STRATEGIC ASSET MANAGEMENT PLAN

For the Federal Columbia River Power System

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1.0 EXECUTIVE SUMMARY

The Federal Columbia River Power System (FCRPS) consists of 31 multipurpose dam and operating projects operated by the U.S. Army Corps of Engineers (Corps) and the Bureau of Reclamation (Reclamation). As a multipurpose system, the FCRPS produces both power and non-power benefits for the Pacific Northwest. The Corps and Reclamation operate and maintain the facilities with a combination of Bonneville Power Administration (BPA) direct funding and federal appropriations. BPA solely funds activities related to power generation and jointly funds activities that support the multiple purposes of the facilities. With 196 hydro generating units and a capacity of 22,050 MW, the FCRPS is the largest hydro system in the United States.

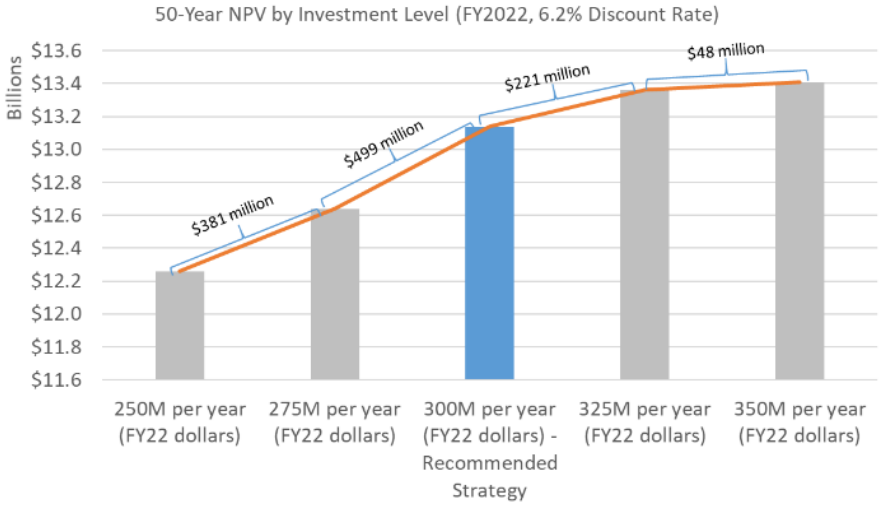
For decades, the FCRPS has been an engine of economic prosperity. It provides low-cost, carbon-free electricity, flood risk management, irrigation, navigation, municipal and industrial water supply, and recreation opportunities throughout the region. Today, the FCRPS' flexibility supports the integration of over 2,700 MW of renewable capacity and is integral to BPA's participation in the energy imbalance market. As trusted stewards of these assets, the Three Agencies also have an obligation to mitigate for the environmental and cultural impacts of the system.

Effective management of FCRPS assets requires balancing the many uses of these shared resources as efficiently as possible. The FCRPS Strategic Asset Management Plan (SAMP) strives to make coordinated operations, maintenance and investment decisions that maximize the value of FCRPS assets by reducing costs, mitigating risk, improving efficiency, and producing incremental value. This involves identifying optimal investment timing and alternatives, tailoring maintenance programs to the level of service necessary to meet obligations, and efficiently planning and operating the system. In these areas, decision making is the most mature for the capital investment program. Since 2008, the Three Agencies have used decision making tools to identify the optimal level of capital investment in the FCRPS based on asset condition, criticality, and risk. Starting in 2017, the Asset Investment Excellence Initiative (AIEI) expanded the use of these tools to develop a 20-year portfolio of capital projects that is optimized on an annual basis based on project costs, benefits, and risks. During 2020 and 2021, the Three Agencies developed a new asset management structure aimed at closing gaps in the FCRPS asset management system, specifically with respect to operations and maintenance (O&M) optimization. Over the coming years, these new teams will expand our O&M decision making capabilities, bringing the level of maturity closer to that of the capital program.

Recommended funding levels for the capital and expense programs are relatively unchanged from those presented in the 2020 SAMP. The capital investment strategy remains to ramp up to $300 million by 2024 and then escalate at the rate of inflation.

	Rate Case FYs		Future Fiscal Years							
$ millions	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Total Capital	300	306	312	320	327	335	343	351	359	367

This level of investment has a $13.1 billion Net Present Value (NPV) through reductions in risk and incremental efficiency benefits. Higher levels of investment begin to show diminishing returns and are logistically more difficult to execute. Lower levels of investment result in significant reductions in NPV.



The expense program has held budgets flat and even decreased budgets in some years since 2018. Expense budgets will remain flat through the BP22 rate period. The previous SAMP identified the intent to return to capturing inflation in subsequent rate periods. For the Corps, expense levels are escalated at 2% per year starting in 2024. For Reclamation, expense levels also begin escalating at approximately 2% per year in 2024, but there is an $8 million reduction in the non-routine expense budget in 2026. This results in slight decrease in total expense between 2025 and 2026. After 2026, Reclamation's budget is escalated at 2% per year. Near-term budget increases are still expected to be less than inflation, which has been significantly higher than 2% since the onset of the pandemic.

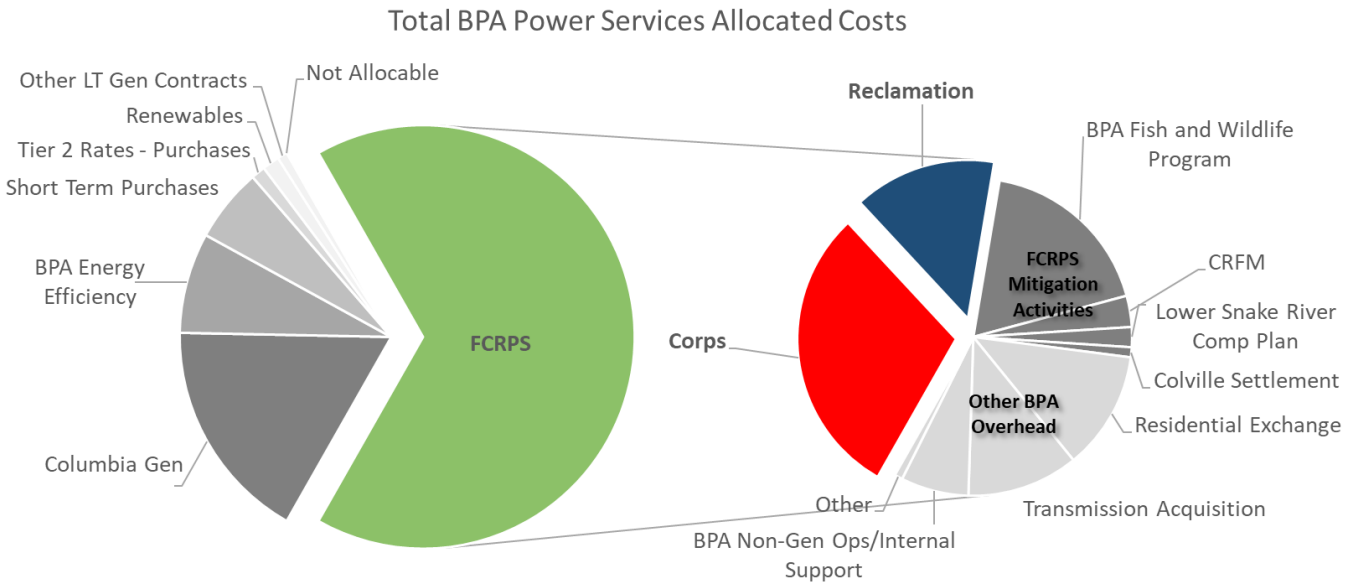
	Rate Case FY's		Future Fiscal Years							
$ millions	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Total Expense	411	419	419	427	436	444	453	462	472	481

In general, the strategy drives capital and expense funding to align proportionately with each plants' contribution to average annual generation. Although Area and Local Support plants appear high relative to their generation importance, a higher percentage of funding for those facilities supports multipurpose activities compared to other Strategic Classes.

Overall, the direct funded capital and expense forecasts addressed in this SAMP are expected to result in a 50-year levelized cost of generation of $10.14/MWh. The 50-year fully loaded cost, which allocates all costs on the Power Income Statement to Power's various generating resources and Energy Efficiency, is $22.13/MWh for the 31 FCRPS plants.

Strategic Class	% of FCRPS Average Annual Generation	% of 50-Year Capital Forecast	% of 50-Year Expense Forecast	50-Year Cost of Generation ($/MWh)	50-Year Fully Loaded Cost ($/MWh)
Main Stem Columbia	77%	63%	66%	$8.08	$19.46
Lower Snake	12%	12%	13%	$12.50	$27.22
Headwater	6%	9%	8%	$13.15	$24.97
Area Support	4%	12%	9%	$32.77	$47.87
Local Support	1%	4%	4%	$42.24	$55.17
FCRPS	100%	100%	100%	$10.14	$22.13

The power share of Corps and Reclamation costs account for 44% of all costs allocated to 31 dams in the FCRPS Total costs allocated to the FCRPS account for 66% of Power Services' total costs. Allocable costs are allocated to the various energy resources Power Services utilizes based on an agreed upon methodology developed by BPA Finance. All of these costs ultimately contribute to the calculation of BPA's Priority Firm (PF) rate.



2.0 ACKNOWLEDGEMENTS

2.1 Senior ownership

2.1.1 FCRPS Asset Management Commitment

In 2019, the Corps, Reclamation and BPA developed the FCRPS Asset Management Commitment. This commitment outlined the asset management mission, vision, and values of the FCRPS and was signed by the Corps' Northwestern Division Commander, Reclamation's Columbia Pacific Northwest Regional Director and BPA's Administrator.

FCRPS Asset Management Commitment

Vision

The FCRPS agencies will strive to sustain the efficiency, affordability and reliability of the System's long-term value through business processes that reflect industry best-practices in asset management. These processes include all aspects of planning, resourcing, and approving work, while informing strategies for operations, maintenance, and reinvestments of FCRPS assets.

Background

The U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and Bonneville Power Administration act together through a strong three-agency alliance as responsible stewards of the Federal Columbia River Power System (FCRPS). The FCRPS is comprised of billions of dollars in assets and provides great economic and social benefits for the Pacific Northwest and beyond.

Mission

The FCRPS exists to deliver benefits to power, irrigation, navigation, and other customers and key stakeholders. We owe it to those customers and stakeholders to proactively implement and utilize industry leading asset management practices. This will enable us to provide those products and services with the highest regard to safety, environment, reliability, reputation, and cost.

Asset Management Values

Customers

- Embrace the FCRPS' role as a service provider to a broad range of customers and stakeholders. Cultivate a culture of commitment as federal partners to deliver demonstrated value to those customers.
- Establish ourselves as competent and transparent providers of the services expected by our customers and stakeholders while being good stewards of the public's assets.

People

- Value safety above all else – every process and action first identifies risks and preventative measures to protect our greatest asset, our employees.
- Ensure that roles and responsibilities of our organizations are clear, meaningful, valuable and rewarding.
- Enable staff to exercise leadership and appropriate levels of decision-making.
- Invest in employee training and development to effectively accomplish their function.

Process/Information

- Balance cost, performance, and risk through a consistent and credible decision-making process. Key stakeholders understand and have confidence in its integrity.
- Manage and utilize information and knowledge to enable informed decisions and effective work execution.
- Leverage innovative solutions and industry best practices to continuously improve achievement of FCRPS objectives.

Plant

- Operate, maintain, and invest in our facilities to optimize their value to customers and stakeholders over the long-term that is consistent with the financial health and stability of the FCRPS.
- Identify the business value of each facility, asset, and component and align performance expectations with that value, including all areas listed below:
  - Generation & Capacity
  - Cost
  - Risk tolerance
  - Health & safety
  - Environmental responsibilities
  - Legislative risks/requirements
  - Regulatory requirements
  - Cultural Resource responsibilities

Brigadier General D. Peter Helmlinger
Commander, Northwestern Division
U.S. Army Corps of Engineers

Ms. Lorri Gray
Regional Director, Pacific Northwest Region
U.S. Bureau of Reclamation

Mr. Elliot Mainzer
Administrator
Bonneville Power Administration

2.1.2 BPA Senior Ownership

The Federal Columbia River Power System is a tremendous asset to the Pacific Northwest, producing low cost, reliable, carbon-free power for the region. As Trusted Stewards of the FCRPS, it is critical that BPA and its federal partners employ sound Asset Management principles to ensure the system is operated safely, efficiently and remains a competitive resource for years to come.

In recent years, the FCRPS partnership has demonstrated its commitment to BPA's 2018-2023 Strategic Plan by bending its cost curve, while continuing to advance our asset management practices, and supporting grid modernization efforts in anticipation of joining the energy imbalance market. These actions have put us in a better position to realize BPA's long-term objective of fully subscribing the federal system to its customers through new long-term contracts in 2028. The strategies presented in this SAMP continue our commitment to maximizing the value of the FCRPS for the benefit of the region.

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SUZANNE COOPER
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Suzanne Cooper
Senior Vice President, Power Services

2.2 Strategy Development Approach

2.2.1 Key Contributors

Agency	Group	Contribution
Bonneville Power Administration	Generating Assets (PGA and PGAF)	• Lifecycle cost minimization models (Copperleaf - Predictive Analytics) • Equipment degradation rates • Risk assessment • Economic analysis • Author of SAMP
	Power Forecast and Planning (PTM)	• Long Term Price Forecasts
	Operations Planning (PGPO)	• Consequences of Unit Outages
	Revenue Requirement, Repayment and Financial Strategy (FTR)	• Discount Rate • Inflation Rate
Army Corps of Engineers	Portland, Seattle, Walla Walla Districts, Northwestern Division	• Project costs estimates and valuation • Joint Investment Identification • SAMP Review
	Plant Staff	• Project information • hydroAMP Condition Assessments
	Hydroelectric Design Center	• Equipment Failure Curves • Technical Expertise
Bureau of Reclamation	Columbia Pacific Northwest Region	• Project cost estimates and valuation • Joint Investment Identification • SAMP Review
	Plant Staff	• Project Information • hydroAMP Condition Assessments
	Technical Services Center	• Technical Expertise
Three Agency Teams	Various	• FCRPS Goals, Objectives, and Initiatives

The SAMP is reviewed internally by Generating Assets (PGA and PGAF) staff and externally by the Corps (Portland District, Seattle District, Walla Walla District, and Northwestern Division) as well as by Reclamation (Columbia Pacific Northwest Region).

2.2.2 Key Activities

Activity	Description
Equipment Condition Assessments	• Plants perform annual condition assessment update
Update Modeling Parameters	• Price Forecast • Inflation Rate • Discount Rate • Condition Degradation Rates • Failure Curves • Equipment Outage Durations • Equipment Outage Consequences • Budget Constraints
Asset Management Maturity Assessment	• Conduct Asset Management maturity assessment by surveying FCRPS employees of various disciplines
Review and Update Goals, Objectives and Initiatives	• Goals, Objectives, and Initiatives are reviewed by FCRPS leadership, incorporating results from the maturity assessment
Run Predictive Analytics	• Analyze costs, benefits, and risk of investment at different budget levels • Identify the optimal level of achievable investment
Share preliminary results with federal partners	• Review Optimal Replacement Dates of equipment • Communicate any major changes to modeling
Develop SAMP	• Produce charts, tables and analysis describing the benefits costs and risks of pertinent investment scenarios • Create/update SAMP document
Review SAMP	• Review SAMP with Federal Partners • Present SAMP summary at Joint Operating Committees
Publish SAMP	• Incorporate changes from review and finalize document • Provide SAMP to Asset Planning team for input into Asset Plan

3.0 STRATEGIC BUSINESS CONTEXT

3.1 Alignment of SAMP with Agency Strategic Plan

The Corps, Reclamation, and BPA have the unique challenge of bringing together the strategic plans of three separate agencies under three different departments of the US government. Many goals are shared across the agencies, but it is important to acknowledge that each agency has its own distinct missions that are served by FCRPS assets and resources. Striving to effectively balance these missions, we have collaboratively developed strategic goals for the FCRPS that incorporate elements of each agency's strategic plan. Each goal is equally important in meeting the collective missions of the Three Agencies.

Long-term Sustainability	Trusted Stewardship	Low Cost, Reliable Power
We will maintain the performance of our assets and the competency of our workforce in line with asset management principles to sustain the long-term value of the FCRPS for the benefit of future generations.	We will balance the multiple uses of our physical assets and natural resources to safely provide benefits to the region for flood risk management, water delivery, navigation, power, fish and wildlife mitigation, cultural resources, and recreation.	We will make sound operations, maintenance, and investment decisions to meet the needs of our power customers, comply with regulations, and support reliable generation and transmission service at competitive rates.

Under these goals, this SAMP directly supports the following objectives from the BPA Strategic Plan:

Objective 1a: Improve Cost Management Discipline - The Corps and Reclamation have supported BPA's goal of holding program costs at or below the rate of inflation by maintaining flat expense budgets, and even taking budget reductions, since 2018. Although continuing on this path will be a challenge, the SAMP outlines strategies and initiatives aimed at identifying long-term efficiencies in support of this objective.

Objective 2a: Administer an Industry Leading Asset Management Program – The Corps, Reclamation and BPA collaboratively develop the SAMP and Asset Plan using asset management processes that align with ISO 55000, the international standard for asset management. Equipment condition, criticality and risk inform asset strategies and plans. On-going initiatives look to further improve our asset management capabilities to ensure our strategies and plans are sustainable for the long-term.

3.2 Scope

The SAMP presents strategies for improvements to the FCRPS Asset Management program as well as strategies for optimally maintaining assets at the 31 hydropower plants in the FCRPS. Asset condition, criticality, and risk drive the development of strategies that seek to minimize the lifecycle cost of the system. This analysis, in addition to input from Corps and Reclamation staff in the field, forms the basis for the investments identified in the FCRPS System Asset Plan (SAP).

Within the 31 plants, there are 196 main generating units plus an additional 16 units that provide station service, fish attraction flows, or pumping capabilities. The SAMP primarily covers powertrain and critical ancillary components that are either directly related to power production or are supporting equipment for day-to-day operations. About 17% of the inventoried assets are joint-use assets. Typically, assets that serve the multiple authorized purposes of a facility, not solely hydropower, are deemed joint-use. For these assets, the Corps and Reclamation must acquire both federal appropriations and direct funding from BPA to execute the project. Due to these complexities, joint-use assets are underrepresented in the asset inventory and the ability to effectively plan their replacement or refurbishment is challenging. Since 2020, roughly 10% of the overall Corps capital budget is set aside for joint assets. Corps joint investments are then optimized separately within this portion of the budget.

Columbia Generating Station (CGS) and other contract generating resources are not within the scope of this SAMP. Unlike FCRPS assets, BPA has less of a direct asset management role with these resources and more generally reviews the strategies and plans created by the operators of the respective assets.

3.3 Asset Description and Delivered Services

The FCRPS is comprised of 31 hydroelectric plants, 21 operated by the Corps and 10 by Reclamation, and has an overall capacity of 22,050 MW. In an average water year, the FCRPS produces 76 million megawatt-hours of electricity. The 31 plants are located throughout the Columbia River Basin in Washington, Oregon, Idaho and Montana. Each plant is grouped into one of five Strategic Classes, which describe their respective roles in the FCRPS.

Table 3.3-1, Assets

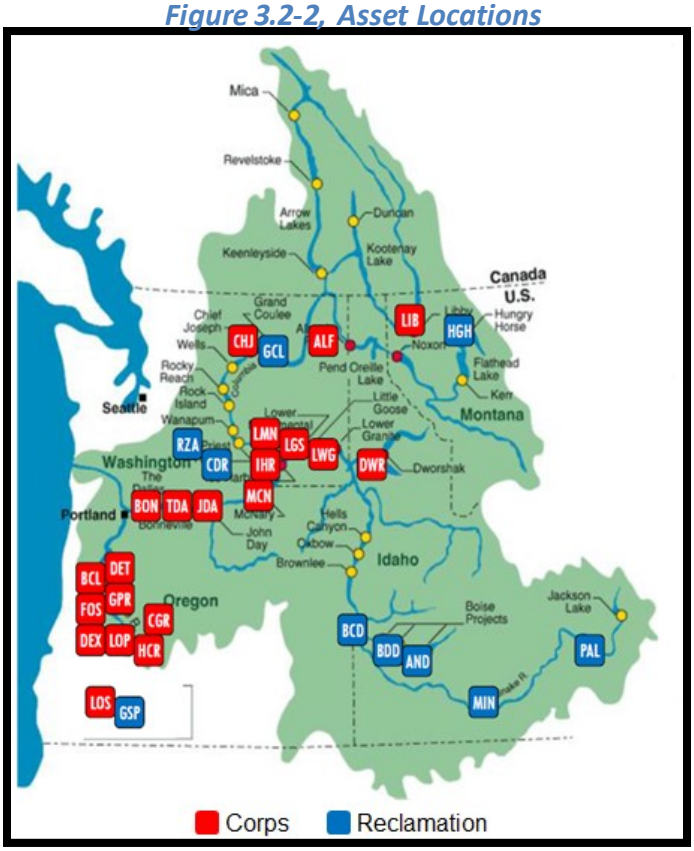
Plant	ID	Units	MW Capacity	aMW Energy	Strategic Class	Operator
Grand Coulee	GCL	24	6,735	2,422	Main Stem Columbia	Reclamation
Chief Joseph	CHJ	27	2,614	1,377	Main Stem Columbia	Corps
McNary	MCN	14	1,120	549	Main Stem Columbia	Corps
John Day	JDA	16	2,480	1017	Main Stem Columbia	Corps
The Dalles	TDA	22	2,052	805	Main Stem Columbia	Corps
Bonneville	BON	18	1,195	552	Main Stem Columbia	Corps
Dworshak	DWR	3	465	216	Headwater	Corps
Lower Granite	LWG	6	930	250	Lower Snake	Corps
Little Goose	LGS	6	930	255	Lower Snake	Corps
Lower Monumental	LMN	6	930	300	Lower Snake	Corps
Ice Harbor	IHR	6	693	227	Lower Snake	Corps
Libby	LIB	5	605	227	Headwater	Corps
Hungry Horse	HGH	4	428	94	Headwater	Reclamation
Albeni Falls	ALF	3	49	21.6	Area Support	Corps
Detroit	DET	2	115	49	Area Support	Corps
Big Cliff	BCL	1	21	12.2	Area Support	Corps
Green Peter	GPR	2	92	29.3	Area Support	Corps
Foster	FOS	2	23	11.9	Area Support	Corps
Lookout Point	LOP	3	138	41.1	Area Support	Corps
Dexter	DEX	1	17	11.2	Area Support	Corps
Cougar	CGR	2	28	19.9	Area Support	Corps
Hills Creek	HCR	2	34	22.5	Area Support	Corps
Lost Creek	LOS	2	56	45.4	Area Support	Corps
Palisades	PAL	4	176	84	Area Support	Reclamation
Minidoka	MIN	4	28	16.6	Local Support	Reclamation
Anderson Ranch	AND	2	40	19.6	Local Support	Reclamation
Boise Diversion	BDD	3	3	1.3	Local Support	Reclamation
Black Canyon	BCD	2	10	7.5	Local Support	Reclamation
Roza	ROZ	1	13	7.6	Local Support	Reclamation
Chandler	CDR	2	12	6.3	Local Support	Reclamation
Green Springs	GSP	1	18	7.3	Local Support	Reclamation
TOTAL		**196**	**22050**	**8705**		

Table 3.3-1, Strategic Classes

Purpose	Main Stem Columbia	Headwater/Lower Snake	Area Support	Local Support
Power	Provides 76% of energy and capacity, and 30% of storage from the FCRPS Provides nearly all the reserves and other ancillary services for supporting the 500 KV grid	Provides 20% of energy and capacity, and 50% of storage from the FCRPS Provides supplementary ancillary services for supporting the 500 KV grid	Provides 3% of energy and capacity, and 18% of storage from the FCRPS Provides voltage support to specific areas of the regional transmission grid	Provides 1% of energy and capacity, and 2% of storage from the FCRPS Provides limited voltage support to local areas of the Pacific Northwest
Flood Risk Management	Seasonal flood risk reduction and water management storage affecting significant parts of the Columbia River basin	Seasonal flood risk reduction and water management storage affecting significant parts of the Columbia River basin	Provides flood risk reduction benefits primarily in the Willamette Valley, but does not contribute significantly to the flood reduction capability of the overall Columbia River basin	Provides flood risk reduction benefits in a local area
Navigation	Provides navigation for the lower Columbia River from below Cascade Locks to the Tri-Cities	Provides navigation for the lower Snake River from the Tri-Cities to Lewiston, ID	None	None
Irrigation	Primary source of irrigation for the Columbia River Basin	Provides incidental irrigation from the reservoirs	Primary source of irrigation within a specific region (Palisades Dam only)	Primary source of irrigation within a specific region
Recreation	Significant recreation for boating and camping Includes several "destination" recreation sites and numerous local sites	Major recreation for boating and camping Includes several "destination" and local sites	Major recreation for boating and camping Includes several "destination" and local sites	Some boating and camping at local sites

The FCRPS provides the following services to BPA's preference customers:

Figure 3.2-2, Asset Locations



Load Following Product: BPA firm power service that meets the customer's Total Retail Load less any firm energy from the customer's Dedicated Resources on a real-time basis.

Block Product: BPA firm power service sold in a specific amount each hour, offered as a flat hourly block or with Shaping Capacity.

Slice Product: BPA power service that includes requirements power, surplus power, and hourly scheduling rights.

Industrial Firm Power: BPA firm power service sold to direct service industrial customers in the Pacific Northwest as defined in the Northwest Power Act.

Renewable Energy Certificate: A derivative product that represents the benefits associated with the generation of electricity from renewable energy sources (including incremental hydropower efficiency improvements).

The FCRPS also provides the following ancillary services:

Reactive Supply and Voltage Control from Generation Sources Service: Required to maintain voltage levels on BPA's transmission facilities within acceptable limits.

Regulation and Frequency Response Service: Necessary for the continuous balancing of resources with load and for maintaining frequency.

Energy Imbalance Service: Provided when a difference occurs between the scheduled and actual delivery of energy to a load located within a Control Area.

Spinning Reserve Service: Needed to serve load immediately in the event of a system contingency.

Supplemental Reserve Service: Needed to serve load in the event of a system contingency, not immediately, but within a short period of time.

Generation Imbalance Service: Provided when there is a difference between scheduled and actual energy delivered from generation resources.

Variable Energy Resource Balancing Service: Comprised of regulating reserves, following reserves and imbalance reserves.

Dispatchable Energy Resource Balancing Service: Provides reserves to compensate for differences between a thermal generator's schedule and actual generation.

Contingency Reserves: Deployed to meet the Disturbance Control Standard (DCS) and other NERC and Regional Reliability Organization contingency requirements.

Surplus Power: Generation in excess of BPA's obligations to preference customers is sold to wholesale parties.

