned with and to address in the power plan.

The Council is then to develop a least-cost resource plan to deal with any projected load-resource gap, whether the result of a reduction in available resources (such as due to a change in operations for fish and wildlife or because of a change in some other existing resource) or an increase in electricity demand, or both (as has always been the case since 1980). The Power Act then obligates Bonneville to have an ongoing conservation program and acquire other resources, if necessary, consistent with the Council's power plan to meet its electricity demand obligations and "to assist in meeting the requirements of section 4(h) of this Act" -- that is, to meet the requirements of the Council's fish and wildlife program and Bonneville's corresponding obligation to protect, mitigate, and enhance fish and wildlife in a manner consistent with the Council's program and power plan.

This is not just an "energy" issue. New or revised fish and wildlife operations do alter the amount of overall energy that the hydropower system can produce, but they also alter the peaking capability of the hydroelectric system in winter and reduce the flexibility of the system to follow load and balance other variable resources, which is a growing issue with the regional power system. The Sixth Power Plan is looking at regional resource needs in all these categories -- energy, capacity, and flexibility. Changes in fish and wildlife operations are one source of effects on all three to take into account.

The last point to reemphasize is these fish and wildlife operations and these power system effects did not happen all at once, or all in one planning period. Flow and passage measures for fish and wildlife began with the "water budget" in the first Fish and Wildlife Program in 1982, and have changed and (largely) increased at every iteration of the program since then. Each successive power plan, and nearly thirty years of resource planning and resource acquisitions by Bonneville -- mostly conservation -- have accommodated those changes. Fish and wildlife operations have changed again since the Fifth Power Plan, and the main integration task the Council faces in this

power plan is to how to deal with those and other effects on the region's load/resource balance in the next five and twenty years.

The 2009 Fish and Wildlife Program and Current Fish Operations

Fish and wildlife actions identified in the 2008 NOAA Fisheries FCRPS Biological Opinion have been recognized in the Council's 2009 Fish and Wildlife Program as the baseline for fish and wildlife operations in the near future. Current operations are actually a combination of flow and passage measures in the 2008 Biological Opinion and additional spill agreed to by the parties and ordered by the federal court in the Biological Opinion litigation, at least for this year.

The authors of the biological opinion attempted to use best available science to develop a least-harm hydroelectric project operations plan by assessing the magnitude of potential adverse effects on fish resulting from a wide range of operational scenarios. The biological effects of the operational scenarios were estimated using the NOAA Fisheries' COMPASS (Comprehensive Passage and Survival) model, designed specifically for the reaches of the Columbia and Snake rivers extending from Lower Granite Dam to Bonneville Dam.

These provisions have substantive effect with regard to the operation of the mainstem hydropower system in the Columbia and Snake rivers. The mainstem portion of the fish and wildlife program consists of two major types of actions to promote anadromous fish survival that will also affect the power supply: 1) storage reservoir operations to affect flows; and 2) bypass spill for fish passage.⁹

Reservoir Operations

The Biological Opinion/Fish and Wildlife Program operations call for federal storage reservoirs in the United States to be at, and not below, the maximum level specified for flood control operations in early April. This has the effect of requiring system operators to keep water levels behind these dams higher in winter and early spring than they would have (in most years) for an optimum power operation. Monthly flow objectives are then provided for both the Snake and Columbia rivers during a part of the juvenile and adult salmon migration season in spring and summer (April through August) and during the spawning season for Kootenai River white sturgeon below Libby Dam. The reservoir operation in spring largely works toward project refill while otherwise passing the snowmelt runoff downstream to try to achieve the flow objectives.

The fish and wildlife operations target reservoirs for refill by end of June. The Biological Opinion then specifies federal storage reservoirs to draft, up to limits specified in the opinion, in order to augment summer flows to aid in fish survival. This operation results in higher flows over this period than would be normal under a purely power-focused operation. For more than a decade, the federal agencies have also entered into supplemental operating agreements with B.C. Hydro to release water from Canadian storage projects to benefit fish migration in the U.S. in ways that would not occur under ordinary Columbia River Treaty operations. Finally, the operating agencies also release water in late fall and early winter to support chum flow spawning

⁹ The Fish and Wildlife Program contains other measures that do not affect system operations, but which do require expenditures by Bonneville, including capital costs for fish passage and the direct cost of other fish and wildlife program actions. These elements of the program are described in more detail below. See the Council's 2009 Fish and Wildlife Program and NOAA Fisheries' 2008 Biological Opinion.

and rearing in the lower Columbia, and control operations in the mid-Columbia River to support fall Chinook spawning and rearing in the Hanford Reach.

The main effect of this operation on the power supply is to reduce the generating capability of the hydroelectric system over the winter, at the time of the region's peak loads, and to increase generation when runoff is passed through in the spring and when it is released from storage in the summer, generally producing surplus generation over native regional demand. There is not a one-to-one shift in energy production from winter to spring/summer because of bypass spill requirements.

Bypass Spill

Bypass spill is the re-routing of river flows away from turbine intakes and into fish passage and spillway systems. The survival of migrating juveniles diverted into fish passage systems and over spillways is considerably higher than fish survival rates through the turbines. The Fish and Wildlife Program and NOAA Fisheries Biological Opinion call for the eight federal dams on the lower Snake and Columbia rivers to divert part of their flows through fish bypass systems during spring and summer. As noted above, additional spill is occurring this year as a result of a court-approved agreement among the parties to the Biological Opinion litigation. It is not clear whether such additional bypass spill will be required in future years, therefore it was not assumed in the analysis.

Hydropower generation is reduced from what it would be without the spillways open. In nearly every year, the difference does not affect the firm power capability of the system, and instead reduces the amount of non-firm or surplus power available for sale on wholesale power markets. Surplus power sales are made to serve peak loads in the Southwest or to allow others to displace more expensive resources that also serve load in the region. The main effect of surplus sales at Bonneville is to generate revenue that helps to cover the cost of Bonneville's operation of the federal hydropower system, reducing Bonneville's debt to the Treasury, and covering its other costs. Spill can also reduce reactive support for the transmission system, which leads to reduced transmission capability and could potentially reduce system reliability.¹⁰

The Biological Opinion/Fish and Wildlife Program specify additional operational limitations, including turbine operating criteria and limits on how fast flows may be ramped up or down through changes in project discharge levels. These constraints have little effect on the total energy production of the system, but instead reduce the system's flexibility to follow load and accommodate varying wind output. These effects are difficult to model or estimate quantitatively, but are real nonetheless.

Modeling the Power System

As part of the power plan effort, the Council has to estimate the current generating capability of the hydroelectric system. Operations for fish and wildlife are only part of this effort, and must be combined with the runoff pattern (both amount and shape), with operational requirements and constraints for purpose of flood control (which are significant) and navigation, irrigation and

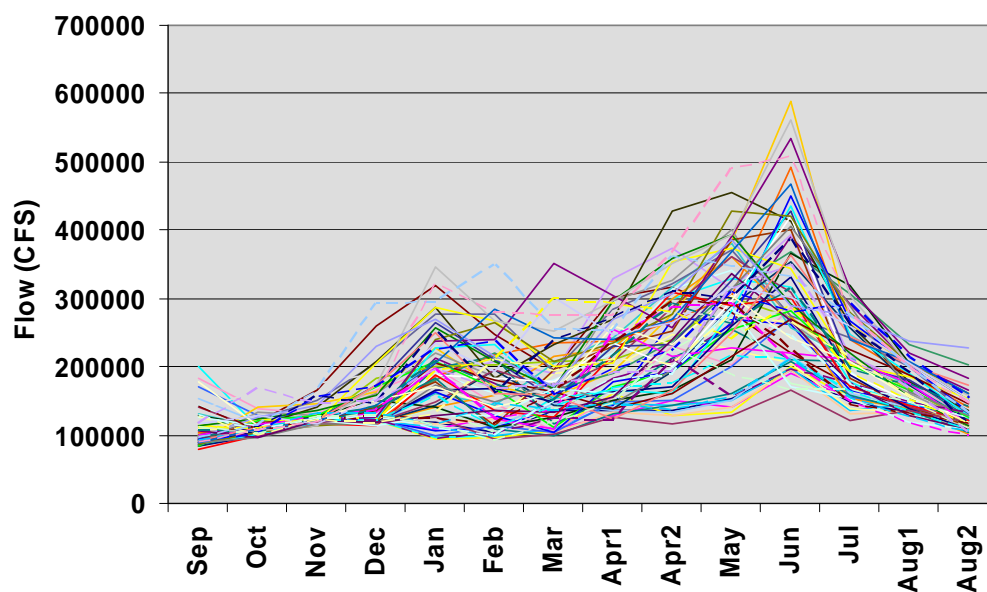
¹⁰ See the Memorandum dated February 24, 1998, memorandum from John Fazio to the Council regarding the transmission impacts of drawing down John Day Reservoir and other fish and wildlife operations (Council document 98-3).

other non-power purposes (relatively minor on overall system operations), and power system objectives (i.e., load objectives). The end result is a series of monthly reservoir elevation and flow profiles, and then, especially, monthly generation patterns (bi-monthly in April and August). The modeling effort can be done on a planning basis, using different runoff patterns representing the 70-year historical water record (and the Council and Bonneville both do this), or on an “actual” basis, looking at a past year’s actual runoff and generation (Bonneville does this).

The analysis of system operation and hydroelectric generation is performed with the GENESYS model.¹¹ The model simulates the operation of regional resources including hydroelectric facilities over many different future conditions. For the hydroelectric system, key outputs include regulated outflows, reservoir elevations, and generation. (Another output is cost, but that is addressed in the second part of the appendix.) GENESYS simulates both a monthly and hourly dispatch of available resources to meet regional load. In the monthly mode, it simulates the operation of individual hydroelectric facilities. In the hourly mode, however, the hydroelectric system is operated in aggregate and the peaking capability of that system is approximated using linear programming techniques.

This model is designed to address both energy (monthly and annual) needs and capacity (hourly) needs. The results depicted below are based on the use of GENESYS to analyze the operations outlined in the Council’s Fish and Wildlife Program, consistent with those in NOAA Fisheries’ 2008 Biological Opinion. Figures M-1 and M-2 show the range of outflows at Lower Granite and The Dalles dams for each of the 70 water conditions modeled. Figure M-3 shows the range of system generation in average megawatts by month and Figures M-4 through M-7 show the range of elevations by month at Libby, Hungry Horse, Grand Coulee and Dworshak dams.

Figure M-1: Flow at The Dalles



¹¹ See <http://www.nwcouncil.org/genesys>.