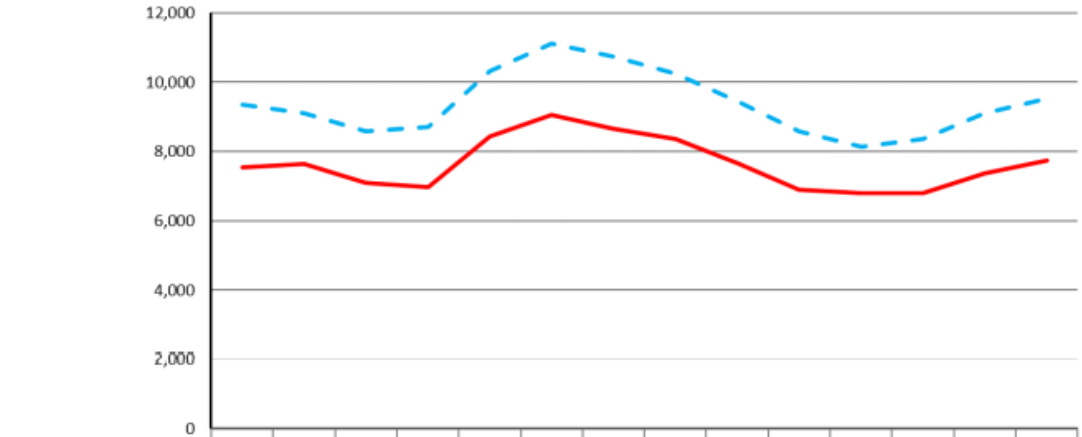
3.4 Demand Forecast for Services

The Pacific Northwest Loads and Resources Study, commonly called "The White Book", is BPA's annual publication of the Federal system and the Pacific Northwest (PNW) region's loads and resources for the upcoming ten-year period. Note that the Federal system includes generation from the 31 dams in the FCRPS, CGS, and other contract generating resources.

BPA uses the White Book as a planning tool, as a data source for the Columbia River Treaty studies, as an information source for customers, and as a published source of loads and resources information for other regional interests. As of the development of this SAMP, the 2019 White Book is the most recent release. The highlights are:

Load Obligations – The types of Federal system load obligation forecasts include: 1) Federal reserve power obligations to Reclamation; 2) Bonneville's Regional Dialogue PSC obligations to public, cooperative, and tribal utilities, and Federal agency customers; 3) contract obligations to investor-owned utilities (IOUs); 4) contract obligations to Direct Service Industry (DSI) customers; and 5) other Bonneville contract obligations, which include contract sales to entities within the PNW region (Intra-Regional Transfers (Out) and to those outside the PNW region (Exports). These load obligations are all considered firm power deliveries and are assumed to be served by the Federal system regardless of weather, water, or economic conditions. The chart below shows total forecasted energy and 120-hour capacity obligations for operating year 2022.

Federal System
Monthly Energy and 120-Hour Capacity Load Obligations
OY 2022



	Aug1	Aug16	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr1	Apr16	May	Jun	Jul
Energy (aMW)	7,554	7,654	7,109	6,973	8,428	9,063	8,653	8,352	7,662	6,893	6,788	6,808	7,374	7,730
120 Hour Cap (MW)	9,355	9,099	8,585	8,709	10,317	11,114	10,748	10,235	9,463	8,587	8,147	8,355	9,111	9,535

Federal System Analysis—forecast of Federal system firm loads and resources based on expected load obligations and different levels of generating resources that vary by water conditions. The results are summarized below:

Annual Energy Surplus/Deficits: Under critical water conditions; the Federal system is projected to have annual energy deficits across the study period, ranging from as low as - 194 aMW, to as large as -354 aMW. These annual energy deficits projections are similar to those projected in the previous White Book, however the first two years are forecasts to have slightly greater deficits and rest of the study period has slightly smaller deficits. Under average water conditions, the Federal system is projected to have annual energy surpluses through the study period.

January 120-Hour Capacity Surplus/Deficits: Under critical water conditions; the Federal system is projected to have January 120-Hour capacity deficits over the study period, ranging from as low as -950 MW to as high as -1,226 MW. While these 120-Hour capacity deficits are similar to those projected in the previous White Book, Operating Year (OY) 2021 is forecasted to have greater deficits and the rest of the study period is forecasted to have smaller deficits. Under average water conditions; the Federal system is projected to have January 120-Hour capacity surpluses over the study period.

As water conditions improve over the critical water year, the Federal system surplus/deficit forecasts can vary greatly. For example, the annual energy surpluses can increase by more than 3,100 aMW under better water conditions, while the monthly surplus/deficit position can vary by almost 7,000 aMW (January). Similarly, Federal system 120-Hour capacity surplus/deficits for OY 2021 can vary by almost 5,000 MW in January, and by almost 6,000 MW during the second half of April, depending on water conditions.

Federal system monthly energy deficits tend to be greater than the 120-Hour capacity deficits under 1937-critical water conditions. This result indicates that the Federal system is more energy constrained than capacity constrained across the study period.

More information can be found here: https://www.bpa.gov/p/Generation/White-Book/Pages/White-Book-2019.aspx

3.5 Strategy Duration

The analysis conducted in this SAMP covers a 50-year study period, primarily to capture the benefits associated with reinvestment in equipment in the hydroelectric facilities. However, the primary focus of this strategy and the associated System Asset Plan is on the first 20 years. This strategy is to be updated and reviewed every two years to align with the BPA IPR cycle.

4.0 STAKEHOLDERS

4.1 Asset Owner and Operators

The Corps and Reclamation operate and maintain the dams while BPA markets and transmits the power they produce. BPA directly funds the power-related capital, operations and maintenance costs of the two agencies through a series of Direct Funding agreements. There are four separate agreements:

- Reclamation capital costs, effective January 15, 1993

- Corps capital costs, effective December 6, 1994
- Reclamation operations and maintenance expense, effective October 1, 1996
- Corps operations and maintenance expenses, December 22, 1997

These agreements established the Joint Operating Committee (JOC), which is tasked with overseeing the implementation of the terms and conditions of the agreements, including the development of expense and capital budgets, coordination of operations, and performance metrics.

A Three Agency Executive Steering Committee (ESC) provides strategic direction to the hydropower program. Sub-committees of the JOC provide direct oversight of specific aspects of the responsibilities outlined in the agreements:

- Capital Workgroup (CWG)
- Asset Planning Team (APT)
- River Management (RMJOC)
- Cultural Resources (CRSC)
- Reliability Implementation Technical Subcommittee (RITS)
- Hydro Optimization Team (HOT)
- Technical Operations & Implementation Subcommittee (TOIS)
- Performance Committee

4.1.1 Corps and Reclamation Operated Transmission Assets

The Corps and Reclamation operate a number of switchyards in the FCRPS including, Grand Coulee 500kV, 230kV, 115kV switchyards; Palisades switchyard; Minidoka switchyard; Hungry Horse switchyard; and Bonneville Powerhouse No. 1 rooftop switchyard. These switchyards provide a dual-purpose benefit to both BPA's Power Services (PS) and Transmission Services (TS) customers as they interconnect federal resources to the greater transmission network, and they support the operation of the high voltage transmission network in their respective geographic areas. This arrangement necessitates that both PS and TS account for these assets in their asset management planning, as well as pay for capital and expense costs associated with the switchyards.

As the assets are operated by the Corps and Reclamation, PS supplies the total expense costs as they are spent, and directly funds the Corps and Reclamation through the direct funding agreements indicated above. Similarly, PS supplies all funds to the Federal Treasury for debt service of these assets, and bonds with the treasury to secure capital funds, which PS then directly funds to the Corps and Reclamation. Transmission Services' share of the capital debt service and expense costs are paid to Power Services through an inter-business allocation each year. Bonding for capital costs are coordinated between PS and TS. When investments in these assets necessitate a capital funding requirement, additional space is made available in PS's borrowing authority that year, which is offset by a decrease in TS's borrowing authority for that year. This process is known as the Transfer of Budget Authority.

BPA and Reclamation are studying the transfer of switchyards at Grand Coulee to BPA Transmission. It is expected that this transfer would lead to an overall cost reduction for BPA. Consolidating the role of transmission owner and transmission operator with BPA Transmission is also expected to improve compliance-related activities.

4.2 Stakeholders and Expectations

The FCRPS has a wide variety of stakeholders with expectations that can be both overlapping and conflicting. BPA, the Corps and Reclamation must balance these varying expectations in order to cost effectively meet the region's needs.

Stakeholders	Expectations	Current Data Sources	Measures
Biological Interests	ESA-Listed Fish Populations	Corps, USFWS, and NOAA Fish Monitoring	Fish Counts, SARs (Smolt to Adult Returns, Juvenile Travel Time, Performance Standards for juvenile Dam Passage Survival)
BPA Power and Transmission	Unit Availability for generation and ancillary services	Outage Tracking System (OTS), hydroAMP, SCADA, PI, THOR, GDACS	Availability, Equipment Condition (hydroAMP), Generation Data
Canada	Columbia River Treaty Compliance	Columbia River Treaty	Assured Operating Plan Detailed Operating Plan Treaty Storage Regulations
Corps and Reclamation	Direct Funding	Sub-agreements, Annual Power Budget	Capital and Expense Expenditure Rates, Equipment Condition (hydroAMP)
	Safety	Corps and Reclamation Safety Management Systems	Safety Metrics (Lost Time Accident Rates, Days Away, Restricted or Transferred, Total Case Incident Rate)
	Employee Satisfaction	Human Resources Databases	Turnover statistics, surveys
Cultural Interests	Trusted Stewardship	FCRPS Cultural Resource Program, Colville Payment, Spokane Payment	Cultural Resources KPIs, Colville Payment Data Spokane Payment Data
Customers	Economical Rates	Integrated Program Review, Long Term Rates Forecasts	Tier 1 PF Rate forecast from Reference Case and LTRF Scenarios
	Reliability	OMBIL (Corps), PO&M (Reclamation)	Availability Metrics (Weighted Scheduled Outage Factor, Weighted Forced Outage Factor)
Environmental Interests	Water Quality – Temperature	Corps and Reclamation Monitoring Systems	State Water Quality Standards
	Water Quality – Total Dissolved Gas	Corps and Reclamation Monitor Systems, Fish Passage Center Smolt Monitoring Program	State Water Quality Standards, Gas Bubble Trauma Incidences
	Water Quality - National Pollutant Discharge Elimination System (NPDES) Permits	Corps and Reclamation Monitoring Systems	NPDES requirements, Oil Accountability Measures
Irrigation Customers	Unit Reliability	Sub-agreements, Annual Power Budget, hydroAMP, Reclamation PO&M database	Equipment Condition (hydroAMP or Corps Operational Condition Assessments)
Navigation Customers	Joint Funding for Corps Investments	Sub-agreements, Annual Power Budget	Equipment Condition (hydroAMP or Corps Operational Condition Assessments)
NERC/WECC	Comply with Regulations	Corps and Reclamation Systems	Reliability Metrics (Standards Compliance, Inherent Risk Assessments)
Northwest Power and Conservation Council	Pursue Actions in The Northwest Power Plan	White papers, analysis results and documentation	Report out to the Council on analysis and results.
Public	Safety	Corps/Reclamation Dam Safety Programs	Operational Condition Assessments
	Recreation	THOR, Corps Reservoir Control Center	Rule Curves, Elevation Data

5.0 EXTERNAL AND INTERNAL INFLUENCES

Table 5.0-1 details the most critical external and internal influences on FCRPS assets and the ability to meet the missions and objectives of the Three Agencies. The table describes how each influence affects the FCRPS and presents actions that have been taken or are planned in response. An emerging influence for the 2022 SAMP are the supply chain and labor shortages resulting from the pandemic. Both have presented new challenges to delivering on asset management objectives.

Table 5.0-1, External and Internal Influences

External Influences	Affects and Actions
Customers	Customers continue to encourage that BPA, the Corps and Reclamation find ways to control spending and make the most efficient, economic investments. The AIEI began in 2015 in order to improve the selection, optimization and execution of large capital expenditures. These processes are now established and continue to mature. The Corps began work on the Operations and Maintenance Optimization Initiative (OMOI) in 2019 to identify similar improvements in the operations and maintenance program. Reclamation is working on a similar initiative. The restructuring of FCRPS Asset Management and formulation of new Asset Management teams beginning in 2022 will also support these efforts.
Energy Markets	BPA's rates are impacted by the ability to market surplus generation produced by the FCRPS. With energy markets recently at historic lows due to an abundant supply of cheap natural gas powered resources and renewables, the value of surplus energy production has been diminished in recent years. The extent to which units are rehabilitated or replaced as well as the number of units within a powerhouse that are addressed by an investment are considered in the context of both the upside and downside market risks. Energy markets could also be impacted by future regulations with respect to carbon taxes, making carbon-free hydropower more attractive.
Energy Policy	Renewable Energy Credits, such as those claimed by Wind and Solar resources, are only available for Small Hydro facilities and incremental efficiency improvements at Large Hydro projects. In addition to electricity generation, the FCRPS also provides ancillary services that help keep the power system stable and integrate sources of renewable generation into the grid. Unlike the robust ability to trade energy products, BPA has historically not had a way to effectively market these ancillary services. The Department of Energy's long-term National Hydropower Vision has called out the need to establish markets that allow hydroelectric generators to receive revenue for the value they can inherently provide for grid stability and renewable energy integration. Entrance into the Energy Imbalance Market in 2022 will allow BPA to start marketing some of these ancillary services.
Fish Operations and Mitigation	The Proposed Action consulted upon with NMFS and USFWS, as altered by the Term Sheet for Stay of Preliminary Injunction Motion and Summary Judgment Schedule (referred to as the 2022 Agreement) for the *NWF et al. v. NMFS et al.* (3:01-cv-00640-SI) litigation, and the Fish Passage Plan mandate spill, flow, temperature, total dissolved gas and other operational requirements for FCRPS facilities. These requirements have significant impacts on the amount of water and operational flexibility available for power generation. In order to improve conditions for fish passage, significant investment in new systems, reinvestment in existing systems, and operational changes may be required. Improved fish passage turbine design has the potential to reduce impacts to power generation in the future if positive biological performance leads the region to agree upon fish screen removal.
Interdepartmental Challenges	The three agencies that make up the FCRPS are part of three separate departments of government. Each is subject to their own policies, codes, and requirements driven by each department's respective headquarters. This can present challenges to project planning and procurement. From a national perspective, hydropower is not the core mission of the Corps or Reclamation which are part of the Department of Defense and Department of the Interior, respectively. Critical pieces of the Asset Management System, such as contracting, are largely outside of the authority of FCRPS leadership.
Intermittent Renewables Integration	Integrating renewable resources such as Wind and Solar has presented a challenge to the system, resulting in operations that were not anticipated in their original design. Increased starts and stops, frequent ramping, and operating in or passing through rough zones are potentially increasing the risk of failure and reducing the lives of generating units. Across the industry, the impacts on unit reliability are not well understood. Continued participation in industry forums and further analysis as more data become available should improve the ability to quantify these impacts. As powerhouses undergo rehabilitation and replacement, the opportunity presents itself to better align unit design with current operating conditions.

External Influences	Affects and Actions
Joint Asset Condition and Appropriations	BPA is obligated to fund the power share of a portion of the non-power specific assets ("Joint Assets") at FCRPS facilities. The power shares were set by Congress when the plants were authorized and were intended to be proportional to the benefits received by each authorized purpose of the facility. Approval and execution of work is contingent on the Corps and Reclamation receiving appropriations from Congress. The uncertainty in the federal appropriations process makes integration of joint assets with the rest of the FCRPS System Asset Plan difficult. The FCRPS may not be able to execute the right projects at the right time if appropriations are not available. Completing the Joint asset inventory and refining how Joint assets are modeled will lead to better communication between the agencies around planned joint work and may improve the Corps' and Reclamations' ability to receive appropriations.
Labor Shortages	The Corps and Reclamation have identified some delays in projects due to shortages in skilled labor. These shortages are reflective of overall trends in the US workforce where unprecedented numbers of individuals throughout the country are changing jobs or leaving federal service. Together, these impacts have created gaps in areas that were already a recruiting challenge. FCRPS management is continuing to monitor the situation over the coming months.
Load Growth/Changes in Load Characteristics	The 2020 Resource Program notes that BPA has seasonal heavy load hour energy needs, specifically in the winter. Although it was determined that BPA can rely on market purchases and conservation to meet system needs, efficiency and capacity improvements on existing turbine units were not modeled as potential resources in the Resource Program. These upgrades can help reduce pressure on the energy deficits at little to no incremental cost while the units undergo modernization. Power Services staff are evaluating including efficiency and capacity improvements on turbine units in future resource programs.
Manufacturer Support	Manufacturers ending support for equipment, especially digital equipment, is leading to extended outages and higher operations and maintenance costs. FCRPS staff have begun determining how to better recognize this step-change in outage duration and cost into planning models.
NERC/WECC Regulation	Generation facilities are required by NERC, CIP and WECC to undergo testing to ensure that they are in compliance with reliability standards. Increasing reliability requirements have resulted in increased operations and maintenance costs, primarily from the necessity to hire staff to oversee regulatory compliance programs. Additionally, physical and cyber security requirements continue to expand requiring more time and investment at the plants.
Supply Chain Issues	Global supply chain issues that emerged with the pandemic and have continued to persist are affecting project costs and schedules. Dramatic increases in the price of steel have led to significant cost increases in FCRPS investments. Various supply shortages have also resulted in project delays due to long lead times. Short-term expectations are actively being revised in the System Asset Plan and staff are evaluating how to better handle these issues in the mid-to-long term.
Water Supply/Climate Change	Changing weather conditions and the resulting changes in water supply create a degree of uncertainty unique to hydropower production. Between years, the difference in energy production from FCRPS can vary by several thousand average megawatts. This presents unique challenges to managing the entire portfolio of power supply needed to meet the demands of BPA customers. Climate change poses additional uncertainty into future energy production in the form of a changing runoff shape. This translates into greater Heavy Load Hour energy deficits in the late summer due to decreased snowpack as well as reduced deficits in the winter due to warmer temperatures and reduced winter loads.

Internal Influences	Affects and Actions
Aging Workforce	With a large portion of FCRPS staff nearing retirement eligibility, considerable amounts of powerplant design, operations, and maintenance knowledge are at risk of being lost. The FCRPS is attempting to preserve this knowledge through the Hydropower Apprenticeship Program, Hydropower Intern Program, Engineer Intern Program as well as through the documentation of maintenance activities with video recordings and written instructions.
Asset Condition	About 25% of FCRPS assets are in Marginal or Poor condition as shown in Section 8.2.2. This percentage is expected to increase over the next ten years, even with significant investment in the system. This suggests that the likelihood of unit outages may continue to increase. To effectively manage risk over the next ten years, investments will primarily target the equipment in Marginal and Poor condition that present the most risk to the system and deliver the highest value.
Horizontal Alignment	In addition to the departmental differences between the Three Agencies, horizontal alignment across the Three Agencies at a local level can be a challenge given each agency's unique missions. The systems currently in place and the continued evolution of asset management across the FCRPS are intended to mitigate these horizontal differences and improve alignment overtime.

Internal Influences	Affects and Actions
New Technologies	New technologies have the capability to reduce future costs or increase revenues, improving the viability of the FCRPS . Through improvements in turbine design since original construction, turbine replacements have provided efficiency improvements in the range of 3 to 6 percent in the FCRPS. Improved fish passage turbine design has the additional benefit of potentially improving fish passage and allowing for fish screen removal. This would not only relieve the need to replace deteriorating fish screens but would remove generation limitations at some plants.
Powerhouse Characteristics	Due to the inherent characteristics of the plants (number of units, unit rating, transmission system support, location within the river system, storage capability, etc.), unit reliability is more important at some plants than others. While plants are undergoing rehabilitation and replacement, it makes sense to evaluate the potential for unit uprates at plants that have low powerhouse capability relative to total plant flow in order to reduce the risk of future unit outages. Equipment in these plants should be prioritized ahead of equipment in plants that have a relatively low impact to unit outages due to excess powerhouse capacity.
Remote Locations	Many FCRPS facilities are located in remote locations and it is becoming increasingly difficult to attract new employees to them. Retention at remote facilities has proven a challenge in recent years with staff taking positions closer to larger cities as they gain experience. A special salary rate was implemented in 2019 for engineering positions that work directly with hydropower as an aid in retention of qualified and uniquely trained employees. Challenges have persisted into 2021, however, with increased housing costs near FCRPS facilities emerging as another barrier to attracting new employees.
Unit Reliability	Unit reliability improvements are made to reduce the impacts of unit failure. These can be financial, safety or environmental impacts, but can also affect public perception, employee satisfaction , and the ability of the FCRPS to comply with regulations. The FCRPS asset planning capabilities provide a common framework to evaluate and optimize these risks within constraints to deliver a portfolio that maximizes the overall value of investment (maximizing benefits and risk mitigation for all Three Agency missions for the portfolio as a whole).

5.1 SWOT Analysis

Table 5.1-1 evaluates the Strengths, Weaknesses, Opportunities, and Threats (SWOT) for the FCRPS.

Table 5.1-1: SWOT

Favorable	*Unfavorable*
Strengths	***Weaknesses***
• **Economies of Scale:** Due to their size, large FCRPS facilities produce an abundance of power at a low relative cost. The FCRPS as a whole is a first quartile performer among the 12 utilities benchmarked in the EUCG Hydro Productivity Committee for total cost per MWh. • **Carbon Free Generation:** The FCRPS provides an average of 76 million megawatt-hours of carbon free energy production per year, which, if produced by a carbon-emitting resource, equates to 32 million tons of avoided CO2 emissions. With increasing pressure on utilities and businesses to reduce their carbon footprint, FCRPS power could be very valuable. • **Flexible and Dispatchable:** Provides critical services to integrate non-dispatchable forms of renewable energy such as wind and solar. • **Asset Management Tools:** The FCRPS employs sophisticated asset management tools to optimize capital investment plans and develop the best investment alternatives.	• **Environmental Impact:** The original construction of the facilities resulted in impacts to affected resources (e.g. fish and wildlife, cultural resources) for which the Three Agencies continue to mitigate to this day. • **Weather Dependence:** The FCRPS has very little water storage compared to other basins in North America. The ability to generate is highly dependent on within year precipitation, snowpack, temperatures, and runoff. • **Market Forces and Ancillary Service Compensation:** The FCRPS' flexibility is undercompensated in today's markets. Reliance on the FCRPS to integrate renewable energy may also be leading to increased wear-and-tear. • **Three Agencies, Three Departments of Government, Multiple Missions:** The FCRPS facilities are multi-purpose projects and the Three Agencies that collectively operate, maintain and market and transmit the power from them have overlapping and occasionally competing missions. Having the various Asset Management functions spread across the Department of Energy, Department of the Interior, and Department of Defense is a challenge, especially when those functions are not specific to hydropower or dams. Although the Agencies have an abundance of data, it exists in disparate systems across the Three Agencies. The flow of data are often restricted due to departmental policies and silos resulting in asset management horizontal alignment challenges. Data interpretation are also inherently different.

Favorable	*Unfavorable*
Opportunities	***Threats***
• **Energy Imbalance Market (EIM):** Entrance into the Energy Imbalance Market in 2022 will create new revenue opportunities for FCRPS products and services. • **Efficiency Improvements:** Replacements to improve unit reliability provide the opportune time to increase efficiency or capacity of units at little incremental cost. • **Fish Passage Improvements:** New turbine designs have focused on improving fish survival through the units. There is potential for removal of fish screens in the future. In addition to avoiding replacement costs for fish screens that are nearing the end of their useful lives, annual installation and removal costs would also be avoided and many units would see an increase in efficiency. • **Optimizing Plant Configuration:** During powerplant modernization projects, the design, capacity, number of units, and possible future standardization of components can be evaluated given the expected future operating environment. Right-sizing and standardizing equipment at the powerplants can reduce long term capital and O&M costs while increasing efficiency. • **Federal Data**: The Three Agencies have an abundance of condition and performance data nationwide that puts the FCRPS in a unique position among utilities to develop lifecycle models to inform Asset Strategies and Plans. Some data are underutilized and could prove to be especially useful for optimization of operations and maintenance programs. • **Three Agency Collaboration:** The Three Agency FCRPS collaboration from multi-purpose perspectives can lead to more robust, positive outcomes than a "one agency" silo approach.	• **Climate Change:** Changes in weather patterns, specifically to more precipitation falling as rain than snow, may present challenges to operations and flexibility in the future. • **Threatened and Endangered Species:** Continued pressure has been put on BPA and the Corps to breach the four lower Snake River dams to support recovery of four species of ESA-listed salmon and steelhead. Breaching the dams would result in significant regional reliability, peaking capacity and ramping capability impacts unless replacement resources are acquired and installed. The costs associated with reliably replacing the services provided by the lower Snake River dams could result in significant rate increases for BPA's customers. • **Rate Pressures:** Pressure to keep rates low has constrained operations and maintenance budgets. In addition to long term impacts on reliability, collecting information needed to make asset management decisions may be impacted depending how activities are prioritized. • **Fish Infrastructure Costs:** Fish protection infrastructure, primarily fish screens, are showing signs of condition degradation and will require significant reinvestment in the coming years. New requirements may also result in the design and construction of new structures to support fish passage. These costs could have adverse impacts on the economic viability of some FCRPS facilities. • **Operational Changes:** Changes in operations to support fish passage could result in more spill, less hydropower production, and less flexibility. This could lead to increasing the risk of regional power shortages. • **Industry Experience Loss:** Loss of experience at the plants and in the industry may result in longer outages and costlier repairs. Some FCRPS units are unique or among the first of their kind. Original documentation is lacking for some plants which has required reverse engineering and even tracking down the long-retired original designers. • **Supply and Procurement:** The pandemic has resulted in serious supply chain challenges in the area of capital construction, operations and maintenance. This is impacting short term work, creating delays that could impact generation, safety, and environmental compliance. There are concerns that these short term delays could impact future work if these conditions continue.

6.0 ASSET MANAGEMENT CAPABILITIES AND SYSTEM

BPA, the Corps, and Reclamation began developing an asset management program in the late 1990s coinciding with the signing of the direct funding agreements. The Three Agencies developed the first FCRPS asset management strategy in 1999 at the direction of Congress. It called for the development of a strategy that maximizes the value of the FCRPS through, "assessing the condition of the system, comparing it to industry benchmarks, identifying investments, evaluating cost effectiveness, and undertaking actions that increase reliability and enhance revenues." With many of the processes and systems called for by the 1999 asset management strategy now in place, particularly with respect to capital investment, much of the original vision has been realized. However, with advancements in asset management practices in the last 20 years, there are still opportunities for refinement and improvement.

BPA adopted the Institute of Asset Management (IAM) model for Asset Management agency-wide. The IAM provides guidance for developing and implementing an Asset Management program compliant with ISO 55000, the international standard for Asset Management. None of the three agencies are currently considering ISO 55000 certification but are instead using the IAM model as a guideline.

In addition to guidelines for ISO 55000 implementation, the IAM also provide a maturity assessment model to assess the asset management maturity of an organization relative to ISO 55000 and IAM guidance. The IAM model focuses on six subject areas shown in the following diagram.

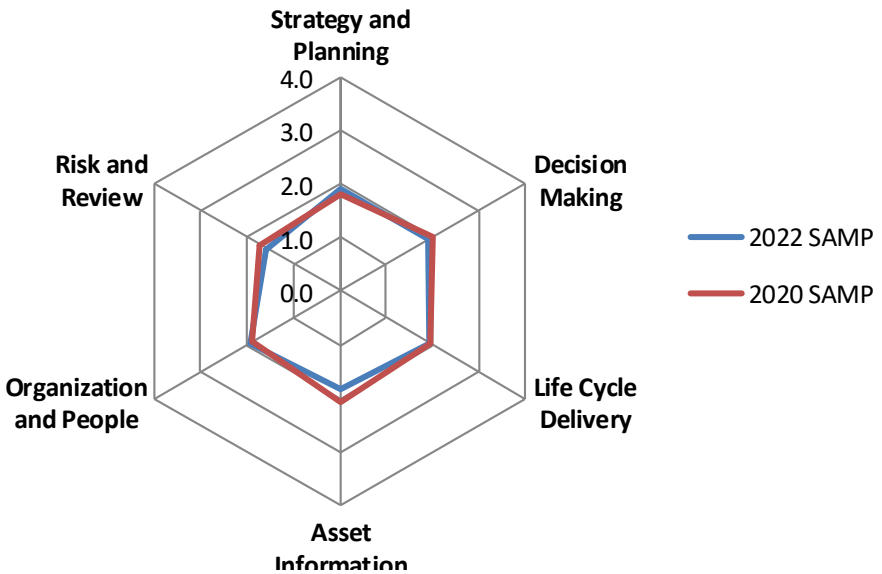
The IAM maturity assessment has 39 questions spanning the subject areas with each question assessed on a scale from 0 to 5. A description of the IAM maturity levels is shown below.

Innocent	Aware	Developing	Competent	Optimising	Excellent
Maturity Level 0	Maturity Level 1	Maturity Level 2	Maturity Level 3	Beyond	
The organisation has not recognised the need for this requirement and/ or there is no evidence of commitment to put it in place.	The organisation has identified the need for this requirement, and there is evidence of intent to progress it.	The organisation has identified the means of systematicaly and consistently achieving the requirements, and can demonstrate that these are being progressed with credible and resourced plans in place.	The organisation can demonstrate that it systematically and consistently achieves relevant requirements set out in ISO 55001.	The organisation can demonstrate that it is systematically and consistently optimising its asset management practice, in line with the organisation's objectives and operating context.	The organisation can demonstrate that it employs the leading practices, and achieves maximum value from the management of its assets, in line with the organisation's objectives and operating context.

A simplified survey based on the IAM Maturity Model was sent to individuals across the FCRPS in 2019. In total, there were 117 respondents across the Corps, Reclamation, and BPA with a range of disciplines and years of experience.

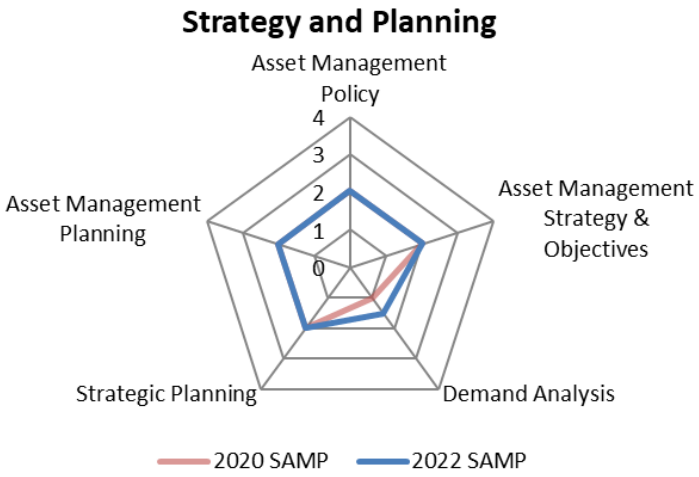
Results from the 16 simplified questions were mapped back to the 39 IAM questions to complete Table 6.1-1. For the 2022 SAMP, FCRPS asset management staff reviewed the 2019 results and updated scores based on progress made in the last two years. Overall, the team identified specific improvements for Strategy and Planning as well as Organization and People, very nearly reaching an average score of 2. Scores for Asset Information and Risk and Review are lower than the previous assessment, but this does not represent a step back. The FCRPS team believed these scores were more representative of actual maturity during the reassessment for 2022.

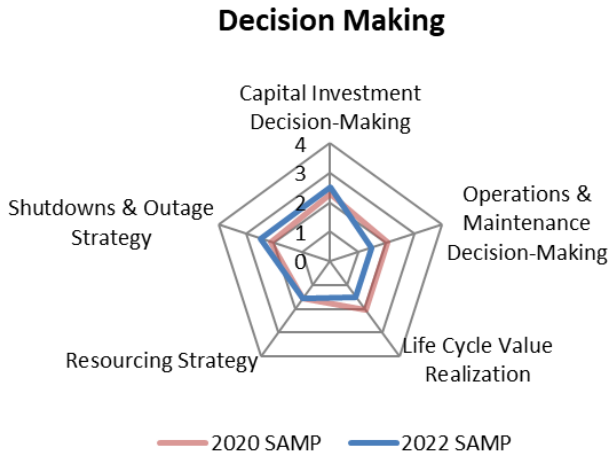
On average, FCRPS asset management is still in a developing phase with most subject areas having an average score near 2. Some areas of Strategy and Planning and Decision Making possess elements of a level 3 (competent) maturity. However, they are held back by horizontal alignment challenges from a lack of communication and understanding of the SAMP as well as operations, maintenance, and investment decisions often made in silos. Risk and Review is the least mature subject area as the Three Agencies are still working towards a shared understanding of risk. Table 6.1-1 describes the strengths and weakness for each subject area in more detail.

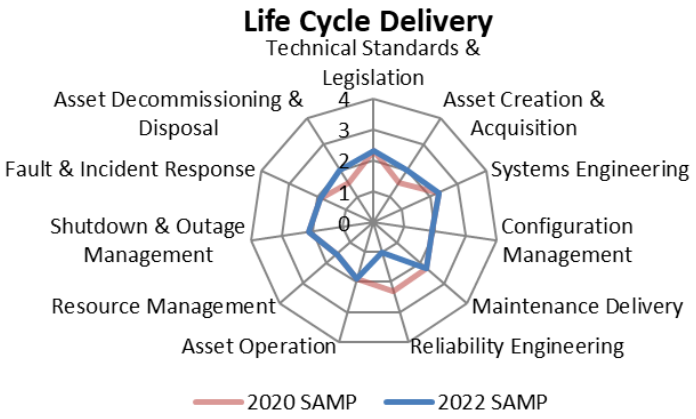


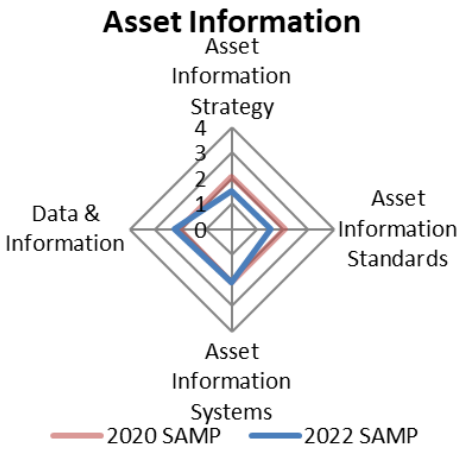
6.1 Current Maturity level

Table 6.1-1 Maturity Level

Subject Area	Maturity Level
Strategy & Planning	**Average Maturity**: 1.9 (Developing)  **Strengths:** Although the average results for most subject areas were just above Level 2 (Developing), the FCRPS Asset Management processes possess many elements of Maturity Level 3 (Competent). Asset Management objectives have been outlined and align with the agency objectives. A structured approach is in place to develop Asset Plans in an iterative way that combines top-down direction with bottom up assets needs. Investments in the asset plan are generally optimized using an agreed upon methodology documented in this SAMP. **Weaknesses:** Horizontal alignment, line-of-sight, demand analysis and integration with human resources and procurement are the major factors holding the FCRPS back from Level 3 (Competent). The survey conducted in 2019 made it clear that an understanding of the SAMP and Asset Plans is not ubiquitous throughout the Three Agencies, especially in the field. Development of the SAMP has historically been done by BPA and it is not seen as a Three Agency document. Human resources and procurement also present a challenge as these functions at the Corps and Reclamation are not specific to the FCRPS and must abide by their respective departments' policies and regulations. The policies and regulations of the Department of Defense and the Department of the Interior differ from each other and were not created with the strategies and plans of the FCRPS in mind. Thus, implementation of the strategies and plans is occasionally hindered. A formal Demand Analysis needs to be conducted to improve understanding of how asset reliability affects the non-power missions of the Corps and Reclamation. This analysis is currently underway. **Changes since 2020:** Improvements are reflective of the progress made by the Corps and Reclamation in their respective demand analyses since 2020. That score will continue to improve as the demand analysis progresses and completes.

Subject Area	Maturity Level
Decision Making	**Average Maturity**: 1.9 (Developing)  **Strengths:** Capital Investment Decision Making and Life Cycle Value Realization contain many elements of Level 3 (Competent). For capital investment planning, a maturing process is in place to identify, plan and execute investments such that the strategic goals of Low Cost, Reliable Power, Trusted Stewardship, and Long-Term Sustainability are met. Capital Investment plans are developed through an understanding of asset criticality which evaluates risk throughout an asset's lifecycle. This understanding of risk, in addition to an assessment of the benefits and costs of an investment, are then used to optimize the capital investment plan and seek to maximize the value of the FCRPS. These methods are applied across all large capital investments in the FCRPS. **Weaknesses:** Maintenance at FCRPS facilities is primarily performed in standard periodic cycles and not fully informed by equipment condition or risk. Maintenance data is inconsistent across the FCRPS, ease of access to documented maintenance data and sharing of this data is challenging and limited. These areas will be under evaluation as part of the Operations and Maintenance Optimization Initiative. Decision Making for both capital and non-routine expense is primarily based on deterministic analysis, with some stochastic elements incorporated into major investment decisions. Mentioned in the Strategy and Planning weaknesses, the resourcing strategy is not yet well integrated with the Strategic Asset Management Plan, which is one of the reasons that the Asset Plan has been difficult to execute. Efforts are ongoing between the Three Agencies for improved and more consistent procurement practices. **Changes since 2020:** Improvements to shutdowns and outage strategy reflect progress made through the demand analysis and outage review processes. Other differences are the result of a more accurate assessment of maturity in 2022 than in 2020 and do not reflect specific setbacks or improvements.

Subject Area	Maturity Level
Life Cycle Delivery	**Average Maturity**: 1.9 (Developing)  **Strengths:** Technical Standards & Legislation, Systems Engineering, and Maintenance Delivery had among the highest scores among the subsections. The Corps' Hydroelectric Design Center (HDC) and Reclamation's Technical Services Center (TSC) are the centers of design and engineering expertise for the respective agencies. These organizations establish standards for their respective agencies. Reclamation maintains a series of manuals that are used by hydro utilities throughout the world called the Facilities Instructions, Standards and Techniques (FIST) manuals. These manuals have information on hydro plant operations, mechanical, electrical, and general maintenance, safety, and facility management. The FIST manuals also set standards for preventive maintenance intervals for most assets. Some areas of the FCRPS have elements of maturity level 3 (competent) but maturity varies from plant to plant. **Weaknesses:** Lifecycle delivery had the lowest response rate of any subject area from the broader survey conducted in 2019, suggesting that visibility throughout the Three agencies is low. Reliability Engineering was re-scored in 2022 to reflect the lack of reliability engineering used to inform asset management decisions, specifically related to operations and maintenance. Current maintenance practices are time-based and all units within a powerplant are generally treated the same. Standardized and regularly updated operational strategies based on asset condition could extend the operating life and reduce maintenance and outage costs. Resource management, specifically procurement, was found to be one of the weakest areas in the 2019 survey. Usage, movement history and repair cost information were identified as gaps for consumable and spare parts. The lack of a procurement and supply chain management strategy was also identified. Best practices and lessons learned are not consistently tracked or captured. **Changes since 2020:** The small team re-scored Reliability Engineering to reflect that there are currently no reliability engineers directly involved in Asset Management decision making at a system level. This gap is intended to be filled by the Asset Reliability Team described in Section 6.3.1. This team will use asset information to inform condition-based and reliability-centered maintenance recommendations that take asset criticality into account.

Subject Area	Maturity Level
Asset Information	**Average Maturity**: 1.8 (Developing) **Strengths:** A common framework, hydroAMP, is used to inventory and assess asset condition. The hydroAMP condition assessment framework was originally developed by the Corps, Reclamation, BPA, and Hydro Quebec and has become the de facto industry standard for hydro equipment condition assessment. Over 10,000 assets are currently inventoried. Nearly all equipment defined as Powertrain and Critical Auxiliary components are inventoried and assessed on a regular basis. **Weaknesses:** Although guidelines exist for asset information through hydroAMP, formal asset information strategies and asset information standards do not exist. Development of BPA's asset information strategy can be leveraged by the Three Agencies and adapted to the FCRPS. Development of a hydroAMP condition assessment process document is currently under way which will improve the consistency, completeness, and recency of condition assessments. Asset Information is not directly integrated with performance information or failure data. Balance of Plant assets are inconsistently inventoried across facilities and standard assessment intervals are not aligned with criticality. Personnel tasked with hydroAMP assessments are often also tasked with other duties that take a higher priority. Increased regulatory requirements have reportedly impacted time spent on hydroAMP condition assessments. **Changes since 2020:** Differences are the result of a more accurate assessment of maturity in 2022 than in 2020 and do not reflect specific setbacks or improvements. 
Organization & People	**Average Maturity**: 1.9 (Developing) **Strengths:** About 70% of respondents were split fairly evenly between 2 (Developing) and 3 (Competent). This suggests that most respondents recognize how they fit into their organization, are committed to achieving the goals and objectives of the Three Agencies and understand the need for collaboration. Training and Competence appears to be strong in some areas and developing in others. 

Subject Area	Maturity Level
	Weaknesses: About 20% of the respondents selected that they were unsure how their role supports leadership's vision and goals. Although the majority responded with higher levels of maturity, this suggests that there are pockets where the Asset Management vision has not been effectively communicated. This reflects the Three Agency structure and the structures within the Three Agencies that makes implementation of a coordinated SAMP challenging. Obtaining the resources needed to complete tasks in a timely manner is also seen as an issue. This has contributed to the under execution of the Asset Plan. **Changes since 2020:** Improvement to Organizational Structure is reflective of the work completed since 2020 to reorganize the Three Agency Asset Management Group based on industry best practice.
Risk & Review	**Average Maturity**: 1.6 (Developing) **Strengths:** FCRPS leadership has hosted roadshows at FCRPS plants, districts, and area offices to talk about BPA's Strategic Plan and how it influences FCRPS Asset Management decisions. Outside of the Integrated Program Review, FCRPS leadership and staff regularly present to the Public Power Council about current performance and the status of FCRPS initiatives. **Weaknesses:** Scores in risk and review were generally low, with many respondents selecting Level 1 (Aware). Metrics to assess the performance of the Asset Management system are being studied within the FCRPS and through hydro industry forums. Risks to each mission are not well documented, including each agency's risk tolerance and overall risk appetite. **Changes since 2020:** Differences are the result of a more accurate assessment of maturity in 2022 than in 2020 and do not reflect specific setbacks or improvements.

6.2 Long Term Objectives

Based on a review of the maturity assessment, FCRPS leadership created two focus areas for improvements in Asset Management. These focus areas look to improve our culture and communication as well as the quality and scope of our strategies and plans. Although not the lowest scoring measures in the maturity assessment, both focus areas are foundational to an Asset Management program and are areas in which all three agencies can contribute to success.

6.2.1 Culture/Communication

Goal: Effectively communicate the FCRPS strategic objectives to improve line-of-sight throughout the Three Agencies.

Objective	Current State	Method to Achieve Desired End State	Timeframe*
1.1) **Improve literacy of Asset Management principles among the workforce**	Awareness of Asset Management principles, including the broader context of FCRPS strategic direction, is mostly limited to those directly involved in asset management.	Identify FCRPS positions that require IAM or similar training. Set training targets and coordinate Asset Management trainings.	FY22: Identify training needs FY23 and beyond: Train positions
1.2) **Update FCRPS Strategic Objectives with Three Agency collaboration and Executive engagement**	FCRPS strategic objectives have been the same for nearly 20 years. Awareness of objectives is low throughout Three Agencies.	Three Agency review of FCRPS strategic objectives. Include revisions, omissions and/or additions in 2022 SAMP	This objective was completed in early FY22 as part of the development of this SAMP.
1.3) **Document and disseminate decision making processes for O&M and capital**	Capital and O&M decision making processes are not understood by all stakeholders, including Corps and Reclamation employees at the plants.	Document decision making processes and share throughout three-agencies.	FY21-23
1.4) **Create more avenues for leadership to communicate priorities**	Line-of-sight is not always clear, especially between the Three Agencies. Some FCRPS employees can't see how day-to-day activities support mission/leadership direction.	Identify and implement a communication plan for asset management and FCRPS strategic direction.	FY21-24
1.5) **Review/improve Asset Management governance processes**	Review and approval of SAMP and Asset Plan documents and asset planning assumptions are ad hoc.	Document existing governance processes. Establish a Three Agency AM governance board. Develop an Asset Management System Manual.	FY22-25

6.2.2 Strategies and Plans

Goal: Expand FCRPS Strategies and Plans based on asset condition and criticality to include all missions that assets support and all programs, including capital, operations, and maintenance. Align performance expectation with the value that each asset provides for the various missions of the Three Agencies.

Objective	Current State	Method to Achieve Desired End State	Timeframe*
2.1) Understand all sources of value at FCRPS facilities, including non-power, by performing a demand analysis	Demand and necessary level of service for FCRPS equipment with respect to non-power missions is not well defined.	Perform demand analysis for power and non-power products and services.	FY21-22 Corps and Reclamation have made significant progress on this objective.
2.2) Define risk appetite and risk tolerance for each business line and agency	Common risk tolerance and risk appetite have not been defined for the FCRPS between the Three Agencies.	Develop a Three Agency risk register. Define and document Three Agency risk tolerance and risk appetite.	FY22-25
2.3) Develop regional O&M strategy and incorporate into SAMP	The SAMP is heavily focused on capital. O&M strategies are not unified and vary from plant to plant.	Use understanding from demand analysis to inform regional O&M strategies and include in 2024 SAMP.	FY22-24
2.4) Develop plant-specific asset plans that integrate and implement O&M and capital strategies	Capital and O&M planning are generally performed independently. O&M is performed on a standard periodic basis and not necessarily influenced by criticality.	Compile plant asset plans that integrate the capital and O&M strategies for each facility, incorporating the demand analysis and Three Agency risk tolerance.	FY23-25

*Timeframes identified are subject to hiring new positions outlined in Section 6.4

6.3 Current Strategies and Initiatives

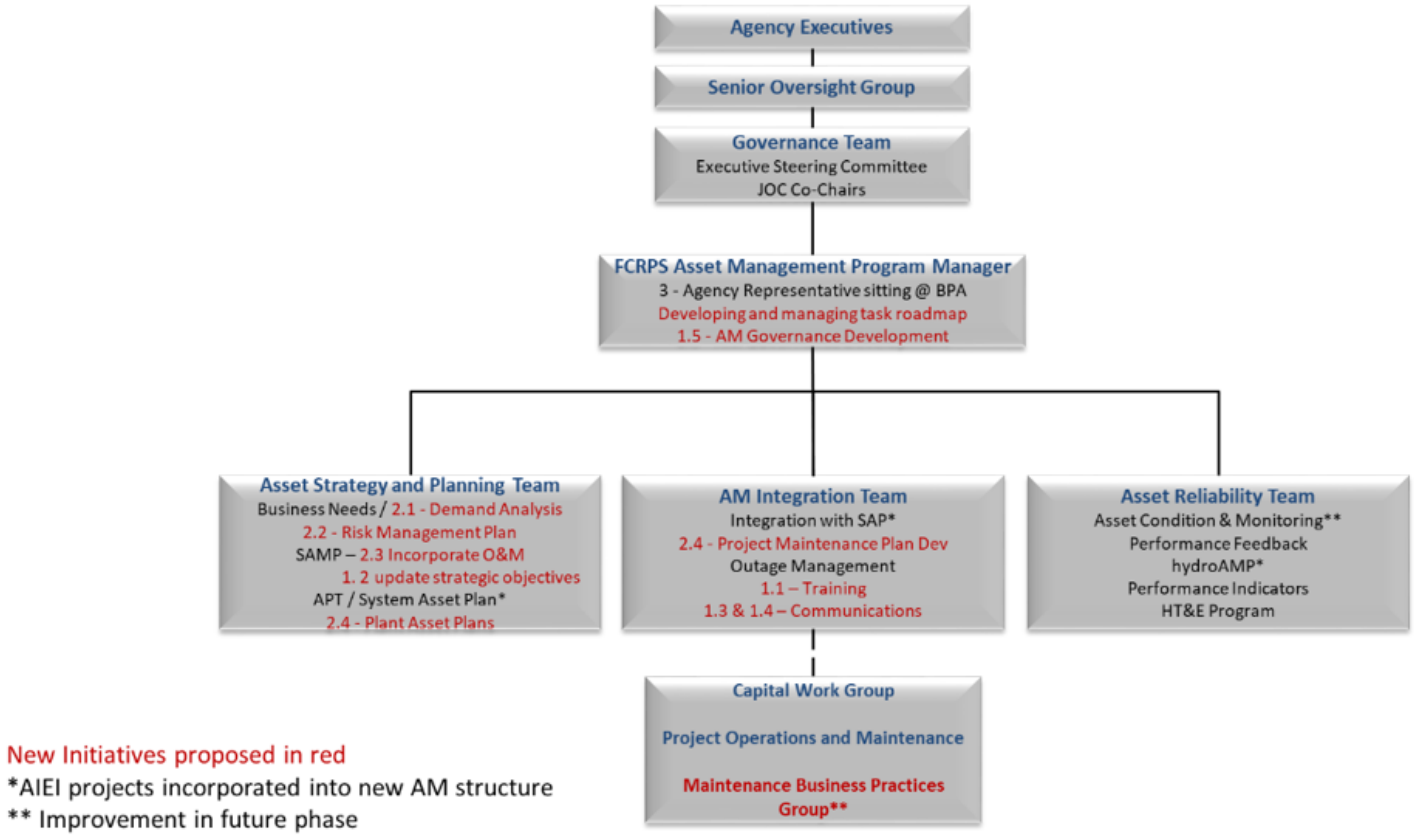
6.3.1 FCRPS Asset Management Group

In 2019, FCRPS leadership tasked a small team of Three Agency Asset Management subject matter experts to create a plan to deliver on the objectives identified in Section 6.2. The team developed a high-level roadmap, identified the resources needed to be successful, and ultimately proposed a new structure for Asset Management in the FCRPS. This new structure is based on the Asset Management structure used at Meridian Energy, a New Zealand utility regarded as a leader in Asset Management. Meridian Energy emphasizes the need for separate strategy, delivery, and reliability teams to enable the unique functions of an organization to work together in a well-defined and cohesive manner. They have designed their asset management program to understand the needs of their business, understand the current and future condition and capability of their assets, identify gaps through assessments, develop strategies and plans to bridge gaps, manage assets throughout their lifecycle, and provide continuous feedback to enhance performance. The FCRPS team drew

from these concepts employed by Meridian Energy and developed a structure that aims to separate strategic and operational functions to sharpen organizational focus on asset strategy, planning, implementation, reliability, and communication processes.

The Asset Management Group (AMG) will consist of three teams that align with this focus on strategy, planning, implementation, and reliability. An Asset Management Program Manager will lead the teams and report directly to an asset management governance team composed of members of the ESC and JOC. The Program Manager will develop FCRPS asset management governance processes and coordinate execution on a roadmap for continuous improvement in the FCRPS asset management program. The three teams making up the AMG are the Asset Strategy and Planning Team, the Asset Management Integration Team, and the Asset Reliability Team. Figure 6.3.1-1 illustrates the AMG structure and shows the objectives from Section 6.2 with which each team will be initially tasked. It is expected that these teams will form as the new positions are hired over the course of the next few fiscal years. The Asset Management Program Manager was hired in Q2 of FY22.

Figure 6.3.1-1



The Asset Strategy and Planning Team (ASPT) will provide the long-term planning function. It will develop and own the FCRPS expense and capital strategies, capturing the current and evolving needs of each agency and their stakeholders. It will also develop plant-specific asset plans that integrate the capital and expense strategies while improving line-of-sight for the plants between plant operational objectives and FCRPS asset strategies. Development of the FCRPS SAMP, SAP and associated planning models will also be owned by the ASPT. These functions already exist today but will be formally brought under the ASPT. The team will also be tasked with

developing a Risk Management Plan that helps the Three Agencies come together on an understanding of how risks are defined and how they should be treated in the FCRPS.

The Asset Management Integration Team (AMIT) will focus on the implementation of strategies and plans by bridging the gap between their development and execution. They will coordinate with plants and asset management staff to ensure that strategies and plans are logical and implementable when viewed from both perspectives. They will communicate the strategic priorities to project staff and discuss the plans to meet those objectives, helping compile feedback from field staff to inform the products of the ASPT. They will ensure that asset management training is widely available and utilized throughout FCRPS staff and ensure that operations and maintenance practices at projects reflect strategic plans, including outage plans and project maintenance management plans. These actions should result in horizontal alignment improvements.

The Asset Reliability Team (ART) will be tasked with providing feedback on asset condition and performance as it changes over time so that strategic plans can be updated on a regular basis. It will monitor existing condition information, including hydroAMP, online condition monitoring data, and other programs such as Operational Condition Assessments (OCA) and Hydro Test and Evaluations (HT&E), providing oversight over data collection and quality control. Whereas currently there is no regional group focused on aggregating such data across multiple plants and mining it for insights to improve asset performance, this team will be tasked with doing so and providing condition-based and predictive maintenance recommendations. Those recommendations will inform maintenance standards and strategies as well as the SAMP and SAP.

The new AMG structure is designed to deliver upon the goals and objectives of the FCRPS in a more focused and streamlined manner while filling the gaps that exist in the FCRPS asset management program. Section 6.4 details the positions required to achieve success under this new structure.

6.3.2 Operations and Maintenance Optimization Initiative:

The goal of the Operations and Maintenance Optimization Initiative (OMOI) is to understand and evaluate the value and importance of hydropower assets in order to optimize how the assets are operated and maintained. The value and importance of the assets will be determined by assessing the needs for water quality, fish passage/attraction, power generation, and ancillary services at each plant. Once the value of the hydropower facilities/assets are established, the business needs of those assets or the value of the output of those assets (power and water) will be used to develop optimized operations and maintenance activities in order to align the level of effort of O&M to the value of the asset. This approach ensures that the assets continue to meet the needs of the organization and that the levels of effort (O&M) are optimized to ensure that those efforts are performed in the most cost-effective manner. Many of the long-term objectives listed in Section 6.2 are addressed under the OMOI.

6.3.3 Centralized Control Program

The Corps's Northwestern Division continues to make progress on their efforts to remotely monitor and control hydropower generation for a more efficient production of power and to meet the needs of an extremely competitive energy market. Since this effort began in November 2018, the Centralized Control Program has been evaluating remoting options and the infrastructure and staffing changes required to support it with the goal to reduce operational costs and promote safety and reliability.

One option under review involves co-locating the Corps' operational staff with BPA's real-time duty schedulers.

An option under consideration is to make use of existing space at BPA's HQ building, thus reducing facilities costs, and promote coordination and efficiency between the Corps and BPA staff.