Figure M-2: Flow at Lower Granite

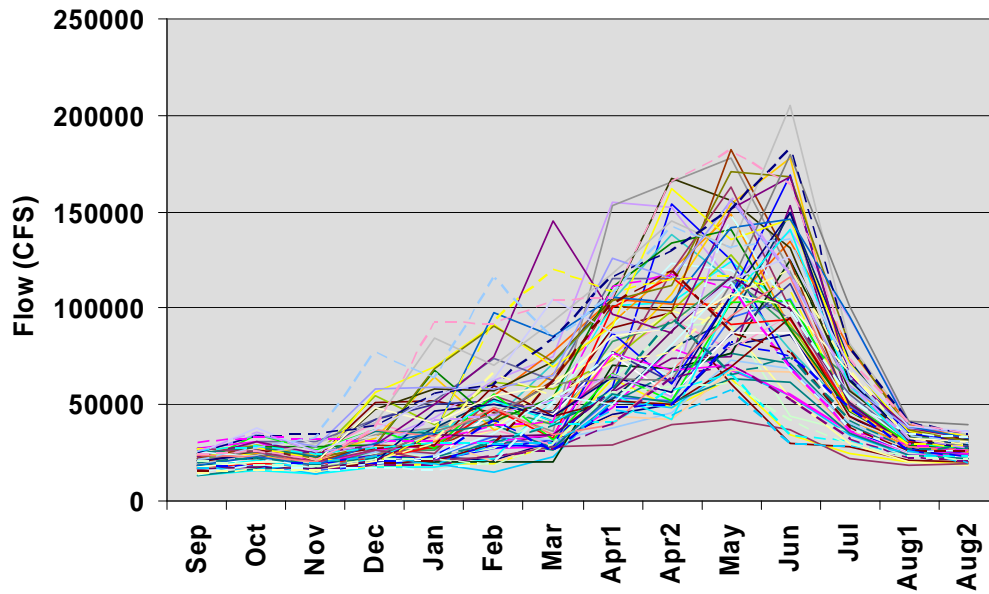


Figure M-3: Hydroelectric Generation

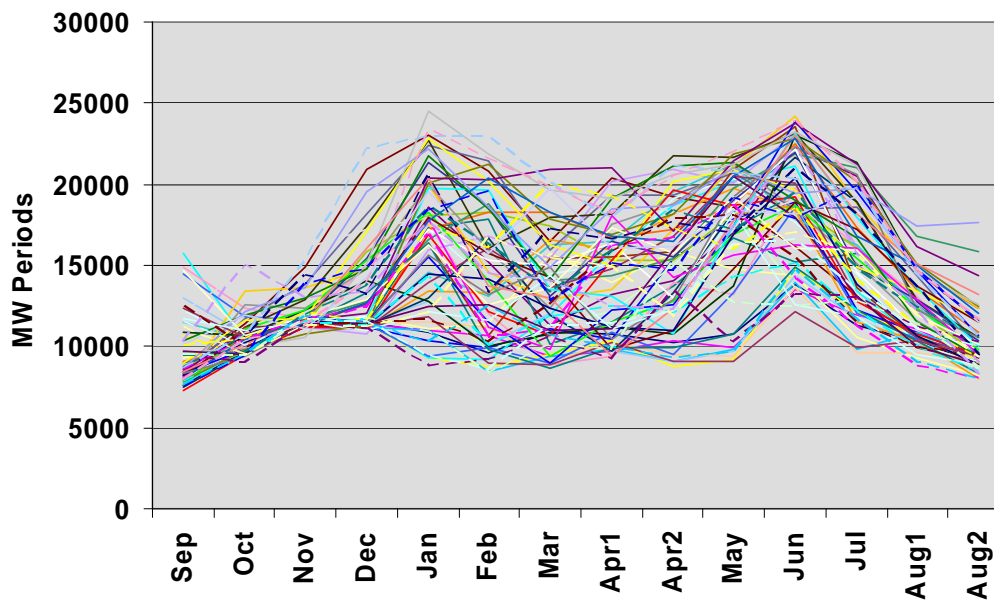


Figure M-4: Elevation at Libby Dam

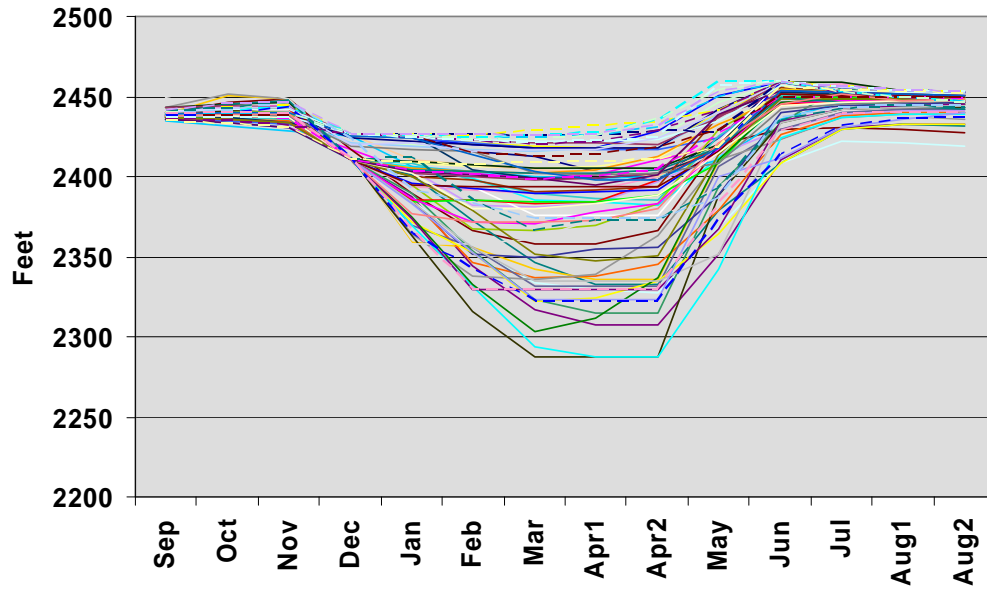


Figure M-5: Elevation at Hungry Horse Dam

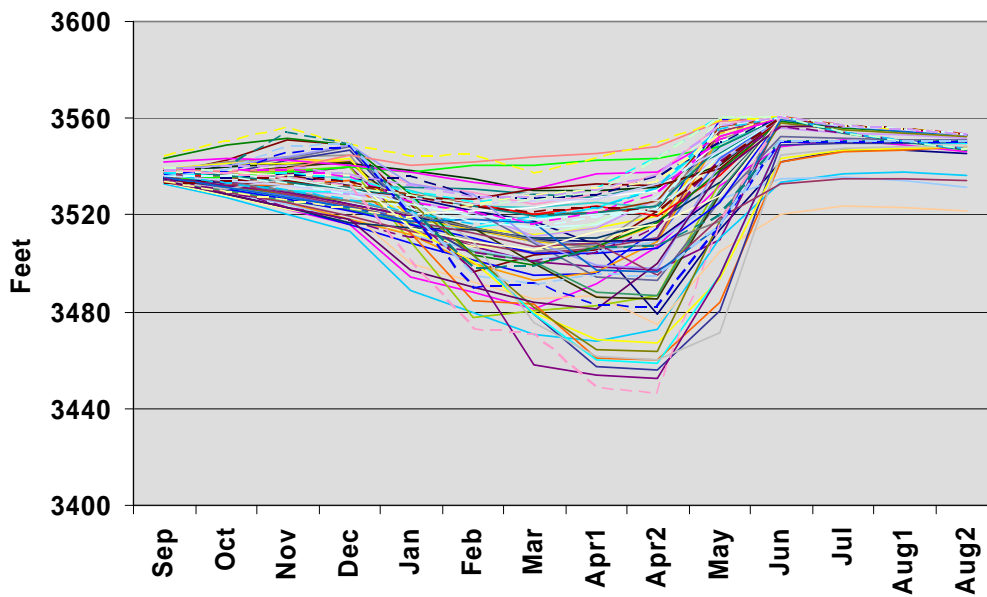


Figure M-6: Elevation at Grand Coulee Dam

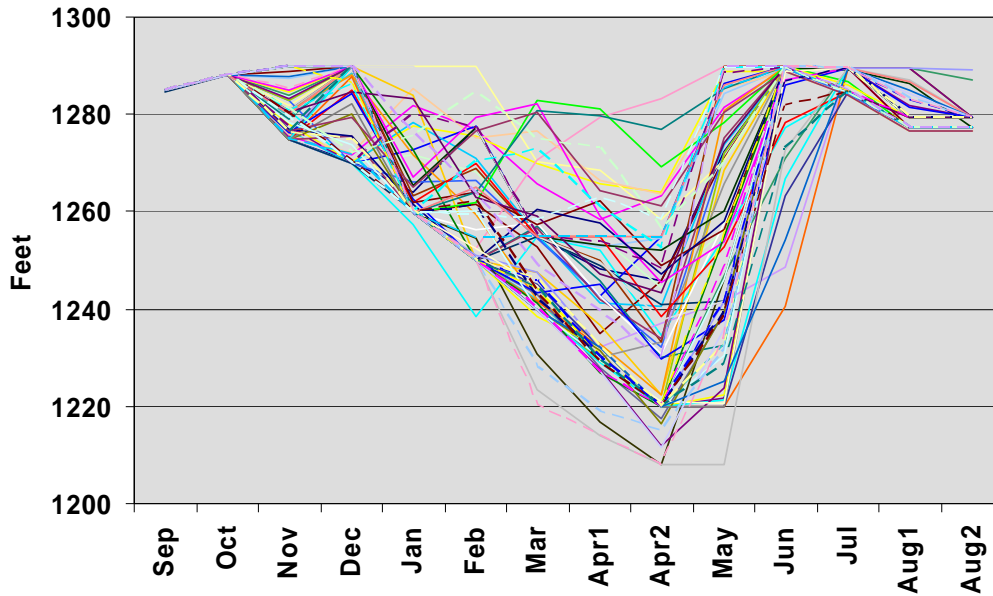
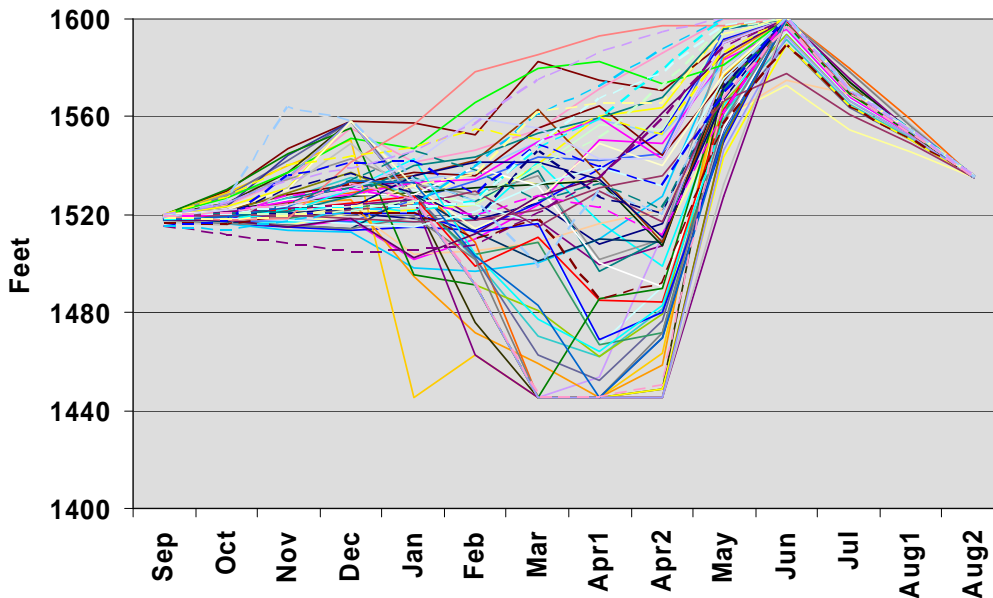


Figure M-7: Elevation at Dworshak Dam



For current resource planning purposes, of course, the more important information is the change in the firm power generating capability since the last iterations of the Fish and Wildlife Program (2003 Mainstem Amendments/2000 FCRPS Biological Opinion) and Power Plan (Fifth Power Plan, December 2004). We did not begin shifting flows and thus generation from winter to spring/summer just recently -- the fish and wildlife program was built to current levels from the original water budget in 1982, with major evolutions ever since. And resource planning and resource acquisitions have accommodated these changes in hydroelectric power production and peak capacity all along. For an historical perspective, however, it is important to note total

changes in hydroelectric operations since before fish and wildlife measures were first adopted. This information is not important for resource planning or for fish and wildlife decision making, but it is useful for understanding the full magnitude of changes over time. The following charts display these differences.