6.3.4 O&M Pilot Projects

Reclamation's Columbia-Pacific Northwest Region, in partnership with other offices within the agency, are in different stages of multiple pilot project efforts. There are nine (9) O&M-related pilot efforts underway within the Columbia-Pacific Northwest Region. Three (3) major efforts are listed below. Other aspects under way are efforts to improve data quality and internal controls for existing data platforms to help ensure the integrity of data that is used in various reporting, modeling, and decision-making processes.

The Hydropower Research Institute pilot project focuses on aggregating from multiple Reclamation power facilities machine condition monitoring data, SCADA data, and eventually other equipment condition monitoring data to drive the digital transformation across the Region and across the agency. It is unit data-driven (generator, excitation system, governor, turbine, etc.) and includes sharing condition/operational data sets from other hydropower utilities to provide a forum to promote collaboration as part of the digital transformation. Some of the value benefits includes a prelude to reliability engineering, comparative maintenance analyses & benchmarking, inform maintenance/operational/investment strategies, reduced outages, remote equipment access and automated data transfer, aggregated de-centralized human resources, and improved root-cause analysis (program).

The Predictive Maintenance (PdM) business case pilot project at Grand Coulee is a business case value effort showing a financial benefit of transitioning from time-based maintenance to PdM. Benefits includes framing a template method to obtain PdM cost savings, inform PdM implementation at other power facilities, inform variable unit operation, and provide insight to BPA regarding EIM implications.

Just initiated is a data processing and analysis of rotating machines pilot project for multiple Reclamation facilities. It includes exploring, testing, and developing software tools to process big data collected from rotating machines to aid in the development of condition-based maintenance and predictive maintenance tools. Some of the value benefits includes reduced maintenance costs, better defined O&M risk, improved O&M data analytics decision making, and further developed asset mitigation strategies.

6.3.5 FCRPS hydroAMP Team

In 2018, a survey consisting of eight questions was sent out to FCRPS facilities to gauge hydroAMP usage and consistency. Following the survey, an FCRPS hydroAMP team was assembled to help improve consistency, completeness, and recency of condition assessments. As part of the effort, it was determined that routine condition assessments needed additional emphasis as part of the O&M program and as an input to capital planning. In February 2021, a process document signed by all three agencies was released that focused on facility condition assessments, peer review of condition assessments, and program peer review of condition assessments (divided into holistic evaluation and technical evaluation). As part of the program peer review, various metrics are being considered and evaluated including previous versus current assessment differences, low score differences, volatility, increasing scores, differences from degradation expected scores, and recommended vs forecasted/planned replacement. Additionally, there are correlated efforts to help improve data integrity within each respective agency and to help address/improve some of the assumptions used to model asset degradation.

6.4 Resource Requirements

FCRPS asset management staff evaluated the positions and skills necessary to achieve these objectives and made a recommendation to executives in 2020. In addition to existing asset management staff, the team identified 10 additional positions across the three agencies to execute on the asset management roadmap. These include:

1 Asset Management Program Manager: The Asset Management Program Manager is an FCRPS position, sitting at BPA that coordinates the activities of the 3 teams that make up the FCRPS Asset Management Team.

2 O&M Strategic Planners: One Corps and one Reclamation position. These individuals will develop O&M strategies and incorporate them into the SAMP.

2 Maintenance Planning Leads: One Corps and one Reclamation position. These individuals will link strategy and execution, ensuring that strategies and plans can be implemented at the facilities.

1 Risk SME: The Risk SME is a BPA position that facilitates development of three-agency risk appetite and risk tolerance objectives for incorporation into decision making.

4 Reliability Engineers: 2 Corps and 2 Reclamation positions. These individuals analyze condition and performance data to inform condition-based and predictive maintenance strategies.

At the time of this writing, hiring the Asset Management Program Manager and O&M strategic planners is the top priority. The Asset Management Program Manager and the Corps' O&M strategic planner were hired in Q2 of 2022. Reclamation expects to hire their O&M Strategic Planner later in FY22. The remaining positions are expected to follow in subsequent FYs. All positions are being funded within current budgets through reallocation of FTE as determined by agency executives.

7.0 ASSET CRITICALITY

7.1 Criteria

There are two levels of asset criticality assessment performed on FCRPS assets. A screening level assessment based on an asset's type, location, and condition produces an initial estimate of safety, environmental, compliance, public perception, and financial risk. This assessment is performed on all inventoried assets and forecast over a fifty-year period. Additional analyses performed as business cases develop capture information unique to each asset that may not have been revealed by the screening level analysis. These additional analyses target near-term investments identified in the System Asset Plan.

At the screening level, safety, environmental, compliance, and public perception consequences of failure are determined for each asset type on a five-level consequence scale. Portions of the financial consequences (lost generation and direct costs resulting from asset failure) are determined at both the asset type *and* individual asset level. Outage durations are estimated for each asset type, but the resulting lost generation and direct costs are specific to each plant and generating unit. Combined with asset condition, which informs a likelihood of failure, this information provides a high-level assessment of the asset failure risk for each asset in the FCRPS asset registry.

Upon investment planning, design, and alternatives formulation, additional or unique information about the related assets are often captured. Corps, Reclamation, and BPA staff assess the likelihood and consequence of failure with respect to safety, environmental, compliance, and public perception on the same five-level consequence scale as the screening analysis. However, the assessment is tailored to the unique conditions in which the specific assets operate. This could either raise or lower failure consequences and potentially modify the likelihood of occurrence.

The likelihood of non-financial consequences is assigned using a five-level probability ordinal scale, shown below. Financial consequence likelihoods are actually calculated based on equipment condition, but are mapped into the five levels for illustrative purposes.

Rare	Unlikely	Possible	Likely	Almost Certain
1% Annual Probability	2% Annual Probability	8% Annual Probability	19% Annual Probability	80% Annual Probability

7.1.1 Value Measure Consequence Levels

7.1.1.1 Safety

Safety Risk captures the impact of injury, disability or death of an employee or member of the public as a consequence of asset failure. The FCRPS does not purposefully expose employees or the public to safety hazards but understanding safety risk is essential to the safe operation of FCRPS assets. Typically, when a hazard is identified the risk is assessed and either eliminated or mitigated. Mitigation can be through physical barriers or operational procedures. The safety risk evaluated per asset type is based on the most likely safety threat due to failure that has not already been mitigated.

Insignificant	Minor	Moderate	Major	Extreme
No or minor injury, first aid	Treatment by medical professional	Lost time accident - temporary disability	Permanent disability	Fatality

7.1.1.2 Environmental

Environmental risk is based on the cost of remediation efforts to mitigate harm done to the environment due to asset failure. Harm so severe as not to be reversible is assigned the most severe consequence ranking classification. Fines associated with environmental consequences are captured by compliance risk.

Insignificant	Minor	Moderate	Major	Extreme
No impact	Impact to on-site environment (simple remediation) or where the remediation costs < $100k	Limited impact off-site (localized remediation required) or where the remediation costs < $1M	Detrimental impact on- or off-site (long-term remediation required) or where the remediation costs < $10M	Detrimental or catastrophic impact off-site (mitigation impossible) or where the remediation costs > $10M

7.1.1.3 Compliance

Compliance risk captures the impact of an event or a failure which would cause the FCRPS to be unable to implement the actions consulted upon in Biological Opinions (BiOps) and the required actions in the Incidental Take Statements. It also captures the risk that the FCRPS is unable to comply with state laws, federal laws, and regulations such as those under the Endangered Species Act.

Insignificant	Minor	Moderate	Major	Extreme
No or insignificant effect on operations or administrative flexibility, or annual mandated costs < $10k	Change in operations or administrative flexibility or annual mandated costs < $100k	Effect on legal principles or precedents, project operations noticeably affected for compliance, inability to maintain system frequency or voltage, or annual mandated costs < $1M	Effect on legal principles or precedents, substantial changes needed in project operations or administration, or annual mandated costs < $10M	Extremely difficult to meet fundamental statutory obligations, extremely unreliable system, extreme changes needed in project operations or administration, or annual mandated costs > $10M

7.1.1.4 Public Perception

Public Perception risk represents the risk that a failure or event will cause the organization's customers or other external stakeholders to lose confidence in the organization.

Insignificant	Minor	Moderate	Major	Extreme
No or isolated internal complaints	Local media attention, widespread internal complaints, some public embarrassment	Transitory local media / federal / customer attention and criticism, some damage control; congressional inquiry, short duration loss of power to islanded community	Ongoing media / federal / customer attention, major damage control, significant impact on staff morale, congressional inquiry, extended duration loss of power to islanded community	Adverse and ongoing media / federal / customer attention, criticism and agency intervention, extreme damage control, secretary called to congress, permanent duration loss of power to islanded community

7.1.1.5 Reliability and Financial

Unlike other value measures, financial value is directly monetized where practicable. When it is not practicable to monetize financial impacts, the categories below are used for a high-level qualitative evaluation of financial risk. This occurs for a limited number of investments where the required information to directly quantify risk is not available. Financial consequences are split into two categories: lost generation and direct cost. Lost generation is the foregone revenue or forced replacement purchases associated with unplanned equipment outages. Direct costs are the incremental costs associated with equipment failure such as emergency repair costs, contract inefficiencies, or damage to nearby equipment.

For illustrative purposes, the monetized values are mapped into the following five-level consequence scale in this SAMP for the purposes of comparison to the other value measures.

Insignificant	Minor	Moderate	Major	Extreme
<$10k	$10k - $100k	$100k - $1M	$1M - $10M	>$10M

7.1.1.5.1 Financial – Lost Generation

Lost generation consequences are determined by calculating the expected marginal outage cost at each facility. The marginal outage cost can be thought of as the annual value that would be lost from the next unit to go out of service, given a base level of availability. In other words, the cost is the value of the last-on-first-off unit after accounting for a base level of outages.

Marginal outage costs are calculated for each plant, by month, over a historical water record. This analysis determines a base availability for each plant, derived from each plant's 5-year outage plan and incorporating recent unit performance. At plants that carry reserves, additional units are held out of service to represent the amount of reserves typically carried at those facilities. To determine marginal outage cost, generation is first simulated under the base availability assumptions described above. Next, a second simulation is run that removes one additional unit from service. The difference in simulated generation between these two scenarios establishes the marginal outage cost at each plant. Marginal outage costs are summarized as average annual values for use in FCRPS long-term planning models.

Starting this year, FCRPS planning models now consider annual changes in marginal outage consequence resulting from changes in forecasted plant availability. This allows for a more accurate depiction of the risk profile over time as the models can recognize that investment strategies will impact future plant availability and, therefore, future outage consequences. There is an inverse relationship between availability and marginal outage cost. As availability declines, each successive unit outage is typically more costly than the previous. As availability improves, outages become less costly. FCRPS long-term planning models are now capable of capturing some of these dynamics rather than relying on an average assumption throughout the entire study period. This level of analysis is sufficient for the long-term planning purposes of this SAMP but more sophisticated modeling is typically employed for business cases to further hone alternatives selection.

Figure 7.1-1 illustrates the relationship between marginal outage cost and total plant generation value. It classifies plants and families of units based on their marginal outage cost and total value in order to illustrate the breadth of criticality and identify the level of analysis typically required. The following descriptions provide context about the financial criticality of a generating unit outage and the level of analysis typically employed for business cases.

Red: High marginal outage cost and total generation value. Unit availability is critically low or generating units are consistently relied on to meet BPA power supply obligations. The financial impact of an unplanned outage is severe in the near-term and potentially detrimental in the long-term if not mitigated. Marginal outage cost methodology is not sufficient for business cases and more sophisticated analysis is required.

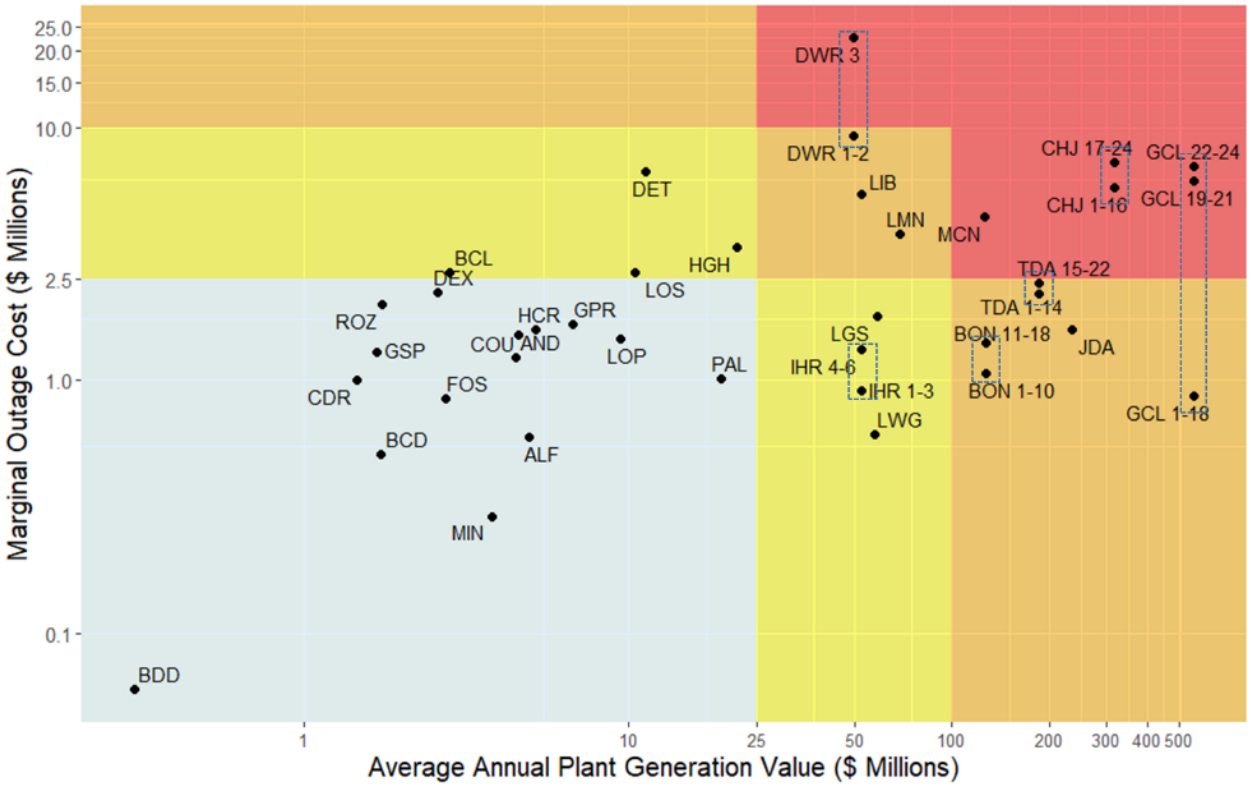
Orange: High marginal outage cost, high total generation value or combination of moderate marginal outage cost and total generation value. Financial impact of outage is high in the near-term and potentially detrimental in the long-term if availability declines. Marginal outage cost methodology is not sufficient for business cases and more sophisticated analysis is required.

Yellow: Moderate marginal outage cost or moderate average plant generation value. Financial impacts are manageable in the near-term and lower availabilities may be acceptable in the long term. Marginal outage cost methodology may be sufficient for business cases but more sophisticated analysis is considered.

Blue: Low marginal outage cost or low total generation value. Financial impacts of outages are not detrimental to the FCRPS. Marginal outage cost methodology may be sufficient for business cases but more sophisticated analysis is considered.

At some plants, families of units with significantly different capacities are broken out to show the difference in marginal outage cost. However, each point plots the annual value for the *entire* plant as operations are interrelated between the families of units within the plant. Plant groupings are bound by blue-dashed boxes. Both axes are shown using a logarithmic scale but note the differences in magnitude.

Figure 7.1-1



This chart provides a current snapshot of marginal outage consequence and total plant value. As previously mentioned, marginal outage costs vary over time as plant availability changes. For example, Grand Coulee (GCL) has a lower marginal outage cost than shown in the 2020 SAMP. This is because availability is expected to be higher than it has been in the last ten years with the completion of the Washington Powerplant overhauls on Units 22-24. Conversely, the marginal outage cost at The Dalles is significantly higher than in the previous SAMP due to declining availability from transformer failures.

Note that for illustrative purposes, average annual plant generation value on the x-axis in 7.1-1 is valued using 5-year average Mid-Columbia energy prices. This represents a lower bound on the value of each plant as it is unlikely, especially for the larger plants, that total plant power production could be reliably replaced with spot market purchases. It also includes no value for the ancillary services and flexibility that the hydropower plants provide.

7.1.1.5.2 Financial – Direct Cost

Direct costs are calculated to capture the non-generation impacts of equipment failure. The intent is to capture the inefficiencies that results from equipment experiencing failures prior to planned replacements. Those inefficiencies could be the typical repair costs to return equipment to service temporarily while plans are made for replacement or incremental costs associated with expediting replacement if repair is not possible. These costs are highly uncertain and depend on failure mode, asset type, and many other factors, but a high-level assumption is made in order to recognize some level of incremental risk associated with allowing equipment condition to degrade. A "direct cost ratio" is estimated for each asset type that estimates expected incremental failure costs as a percentage of its replacement cost. The following examples demonstrate how the direct cost ratio is estimated under different failure conditions.

Failure Scenario	Direct Cost Ratio Implication	Example
Failure resulting in repair and return to service	The full cost of the repair should be recognized because the repair cost is an entirely incremental cost in the lifecycle of the asset.	A generator winding fault results in a $1,000,000 repair to return the unit to service at a derated capacity. Planned winding replacement occurs two years later at $10,000,000. The Direct Cost Ratio in this example is: $$\frac{1{,}000{,}000}{10{,}000{,}000} = 10\%$$ In terms of the lifecycle cost, only the $1,000,000 is an incremental cost.
Failure resulting in substantial replacement	Only the costs that exceed a typical replacement are recognized. This could include contracting inefficiencies, repair costs for other damaged equipment, cleanup costs, or other costs that are realized when having to replace equipment that has failed that otherwise would be avoided in a planned replacement scenario.	A transformer failure results in the need for total replacement of the transformer, repair to damaged iso-phase bus, and cleanup costs for spilled oil. In a planned scenario, this transformer would cost $5,000,000 to replace. Due to the criticality of the related units, the contract has been expedited resulting in a total replacement cost of $6,000,000. Iso-phase bus repairs cost $1,000,000 and oil cleanup costs amount to $750,000. The Direct Cost Ratio in this example is: $$\frac{[(6{,}000{,}000 - 5{,}000{,}000) + 1{,}000{,}000 + 750{,}000]}{5{,}000{,}000} = 55\%$$ The incremental costs are just the costs associated with oil spill cleanup, repair to damaged iso-phase bus and the contract costs in excess of planned replacement costs resulting from expediting the contract. The $5,000,000 planned replacement cost is netted out to determine just the additional costs of the failure over a planned replacement.

A new process was piloted for updating direct cost ratio assumptions for this SAMP and is expected to be fully employed for subsequent SAMPs. Subject Matter Experts are asked to outline failure modes for a specific asset type, assess the probability that each of those failure modes is realized in the event of failure, and estimate the cost to remedy the consequences associated with each failure mode. The direct cost ratio is calculated by taking the expected value of the consequences, weighted by the probability that they occur.

7.1.1.6 Operational - Mission Importance

The Corps is developing a relative value versus importance matrix for their FCRPS plants. This effort will rank the relative generation value of units at Corps plants against their relative importance to non-hydropower missions. Larger plants with more units and higher capacities generally have a higher total value of generation. Plants where hydropower assets are frequently used for water management in coordination with other water conveyance features at the plant generally have a higher importance. Reclamation is going through a similar process to evaluate unit importance given their particular mission objectives.

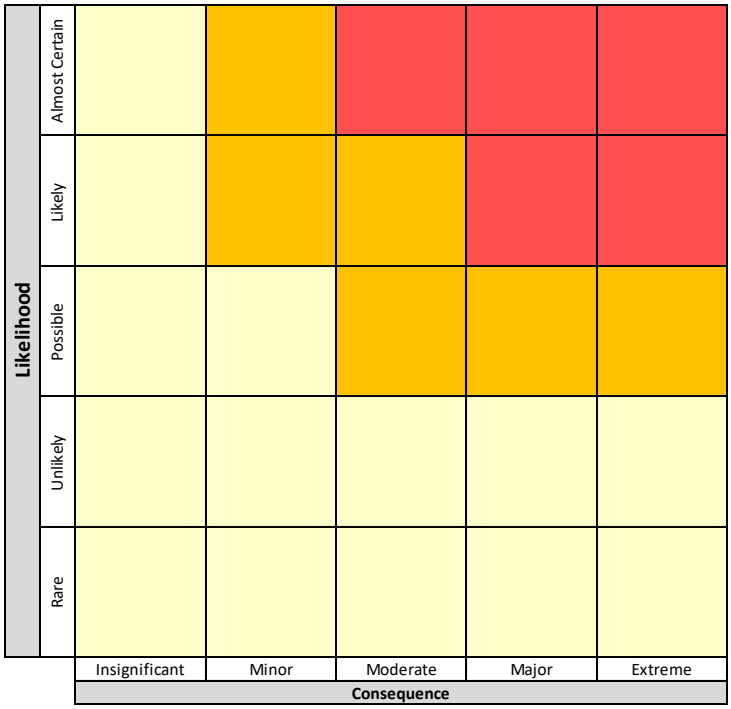
7.2 Usage of Criticality Model

Referenced earlier, there are two different levels of assessment for asset criticality. The first level of assessment uses Copperleaf's Predictive Analytics to identify the optimal time to replace assets based on a lifecycle cost minimization function. This analysis provides information to determine optimal long-term investment levels and analyze the impacts of differing levels of investment. The second level of assessment comes at the Investment Portfolio Optimization level where the specific costs and benefits of planned investments are assessed in the 20-year plan.

At both levels, financial risks and benefits are directly monetized, so the five-level consequence and likelihood scales are simply used to categorize and communicate risk information. For non-monetized benefits or benefits that are difficult to quantify, the five-level scales are the primary method of evaluation. Benefits and risks are calculated based on the selected likelihood and consequence on the five-level scales. The table below shows the value measures used at both levels of analysis. Since the 2020 SAMP, compliance and public perception risks have been added into the Predictive Analytics analysis.

Value Measure	Predictive Analytics	Investment Portfolio Optimization
Safety	✓	✓
Environmental	✓	✓
Compliance	✓	✓
Public Perception	✓	✓
Financial	✓	✓
Operational		

Predictive Analytics: Predictive Analytics is the first, high-level assessment run on all assets to determine their respective recommended intervention dates and collectively determines the long-term funding levels needed for the system. Economics are the first driver in the optimal intervention date calculation. The Predictive Analytics model calculates the optimal intervention date by minimizing quantified financial costs (see the detailed description in Section 10). Safety, environmental, compliance or public perception risk can override this calculation. Predictive Analytics triggers an intervention in the year in which an asset crosses into the high-risk category of the risk map based on the asset's condition and likelihood of failure. High-risk regions are shaded red on the risk map.



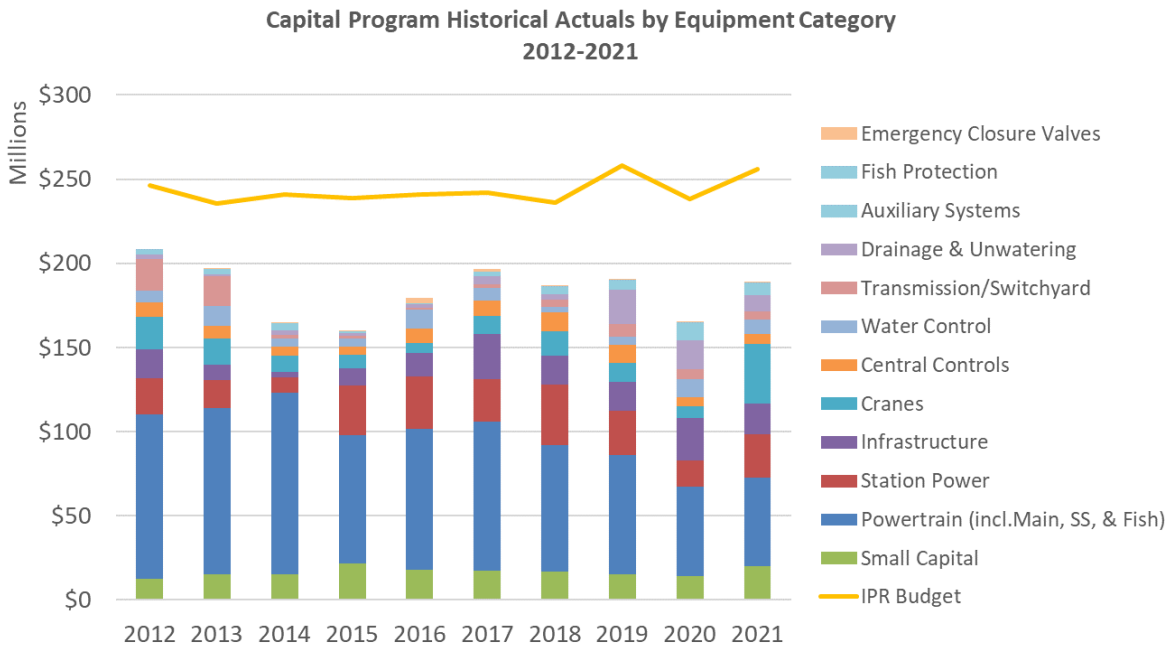
Investment Portfolio Optimization: For most investments, financial risks and benefits are quantified directly using the same models that drive Predictive Analytics. More sophisticated analyses are performed as major powertrain investments progress through the scoping and design phases. Benefits calculated in these analyses replace the benefits that Predictive Analytics produces which can impact the optimal time to execute the investment. Safety and Environmental benefits and risks are treated differently at the Investment Portfolio Optimization stage. An assessment of the safety, environmental, compliance and public perception risks is made specific to each identified investment. This refines the high-level analysis that is performed for each asset based on its asset type. These measures are assigned a value based on the consequence and likelihood levels selected from the five-level consequence and likelihood scales. The value is then equated to the equivalent five-level financial consequence scale and any value measure weightings are applied. Currently, safety and environmental consequences receive a weight of 2 and 1.5, respectively, in order to more adequately reflect the collective missions of the Three Agencies in the portfolio optimization process. For example, this means a major safety consequence receives twice the value of a major financial consequence when the portfolio is optimized.

8.0 CURRENT STATE

8.1 Historical Costs

Capital investments have varied between $150 and $200 million over the last 10 years. Although analyses have supported higher levels of capital investment for many years, the FCRPS has not yet ramped up to the levels identified in previous IPRs.

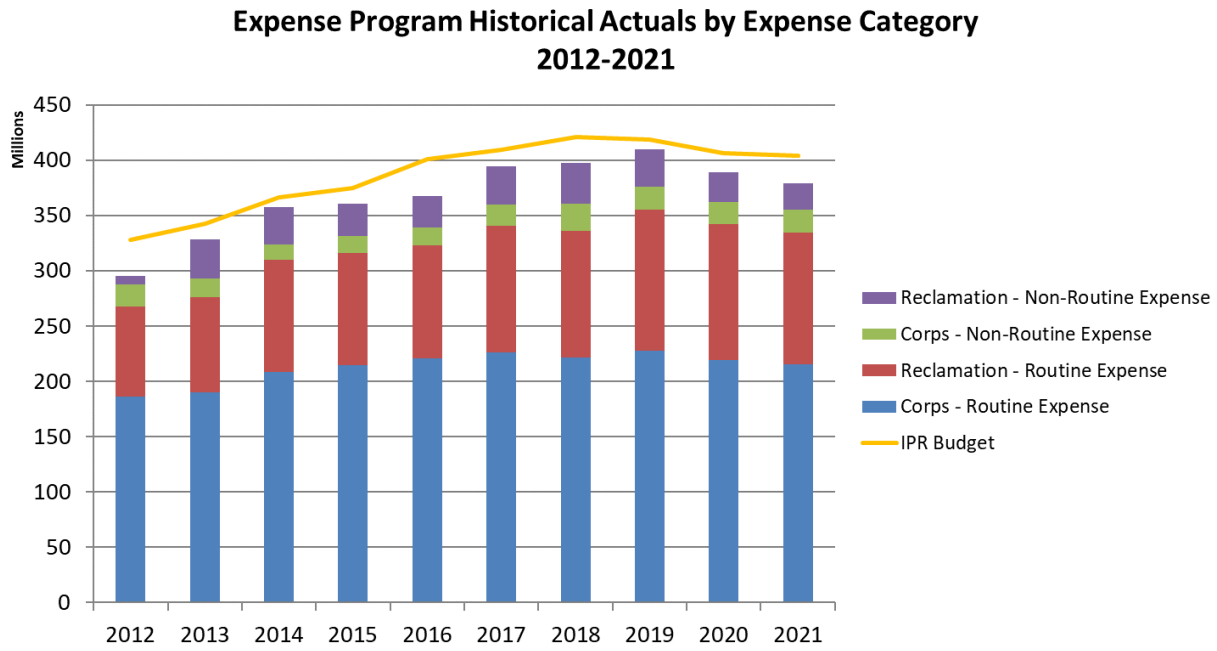
Figure 8.1-1 Historical Expenditures - Capital



The ability to ramp up the program relies on several large powertrain investments, specifically at Grand Coulee, McNary and Chief Joseph dams. These investments have taken longer to plan, design and execute than expected but are core to the business case for a higher level of investment. Advancing projects to fill in the gaps caused by delays in large investments is not always possible or optimal. A critical piece of the FCRPS investment strategy is optimizing the timing of investment. Investments are moved forward if analysis shows that it is both optimal and logistically possible. If the investment has higher value in the future, it will not be moved forward to fill a gap.

Investment in powertrain components declined in the second half of the decade with more investment devoted to the Station Power, Infrastructure and Cranes equipment categories. Many of these investments were made in anticipation of major powertrain investments in the 2020s. As powertrain investments reach the execution phase at Grand Coulee, McNary and Chief Joseph dams in the next 10 years, we expect that the share of investments dedicated to powertrain equipment will rise and that the rate of execution will increase.

Figure 8.1-2 Historical Expenditures - Expense



The expense program averaged a 5% increase per year from 2012 to 2018. This outpaced inflation over the period and led the FCRPS to seek efficiencies in support of BPA's goal of bending the cost curve by holding program costs at or below the rate of inflation. Since 2018, total expense budgets for the FCRPS have declined. This has been accomplished through reorganization of positions, consolidation of duties, and attrition. At the same time, wages have increased at a rate that is a greater than inflation. The FCRPS continues to seek efficiencies through operations and maintenance optimization initiatives but it is anticipated that budgets will eventually need to reflect inflation.

Table 8.1-1 Historical Spend

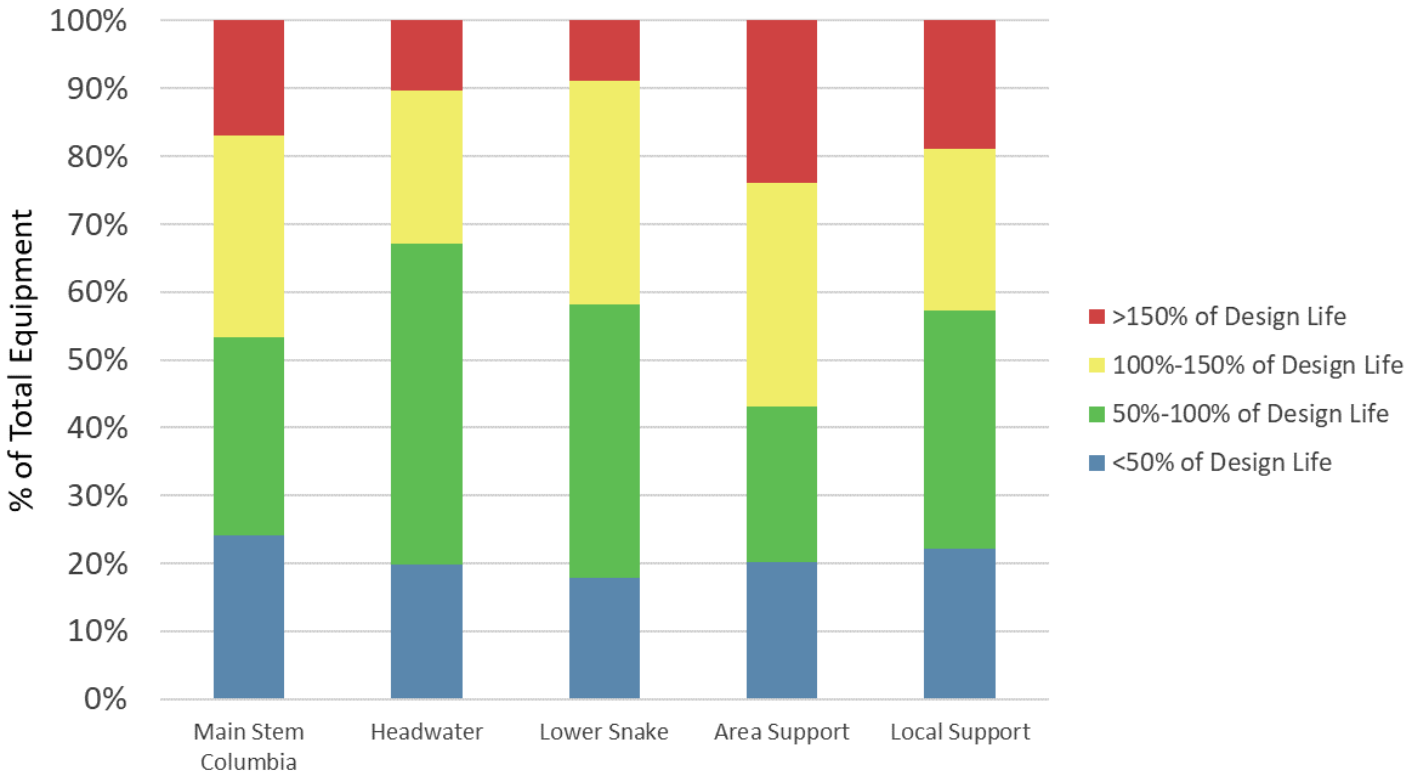
Program	Historical Spend (in thousands) With Current Rate Case						
Capital Expand (CapEx)	2017	2018	2019	2020	2021	2022	2023
Corps of Engineers	0	0	0	0	0	0	0
Bureau of Reclamation	0	0	0	0	0	0	0
Total Capital Expand	0	0	0	0	0	0	0
Capital Sustain							
Corps of Engineers	160,507	157,259	158,793	170,971	206,895	216,296	229,286
Bureau of Reclamation	36,203	29,302	31,675	37,500	26,855	47,824	51,974
Total Capital Sustain	196,710	186,561	190,468	165,009	188,871	264,120	281,260
Expense (OpEx)							
Corps of Engineers	245,029	245,029	248,720	239,078	236,071	252,557	252,557
Bureau of Reclamation	149,658	152,105	161,124	150,074	143,166	152,269	152,963
Total Expense	394,687	397,693	409,844	389,152	379,237	404,826	405,520

8.2 Asset Condition and Trends

For the FCRPS, the average unit is over 50 years old with many components still in service from original construction. For Main Stem Columbia, Headwater, Lower Snake and Local Support asset classes, about 45% of assets have exceeded their design lives. For Area Support plants, more than 50% have exceeded their design lives.

8.2.1 Asset Age

Figure 8.2-1, Current Asset Age by Classification

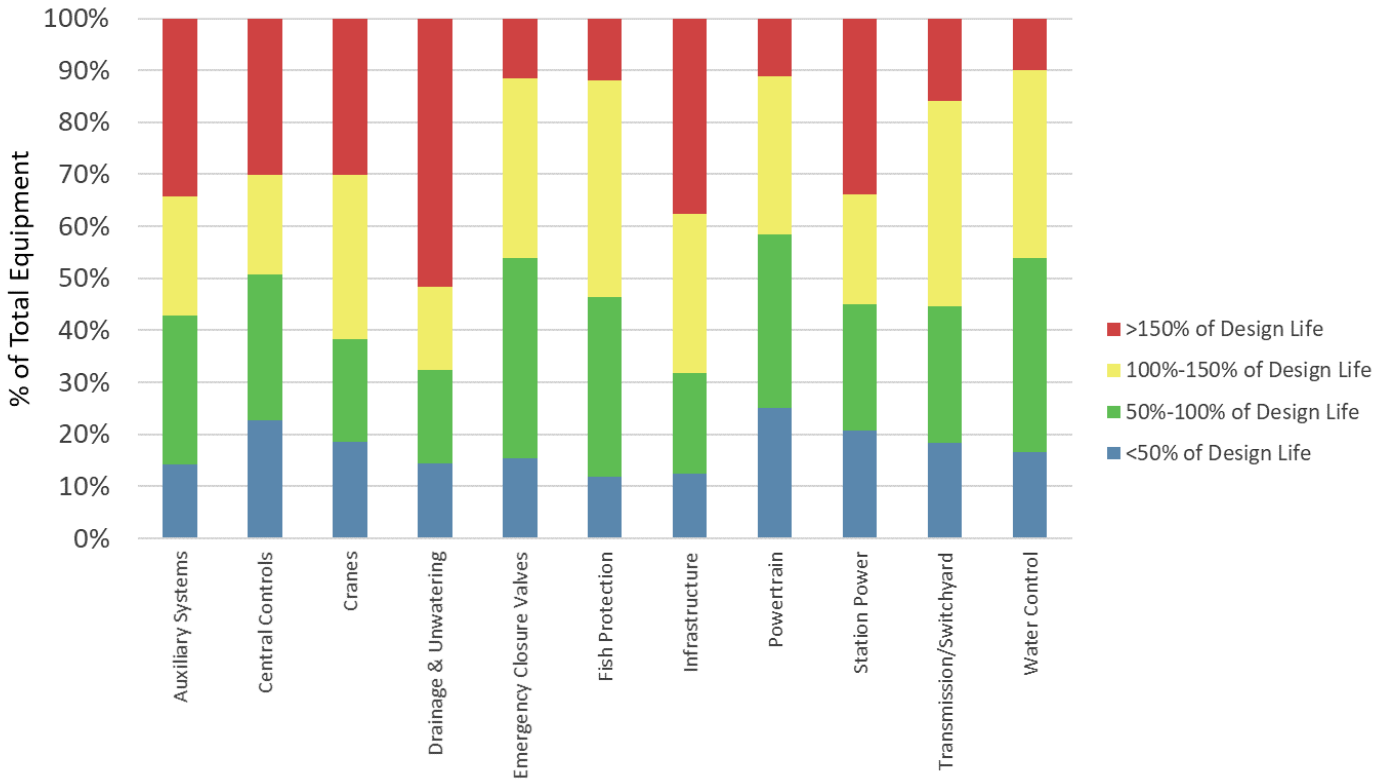


Although exceeding design life is not by itself a cause for replacement, looking at the population demographics in aggregate provides useful information about potential near-term replacement needs.

Assets in the Auxiliary System, Drainage and Unwatering, Infrastructure and Transmission/Switchyard categories tend to be pushed further beyond their design lives than other equipment categories. Generally, these systems are built with a fair amount of redundancy or have more rigorous tests and inspections enabling them to stay in service for longer periods of time.

Since the 2020 SAMP, assets at the lower Snake dams and John Day crossed the 50-year mark. This means that a significant amount of equipment has crossed into the "100-150% of Design Life" category since the last SAMP. Across the system, 46% of inventoried assets have exceeded their design lives. By 2030, that number would rise to 62% without additional investment.

Figure 8.2-2, Current Asset Age by Equipment Category



8.2.2 *Asset Condition*

FCRPS equipment condition is assessed using the hydroAMP condition assessment framework, a methodology used throughout the world for hydro asset condition assessment. In total, the condition of over 10,000 pieces of FCRPS equipment and equipment systems are tracked using the hydroAMP application. The hydroAMP Condition Assessment Guide contains specific instructions for the objective condition assessment of powertrain and critical ancillary equipment. Other asset types are assessed using a more subjective but consistent "balance of plant" guide.

Condition Assessment guides have been written collaboratively by subject matter expert teams with members from BPA, the Corps, Reclamation, Chelan PUD, Seattle City Light and Hydro Quebec. Guides are periodically reviewed and revisited by the hydroAMP Steering Committee of which the above utilities are members. Development of the hydroAMP framework is supported by the 60+ member utilities of CEATI's Hydraulic Plant Life Interest Group (HPLIG).

Of the approximately 10,000 pieces of FCRPS equipment in hydroAMP, powertrain assets (Turbines, Generator Rotors and Stators, Governors, Excitation Systems, Transformers and Circuit Breakers) represent about a third. These assets are inventoried for each of the 31 plants in a consistent manner.

Remaining components are categorized as critical ancillary and balance of plant equipment, some of which have direct impacts on generation. The inventory of equipment in these categories is less consistent across the plants. Improvements in the consistency of asset identification throughout the FCRPS as well as improvements in how the condition assessments are collected and quality-controlled are ongoing.

Condition ratings for each asset type are based on a set of objective condition indicators related to operational performance, maintenance history, physical inspection, and age. Condition indicators are weighted and summed to derive a condition rating, ranging from 0 to 10. Numeric scores are further categorized qualitatively as follows:

Condition Score	Condition Description
8.0 – 10.0	Good
6.0 – 7.9	Fair
3.0 – 5.9	Marginal
0.0 – 2.9	Poor

Although the Main Stem Columbia, Headwater and Lower Snake facilities have similar age demographics, their condition paints a different picture. At Headwater and Lower Snake plants, about 30% of the assets are in marginal or poor condition while about 22% Main Stem Columbia assets are in marginal or poor condition.

Figure 8.2-3, Current Asset Condition by Classification

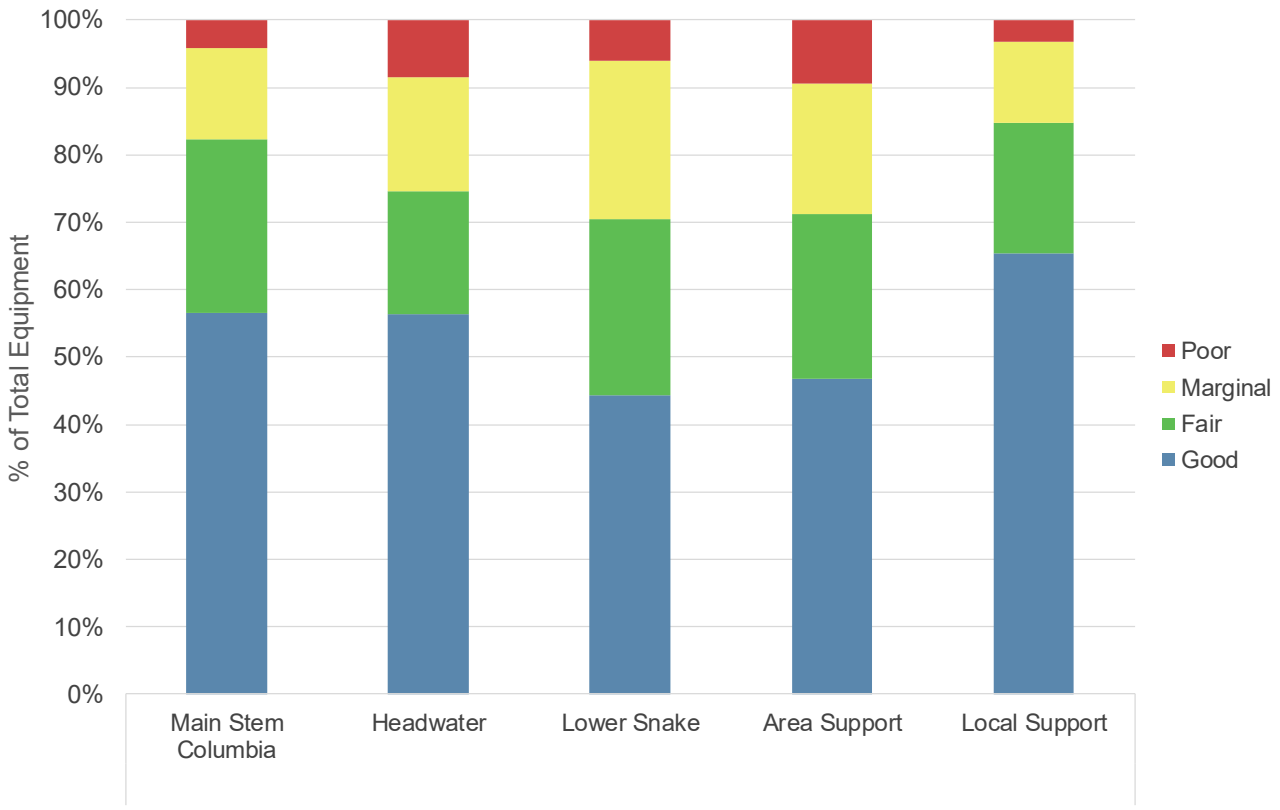
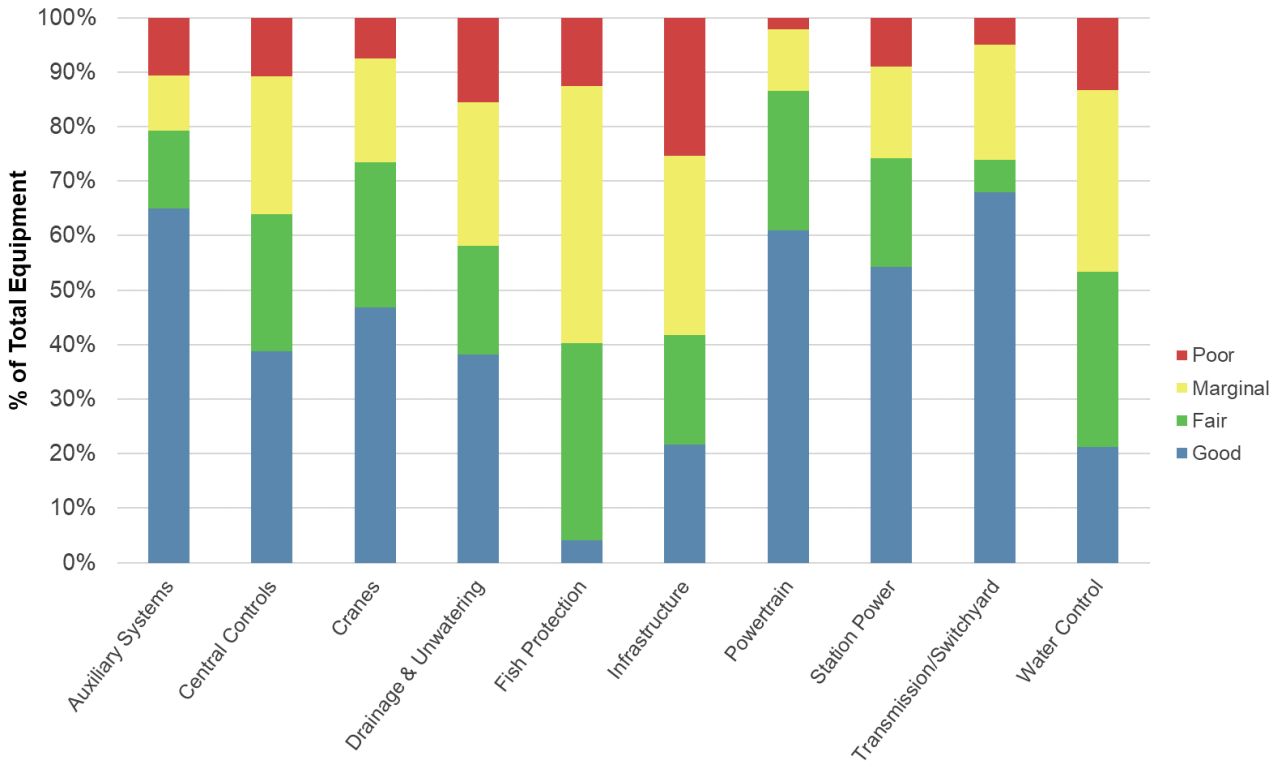


Figure 8.2-4 illustrates asset condition by equipment category. Equipment Categories summarize groups of equipment into higher-level categories for illustrative purposes.

Figure 8.2-4, Current Asset Condition by Equipment Category



Auxiliary Systems: 22% are in marginal or poor condition. Fire Detection Systems and Compressed Air Systems are the primary drivers.

Central Controls: 39% are in marginal or poor condition. SCADA/GDACS, Station Control Boards, Main Consoles and Annunciation Systems are the primary drivers. Over 80% would be in marginal or poor condition in 10 years without investment.

Cranes: 24% are in marginal or poor condition. This has improved from 60% in the previous SAMP due to investments made throughout the system.

Drainage and Unwatering: 41% are in marginal or poor condition. Pumps are the primary driver.

Fish Protection: 81% are in marginal or poor condition. Fish screens are the primary driver. Over 90% would be in marginal or poor condition in the next 10 years without investment.

Infrastructure: 59% are in marginal or poor condition. Communications Hardware, Elevators and HVAC are the primary drivers.

Powertrain: 15% are in marginal or poor condition. Generator windings, Turbine Runners and Transformers are the primary drivers. This number was closer to 30% in the previous SAMP. Since the 2020 SAMP, condition assessments have been completed for many of the recently added turbine components, which make up about 25% of currently inventoried assets. In general, condition for turbine components is higher than for turbine runners across the system.

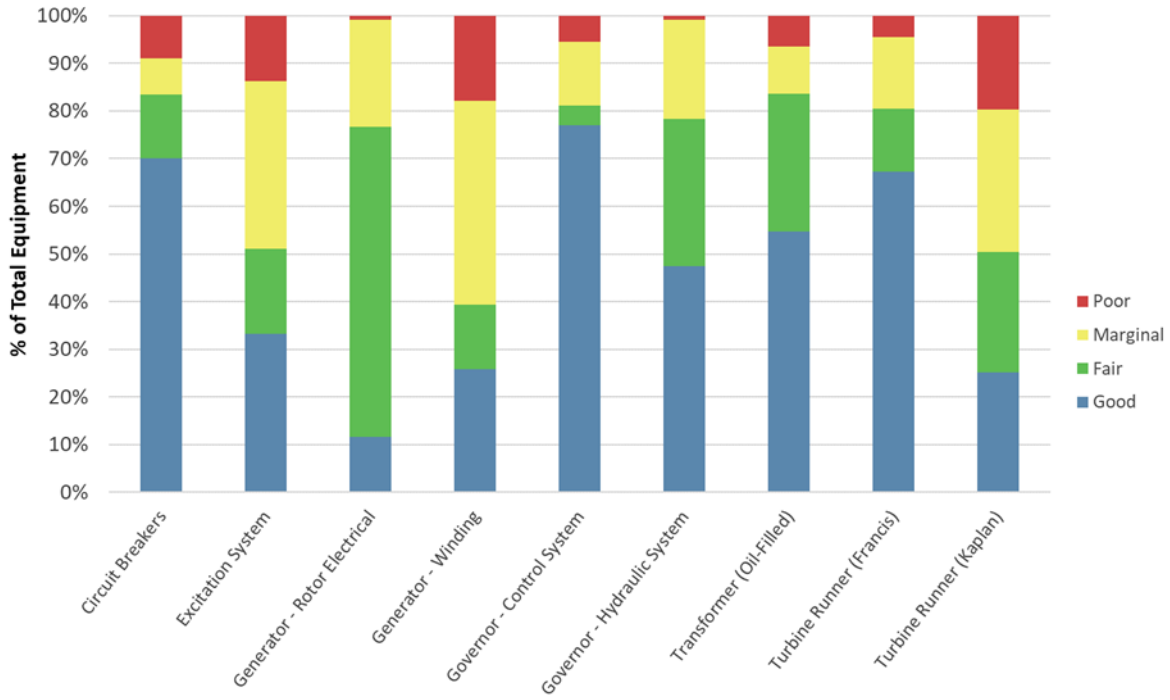
Station Power: 26% are in marginal or poor condition. Iso-Phase buses and switchgear are the primary drivers. This number rises to over 60% in the next 10 years without investment.

Transmission/Switchyard: 30% are in marginal or poor condition. Disconnects and Bus Work are the primary drivers.

Water Control: 49% are in marginal or poor condition. Emergency and Non-Emergency Closure gates are the primary drivers.

Although a small percentage of powertrain equipment is in marginal or poor condition, those tend to be some of the most critical equipment from an outage cost and replacement cost perspective. The following chart displays condition for critical powertrain components.

Figure 8.2-5, Current Asset Condition by Critical Powertrain Asset Type



About 50% of Kaplan Turbine Runners and nearly 60% of Generator Windings in the FCRPS are in marginal or poor condition. These two asset types have some of the longest expected outage durations in the event of failure and are among the costliest components of a generating unit. Together, runners and windings represent close to half of the cost of a generating unit. As such, investments are often driven by generator winding or turbine runner replacements. Although not as costly as windings or runners, excitation systems can also have significant impacts on unit availability. About 50% of the excitation systems across the FCRPS are in marginal or poor condition. Most oil circuit breakers have been replaced by either SF6 or vacuum breakers; however, there are 34 remaining in asset inventory. These breakers are all rated in poor condition and are planned for near-term replacement.

8.3 Asset Performance

Maintaining performance metrics is a requirement of the Corps and Reclamation's respective Direct Funding Agreements with BPA. The Performance Committee, a Three Agency subcommittee of the JOC, develops, revises, tracks, and reports on performance metrics in accordance with the Direct Funding Agreements. Performance metrics, including their addition or removal, are reviewed, and approved by the JOC and Executive Steering Committee on an annual basis. During the development of this SAMP, many changes to performance metrics were under consideration for FY20. For this SAMP, performance metrics are shown relative to the FY19 list of metrics and respective targets. Updates will be reflected in the 2022 SAMP when the suite of new and revised metrics has been finalized.

8.3.1 Safety

The FCRPS uses three metrics to track Safety Performance in the hydro business line. Days Away Restricted or Transferred (DART) has been the primary safety metric since 2015. Lost Time Accident Rates (LTAR) and Total Case Incident Rates (TCIR) are also tracked and compared to industry averages. Moving to DART in 2015 signaled a focus on FCRPS Safety performance, which had historically been significantly worse than industry average. Safety performance has improved each year and is now approaching industry average.