Figure M-8: Average Outflow at The Dalles Dam

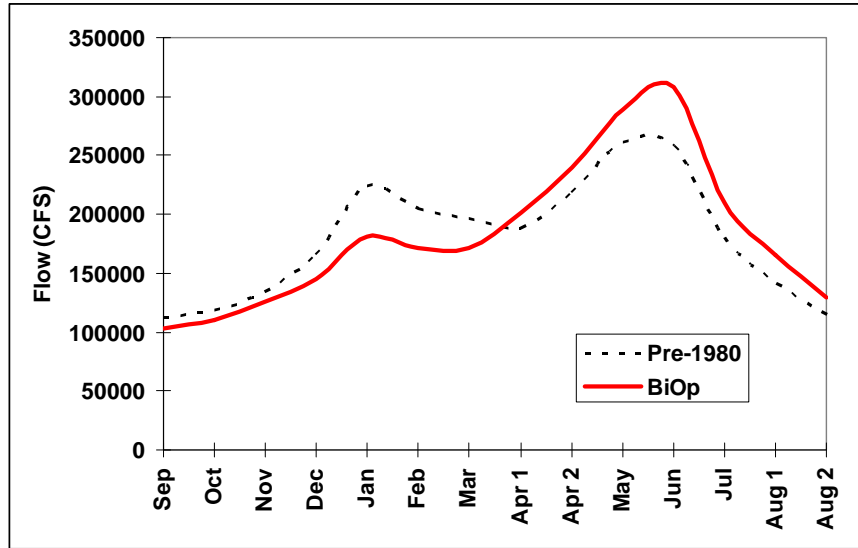
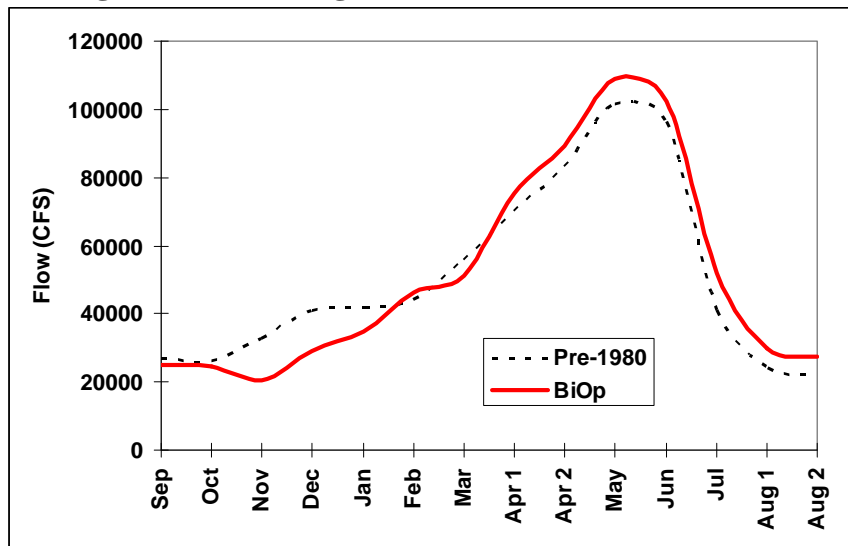


Figure M-9: Average Outflow at Lower Granite Dam



In order to reshape river flows, water in reservoirs that would have been used for power production during winter months is kept in storage for later release during spring and summer. The following four charts (Figures M-10 to M-13) show the average reservoir content for Libby, Hungry Horse, Grand Coulee and Dworshak dams, in units of thousands of second-foot days or KSFD (one KSFD is equal to about 2000 acre feet or 2 KAF). The pattern of keeping more water in these reservoirs during winter months is clearly apparent in these charts. Additional water is also released at these projects over the summer months, which leaves these reservoirs at lower elevations by the end of August or September. On average, Dworshak reservoir is 80 feet

below full, Libby and Hungry Horse are 10 to 20 feet lower and Grand Coulee is between 10 and 12 feet lower by summer's end.

Figure M-10: Average Reservoir Content at Libby Dam

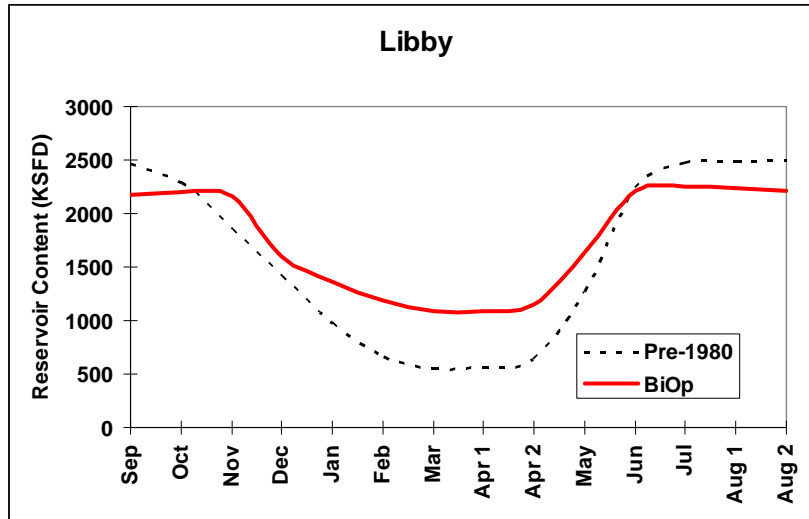


Figure M-11: Average Reservoir Content at Hungry Horse Dam

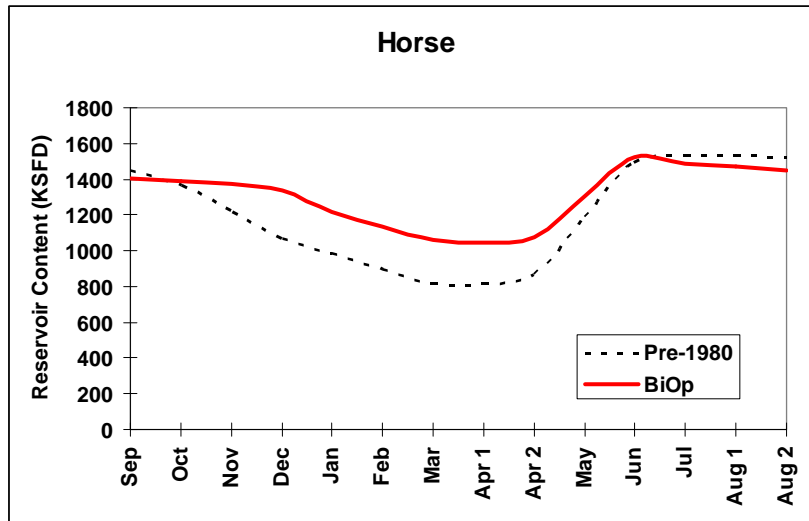
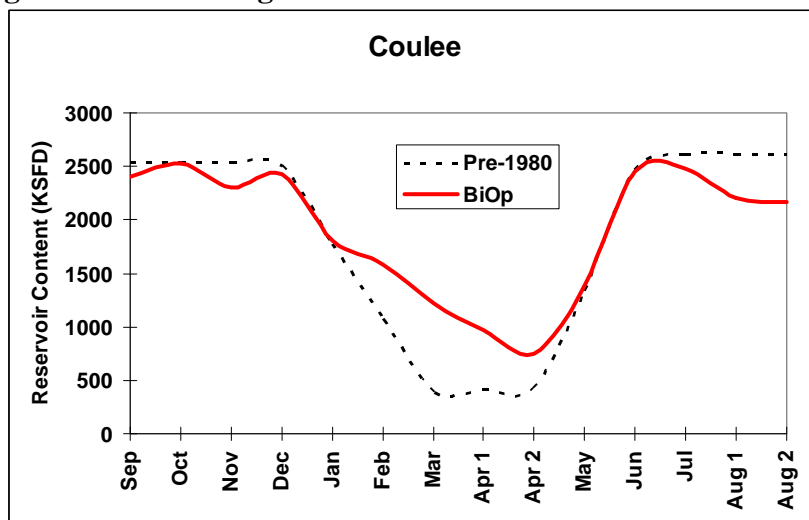
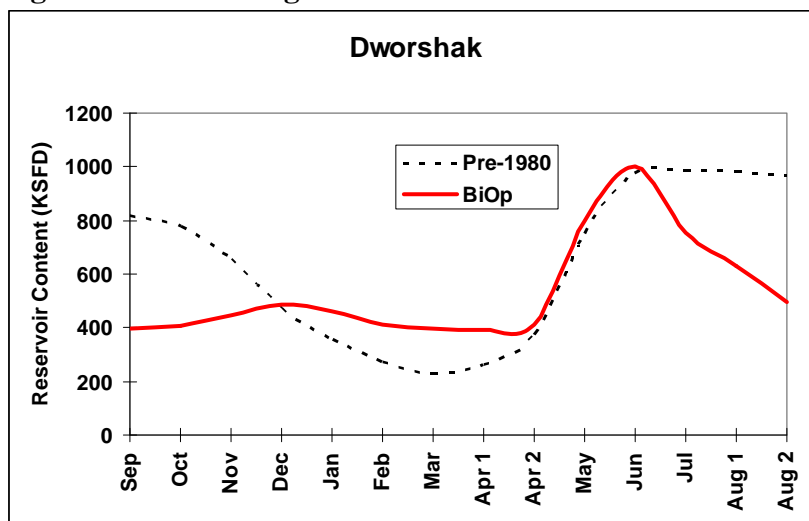
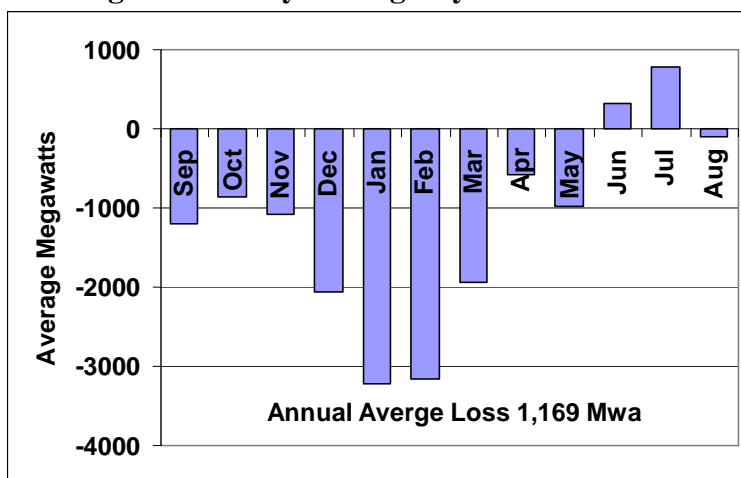