FY 21 Safety Performance Targets

	DART	LTAR	TCIR
Stretch	0.8	0.5	2.3
Mid	1.3	0.95	3.7
Min	2.2	1.05	5.3

Days Away Restricted or Transferred per 200,000 person-hours

	2017	2018	2019	2020	2021
FCRPS	1.93	1.91	1.80	1.26	1.0
Industry Average	0.55	0.55	0.69	0.63	

Lost Time Accidents per 200,000 person-hours

	2017	2018	2019	2020	2021
FCRPS	0.82	0.74	1.41	0.6	0.7
Industry Average	0.36	0.28	0.37	0.37	

Total Case Incident Rate per 200,000 person-hours

	2017	2018	2019	2020	2021
FCRPS	3.39	4.99	3.33	1.93	1.0
Industry Average	1.28	1.01	1.24	1.03	

8.3.2 Compliance

The FCRPS does not currently track any asset-specific performance metrics related to compliance under the FCRPS performance committee.

8.3.3 Financial

The FCRPS tracks expenditure rates on its capital and expense programs relative to Start of Year budgets. Performance for the last 10 years is shown below.

Past and Current Year Performance										
Metric	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Power Expense Expenditure Rate	91%	94%	96%	94%	92%	97%	95%	98%	98%	97%
NREX Expenditure Rate			82%	79%	72%	89%	86%	99%	84%	80%
Large Capital Budget Expenditure Rate	95%	86%	90%	79%	93%	97%	103%	100%	77%	95%

Outside of the FCRPS performance committee, BPA also tracks the number of "units complete" versus a start of year expectation to measure work plan completion. This metric measures both physical completion and construction milestones that are planned for completion within the fiscal year. Targets were met and exceeded in 2020 and 2021.

Metric	**2019**	**2020**	**2021**
Actual Units Complete	23	31	27
Target	34	24	23

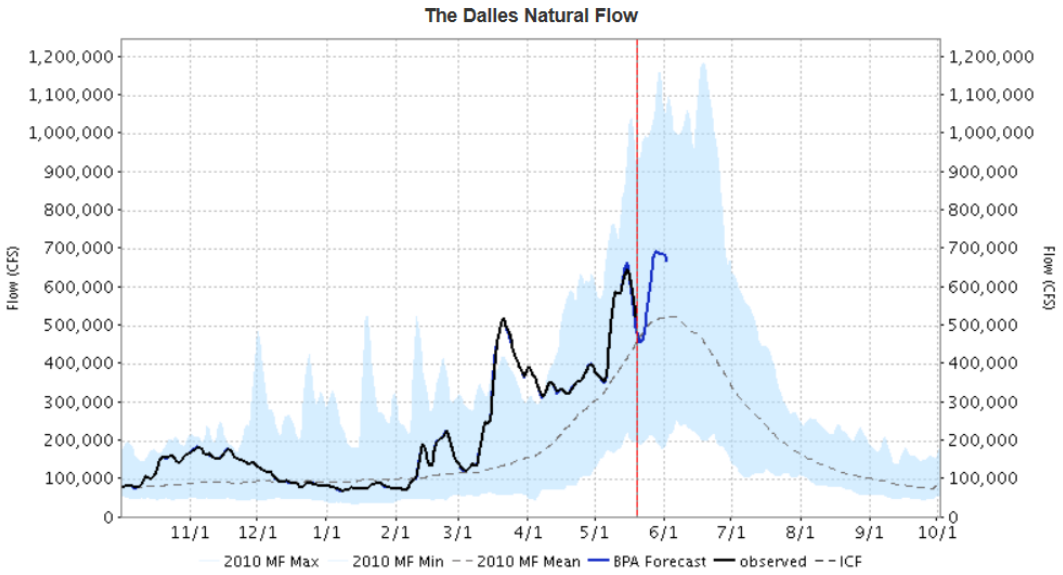
8.3.4 Environmental/Trusted Stewardship

While BPA, the Corps and Reclamation track environmental indicators related to operations, the FCRPS Performance Committee is not currently tracking any environmental performance indicators directly related to asset performance.

8.3.5 Availability

Availability metrics are the primary performance indicators used to measure the performance of electric generating equipment. Generally, higher availability equates to more generation and revenue. However, hydropower resources differ from other generation resources due to the variability in their fuel source. Unlike more conventional dispatchable resources that can choose to produce when it is economical, hydro facilities are bound by the amount of water available for generation, which makes availability metrics a moving target. This is accentuated in the Columbia River Basin by the highly variable within-year and year-to-year flows. Between fall and summer, natural flows can change by up to a factor of 10 in wet years or by as little as a factor of two in dry years.

Annual Flow Uncertainty at The Dalles Dam



This highly variable water supply makes setting availability targets and comparing FCRPS availability to industry metrics challenging. Due to the unique configuration of each facility as well as the conditions in which they operate, the optimal level of availability will differ by plant, by month and by year. Currently, availability targets are informed by each plant's 5-year outage plan and are updated on an annual basis. Baseline forced outage targets are developed by blending industry average forced outage factors with a 5-year average of each plant's forced outage factor. The combination of forced outage factor estimates and each plant's 5-year outage plan result in the availability targets shown in the table below.

For BPA, the level of availability is often less important than how closely plants follow their outage plans. Given enough time, BPA can adjust operations or rely on energy markets to mitigate for the impacts of outages. Unexpected changes in outages, either units going out of service or unexpectedly returning to service, tend to result in the most costly impacts. As a result, the FCRPS has recently focused on schedule outage factors. Performance targets are set to incentivize alignment with outage schedules set at the start of each fiscal year. FY21 performance and performance targets are shown below.

FY21 Scheduled Outage Factor Performance

	YTD Weighted Scheduled Outage Factor	Min Lower Target (-5%)	Mid Lower Target (-3%)	Stretch Target (+/-2%)	Mid Upper Target (+3%)	Min Upper Target (+5%)
FCRPS	**18.0%**	**12.82% - 14.82%**	**14.82% - 15.82%**	**15.82% - 19.82%**	**19.82% - 20.82%**	**20.82% - 22.82%**
Corps	**13.6%**	**10.40% - 12.40%**	**12.40% - 13.40%**	**13.40% - 17.40%**	**17.40% - 18.40%**	**18.40% - 20.40%**
Chief Joseph	7.7%	0.90% - 2.90%	2.90% - 3.90%	3.90% - 7.90%	7.90% - 8.90%	8.90% - 10.90%
Libby	18.2%	8.83% - 10.83%	10.83% - 11.83%	11.83% - 15.83%	15.83% - 16.83%	16.83% - 18.83%
Albeni Falls	8.0%	6.80% - 8.80%	8.80% - 9.80%	9.80% - 13.80%	13.80% - 14.80%	14.80% - 16.80%
Seattle District	**9.7%**	**5.12% - 7.12%**	**7.12% - 8.12%**	**8.12% - 12.12%**	**12.12% - 13.12%**	**13.12% - 15.12%**
John Day	13.4%	10.81% - 12.81%	12.81% - 13.81%	13.81% - 17.81%	17.81% - 18.81%	18.81% - 20.81%
The Dalles	13.7%	5.68% - 7.68%	7.68% - 8.68%	8.68% - 12.68%	12.68% - 13.68%	13.68% - 15.68%
Bonneville	12.1%	11.45% - 13.45%	13.45% - 14.45%	14.45% - 18.45%	18.45% - 19.45%	19.45% - 21.45%
Detroit	0.1%	17.63% - 19.63%	19.63% - 20.63%	20.63% - 24.63%	24.63% - 25.63%	25.63% - 27.63%
Big Cliff	4.4%	0.33% - 2.33%	2.33% - 3.33%	3.33% - 7.33%	7.33% - 8.33%	8.33% - 10.33%
Green Peter	3.7%	0.00% - 1.06%	1.06% - 2.06%	2.06% - 6.06%	6.06% - 7.06%	7.06% - 9.06%
Foster	3.6%	0.00% - 1.06%	1.06% - 2.06%	2.06% - 6.06%	6.06% - 7.06%	7.06% - 9.06%
Lookout Point	0.7%	4.93% - 6.93%	6.93% - 7.93%	7.93% - 11.93%	11.93% - 12.93%	12.93% - 14.93%
Dexter	4.7%	0.42% - 2.42%	2.42% - 3.42%	3.42% - 7.42%	7.42% - 8.42%	8.42% - 10.42%
Cougar	3.9%	6.47% - 8.47%	8.47% - 9.47%	9.47% - 13.47%	13.47% - 14.47%	14.47% - 16.47%
Hills Creek	7.8%	0.97% - 2.97%	2.97% - 3.97%	3.97% - 7.97%	7.97% - 8.97%	8.97% - 10.97%
Lost Creek	6.4%	1.76% - 3.76%	3.76% - 4.76%	4.76% - 8.76%	8.76% - 9.76%	9.76% - 11.76%
Portland District	**12.3%**	**8.81% - 10.81%**	**10.81% - 11.81%**	**11.81% - 15.81%**	**15.81% - 16.81%**	**16.81% - 18.81%**
Dworshak	20.4%	0.01% - 2.01%	2.01% - 3.01%	3.01% - 7.01%	7.01% - 8.01%	8.01% - 10.01%
Lower Granite	9.9%	5.21% - 7.21%	7.21% - 8.21%	8.21% - 12.21%	12.21% - 13.21%	13.21% - 15.21%
Little Goose	30.4%	19.27% - 21.27%	21.27% - 22.27%	22.27% - 26.27%	26.27% - 27.27%	27.27% - 29.27%
Lower Monumental	24.9%	36.26% - 38.26%	38.26% - 39.26%	39.26% - 43.26%	43.26% - 44.26%	44.26% - 46.26%
Ice Harbor	23.3%	14.03% - 16.03%	16.03% - 17.03%	17.03% - 21.03%	21.03% - 22.03%	22.03% - 24.03%
McNary	10.9%	0.45% - 2.45%	2.45% - 3.45%	3.45% - 7.45%	7.45% - 8.45%	8.45% - 10.45%
Walla Walla District	**17.6%**	**13.18% - 15.18%**	**15.18% - 16.18%**	**16.18% - 20.18%**	**20.18% - 21.18%**	**21.18% - 23.18%**
Reclamation	**26.8%**	**17.55% - 19.55%**	**19.55% - 20.55%**	**20.55% - 24.55%**	**24.55% - 25.55%**	**25.55% - 27.55%**
Grand Coulee	26.6%	16.91% - 18.91%	18.91% - 19.91%	19.91% - 23.91%	23.91% - 24.91%	24.91% - 26.91%
Hungry Horse	37.6%	34.55% - 36.55%	36.55% - 37.55%	37.55% - 41.55%	41.55% - 42.55%	42.55% - 44.55%
Grand Coulee Power Office	**27.3%**	**17.97% - 19.97%**	**19.97% - 20.97%**	**20.97% - 24.97%**	**24.97% - 25.97%**	**25.97% - 27.97%**
Palisades	11.0%	6.07% - 8.07%	8.07% - 9.07%	9.07% - 13.07%	13.07% - 14.07%	14.07% - 16.07%
Minidoka	51.3%	6.79% - 8.79%	8.79% - 9.79%	9.79% - 13.79%	13.79% - 14.79%	14.79% - 16.79%
Upper Snake Field Office	**16.7%**	**6.17% - 8.17%**	**8.17% - 9.17%**	**9.17% - 13.17%**	**13.17% - 14.17%**	**14.17% - 16.17%**
Anderson Ranch	2.8%	2.60% - 4.60%	4.60% - 5.60%	5.60% - 9.60%	9.60% - 10.60%	10.60% - 12.60%
Boise Diversion	4.9%	0.00% - 0.00%	0.00% - 0.00%	0.00% - 3.57%	3.57% - 4.57%	4.57% - 6.57%
Black Canyon	8.9%	37.03% - 39.03%	39.03% - 40.03%	40.03% - 44.03%	44.03% - 45.03%	45.03% - 47.03%
Middle Snake Field Office	**4.1%**	**8.75% - 10.75%**	**10.75% - 11.75%**	**11.75% - 15.75%**	**15.75% - 16.75%**	**16.75% - 18.75%**
Chandler	22.3%	20.76% - 22.76%	22.76% - 23.76%	23.76% - 27.76%	27.76% - 28.76%	28.76% - 30.76%
Roza	5.2%	12.24% - 14.24%	14.24% - 15.24%	15.24% - 19.24%	19.24% - 20.24%	20.24% - 22.24%
Green Springs	22.7%	1.85% - 3.85%	3.85% - 4.85%	4.85% - 8.85%	8.85% - 9.85%	9.85% - 11.85%
Columbia-Cascades Area Office	**17.2%**	**10.47% - 12.47%**	**12.47% - 13.47%**	**13.47% - 17.47%**	**17.47% - 18.47%**	**18.47% - 20.47%**

Internally, BPA tracks the FCRPS Forced Outage Factor on its performance scorecard. Forced outage factor measures the percentage of hours within a period that a generating unit is not available to run due to an unplanned event. This metric is megawatt-weighted, so larger units have a bigger influence on the Forced Outage Factor than smaller units.

Table 8.3-1 Historical Asset Performance Summary

Strategic Goal	Objective	Measure	Units	2017	2018	2019	2020	2021
Modernize assets	Power Reliability	Fed Hydro Forced Outage Factor	%	5.9	4.5	4.1	6.76	4.6
Modernize assets	Power Reliability	Target - Fed Hydro Forced Outage Factor	%	5.1	5.9	4.4	4.49	4.5

8.3.6 Cost of Power

BPA Power and Finance recently developed an agreed upon methodology to calculate the cost of generation and fully loaded cost of FCRPS plants. Both metrics will be trended over time and potential targets will be investigated and considered. Some tweaks to allocation methodologies may still be made as this process matures. The definitions of each metric are below.

Table 8.3.6-1 – 3-year Average Cost of Power Metrics (FY18-FY20)

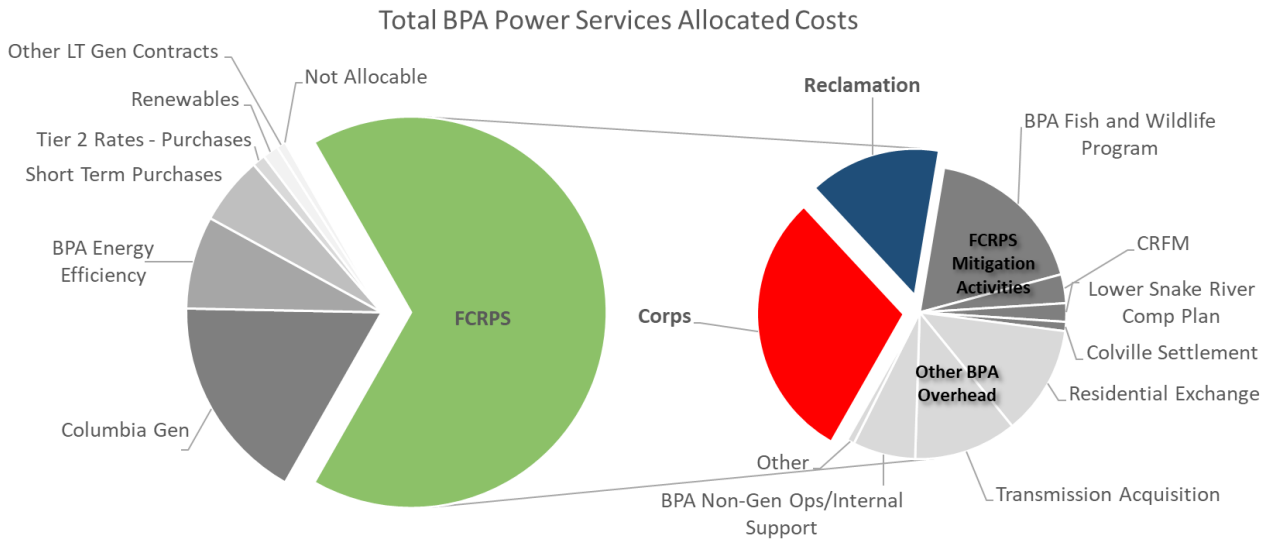
Strategic Class	Cost of Generation ($/MWh)	Fully Loaded Cost ($/MWh)
Main Stem Columbia	7.75	18.30
Lower Snake	14.63	27.42
Headwater	13.08	23.51
Area Support	25.08	39.93
Local Support	31.02	41.57
FCRPS Hydro	9.48	20.70

Cost of Generation: The direct cost and administrative overheads of producing power at a plant. Includes operations, maintenance, administrative, and capital related costs (interest expense).

Fully Loaded Cost: All costs of doing business associated with the hydro plant operations, power marketing, and delivery. Includes all costs from the costs of generation plus all other allocable costs to the hydro system such as BPA's Fish and Wildlife program, Residential Exchange, transmission acquisition, and other obligations.

The 3-year average cost of power metrics for FY18-FY20 are shown in Table 8.3.6-1. Average costs are shown as per unit of output costs by incorporating average annual generation in the metric. The FCRPS hydro cost of generation of $9.48/MWh shows that the system as a whole is a very cost effective resource when looking at the direct costs of power production. This measure is the most comparable to spot market prices, which are more closely tied to the marginal cost of power production. The fully loaded cost of the system was $20.70/MWh, which itself is also in the competitive range with recent Mid-Columbia spot market prices.

Costs allocated to Federal Hydro accounted for about 66% of Power Services total costs. Of the costs allocated to Federal Hydro, the Corps and Reclamation accounted for 44% while BPA's Fish and Wildlife Program, Residential Exchange, Transmission Acquisition and support costs accounted for an equivalent amount.

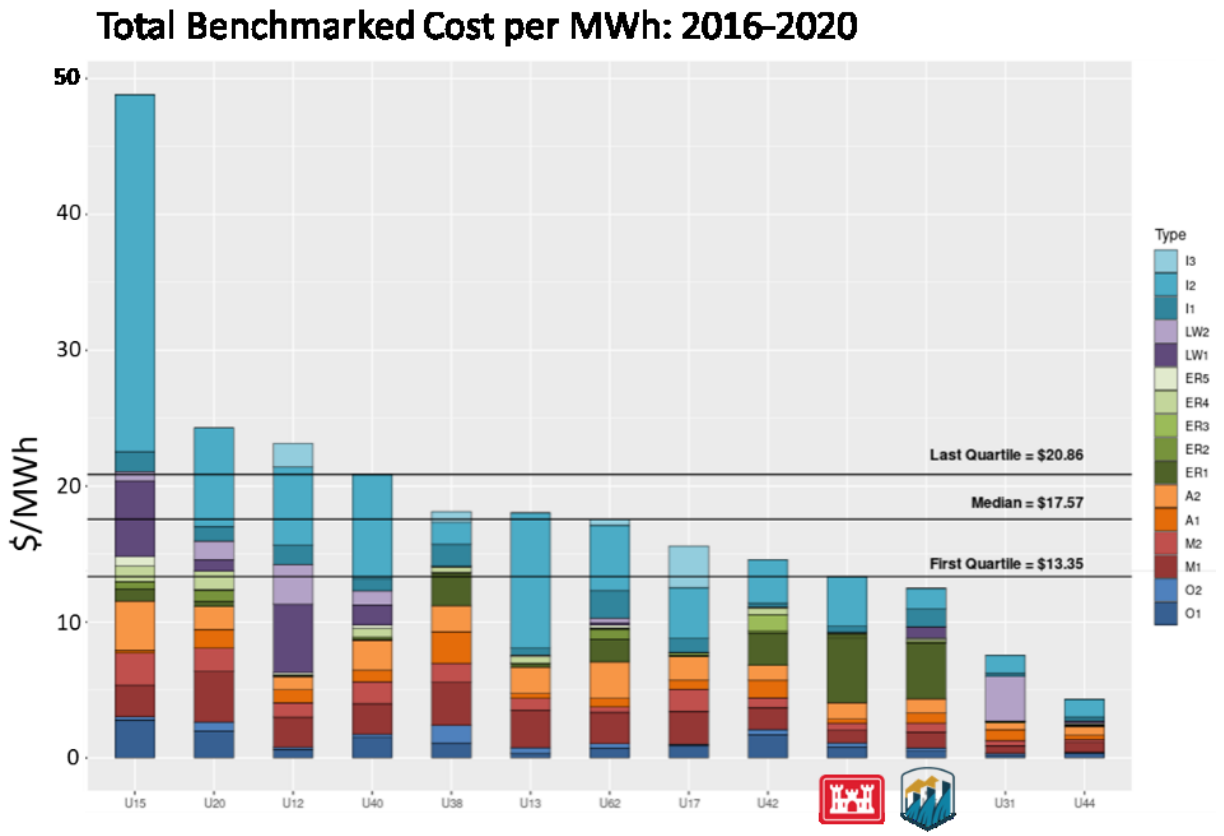


8.4 Performance and Practices Benchmarking

The FCRPS benchmarks its plants in the Hydro Productivity Committee (HPC) of the Electric Utility Cost Group (EUCG). As of 2020, there were 16 utilities in the HPC that benchmarked 379 plants. The HPC maintains a data guide that provides instructions on what costs should be included, excluded and recommendations for cost allocations. The following cost categories are used to compare costs between utilities within EUCG:

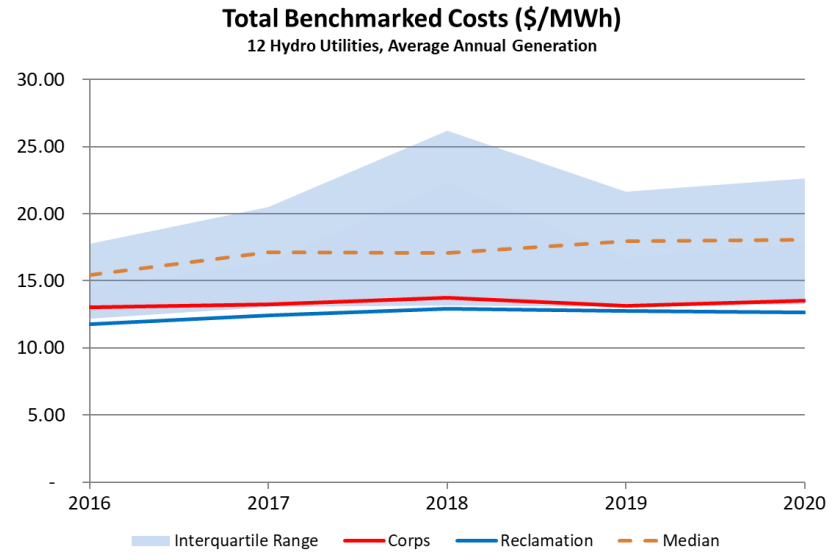
- Operations (O – blues) includes facility operations and all operations planning
- Maintenance (M – reds) includes all facility maintenance
- Administration (A – oranges) includes IT, Finance, HR, Telecom, Asset Management, and more
- Environmental/Regulatory (ER – greens) includes Fish & Wildlife, Recreation, and Cultural Resources
- Land and Water Fees (LW – purples) includes rentals or fees for use of land or water
- Investment (I – cyan) includes non-routine expense

Note that the benchmarked costs and resulting $/MWh will differ from BPA's cost of generation and fully allocated cost numbers. There are two major differences in the formulation of these numbers: (1) Benchmarked costs are based on a 5-year average while the cost of generation and fully allocated cost reflects a single fiscal year, and (2) interest expense is not included in benchmarked costs, rather, actual capital costs are recognized in the year in which they are incurred.

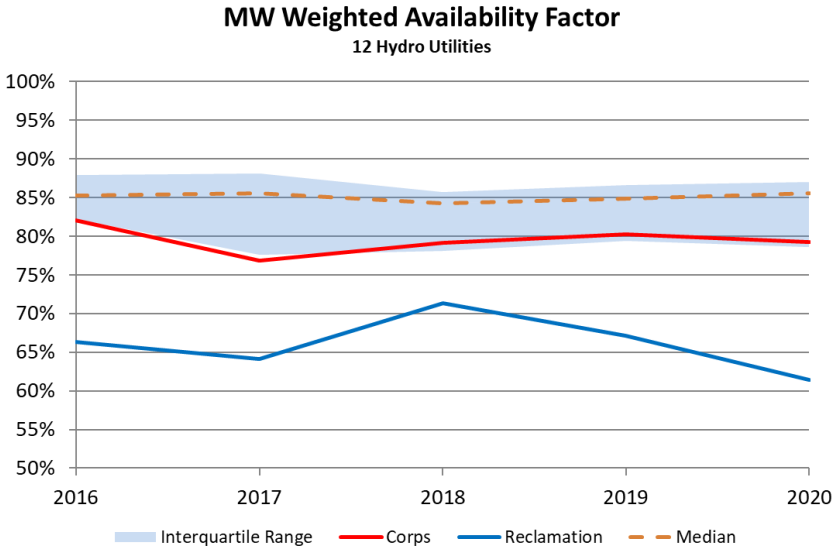


Over the 2016 to 2020 period, the Corps and Reclamation were at the threshold between first and second quartile for lowest total benchmarked costs per MWh. Compared to other hydro utilities, the Corps and Reclamation have much larger facilities that benefit from economies of scale. Due to these economies of scale, it is expected that the Corps and Reclamation will benchmark well against other utilities. Efforts to bend the cost curve in recent years will further improve their standing.

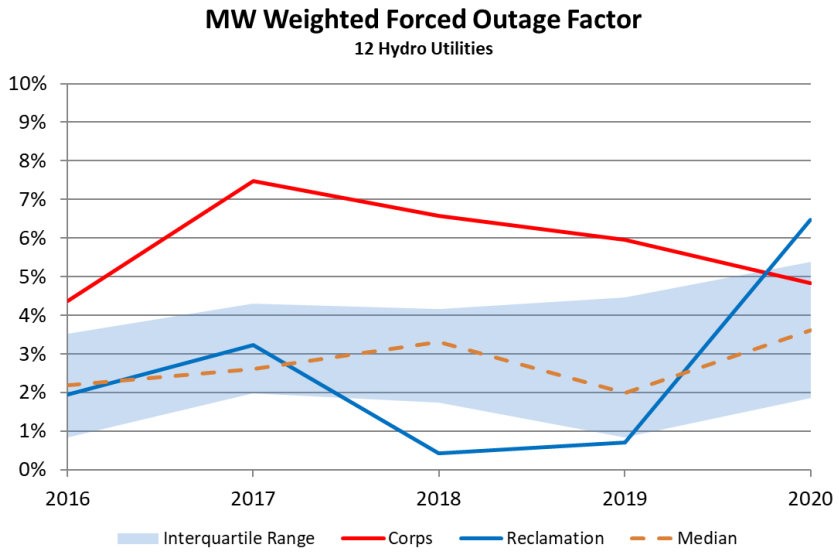
Corps and Reclamation total benchmarked costs have been essentially flat in nominal terms since 2018, with minor increases in the years prior. This means that Corps and Reclamation costs have actually declined in real terms as inflationary pressures have been absorbed. The industry has averaged a 5% increase in total benchmarked costs per MWh over the same period.



Availability has consistently been below the industry median. The Corps has tended to be at the lowest quartile of availability while Reclamation has been far below the interquartile range.



For Reclamation, the primary driver has been scheduled outages in the Third Powerplant at Grand Coulee. For the Corps, forced outages have been a major contributor to reduced availability since 2016 and have been far higher than the rest of the industry. Due to the unplanned nature of forced outages, they often prove to be costlier than scheduled outages as they can occur during times when unit availability is critical and mitigation efforts are difficult to implement on short notice. With tightening expense budgets, the FCRPS strategy is to rely on ramping up the capital program to reduce forced outages in the long-term. John Day, The Dalles, McNary and Ice Harbor have been major contributors to the high forced outage factor in recent years. At The Dalles and Ice Harbor, capital investments are currently underway on equipment responsible for prior forced outages. Investments in the 2020s and 2030s at McNary and John Day will also address reliability concerns.



9.0 RISK ASSESSMENT

The following risk matrices show where each inventoried asset falls based on current asset condition and the resulting likelihood and consequence of failure. Risk maps are divided into three regions, described as follows:

Low Risk
Moderate Risk
High Risk

Risk matrices reflect a snapshot in time. As condition degrades and likelihood of failure increases, assets move up the risk matrix into the moderate and high risk categories. Replacements and refurbishments reduce the likelihood of failure, causing assets to return to the low risk category.

Safety Risk

Figure 9.0-1, Risk Assessment, Safety

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	218	49	55	37	5
Likely	336	21	139	51	30
Possible	1296	148	308	286	17
Unlikely	1400	123	198	221	9
Rare	3656	288	366	304	101
	Consequence				

Assets in High Risk Category

Equipment Category	# of Assets
Auxiliary Systems	32
Central Controls	13
Cranes	17
Drainage & Unwatering	
Emergency Closure Valves	
Fish Protection	
Infrastructure	10
Powertrain (incl.Main, SS, & Fish)	50
Station Power	19
Transmission/Switchyard	36
Water Control	1
Total	**178**

A total of 178 assets pose high safety risks listed by equipment category in the table to the right of the risk map. Since the 2020 SAMP, Reclamation performed a pilot project to thoroughly inventory assets at two of their facilities. This resulted in a significant increase in Auxiliary Systems, Station Power and Transmission/Switchyard assets in the inventory rated high risk. Preliminary condition assessments were heavily reliant on the age of the equipment, placing many in the high risk category as a result.

74 of the 178 assets have investments identified to mitigate their safety risk in the next 10 years. Risk is mitigated with operational procedures for assets that do not have an investment identified. Typically, investments are planned when operational procedures are excessively costly or do not effectively mitigate the risk.

The Corps is currently programmatically evaluating and prioritizing life safety improvements across their powerhouses and control rooms. This prioritization will likely result in more assets with identified investments to mitigate their risks.

Compliance Risk

In its current state, the risk map for Compliance Risk primarily measures the risk associated with failing to meet WECC/NERC standards. As mentioned in 7.1.1.3, compliance risk is also intended to capture the need to implement the actions consulted upon in the BiOps and the required actions in the Incidental Take Statements and comply with other state laws, federal laws, and regulations such as those under the Endangered Species Act. These risks will be captured at the asset level in the 2024 SAMP. They are already captured when investments are created as described in Section 7.1. Relative to WECC/NERC compliance, it is not believed that many FCRPS assets pose a significantly high risk, individually. There is sufficient redundancy to ensure that consequences for any individual failures remain manageable. The highest

consequence identified for an individual asset is "moderate." There are currently 11 assets in the high risk category, four of which have an active investment identified. As a response to the weather events of winter 2021, Corps and Reclamation will be collecting new data on how temperatures can impact the ability of FCRPS generators to operate. This data may lead to future revisions in this risk assessment depending on changes to regulations.

Figure 9.0-2, Risk Assessment, Reliability and Compliance Risk

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	310	43	11		
Likely	413	118	46		
Possible	1841	163	51		
Unlikely	1819	68	64		
Rare	4412	154	149		
	Consequence				

Assets in High Risk Category

Equipment Category	# of Assets
Auxiliary Systems	
Central Controls	5
Cranes	
Drainage & Unwatering	1
Emergency Closure Valves	
Fish Protection	
Infrastructure	
Powertrain (incl.Main, SS, & Fish)	
Station Power	
Transmission/Switchyard	5
Water Control	
Total	**11**

Reliability and Financial Risk

Reliability and financial risks are assessed through lost generation risk and direct cost risk. Lost generation risk measures the lost revenue associated with equipment not being able to generate. Direct cost risk measures the non-generation impacts of failures such as repair costs, damage to adjacent equipment, or other incremental costs incurred to restore equipment to service.

Figure 9.0-3-1 Lost Generation Risk

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	1	18	43	47	
Likely	19	45	130	144	4
Possible	60	114	579	742	30
Unlikely	20	103	538	916	13
Rare	115	389	1350	2078	108
	Consequence				

Assets in High Risk Category

Equipment Category	# of Assets
Auxiliary Systems	
Central Controls	17
Cranes	23
Drainage & Unwatering	1
Emergency Closure Valves	
Fish Protection	
Infrastructure	
Powertrain (incl.Main, SS, & Fish)	155
Station Power	35
Transmission/Switchyard	7
Water Control	
Total	**238**

There are currently 238 assets in the high-risk category for lost generation risk. 142 of these assets have active investments planned in the next 10 years. For direct cost risk, there are 402 assets in the high risk category. 193 of these assets have an investment planned in the next 10 years to mitigate these risks.

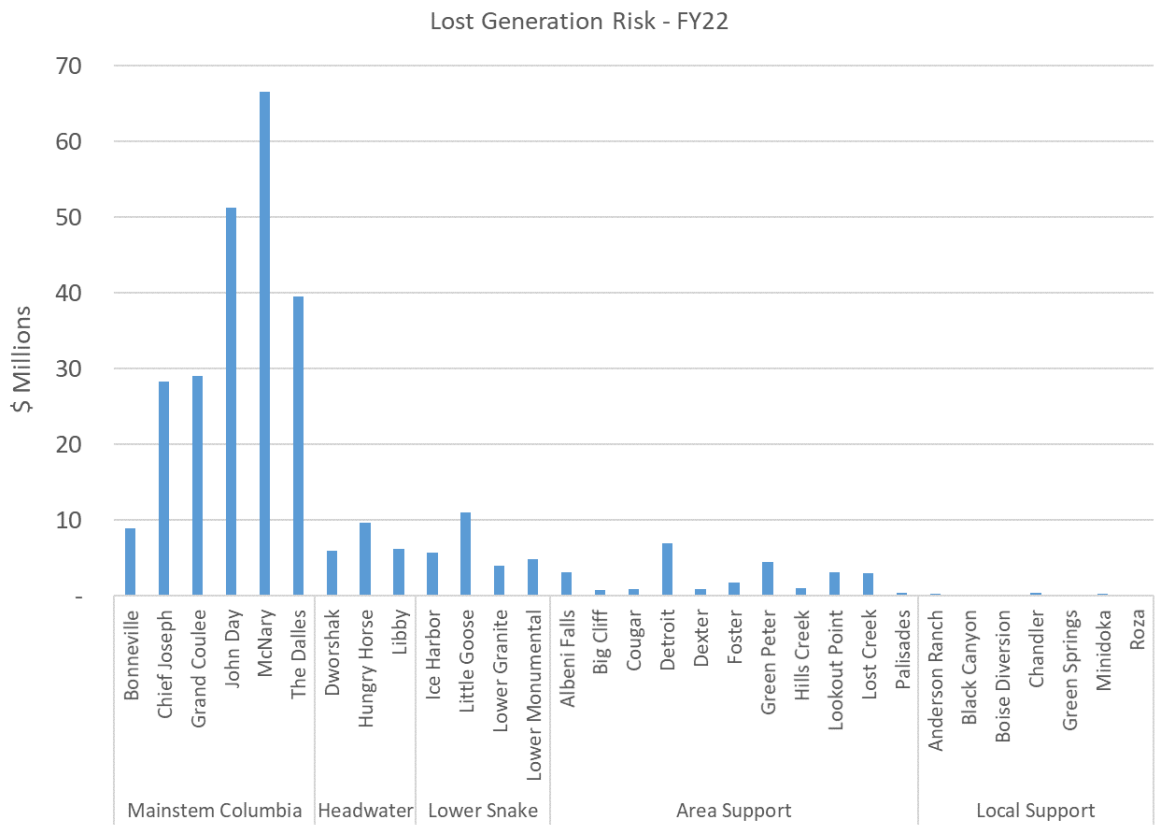
Figure 9.0-3-2 Direct Cost Risk

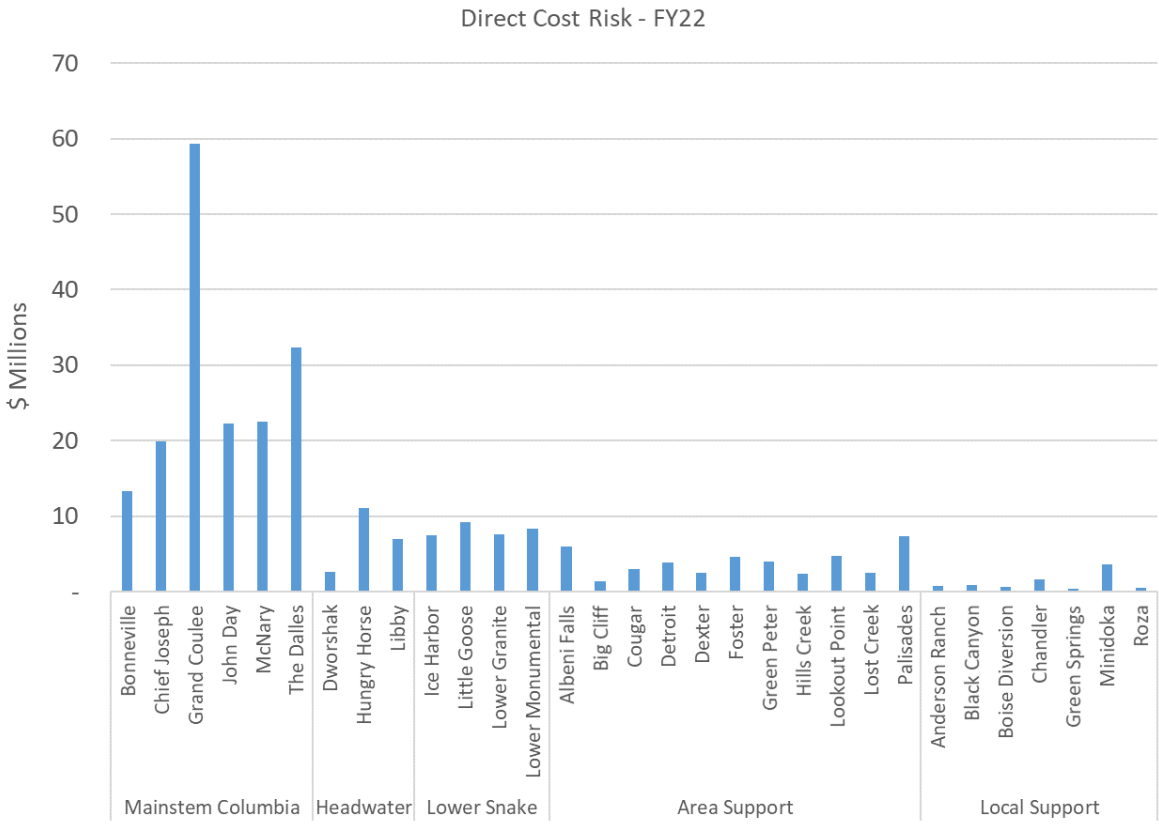
Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	14	68	225	60	
Likely	8	127	331	115	2
Possible	36	326	1376	337	5
Unlikely	13	528	1147	276	10
Rare	15	1190	2971	588	5
	Consequence				

Assets in High Risk Category

Equipment Category	# of Assets
Auxiliary Systems	66
Central Controls	22
Cranes	51
Drainage & Unwatering	6
Emergency Closure Valves	
Fish Protection	
Infrastructure	49
Powertrain (incl.Main, SS, & Fish)	126
Station Power	29
Transmission/Switchyard	
Water Control	53
Total	**402**

As lost generation and direct cost risks are directly quantified, the following charts display their current levels at each of the 31 plants. With the completion of the mechanical overhauls in the Washington Powerplant at Grand Coulee, lost generation risk at the plant has declined since the 2020 SAMP. This reflects the near-term expectation of higher overall availability at Grand Coulee than has been experienced in the last 10 years. Lower availability and improved modeling techniques have resulted in significant increases in the lost generation risk quantified at John Day, McNary and The Dalles dams compared to the 2020 SAMP.


Lost Generation Risk - FY22
$ Millions
70
60
50
40
30
20
10
-
Bonneville
Chief Joseph
Grand Coulee
John Day
McNary
The Dalles
Dworshak
Hungry Horse
Libby
Ice Harbor
Little Goose
Lower Granite
Lower Monumental
Albeni Falls
Big Cliff
Cougar
Detroit
Dexter
Foster
Green Peter
Hills Creek
Lookout Point
Lost Creek
Palisades
Anderson Ranch
Black Canyon
Boise Diversion
Chandler
Green Springs
Minidoka
Roza
Mainstem Columbia
Headwater
Lower Snake
Area Support
Local Support


Direct Cost Risk - FY22
$ Millions
70
60
50
40
30
20
10
-
Bonneville
Chief Joseph
Grand Coulee
John Day
McNary
The Dalles
Dworshak
Hungry Horse
Libby
Ice Harbor
Little Goose
Lower Granite
Lower Monumental
Albeni Falls
Big Cliff
Cougar
Detroit
Dexter
Foster
Green Peter
Hills Creek
Lookout Point
Lost Creek
Palisades
Anderson Ranch
Black Canyon
Boise Diversion
Chandler
Green Springs
Minidoka
Roza
Mainstem Columbia
Headwater
Lower Snake
Area Support
Local Support

Environmental Risk

Figure 9.0-4, Risk Assessment, Environment/Trusted Stewardship

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	238	76	10	40	
Likely	385	115	24	53	
Possible	1181	334	315	225	
Unlikely	1312	206	265	167	1
Rare	3691	547	163	313	1

Consequence

Assets in High Risk Category

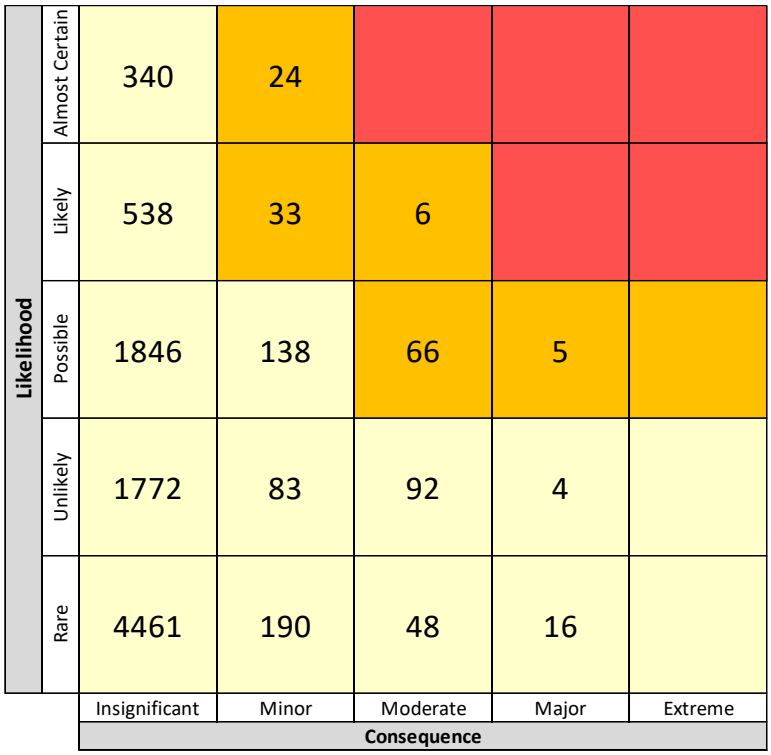
Equipment Category	# of Assets
Auxiliary Systems	3
Central Controls	15
Cranes	
Drainage & Unwatering	7
Emergency Closure Valves	
Fish Protection	
Infrastructure	
Powertrain (incl.Main, SS, & Fish)	23
Station Power	1
Transmission/Switchyard	
Water Control	54
Total	**103**

There are currently 103 assets in the high environmental risk category. 29 of these assets have active investments planned over the next 10 years. The risk associated with the remaining assets is typically mitigated through operational measures or through the installation of new assets such as oil water separators. Once installed, those assets would likely reduce the consequence of failure below the high risk category.

Public Perception Risk

At this time, there are no assets in the high-risk category for public perception risk. Six assets with a moderate consequence of failure and five assets with a major consequence of failure are on the verge of the high risk category. As conditions degrade over time, an increase in failure likelihood from Likely to Almost Certain for the moderate-consequence assets or an increase from possible to likely for the major-consequence assets will push those assets into the high risk category if they are not replaced or refurbished beforehand.

Figure 9.0-5, Risk Assessment, Public Perception Risk



Assets in High Risk Category	
Equipment Category	**# of Assets**
Auxiliary Systems	
Central Controls	
Cranes	
Drainage & Unwatering	
Emergency Closure Valves	
Fish Protection	
Infrastructure	
Powertrain (incl.Main, SS, & Fish)	
Station Power	
Transmission/Switchyard	
Water Control	
Total	**0**

10.0 STRATEGY AND FUTURE STATE

10.1 Future State Asset Performance

Minimizing lifecycle cost at the asset level and maximizing investment portfolio value are the goals of the FCRPS investment strategy rather than meeting specific asset performance objectives. This is because BPA's obligations to its power customers can typically be fulfilled for short periods of time, if necessary, through market purchases if FCRPS assets are unavailable. Although this preserves the load-resource balance and ensures the lights stay on, the replacement power may come at a higher cost or from a carbon-emitting resource (or both). As a result, asset-related decisions are largely based on economics rather than meeting specific availability goals. FCRPS strategies focus on optimizing asset-level tradeoffs between equipment reliability, failure costs and other benefits associated with equipment replacement rather than targeting specific performance levels. This methodology is described in detail in Section 10.2. For the FCRPS, optimal plant availability is a result of the strategy rather than a driver.

BPA, the Corps and Reclamation develop a 5-year availability forecast that includes a flat long-term outlook for out-year availability. Plants develop and submit these forecasts on an annual basis based on known maintenance, capital, and forced outage expectations. Current year forecasts are used to set plant level scheduled outage targets. Future year forecasts fluctuate from year-to-year as investment timing changes with the annual optimization of the asset plan. The future availability simulation produced in the asset planning models described in Section 7.1.1.5.1 is not yet integrated with this process. In the future, it could be used to provide more definition in the timeline beyond 5 years out.

Table 10.1-1 Future Asset Performance Objectives

Objective	Plant	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
Weighted Availability Factor	Albeni Falls	85%	86%	91%	91%	90%	91%	91%	91%	91%	91%	91%
Weighted Availability Factor	Anderson Ranch	88%	88%	88%	89%	90%	90%	90%	90%	90%	90%	90%
Weighted Availability Factor	Big Cliff	82%	86%	85%	94%	94%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Black Canyon	93%	93%	91%	93%	93%	92%	92%	92%	92%	92%	92%
Weighted Availability Factor	Boise Diversion	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%
Weighted Availability Factor	Bonneville	91%	85%	90%	92%	92%	91%	91%	91%	91%	91%	91%
Weighted Availability Factor	Chandler	70%	57%	36%	52%	57%	54%	54%	54%	54%	54%	54%
Weighted Availability Factor	Chief Joseph	91%	92%	96%	95%	96%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Cougar	97%	95%	96%	96%	96%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Detroit	86%	60%	87%	90%	90%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Dexter	98%	96%	90%	96%	96%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Dworshak	94%	94%	91%	92%	94%	92%	92%	92%	92%	92%	92%
Weighted Availability Factor	Foster	53%	76%	47%	47%	96%	63%	63%	63%	63%	63%	63%
Weighted Availability Factor	Grand Coulee	79%	82%	72%	83%	79%	76%	76%	76%	76%	76%	76%
Weighted Availability Factor	Green Peter	95%	94%	48%	87%	95%	93%	93%	93%	93%	93%	93%
Weighted Availability Factor	Green Springs	97%	84%	93%	93%	93%	90%	90%	90%	90%	90%	90%
Weighted Availability Factor	Hills Creek	97%	92%	96%	96%	98%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Hungry Horse	79%	71%	72%	69%	63%	67%	67%	67%	67%	67%	67%
Weighted Availability Factor	Ice Harbor	73%	79%	89%	88%	88%	86%	86%	86%	86%	86%	86%
Weighted Availability Factor	John Day	77%	78%	84%	83%	86%	92%	92%	92%	92%	92%	92%
Weighted Availability Factor	Libby	88%	88%	88%	85%	89%	87%	87%	87%	87%	87%	87%
Weighted Availability Factor	Little Goose	83%	81%	90%	90%	89%	89%	89%	89%	89%	89%	89%
Weighted Availability Factor	Lookout Point	97%	96%	87%	92%	95%	94%	94%	94%	94%	94%	94%
Weighted Availability Factor	Lost Creek	90%	93%	93%	92%	93%	93%	93%	93%	93%	93%	93%
Weighted Availability Factor	Lower Granite	86%	90%	90%	90%	88%	89%	89%	89%	89%	89%	89%
Weighted Availability Factor	Lower Monumental	86%	86%	90%	89%	91%	90%	90%	90%	90%	90%	90%
Weighted Availability Factor	McNary	86%	80%	73%	79%	95%	85%	85%	85%	85%	85%	85%
Weighted Availability Factor	Minidoka	89%	89%	91%	90%	91%	89%	89%	89%	89%	89%	89%
Weighted Availability Factor	Palisades	85%	91%	91%	91%	92%	90%	90%	90%	90%	90%	90%
Weighted Availability Factor	Roza	96%	83%	83%	83%	83%	79%	79%	79%	79%	79%	79%
Weighted Availability Factor	The Dalles	59%	64%	79%	84%	93%	86%	86%	86%	86%	86%	86%

In terms of driving strategic direction, a financial performance measure such as the cost of generation ($/MWh) may be more valuable to focus on than availability. These measures are tracked and forecasted into the future, but more work is required between the Three Agencies to determine if developing targets would add value in the current asset management process. This will be evaluated by the new Asset Management Group but remains to be prioritized in the Asset Management roadmap.

10.2 Strategy

The FCRPS long-term strategy is to make coordinated operations, maintenance, and investment decisions that maximize the value of FCRPS assets by reducing costs, mitigating risk, improving efficiency, and producing incremental value. A cornerstone of the strategy is decision making that is risk-informed and considers asset condition, probability of failure, and the impacts to each of the Three Agencies' missions. These factors already drive the capital investment program and expanding a similar process into operations and maintenance decision making is a key initiative.

A key component in building the FCRPS strategy and identifying recommended funding levels is determining the optimal time to reinvest in FCRPS assets. FCRPS staff use Copperleaf, an Asset Investment Planning and Management tool, to develop the capital investment strategy and plan. Copperleaf tracks the benefits, costs, and assets associated with investments and provides tools for future investment identification as well as investment decision optimization. Using asset condition, failure characteristics, and investment information, Copperleaf can calculate the optimal time to invest in an asset, optimize the timing of investments in an investment portfolio, and illustrate the costs and benefits of different investment strategies or funding levels. There are two primary capabilities leveraged by FCRPS staff to develop investment strategies and plans:

Predictive Analytics: Identifies the optimal replacement date for each asset in the FCRPS asset registry by minimizing lifecycle cost and mitigating high safety and environmental risks within budget constraints. The optimal replacement dates produced by Predictive Analytics are intended to be directional and form the basis for investment identification and long-term funding levels.

Value Framework and Investment Decision Optimization: This process optimizes the timing and alternatives of investments in a portfolio to maximize value within constraints. Projects identified to address the recommendations of Predictive Analytics as well as projects proposed by the plants are created in Copperleaf and added to an investment portfolio. The benefits and costs of each project are assessed and the optimization tools are used to develop the Asset Plan.

Predictive Analytics

A risk-based approach is taken to identify the optimal timing for investment. Copperleaf Predictive Analytics calculate optimal replacement dates by:

- Assessing current condition and forecasting how it changes over time;
- Relating asset condition to an effective age and probability of failure for each asset type;
- Multiplying the consequence of failure by the probability of failure for each respective asset to determine the risk it poses in a given year; and
- Minimizing the sum of the present value risk costs and replacement cost.

Condition

Historically, the Corps and Reclamation assessed equipment condition for powertrain and critical auxiliary components annually and balance of plant equipment semiannually. With the ongoing expansion of the asset registry, the FCRPS has moved to requiring assessments at intervals tied to common maintenance and inspection practices. This is intended to maximize the value of time spent on condition assessment. Equipment Condition is assessed using the hydroAMP Condition Assessment framework, described in detail in Section 8.2.2.

Future condition is forecast using expected degradation rates developed using regression analyses on hydroAMP condition data relating equipment condition to equipment age. The analysis groups condition scores into eleven buckets, rounding condition scores to ratings of 0 through 10. Logistic regressions then give the probability that a piece of equipment falls into each of the 11 buckets at a given age. The expected condition decay curve is built up from these regressions, which are the expected values at each age.

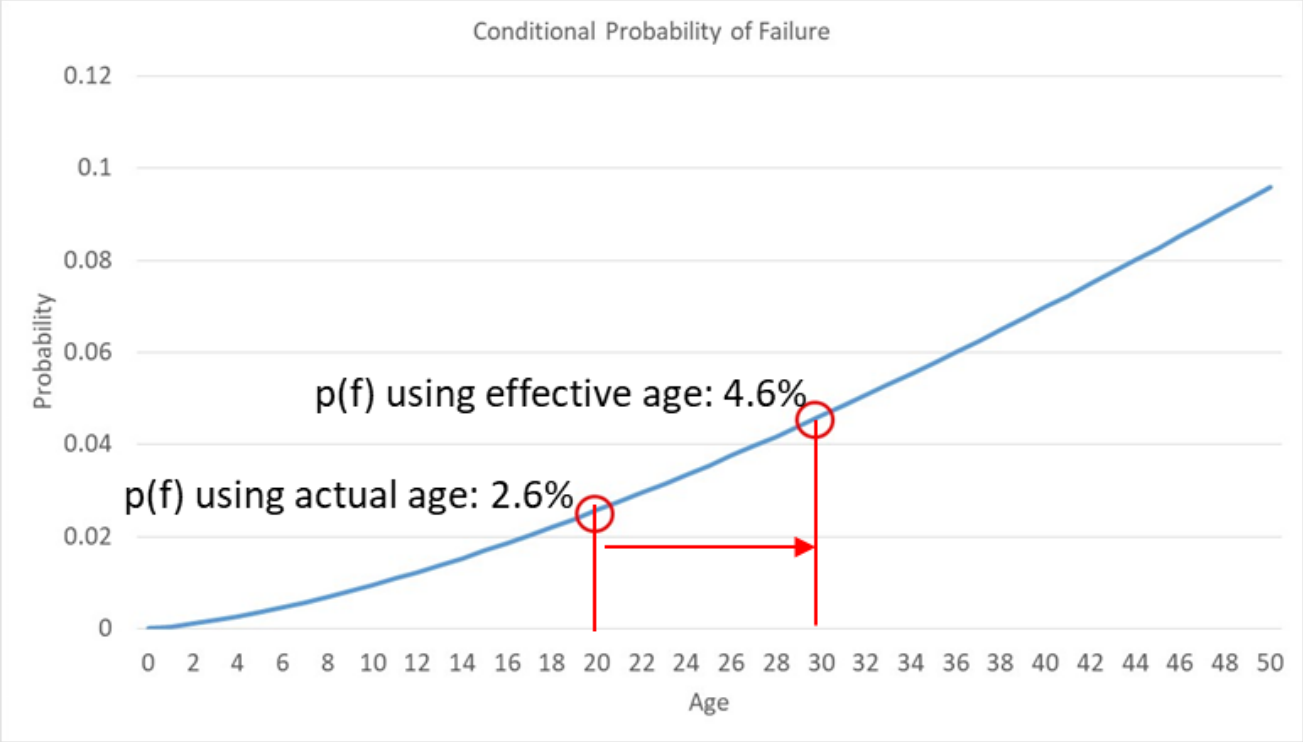
Example Equipment Condition Degradation Curve

The chart above illustrates an expected degradation curve with each individual point representing a condition assessment at a specific equipment age. Each individual assessment is shown on the graph with a

semitransparent colored circle so that overlapping assessments produce darker regions where the data is most concentrated. This reveals the emerging expected relationships between age and condition as well as the level of variability around those patterns. The colors represent assessments from different plants in the FCRPS. Effective age is determined by comparing current asset condition to the expected degradation curve. In the example above, the circled assessment with a condition score of 5 at an actual age of 20 is more representative of an effective age of 30 based on expected degradation across the population.