Figure M-12: Average Reservoir Content at Grand Coulee Dam**Figure M-13: Average Reservoir Content at Dworshak Dam**

Council analysis indicates that, on average, implementation of the program will reduce hydroelectric generation by about 1,170 average megawatts, relative to an operation without any constraints for fish and wildlife.¹² For perspective, this energy loss represents about 10 percent of the hydroelectric system's firm generating capability.¹³ Figure M-14 below shows the monthly average change in hydroelectric generation between current operations and a pre-1980 operation, which includes no fish and wildlife constraints.

¹² The comparison study, which includes no actions for fish and wildlife, is represented by hydroelectric operations prior to 1980.

¹³ Firm hydroelectric generating capability is about 11,900 average megawatts (2007 Bonneville White Book) and is based on the critical hydro year, which is currently defined to be the 1937 historical water year.

Figure M-14: Change in Monthly Average Hydroelectric Generation since 1980

Resource Planning

As described above, the central purpose of the power plan is to assess the current and projected demand for electricity for the next 20 years, compare that to current resources (hydroelectric and other generation), and develop a plan for adding conservation and generating resources to avoid or close a resource/load gap. Addressing the firm power effects of the fish and wildlife program is just one part of that resource analysis. The relevant resource analysis and the plan to add resources are described in the main chapters of the Power Plan and in the Action Plan. No particular effort is made to assign certain resources to cover different reasons for a possible load/resource gap, so no particular effort can be made here to identify particular resources as the replacement resources for the reduction in hydroelectric generation due to fish and wildlife operations. The firm power effects of those operations are addressed through this method, however.

The resource planning effects of the fish and wildlife program, since the Fifth Power Plan was adopted, are relatively small compared to other aspects of the load/resource balance. For example, the annual average incremental loss of hydroelectric generation since 2005 due to fish operations is on the order of 20 average megawatts. In comparison, the Sixth Power Plan targets 1,200 average megawatts of conservation acquisitions over the next five years, which nearly covers all of the expected load growth of 1,500 average megawatts over that period.

Fish and wildlife operations, however, do not just have a firm power energy effect. As noted above, they also contribute to reductions in capacity and within-hour system flexibility. Capacity and flexibility adjustments that necessarily include addressing these effects and others are described in Chapter 11. Fish operations, especially bypass spill, also reduce the ability of the system to generate surplus power and thus additional revenue. The revenue effects are described below, in the section on costs.

Providing an Adequate Operation for Power and Fish

Bonneville and the other federal operating agencies implement the fish and wildlife operations, and the rest of the Fish and Wildlife Program, consistent with the Northwest Power Act, the federal Endangered Species Act, the project authorizations, and other applicable law. The

hydroelectric operations to improve fish survival that are specified in the Council's Fish and Wildlife Program also become a part of the power plan. The power plan must be designed to provide both an adequate and reliable power supply and an adequate and reliable implementation of fish operations. The impacts of those operations are substantial and would definitely affect the adequacy and reliability of the power system, if implemented over a short period of time. However, this has not been the case. As described above, since 1980, the region has periodically amended fish and wildlife-related hydroelectric operations and in each case, the power system has had time to adapt to these incremental changes and has maintained an adequate and reliable power supply.

The Council staff produced a preliminary assessment of the impacts of fish operations on the adequacy and reliability of the power supply during the recent fish and wildlife program amendment process. A more detailed adequacy and reliability assessment is provided in this power plan. That assessment (Chapter 13) indicates that the regional power supply can reliably provide the actions specified to benefit fish and wildlife (and absorb their cost), respond to other challenges to the reliability and adequacy of the regional system described in that chapter, and maintain an adequate, efficient, economic, and reliable energy supply. Moving forward, the Council's resource adequacy standard provides a minimum threshold for resource development that minimizes the likelihood of curtailments to both power and fish operations.

It should be noted that prescribed mainstem operations for fish and wildlife are subject to change, because some of those operations are currently under litigation. The Council's assessment of the hydroelectric system's contribution to the region's power resources is based on current fish operations, as is the Council's conclusion that the current system can accommodate fish operations while maintaining an adequate and reliable supply. Some of those operations that could change in the near-term include:

- Increased spring and summer bypass spill
- Revisions to the Hungry Horse and Libby late summer/fall operation, or to other reservoir operations
- Potential changes to the Non-Power Uses Agreement under the Columbia River Treaty, which stores an additional 1 million acre feet of water for later release to support needs of fish
- Annual changes to other Columbia River Treaty supplemental agreements for non-power operations
- Potential reductions in bypass spill requirements upon installation and effective operation of spillway weirs

Whenever non-power operations are modified, resource planning and acquisition considerations may need to be reviewed, and the Council and Bonneville will need to undertake a new adequacy assessment. However, while the above mentioned actions may affect power generation to some degree, none of them would jeopardize the power supply's near-term adequacy. Longer-term changes, which might affect power supply adequacy, are discussed in the section entitled

“Dealing with an Uncertain Future” and include issues such as climate change, the expiration of the Canadian Treaty and dam removal.

In addition to the adequacy standard, power planners have become more cognizant of non-emergency situations, such as isolated low flow events, night-time over-generation conditions, and rapid load changes that have compromised fish operations in the past. Planners are actively developing operational protocols to address these situations and to alleviate the pressure to curtail fish operations. For example, the U.S. Army Corps of Engineers (Corps) describes how it intends to deal with these situations in its planned operations for fish passage for 2009 (Corps document number 1693-2, “2009 Spring Fish Operations Plan”).

In spite of best laid plans, however, emergencies sometimes occur, and all utilities have contingency actions in place to avoid potential curtailments. We do not and cannot plan and build for 100% assurance of power system operations, nor the same for the operations specified for fish. What we can do is reduce the likelihood of emergencies to an acceptable level (mostly through adding sufficient resources to the system), and then have contingency plans in place to deal with power and fish emergencies in a comparable fashion.

Hydro flexibility is one method for dealing with power system emergencies. During periods of rapid load changes or the loss of a major resource or transmission line, reservoirs can be drafted below their normal operating elevations to sustain electricity service. This use of additional hydroelectric generation is often referred to as “hydro flexibility.” Hydro flexibility is generally used during cold snaps or heat waves when no other resources are available, including imports from out of region. The additional water drafted to produce extra energy is replaced as soon as possible, even if energy must be imported. Most often reservoirs can recover and get back to required refill elevations. However, in the event that hydro flexibility can not be replaced by early spring, less water would be available for the spring flow operation for fish and wildlife augmentation. The power plan, resource additions, and in-season planning strategies should be designed to minimize situations when hydro flexibility cannot be replaced prior to the migration season.

Both bypass spill requirements and reduced mainstem reservoir operating limits imposed by the program limit the flexibility of the hydroelectric system. This is important because less flexibility means a reduced ability to meet peaking requirements, provide ancillary services, and integrate wind and other variable resources. Once system flexibility is used up, additional resources may need to be added along with variable generators to provide a reliable supply. This will clearly increase the cost of meeting renewable portfolio standards and may also increase carbon emissions. As discussed in Chapter 11, creative strategies for operating the system to balance renewable resources, and then careful planning to add least-cost resources to meet the system’s capacity and flexibility requirements are key to preserving reliable implementation of fish and wildlife operations while maintaining power system reliability.

The biological opinion allows for curtailment of fish and wildlife operations during power system emergencies, as happened in the very low water year of 2001, but it does not specify an upper bound for such actions. It also includes comparable language that allows deviations from normal power system operations during rare occasions when emergency fish passage conditions occur.

Whenever the region's generating capability lags behind demand growth (as happened in the late 1990s), the risk of having to curtail fish and wildlife operations will increase. Using curtailment of fish and wildlife operations as a last-resort alternative during rare emergencies is allowed under the biological opinion language¹⁴. The key word in the previous sentence is "rare." Analysis showing a high frequency of curtailment to fish and wildlife operations would indicate that the power supply is not adequate. Curtailment of fish and wildlife operations cannot be used in lieu of acquiring resources to maintain an adequate regional power supply. In the same way, power system operations should not be jeopardized an inordinate amount to deal with fish emergencies.¹⁵

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 these policies in place prior to an emergency, in order to minimize the risk to fish. Action item F&W-2 (see the Action Plan) calls for the Council to work with fish and wildlife managers and regional power planners to develop contingency plans.

PART 2: ASSESSING COSTS

The second part of this appendix discusses the costs of the fish/power integration, from a number of different viewpoints. The costs of using the hydroelectric system to provide suitable conditions for fish and wildlife are largely assigned to the power system and its ability to generate revenue. Part of the purpose of the power plan is to accommodate these costs and the loss of generating capability that fish and wildlife measures may induce. This means acquiring additional resources, whenever needed, to maintain an acceptable level of adequacy, efficiency, economy, and reliability. To assess the "cost" of fish and wildlife operations, Bonneville, the Council, and others have been in the habit of comparing whatever are the current operations for fish and wildlife to a hydrosystem operation without fish and wildlife constraints, estimating the difference in generation per month, pricing that difference at whatever is the current market price for electricity, and summing the differences for each month to get a total net "cost" for those operations. Just as many others, inside and outside the Council, have objected to that practice, for a number of reasons. What has been missing, at least in part, has been a discussion as to precisely why cost information is important under the Northwest Power Act -- to what ends and for what decisions is cost information important. When that is done, the result is a set of conceptual categories for assessing costs, categories that require different information and different perspectives on costs.

As noted in the introduction, the focus here is to carefully describe the cost categories, and take the focus off the specific numbers. There are at least four different purposes for assessing the cost of fish and wildlife operations. First, the Council must assess the costs of the resources added to the power system to accommodate the change in hydropower generation due to fish and wildlife operations as well as meet load growth. Second, identifying the cost of individual fish and wildlife program measures allows the Council to assess the power system value of each measure relative to its biological benefits. Performing a strict cost-effectiveness analysis is impossible because absolute biological benefits are difficult to identify and value in terms of dollars. Nonetheless, this analysis at least allows the Council to group various measures into

¹⁴ Reference the NOAA BiOp RPA number 8 here.

¹⁵ Reference the NOAA BiOp RPA number 9 here.

broad categories, such as those that are very high cost and have very highly uncertain biological benefits. This may help the Council rule out certain measures to include its fish and wildlife program. Ideally, should two different measures provide the same biological benefits; the Council should choose to include the least costly one. Third, under section 4h(10)(C) of the Northwest Power Act, the Bonneville Power Administration receives a credit from the US Treasury for part of its expenses related to non-power operations. Finally, it is important to assess how the fish and wildlife program has affected overall revenues and electricity rates. The following sections describe in more detail these cost assessments and their purposes.

Assessing the Resource Cost Effects of Fish and Wildlife Operations

As described above, the power planning effect of a change in generation due to operations for fish and wildlife is how it affects the load-resource balancing and contributes to the resource acquisition strategies outlined in the Power Plan. Thus in this particular power plan setting, as in any other, the cost to the system of the latest changes in fish operations that affect the firm power energy and capacity of the system is the average cost of the resource acquisitions needed to make up the projected load-resource gap, the same as it is for addressing load growth and other resource changes. No particular added resource is tied to the fish operations part of the load-resource calculation. Looked at over the entirety of the Fish and Wildlife Program and the Power Plan, the federal power system is serving the “fish operations” part of Bonneville’s obligations at an average system cost, just as it serving all other aspects of Bonneville’s load obligations. In the main chapters of the Power Plan, the Council estimates the long-term average cost of resources added to the system to meet load obligations and reductions in supply capability due to non-power operations.

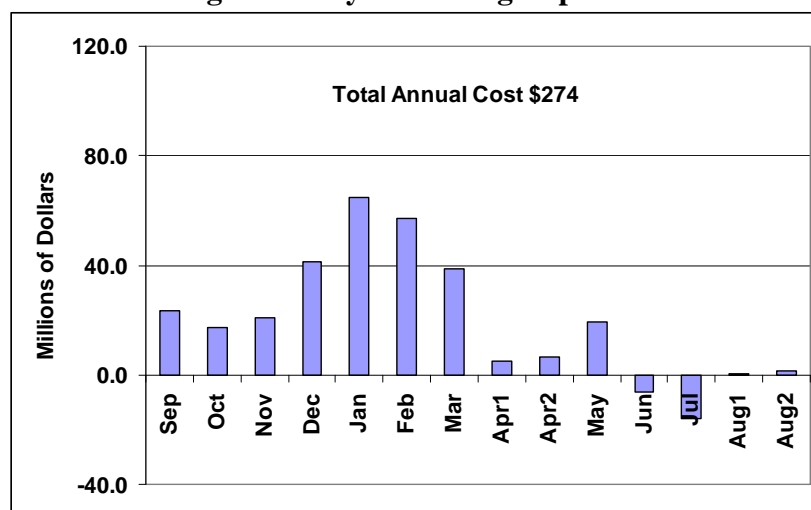
More precisely, the Power Act directs the Council to plan for the addition of the most cost-effective resources to address a gap between expected loads and current resources (again, *whatever* the reasons for the gap), with a priority for an ongoing program to add cost-effective conservation to avoid having to add other generating resources. This question is never looked at in isolation -- that is, one resource is added to make up for lost generation due to fish operations, while another resource is added to avoid or address load growth. Instead, the load-resource balance is looked at as a whole, deficiencies are identified and low-cost resources are added to fill those deficiencies. The average cost of those added resources is thus one way to determine the “cost” of accommodating the latest changes in fish and wildlife operations to the power system, at least those that affect the firm power resource balance, as well as accommodating (or avoiding) load growth. And looking at the system as a whole, the average system cost of meeting load obligations includes meeting the obligation to accommodate fish operations and still provide an adequate and reliable power supply.

For most of the life of the Council’s power planning efforts, the cost-effective available resources planned for addition, especially conservation, have cost significantly less than ongoing purchases of electricity at wholesale market prices. The same is true for the resources in the plan this time, again, mostly cost-effective conservation. The traditional “market price” calculation of the total effect on generation from fish and wildlife operations is essentially irrelevant to the power plan’s resource development efforts, and the Power Act’s provisions for accommodating the fish and wildlife program through resource planning and additions. Fish and wildlife operations have been incrementally decreasing the portion of firm power supply from hydropower generation since 1981, just as the Northwest has seen incrementally increasing

demand for electricity over the same time period. The Council’s power plan has been describing the least-cost resources to address those developments, and Bonneville and the region’s utilities have been developing conservation measures and adding resources in that context to keep the power system adequate and reliable and as economical as those changes have allowed it to be. Part of those resource additions undoubtedly were added because of fish and wildlife operations and thus can be used to assess the replacement “cost” to the power system of the fish and wildlife program.

Unfortunately, this assessment is effectively impossible to do since we have not and do not distinguish resource acquisition for specific reasons. However, as a means to estimate the cost of the program, average resource replacement costs can be used and as a surrogate for those costs, Bonneville’s Priority Firm Power Rate (\$27 per megawatt-hour) can be used. Applying these costs to the average monthly energy losses in Figure M-14 yields the results in Figure M-15. The average annual cost of the fish and wildlife program is approximated to be in the range of \$300 million. The cost in any particular year, however, can vary dramatically depending on water conditions (see the section below on cost uncertainty).

Figure M-15: Average Monthly Cost using Replacement Resource Cost



Finally, at any particular moment in time, the Council and Bonneville must be able to make the overall determination that the region’s power supply is not just adequate and reliable, but also “economical.” The Fish and Wildlife Program does add costs to the system, as expected under the Power Act, but maintaining an economical power system should not limit the development of the program. Power planners must assess reductions in the power supply due to program measures and develop a least-cost resource acquisition strategy to offset these deficiencies, just as they would for projected load growth. In the context of the Power Act, the power system remains “economical” when sufficient time is allowed to add least-cost resources in a reasonable manner and recover costs in a businesslike fashion. This is the process that has occurred since 1981 when the first fish and wildlife measures were implemented.

Relative Cost of Individual Fish and Wildlife Measures

The range of actual decision making is *not*, under the Northwest Power Act or the Endangered Species Act, the difference between current operations that include fish and wildlife measures

and an operation that does not include fish and wildlife measures. Instead, at any particular moment in the last 30 years (and presumably in the foreseeable future), the range of active decision making has proven to be between current operations (as the base) and an indeterminate and evolving range of operations in either direction from that base (e.g., periodic adjustments in storage reservoir operations and dam operations affecting flow amounts and velocities; bypass spill increases or decreases, proposed or implemented, of a certain magnitude).

Within this range of actual fish and wildlife decision making -- that is, current operations to improve conditions for fish within a certain range of flow and spill changes -- it is important to know what would be the power system effects of a proposed or implemented change, and what would be the costs to the power system and ratepayers of dealing with that change. This is useful as a way of understanding the power system effects of a change just made in the Fish and Wildlife Program, or proposed to be made pending the next power plan.

It is particularly useful information to be able to compare the costs of proposed changes (and the benefits to be gained) against the costs and benefits of other possible actions. In theory, this sort of cost information allows for a cost-effectiveness comparison of the costs and benefits of different actions -- e.g., what would be the comparative benefits of different actions for fish and wildlife that could be done for the same cost? And vice versa -- how much is the difference in cost to get comparable survival benefits from actions that improve mainstem habitat conditions or tributary/estuary habitat conditions, assuming some comparable way of estimating survival benefits can also be used?

For this purpose, the short-term costs of any generation changes caused by an operational change related to fish and wildlife would be assessed using market electricity prices. This should include loss of revenue (or foregone revenues) for bypass spill operations. Assessing costs using market prices is used in this case only to compare and rank various fish and wildlife measures. These costs are not intended to represent the actual or true cost of the fish and wildlife program as a whole. The overall cost assessment (as described in a later section) should be based on long-term levelized resource replacement costs (as would the assessment of cost to meet a particular magnitude of future load growth).

However, to reiterate an earlier statement, the cost of the difference between current fish operations and no fish operations is irrelevant to current decision making. It is not a real opportunity under the current understandings of law and policy. However, what it might cost and what benefits might be gained, for example, by increasing or decreasing the percentage of the flow spilled at John Day Dam by 10% in mid-summer, or drafting a storage reservoir five feet less or more than before, or buying up a 100 cfs of water for in stream use, or various other actions, *is* relevant information that can inform decision makers of the comparative value of real choices.

As an example of the type of information that can be useful in developing a fish and wildlife program, Figures M-16 through M-19 show bypass spill costs by project and by month, assessed using market electricity prices. Figure M-16 illustrates the average cost of bypass spill by project. Overall, using market electricity prices, the total average cost for bypass spill is about \$220 million per year, with \$100 million for spring months and \$120 million for summer months. As indicated in Figure M-16 above, spill at John Day, The Dalles and Bonneville dams makes up the majority of the total cost of bypass spill, both for spring and summer (see Figure

M-17 and M-18). On a monthly basis, bypass spill is most costly in July with an average cost of about \$60 million per year (Figure M-19).

Figure M-16: Total Bypass Spill Costs

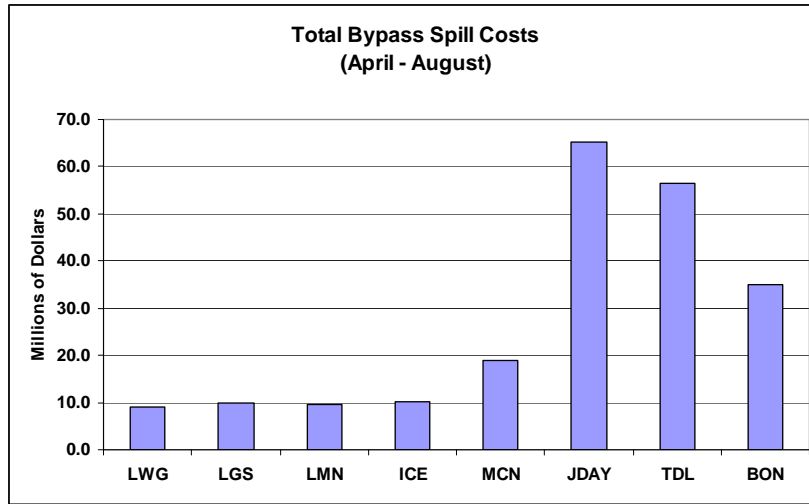


Figure M-17: Bypass Spill Costs (Spring Only)

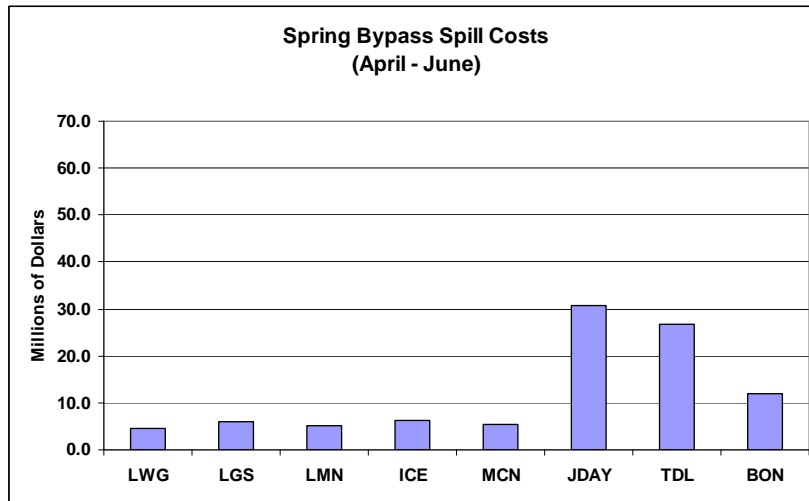
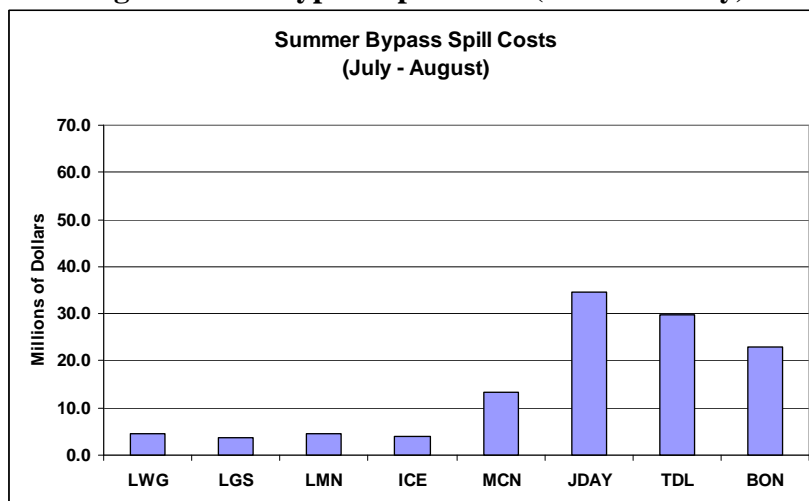
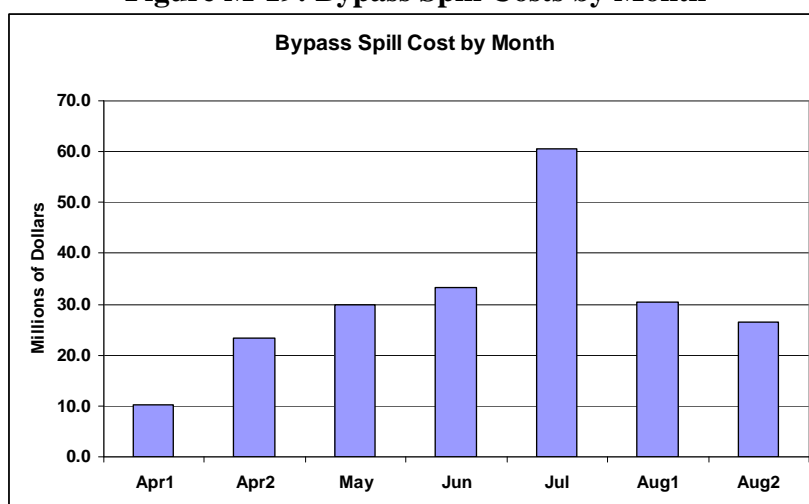


Figure M-18: Bypass Spill Costs (Summer Only)**Figure M-19: Bypass Spill Costs by Month**

Section 4h(10)(C) Credits

Section 4(h)(10)(C) of the Northwest Power Act provides that the amounts expended by Bonneville to address the effects of the dams on fish and wildlife are ultimately to be allocated among the various project purposes. The federal agencies agreed some time ago that the hydropower purpose should bear approximately 75% of such costs. Thus Bonneville's ratepayers are ultimately responsible for 75% of the costs of the actions to address the adverse effects of the projects on fish and wildlife.

Bonneville routinely pays 100% of the cost of a number of fish and wildlife actions, however. So, Bonneville has an understanding with the Treasury and the Office of Management and Budget (OMB) on a mechanism that will allow Bonneville to recoup the over-investment of the hydrosystem by crediting or offsetting against Bonneville's Treasury payment the non-power share (or approximately 25%) of such expenditures.

The understanding with Treasury/OMB applies to all expenditures or actual money paid by Bonneville for fish and wildlife purposes. As such, it also applies to Bonneville's direct expenditures, such as on habitat or production projects. Bonneville also expends money on power purchases throughout the year to meet instantaneous load requirements. And the understanding also extends to those power purchases Bonneville would not have had to make if it at that moment it could have generated more rather than store or spill water for fish purposes. *The understanding does not apply to, and no 4(h)(10)(C) credit is given for, foregone revenues, as these are not actual expenditures by Bonneville.*

The effect of the credit is to reduce Bonneville's annual Treasury payment, thus reducing the revenue requirement to cover costs that must be recovered in rates. How Bonneville determines and demonstrates that a power purchase is related to the fish and wildlife program is a matter for Bonneville and Treasury/OMB to agree to. For 4(h)(10)(C) credit purposes, Bonneville calculates energy purchase costs associated with fish and wildlife operations using market electricity prices but it does not include foregone revenue from loss of spring and summer sales due to bypass spill. This method of calculating costs is not a Fish and Wildlife Program or Power Plan issue for the Council, and the Council does not analyze or estimate the amount of the 4(h)(10)(C) credit in any year. However, the Council does support Bonneville's effort to account for and obtain the full amount of credit it is due.

Revenue and Rate Effects

As noted above, changes in system operations for fish and wildlife purposes have an effect on generation, and thus on power sales, and thus on Bonneville's revenue. Changes in generation patterns that affect the ability of the system to serve firm power loads will have an immediate revenue effect perhaps, but may not necessarily reduce revenues in the long-term. This is because the resource deficit is replaced in some way by other resources and may or may not have a *revenue* effect depending on how it is replaced. Resources added to replace lost hydroelectric capability will have cost impacts, of course, as do all conservation and generation resource additions and thus will have an impact on rates.

On the other hand, a significant portion of the operational requirements for fish -- and especially all or most of the spring and summer spill -- has an effect not on firm power but on the amount of nonfirm or surplus power the system is able to produce for sale on the wholesale power market. That, at the time spill occurs, the hydropower system ordinarily produces more than enough power to meet firm loads and also generate for surplus sales; if the system could spill less, the result would be more power for surplus market sales. These generation impacts do not necessarily require resource planning and resource acquisitions to meet load obligations -- instead, the primary if not the only "cost" effect is on revenue. (A change in the amount of surplus hydropower sales may also have an effect on carbon emissions, if such sales displace others' use of carbon-emitting resources.)

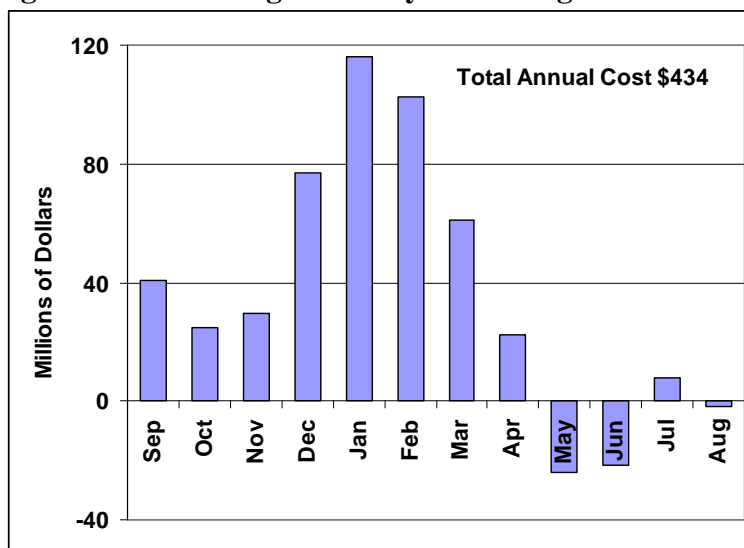
To date, no firm resources have been acquired to replace energy loss due to bypass spill requirements. This could change in the future because the region is quickly approaching a condition where summer capacity needs may outweigh winter or annual needs. When that happens, and resources are acquired to serve firm summer loads, then simply using market prices to assess spill cost would not be appropriate. For the present, using market prices to assess bypass spill costs is appropriate.

The real effect at Bonneville is to alter the relative level of contributions from (a) surplus sale revenues and (b) firm power rates in covering Bonneville's costs. The greater the surplus sale revenue, the less the contribution needs to be in rates, and vice versa. Bonneville will still collect the revenue and cover its costs -- the effect is to alter the allocation of those costs to different revenue streams.

In this perspective, this is a rate and revenue matter at Bonneville, not a Power Plan resource issue and not a Fish and Wildlife Program issue. The size of this revenue effect is routinely calculated for the entire difference between the revenue generated assuming current fish operations and the estimated revenue that might be generated assuming no fish operations, usually valued at market prices. Some find this a useful number to know, to understand the magnitude of the revenue/rate shifting effect over time, although the total amount is largely irrelevant in terms of having an effect on current decisions (and presumably overstates the rate impact of replacing the generation related to firm power, as Bonneville should have replaced this resource at an average system cost for the added resources, not at market prices).

In any event, this overall value is determined by first assessing the expected monthly secondary (or surplus) sales or market purchases for both current and pre-1980 operations over the entire range of potential water conditions. The secondary energy sales or purchases are converted to dollars by multiplying the associated energy by the expected monthly electricity price. The expected monthly electricity price will vary by water condition and by hydroelectric system generation. The monthly price is further adjusted to take into account peak and off-peak effects. Thus, a pattern of monthly electricity prices is created for each of the 70 water conditions analyzed. This matrix of electricity prices is multiplied by the matrix of energy sales or purchases for each case. The monthly cost or benefit is averaged across all water conditions and is then summed over all months to yield a total, which for this case is in the range of \$450 million. On average, the power system cost is almost evenly divided between flow augmentation (average cost of about \$230 million/year) and bypass spill (average cost of about \$220 million/year).

Figure M-20 summarizes the average monthly cost of the fish and wildlife program relative to a pre-1980 operation. Positive values in Figure M-20 reflect regional costs and negative values represent benefits. Generally, the cost of a particular change in hydroelectric system operation is inversely proportional to the change in generation, so the pattern in Figure M-8 is similar but reversed from that in Figure M-14. In other words, an operation that causes a decrease in generation usually represents a cost to the system. However, this pattern is not exactly inversely proportional because cost depends on electricity prices and they depend on available generation. For example, May shows a decrease in average generation in Figure M-14 but in Figure M-20 it shows a net revenue increase. This is because a reduction in the available generation during that month causes electricity market prices to increase. Thus, even though less energy is available for sale, it is being sold at a higher price and produces higher revenues. A more detailed description of how cost is assessed is provided below.

Figure M-20: Average Monthly Cost using Market Prices

Bonneville also incurs a number of the other costs of implementing the Fish and Wildlife Program that must be covered through rates and surplus revenues. These include:

Capital Costs: These costs include the projected amortization, depreciation and interest payments for fish and wildlife-related capital investments by the Corps of Engineers and Bureau of Reclamation for which Bonneville is obligated to repay the power share to the US Treasury, as well as similar costs generated by direct capital investments by Bonneville. This includes construction and installation of fish bypass systems, turbine intake deflector screens, spillway weirs, fish collection systems, artificial production facilities, and land acquisition for habitat purposes.

Reimbursable/Direct Funding Costs: These costs include the hydroelectric system's share of operations and maintenance costs and other non-capital expenditures for fish and wildlife activities by the Corps of Engineers, Bureau of Reclamation and U.S. Fish & Wildlife Service that pre-dated the Northwest Power Act.

Direct Program Costs: These costs include expenditures for non-capital fish and wildlife activities consistent with the Council's Fish and Wildlife Program and elements of NOAA Fisheries' and the FWS' Biological Opinions. This includes funding for tributary and estuary habitat improvements, predation control, operations and maintenance costs for direct program investments in habitat and production activities, and monitoring, evaluation, research, and coordination projects. Bonneville estimates these expenditures will amount to \$231 million per year¹⁶ over the next five years. The direct program costs also include the costs of servicing the direct capital investments Bonneville has made and intends to make for fish and wildlife purposes. Bonneville estimates it will invest an average of \$56 million per year over the next five years¹⁷.

¹⁶ The direct Program, 2008 BiOp and Fish Accord budget estimates for the next five years represent budget ceilings; actual expenditures may be less.

¹⁷ Taken from Bonneville's 2008 Integrated Program Review, the capital budget estimate for the next five years represents the maximum cost; actual expenditures may be less.

The current power system has absorbed these costs and remains economical, although there are alternative ways of thinking about the economical criterion. One is whether the per-kilowatt-hour costs of the system have increased significantly in comparison to other regions. On this basis, the power system is clearly less economical than it was. However, in terms of absolute electricity cost, the Northwest still ranks as one of the lowest cost regions in the nation. Unfortunately, this aggregate assessment does not capture potential impacts on specific sectors of the economy. In particular, electricity-intensive industries, such as aluminum smelting, are proportionately harder hit by increases in electricity costs. In fact, most aluminum plants in the region have ceased operation due to high operating costs. Fish recovery costs have contributed to this, although in the current context, they are not the major contributor.

In aggregate, the region's power system has been assessed to be adequate both in terms of energy and capacity needs for at least the next five years.¹⁸ That assessment shows that the balance between resources and loads is above the minimum thresholds defined in the Council's resource adequacy standard.¹⁹ Those minimum thresholds, however, should not be mistaken as a resource planning targets. The types and amounts of resources the Northwest should acquire over and above the minimum thresholds must be assessed in an integrated resource planning process, so that other factors, such as economic risk, can be taken into account.

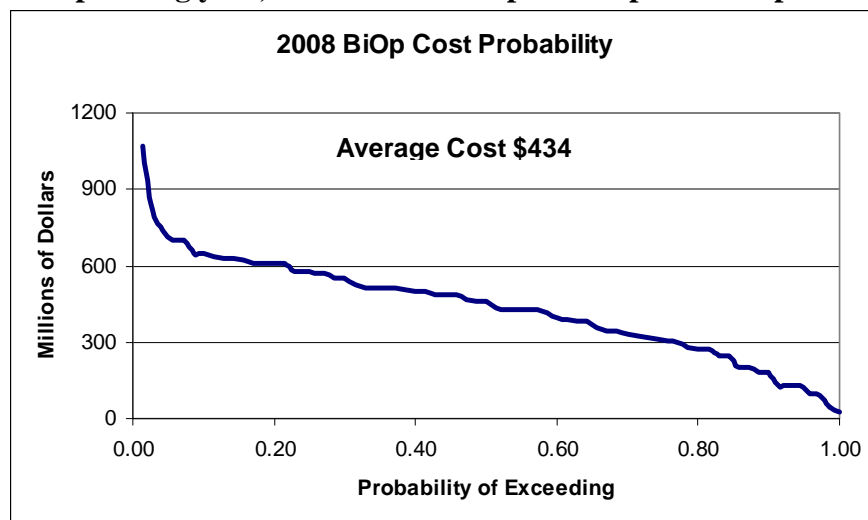
Cost Uncertainty

Although the average *power system operations* cost of the fish and wildlife program is about \$450 million (*if* for convenience sake using market prices to represent the entirety of the operational effects; *but see* the discussion of replacement resource costs above), differences in water conditions from year-to-year result in a range of actual effects, and so costs can range from a high of about one billion dollars to a low of just several million dollars, as shown in Figure M-21. The likelihood of the region experiencing a cost greater than \$600 million in any given year, however, is only about 20 percent. Similarly, the likelihood of a cost less than \$300 million is also about 20 percent.

¹⁸ See <http://www.nwcouncil.org/energy/resource/Adequacy%20Assessment%20Final.doc>.

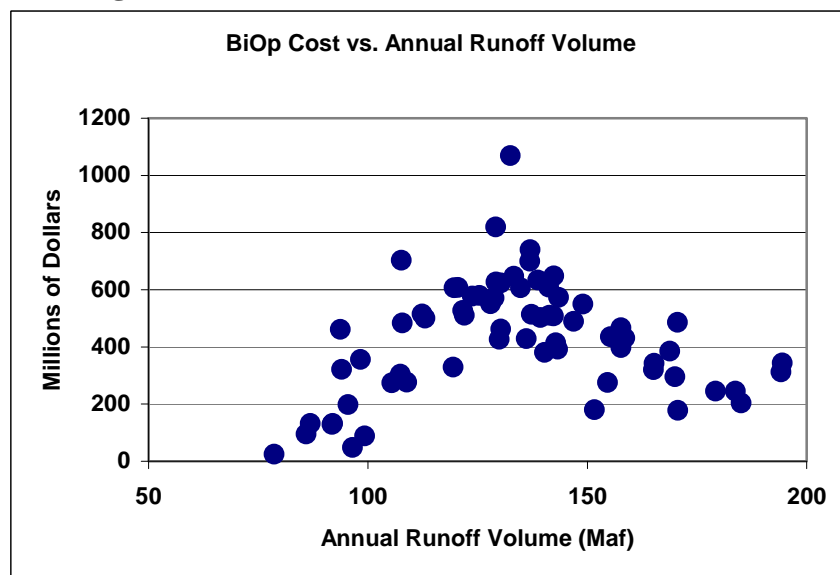
¹⁹ See <http://www.nwcouncil.org/library/2008/2008-07.pdf>.

**Figure M-21: Range of Annual Cost for Fish and Wildlife Operations
(2010 operating year, 2008 dollars compared to pre-1980 operations)**



It is beneficial for planners to understand how these costs vary with water conditions. Figure M-22 plots the power system cost of the fish and wildlife program as a function of the annual runoff volume. Initially, one might think that costs would be greater in dry years since water is scarcer. However, the pattern of costs shown in Figure M-22 does not reflect that relationship. In that figure, costs are low in the dry years as well as the wet years and are highest for more average runoff conditions. In order to explain this apparently non-intuitive phenomenon we must describe in more detail the two major components of fish and wildlife operations, that is, flow augmentation and bypass spill.

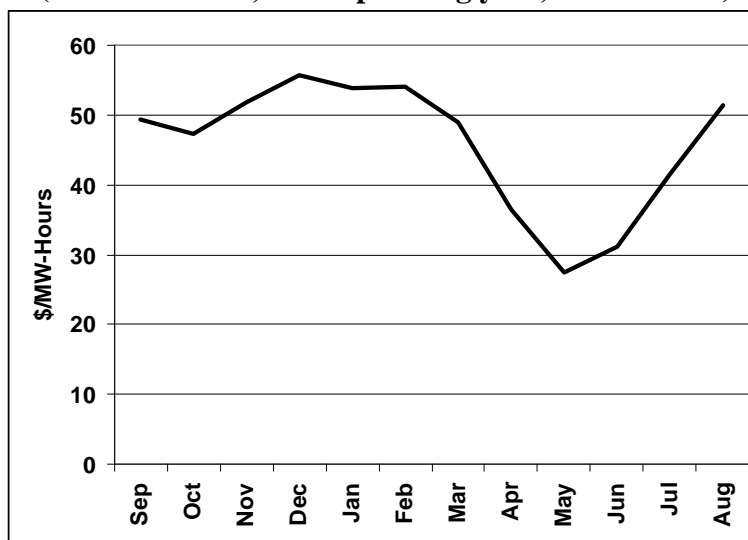
Figure M-22: Cost as a function of Runoff Volume



Flow augmentation or holding water back during winter months for release in spring and summer, effectively moves hydroelectric generation from months with high electricity prices into months with lower prices (see Figure M-23). The amount of water that is shifted depends on the forecasted runoff volume. Generally more water is held in reservoirs for flow augmentation

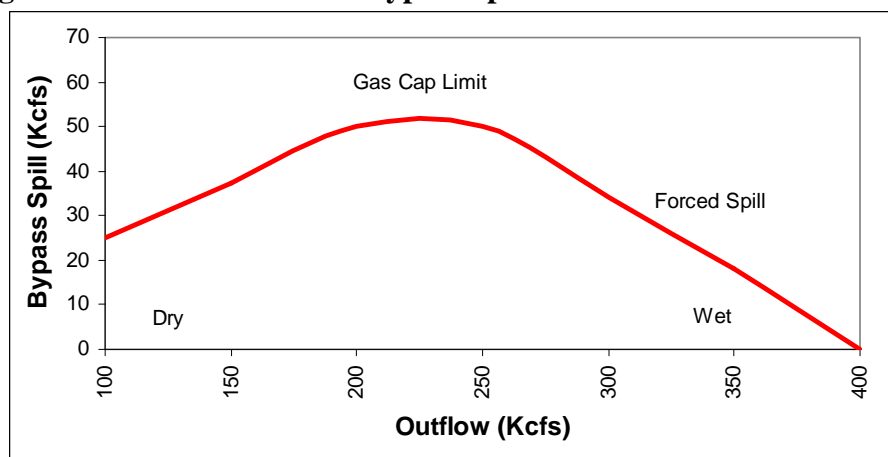
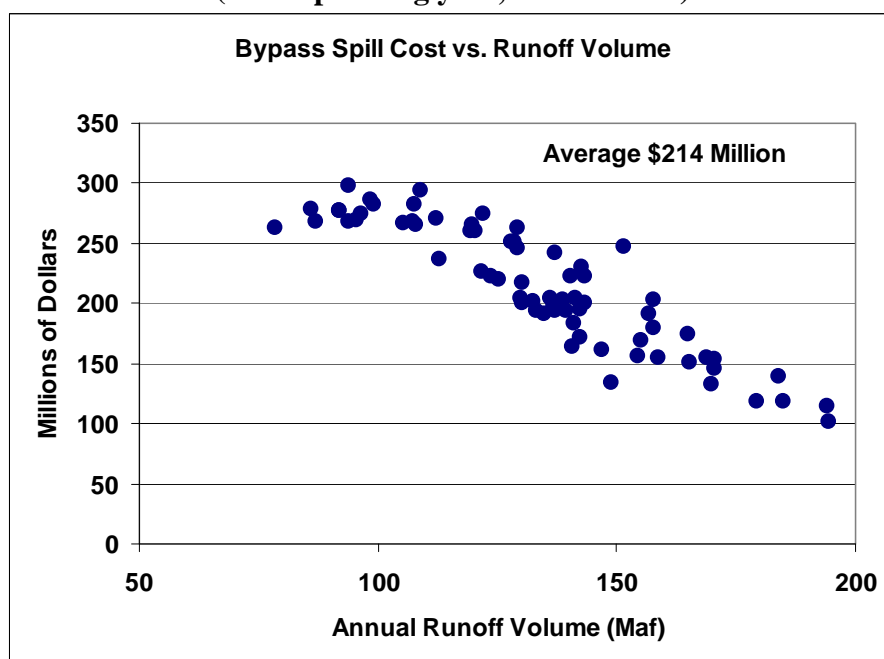
during dry years. In wet years, water must be evacuated by early spring for flood protection thus leaving less water in reservoirs for augmentation. Given this general observation, one would assume that fish and wildlife costs would be highest in the dry years and lowest in the wet years. However, electricity prices are affected by the availability of hydroelectric generation and in general are higher in years with low runoff volume. So, in some dry years, shifting water from winter months into summer months may actually cost less than in a year with average runoff conditions. But that is not the whole story. We must also remember that the costs in Figure M-22 also include the effects of bypass spill.

**Figure M-23: Forecast Bulk Electricity Prices
(Mid-Columbia, 2010 operating year, 2008 dollars)**



Bypass spill is water that is routed around turbines to enhance survival of migrating smolts. It always represents a loss of generation and revenue. The cost of spill varies with water conditions and electricity prices. Generally, as the runoff volume increases, so does bypass spill because for some projects bypass spill is specified as a percentage of outflow. However, as runoff volumes begin to approach average conditions, spill is often limited by total dissolved gas supersaturation limits imposed under the Clean Water Act by the state water quality agencies. That is, once the absolute volume of spill causes gas levels to reach the gas limit, no more volume is spilled. At this point, bypass spill costs level off.

As runoff volumes continue to increase, however, bypass spill costs actually begin to decrease (illustrated in Figure M-24). That is because of a condition referred to as forced spill. When the hydraulic capacity at dams is exceeded, water in excess of that capacity must be spilled. This forced spill volume counts toward the required bypass spill and because forced spill would have occurred anyway, some of the bypass spill requirement is provided at no cost. For very wet years, forced spill can equal or sometimes even exceed the required bypass spill volume. The actual relationship between bypass spill cost and runoff volume is shown in Figure M-25 and its effect on the overall pattern of fish and wildlife costs (Figure M-21) is evident.

Figure M-24: Illustration of Bypass Spill Flow as a function of Outflow**Figure M-25: Bypass Spill Cost as a function of Runoff Volume (2010 operating year, 2008 dollars)**

PART 3: DEALING WITH AN UNCERTAIN FUTURE

Finally, even if we are able at present to integrate the needs of the river's fish and wildlife and the region's power supply adequately, the future holds a number of challenges for our continued ability to do so. These include the uncertainties and risks related to (1) possible further changes in the operations to benefit fish and wildlife; (2) an evolving power system that is integrating different kinds of generating resources than in the past, resources that put new and different requirements on the hydropower system; (3) possible modifications in Columbia River Treaty operations in the next decade, for both power and non-power reasons; and (4) climate change effects on the amount and shape of runoff and on electricity demands that will pose problems for both fish and wildlife and power generation. This part of the appendix addresses future uncertainty and risk.

The power plan has a 20-year planning horizon, which requires that potential future changes must be assessed in the hydroelectric system or fish and wildlife needs over that time period. The resource strategy developed in this power plan must be sufficiently robust to accommodate these potential changes in order to continue to provide desired fish conditions and an adequate and reliable power supply. The challenge is to identify the uncertain but possible areas of change, assess the possible range of effects and develop a set of actions to accommodate these changes. This implies that the power plan must be flexible and dynamic so that it can deal with uncertainties if and when they occur.

Likely categories for significant change include additional operations for fish, reduction in hydroelectric system flexibility due to increasing amounts of variable resources (such as wind), possible changes in the Columbia River Treaty, climate change, and potential bypass spill reductions associated with spillway weirs.

The Council along with other regional entities, including the Independent Economic Advisory Board²⁰ recently examined the interactions between fish and power operations and identified several important factors to be considered in the development of this plan:

- In the long term, hydroelectric generation could increase due to installation of spillway weirs at federal dams. Spillway weirs are designed to increase juvenile migrant passage survival while reducing the volume of bypass spill. Unfortunately, evaluation of the effectiveness of these weirs has been mixed and projections of future energy savings cannot be assumed at this time. The Council assumed no long-term increase in hydroelectric generation due to spillway weirs.
- There remains a great deal of uncertainty regarding the amount of future bypass spill, which is still being litigated. It is possible that long-term hydroelectric generation will decrease due to increased spill requirements, similar to the increased spill that a federal judge has required for 2009. However, quantifying this potential loss is difficult because of the possibility of future legal actions. The Council's set of current operations used to develop its resource strategy do not include additional bypass spill.
- Mainstem operations for fish and wildlife tend to reduce the hydroelectric system's flexibility and increase the cost of integrating wind resources. Flexibility of electricity supplies is vital to ensuring a reliable power system. Efforts are underway to quantify this loss of flexibility. Some, but not all, of the effects of this loss of flexibility were captured in the Council's analysis for the plan. However, the Council recommends continued regional participation in discussions and analysis of this issue.
- New water management strategies or development of new storage facilities would clearly affect hydroelectric generation in the long term. However, given the long lead time required to develop and implement these projects, it is not likely to happen in the short term, if at all. Thus the Council assumes that no new water management strategies or storage facilities will be implemented for the power plan analysis.
- Terrestrial and wetland habitat protection and restoration funded by the fish and wildlife program may create opportunities to develop carbon credits. Discussions of potential

²⁰ [Reference IEAB report here.](#)

benefits to the power system are just barely underway. No assumptions regarding potential future carbon credits for habitat development were included in the plan.

Other potential long-term changes may include additional or different operations for fish such as:

- Lower operating elevations during the migration season (e.g., John Day Dam at minimum operating pool elevation instead of minimum irrigation pool elevation);
- Additional volumes of water for flow augmentation (i.e., allowing reservoirs to be drafted deeper by summer's end);
- Different pattern of water releases during the migration season;
- Removal of one or more mainstem federal dams;
- Revised Columbia River Treaty operations;
- Revised use of non-treaty storage; and
- Changes to flood control operations

The potential effects of climate change show impacts to both power and fish. Current analysis indicates that the Northwest is likely to see higher winter river flows and lower summer flows. At the same time, winter demand for electricity should decrease and summer demand would increase with rising temperatures. This effect should ease the pressure on the hydroelectric system in winter but make it more difficult over summer months, especially with the addition of more and more variable resources. Also, current renewable portfolio standards have already affected resource acquisition strategies and will likely continue to do so if they are modified or replaced by federal legislation. Potential carbon tax or cap-and-trade mechanisms will also alter future resource plans.

Ongoing changes in power markets and westwide power integration may also bring changes to the way we use and value the power system (e.g. generation in summer may become more and more profitable). These kinds of changes present challenges for fish and wildlife operations, but may also present positive opportunities. For example, releasing more stored water during summer months not only increases revenues but also provides higher river flows for migrating smolts.

For this plan, long-term uncertainties already include load, fuel and electricity prices, runoff conditions and carbon penalties. Uncertainties not explicitly incorporated into resource plan development include the effects of climate change, modifications to fish operations or changes in the Columbia River Treaty. Because of difficulties in quantifying the range and magnitude of these latter uncertainties, it is best to assess these by means of sensitivity analysis. Studies can be performed to determine the potential effects of these changes, either independently or in combination. However, the magnitude of potential impacts must be considered in conjunction with the likelihood of occurrence, that is, a potential uncertainty may have a large impact but might be extremely unlikely. The region should continue to explore and analyze such scenarios to be better prepared should these unlikely events occur.

While there is much the Council can do as part of both the fish and wildlife program and the power planning process to analyze and respond to these long-term agencies, regional cooperation is also needed. Federal agencies have already formed several committees to deal with in-season operational issues affecting fish and power. For example, the Technical Management Team (TMT) consists of technical staff from federal, state, and tribal agencies that usually meet on a weekly basis during the fish migration seasons 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 Regional Implementation Oversight Group (RIOG), which consists of higher policy-level staff. This new process of resolving conflicts in proposed hydroelectric operations is untested.

While the existing committee structure is intended to solve in-season problems, no currently active process exists to address long-term planning issues related to both power planning and fish and wildlife operations. The Council encourages the creation of an open forum where fish and wildlife managers and power planners could jointly explore strategies to improve both fish and wildlife benefits and hydroelectric power operations. In such a forum, synergistic effects between fish and wildlife operations and power planning could be examined. For example, conservation savings in irrigation should also provide savings in water quantity and energy, which could benefit both in-stream flows for fish and reduce load on the power system. Also, the State of Washington is currently exploring options for new storage sites, which could benefit fish, power and irrigation. And finally, potential carbon emission mitigation benefits of actions to acquire or improve fish and wildlife habitat should be assessed.

Action Plan items F&W-1 (long-term planning forum); F&W-3 (analytical capability), F&W-4 (Columbia River Treaty), and F&W-5 (climate change) are intended to help the Council and the region to develop the tools needed to address these uncertainties.