Probability of Failure

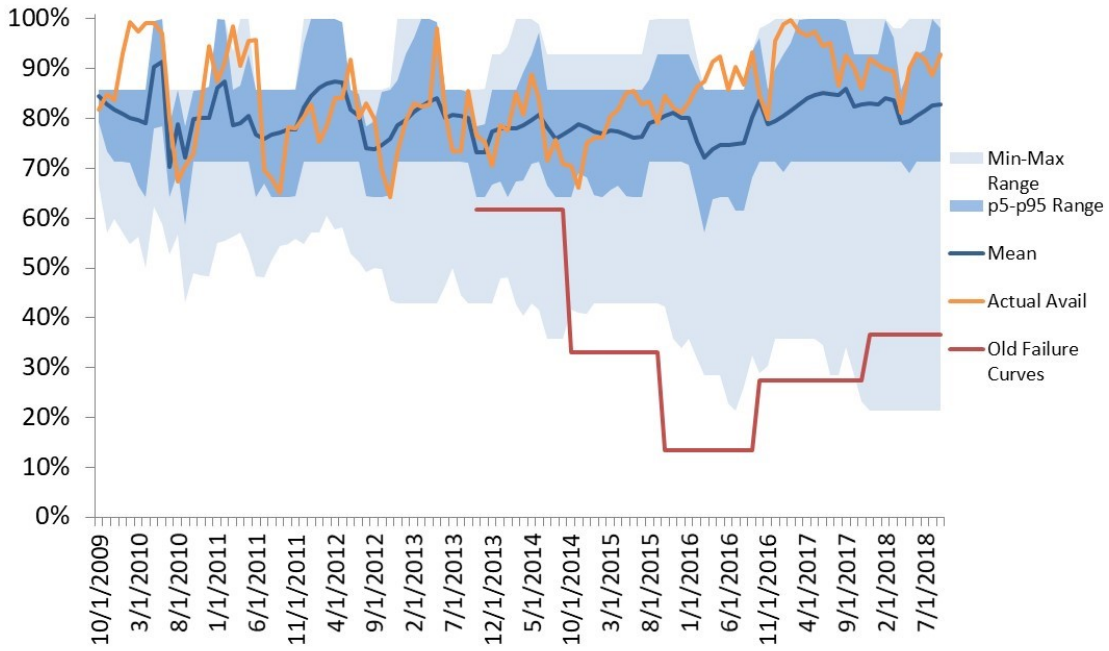
An asset's effective age is used in combination with Weibull curves associated with an asset's respective asset type to determine probability of failure. Continuing with the previous example, an asset with an actual age of 20 is shown to have a 2.6% probability of failure between the age of 20 and 21. The asset's effective age of 30 results in a movement along the curve, resulting in a condition-adjusted probability of failure of 4.6%.



Failure Curves for powertrain and critical auxiliary equipment were updated in 2016 using an Expert Opinion Elicitation process facilitated by the Corps' Risk Management Center. The curves were developed for twenty-eight major hydropower assets using the opinion of Subject Matter Experts from the Corps, including the Hydroelectric Design Center, BPA, Reclamation, Tennessee Valley Authority, Chelan County Public Utility District, and Western Area Power Administration. The Corps plans to update these curves with actual failures as data is collected in the coming years.

This task was initiated to replace existing failure curves that relied on empirical data containing both equipment replacements and retirements. Since the existing failure curves included retirement data that did not necessarily result from equipment failure, the curves likely overstated probability of failure and understated reliability as assets age. Validation of the new curves performed using Monte Carlo simulation has shown results more in line with actual availability than similar results using the old curves. The validation analysis was performed by taking

equipment condition as it was known on 10/1/2009 and running a Monte Carlo simulation up until present day simulating plant availability. The blue line represents the average availability across 1000 simulations, the darker blue shaded region represents the 5th to 95th percentile range and the light blue shaded region represents the minimum and maximum range. The orange line is the actual availability observed over the period. Generally speaking, we hope to see actual availability occurring within the 90% confidence interval (5th-95th percentile range) about 90% of the time. Overall, the simulations with the expert opinion curves have tended to produce reasonable results about in line with this goal. Compare this to the red line on the chart that shows results from early simulations performed in 2014 using the old curves. As previously noted, the failure curves resulted in unrealistically low availability forecasts.



Failure curves for all other components were updated for the 2020 SAMP using the Corps' Balance of Plant Weibull curves used nationally by their navigation and flood risk mitigation lines of business.

Risks and Costs

Lost Generation Risk (LGR): Equipment failure may also result in longer outages and, thus, more lost generation than if replaced on a planned basis. LGR also increases as equipment condition degrades over time.

Direct Cost Risk (DCR): If equipment fails during the deferral period, intervention costs may be incrementally higher for collateral damage and planning, procurement, and scheduling inefficiencies (overtime, emergency hiring, contract premiums, etc.). This cost risk increases as equipment condition degrades over time and is estimated for each component.

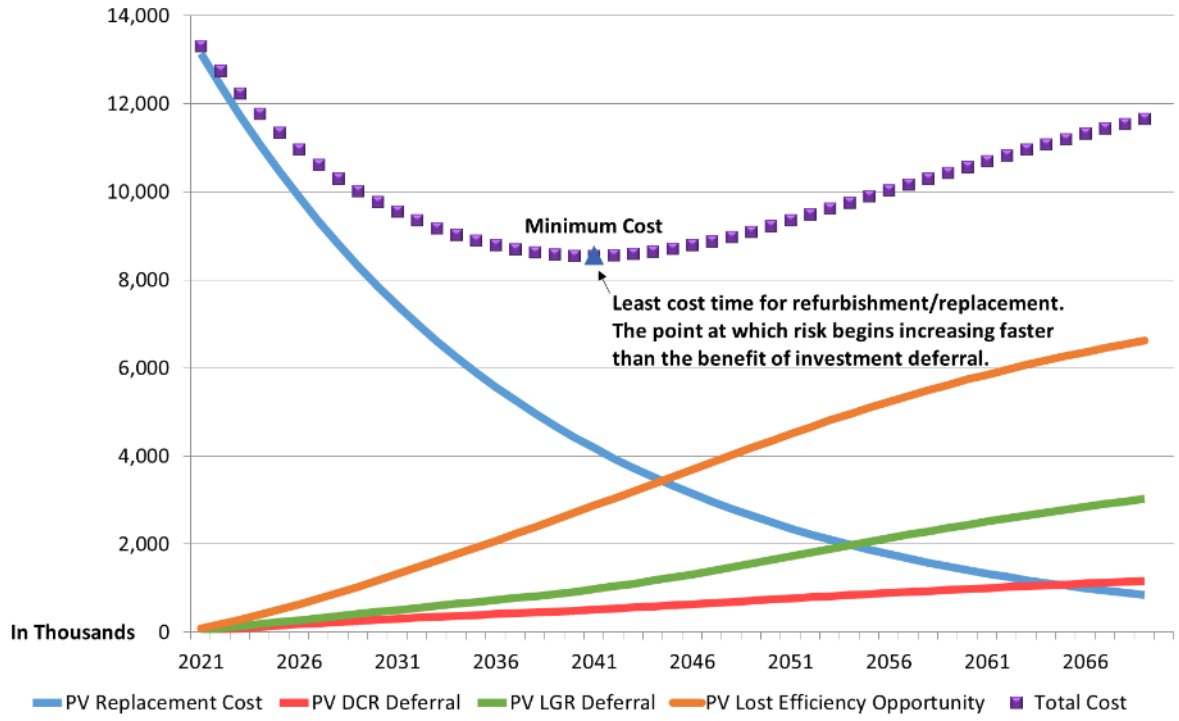
Lost Efficiency Opportunity (LEO): Some equipment replacements (turbine runners, transformers and generator windings) reduce efficiency losses. Deferring replacement results in a lost opportunity to capture increased generation from higher efficiency equipment. This foregone benefit is treated as a cost for purposes of lifecycle cost minimization.

Project Cost: The cost of the replacement or refurbishment activity.

Lifecycle Cost Minimization

To determine the optimal timing for replacement, each equipment component is evaluated in yearly time steps. In each year, the present value of accumulated financial risk cost is added to the present value cost of replacing the equipment in that year. The sum of these present value costs is the Total Cost related to a decision to delay equipment replacement until that year. This algorithm is described graphically below.

FCRPS Equipment Lifecycle Cost Minimization Methodology



The optimal time to plan on equipment replacement is at minimum point on the Total Cost curve. This minimum point is the time at which the sum of financial risk costs and potential lost efficiency opportunity begin growing faster than the benefit of deferring the investment. Up until that time the value of investment deferral is greater than the expected increase in financial risk and lost efficiency opportunity costs, so it makes financial sense to continue deferring equipment replacement.

When a constraint is introduced, Predictive Analytics prioritizes all assets at or past their respective optimal replacement dates based on their cost of deferral. Assets are chosen for replacement ranked by their respective deferral cost until there is no longer room within the budget. The analytics will then seek to replace the next highest deferral cost asset that remains within the budget constraint until either the constraint is reached in full or no further assets can be selected while remaining within constraints.

Value Framework

After optimal replacement dates are established, the Asset Planning Team, in coordination with other Corps and Reclamation planning functions, develops projects to address the risks identified by Predictive Analytics. These projects, along with other needs identified by the plants, are entered into the Portfolio Management module of Copperleaf with a forecast for their annual spend and a preliminary assessment of their risks and benefits.

Benefits and risks associated with investment activities are evaluated using the Value Framework component of Copperleaf. The establishment of the FCRPS Value Framework was one of the first outcomes of the Asset Investment Excellence Initiative. The value measures upon which investments are assessed are summarized in the table below.

FCRPS Value Framework

Value Measure Categories	Value Measures	Organizational Goals
Financial	Financial Benefits	Maximize cost savings and increase efficiency to ensure low cost power Maintain ability to reliably supply energy to the grid
	Generation Efficiency Benefits	
	Direct Cost Risk	
	Lost Generation Risk	
Trusted Stewardship	Compliance Risk	Reduce Safety, Environmental and Compliance risks to as low as reasonably practicable. Ensure employee and public safety Maintain mandate to operate
	Environmental Risk	
	Productive Workplace Benefit	
Safety	Safety Risk	
Community	Public Perception Risk	

As described in Section 7.1, financial risks are assessed in dollars while trusted stewardship, safety, and community value measures are assessed qualitatively. These qualitative measures are assessed using a 5 by 5 risk matrix that aligns the consequence scales of the qualitative measures to the quantified financial risks and benefits. This creates a method of assigning value to qualitative benefits and risks. For optimization purposes, safety and environmental risk receive weightings of 2.0 and 1.5, respectively. This means that Safety risks are weighted twice as heavily as an equivalent lost generation risk and environmental risks are weighted 1.5 times as heavily as an equivalent lost generation risk.

FCRPS Risk Matrix Consequence Descriptions

Consequence	Insignifcant	Minor	Moderate	Major	Extreme
Financial Risk	<$10k	$10k - $100k	$100k - $1M	$1M - $10M	>$10M
Lost Generation Risk	<280 MWh	20 MWh - 2,800 MWh	2,800 MWh - 28,000 MWh	28,000 - MWh - 280,000	>280,000 MWh
Compliance Risk	No or insignificant effect on operations or administrative flexibility, or annual mandated costs <$10k	Change in operations or administrative flexibility or annual mandated costs < $100k	Effect on legal principles or precedents, project operations noticeably affected for compliance, inability to maintain system frequency or voltage, or annual mandated costs <$1M	Effect on legal principles or precedents, substantial changes needed in project operations or administration, or annual mandated costs <$10M	Extremely difficult to meet fundamental statutory obligations, extremely unreliable system, extreme changes needed in project operations or administration, or annual mandated costs >$10M
Environmental Risk	No impact	Impact to on-site environment (simple remediation) or where the remediation costs <$100k	Limited impact off-site (localized remediation required) orwhere the remediation costs <$1M	Detrimental impact on- or off-site (long-term remediation required) or where the remediation costs <$10M	Detrimental or catastrophic impact off-site (mitigation impossible) orwhere the remediation costs >$10M
Safety Risk	No or minor injury, first aid	Treatment by medical professional	Lost time accident - temporary disability	Permanent disability	Fatality
Public Perception Risk	No or isolated internal complaints	Local media attention, widespread internal complaints, some public embarrassment	Transitory local media / federal / customer attention and criticism, some damage control; congressional inquiry, short duration loss of power to islanded community	Ongoing media / federal / customer attention, major damage control, significant impact on staff morale, congressional inquiry, extended duration loss of power to islanded community	Adverse and ongoing media / federal / customer attention, criticism and agency intervention, extreme damage control, secretary called to congress, permanent duration loss of power to islanded community

Lost Generation Risk and Direct Cost Risk (captured by "Financial Risk" above) are automatically calculated for assets that are attached to investments using the same analysis performed in Predictive Analytics described above. Investment impact dates and resulting condition scores from replacements or refurbishments are forecast and the mitigated Lost Generation and Direct Cost risks are calculated between the baseline and investment scenarios. For the remaining Value Measures, risk is calculated by multiplying the consequences selected from the matrix above by the assessed probability of occurrence. Mitigated risk is the difference between the assessed probabilities of occurrence with and without an investment as well as any change in future consequence that may result from an investment alternative. The risk matrix below displays the interaction of probability and consequence scales.

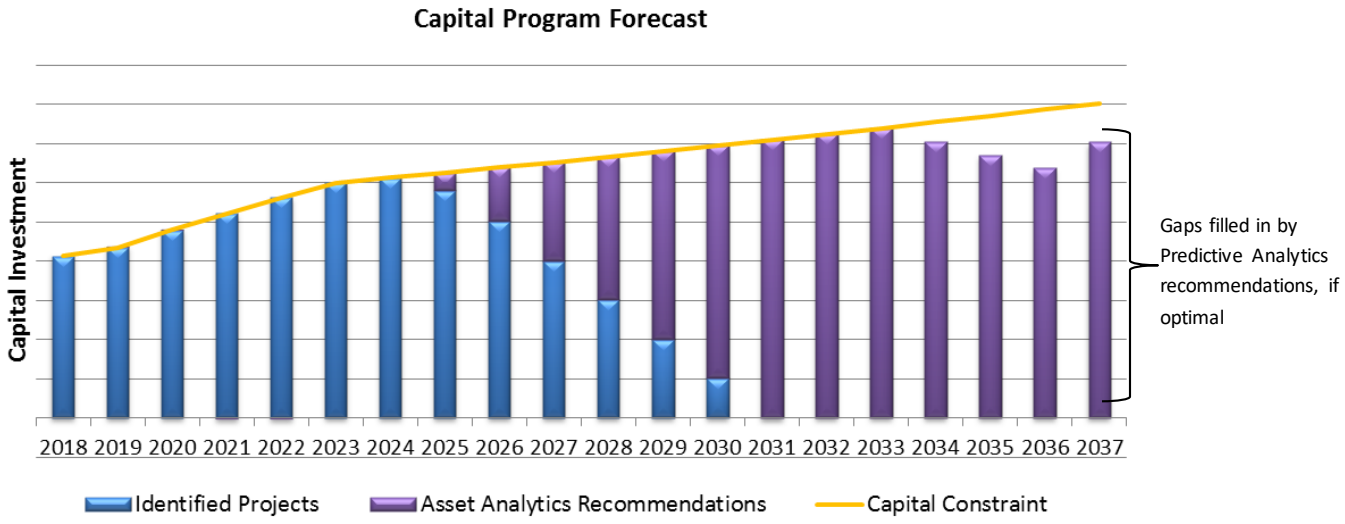
FCRPS Risk Matrix

Probability		Insignificant	Minor	Moderate	Major	Extreme
	Almost Certain This event could occur within the next 2 years					
	Likely This event could occur within the next 5 years					
	Possible This event could occur within the next 13 years					
	Unlikely This event could occur within the next 50 years					
	Rare This event could occur within the next 100 years					
		Consequence				

Risk Level	Low	Medium	High

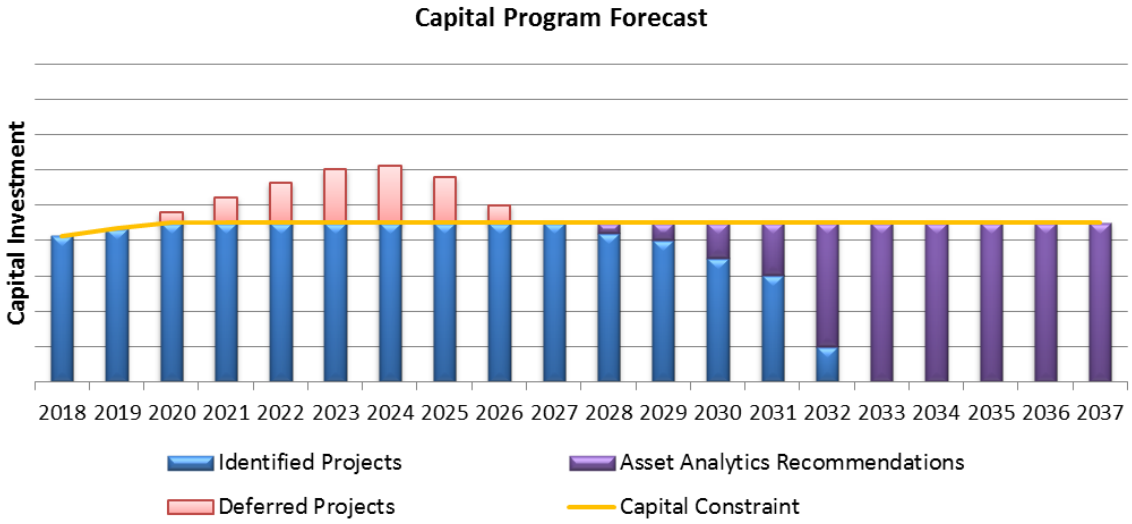
The Asset Plan is constructed through iterative optimizations of the FCRPS capital investment portfolio. For development of the SAMP, planned investments from the Asset Plan are optimized under the planning levels identified in each respective Strategy Alternative. If identified projects exceed the planning levels identified in the strategy alternatives, the optimization will defer investments in order to maximize the value of available capital funding. In future years in which the Asset Plan is not fully programmed up to the budget constraint, Predictive Analytics will identify assets for which it is optimal to plan a replacement but a project has yet to be identified. However, if there are no assets at or past their optimal replacement dates, Predictive Analytics is not required to spend all available funds. The strategy presented in Section 10.2 is a result of these iterative analytics. The example below illustrates how optimization defers projects to stay within constraints.

The chart below shows hypothetical capital investment for planned projects in blue, which represent mature investments tracked in Copperleaf. As the capital forecast associated with planned projects declines, Predictive Analytics fills in gaps by selecting assets to replace, if optimal. In some cases, it may not be optimal to spend the entire budget.



With a more constrained budget, the existing portfolio of identified investments is optimized resulting in a number of projects moving to a later date. The forecast associated with deferred investment is highlighted in

red in the example below. A lower budget constraint results in planned projects lasting further into the future before Predictive Analytics is required to fill in gaps in the long-term plan.



These processes develop the sustainment and expansion strategies, and plans are formulated using the methodologies described above.

10.2.1 Sustainment Strategy

The Three Agencies aspire to develop sustainment strategies that combine maintenance, reinvestment, and operational strategies in order to maximize the value of FCRPS assets. Integration of these strategies is currently ad hoc and the maturity varies from plant-to-plant. As asset management practices continues to mature over the next decade, integration and tradeoffs between capital and expense will be better understood. At present, the sustainment strategies for the capital and expense programs can be described as follows:

10.2.1.1 Capital Investment Strategy:

- Identify the level of investment associated with minimizing asset lifecycle costs at each plant while meeting the respective missions of the Three Agencies
- Develop projects that incorporate the results from this analysis while considering logistical requirements and potential efficiencies such as combining work into a single outage window
- During the scoping of major plant-wide powertrain replacements, evaluate unit efficiency and capacity improvements as well as the optimal number of units to fully replace
- Optimize the investment portfolio on an annual basis to maximize the value of the portfolio within constraints
- Reserve a portion of the capital budget for joint assets that will be optimized separately from power assets

10.2.1.2 Expense Strategy:

- Hold operations and maintenance costs at or below the rate of inflation.
- Incorporate asset criticality into decision making to optimize use of constrained operations and maintenance budgets.

10.2.1.3 Willamette Valley Strategy

An Environmental Impact Statement (EIS) is currently underway for the thirteen Willamette Valley System dams, including eight hydroelectric projects. The resulting structural and operational measures will likely result in significant increases in the costs of generation and impact the economic viability of power production. At the time of writing for this SAMP, and specifically the analysis that supports it, the Preferred Alternative and associated structural and operational measures are not yet known. Due to the timing of the analysis that supports this SAMP, impacts of the EIS have not been incorporated into asset optimal replacement dates or capital program forecasts for the Willamette Valley. Therefore, the levelized costs of generation and fully loaded costs are reflective of the No Action Alternative.

BPA expects the EIS to result in significantly higher costs of generation regardless of the selected alternative. Until these impacts are better understood, BPA has notified the Corps' Portland District that it intends to pause direct funding of capital investments for the electric power generation components at the power-producing Willamette Valley federal dams. BPA expects to continue to direct fund the power share of investments for "joint" facilities of those dams, meaning the features that are essential for the multiple purpose functions of the dams. This decision is not intended to include pausing direct funding of investments that are critical for personnel or dam safety, or implementation of the measures included in the current District Court of Oregon injunction for Willamette Valley System operations.

Due to the timing of this decision, it has not yet been incorporated into the modeling that drives the analysis for this SAMP. Upon completion of the EIS, marginal outage cost consequences will be reassessed (as discussed in Section 7.1.1.5.1) and models will be updated to reflect the operational changes. This will allow for the optimal replacement dates to be calculated and investments in the asset plan to be optimized in order to inform how the EIS changes impact the right time to perform work on power generation components in the Willamette Valley. At this time, it is expected that those modeling changes will be incorporated into the 2024 SAMP. It is possible that these changes could be incorporated into the Asset Plan as early as 2023.

Over the next 10 years, forecasts for Willamette Valley power generation components represent about 4% of the total FCRPS capital forecast resulting from this SAMP analysis. BPA does not expect that total capital program forecasts would materially change as the asset plan would be reoptimized within the existing recommended level of investment for the FCRPS.

10.2.2 Growth (Expand) Strategy

At present, BPA is not looking to expand FCRPS capacity from a resource adequacy perspective. However, there are incremental benefits and risk reductions that can be achieved from unit upgrades or additions. The primary source of incremental generation capability is actually a derivative of the sustainment program. Unit uprates and efficiency improvements are evaluated in conjunction with unit reliability improvements and can typically be achieved at minimal incremental cost. Both improvements are factored into business case alternatives analyses and are selected if they deliver the best value.

Dworshak and Libby Dams have been identified as powerhouses that are undersized relative to water availability. Both plants were originally designed to have more units than were ultimately completed. As a result, unplanned outages pose high financial and environmental risks, especially if they occur while other units are already out of service. To reduce these risks during planned replacements in the next decade, completing an additional unit at the two plants by leveraging existing infrastructure and components is under consideration.

The Corps and BPA recently completed extensive analyses to determine if an additional unit is a cost-effective risk mitigation measure at either plant. A summary of the two projects are provided below:

10.2.2.1 Libby Unit 6

A total of eight units were originally authorized by Congress at Libby Dam but only five were fully constructed. Original plans called for a reregulation dam downstream of Libby; however, these plans were abandoned following a legal injunction in the 1980s. Absent the reregulation dam, units 6 through 8 were seen as unnecessary and construction was halted after the turbine components were installed. Remaining components for those units were put into a long-term storage condition, where they now remain.

Upcoming outages on Units 1-5 for capital investments raised the need for financial, operational, and environmental review. BPA undertook a study in 2017 to determine the cost of completing one of the unfinished units and evaluate whether it would be a cost-effective risk mitigation measure during the long-term capital outages.

An economic analysis was performed on 12 different scenarios that assessed replacement timings on Units 1-5 with and without completing Unit 6. All scenarios that included Unit 6 had higher Net Present Values and Benefit Cost Ratios than scenarios in which Unit 6 was not completed. The scenario with the highest Net Present Value included building Unit 6 and completing capital improvements on all five existing units while the scenario with the highest Benefit Cost Ratio included building Unit 6 and completing capital improvements on four units. These results suggest building Unit 6 provides a cost-effective mitigation measure and leaves the option open to reduce the scope of future capital improvements.

The total cost to complete Unit 6 is $23 million dollars and it would be expected to produce a Net Present Value of $80 million over its lifetime (2019 analysis). Design is currently proceeding on this project, but installation remains under consideration by BPA executives and is dependent upon the final design cost estimate.

10.2.2.2 Dworshak Unit 4

Dworshak Dam was originally planned to have six units but only three were constructed. Unlike at Libby, only skeleton bays and intake structures exist for the remaining three units. No equipment was installed in those bays and the powerhouse structure only encloses the first three bays. Dworshak has one of the highest marginal outage costs in the FCRPS, as demonstrated in Figure 7.1-1. This is a result of Dworshak's unique configuration of two 103 MW units and one 259 MW unit. When the larger unit is out of service, the smaller units are not adequate to pass flows during much of the year, which results in large generation losses as well as environmental impacts from spill. Unit 3, the larger unit, is critical for water quality and water management. Units 1 and 2 also have a fairly high marginal outage costs as there are times of the year where outflows exceed powerplant capacity even when all units are available. Unlike other plants in the system, these high marginal outage costs are not a result of reduced unit reliability but powerplant design. Units 1 and 2 are expected to be out of service for capital improvements in the next 10 years and Unit 3's recent extended outage is estimated to have cost more than $20 million per year.

The Corps and BPA studied the economics of installing a fourth unit to determine if it could be a cost effective risk mitigation measure for future unit outages in addition to providing some incremental generation. Unit sizes ranging from 150 to 300 MW were studied to determine what would be the most cost effective. A 300 MW unit produced the highest Net Present Value and Benefit Cost Ratio of $80 million and 1.52 respectively and is expected to cost $239 million (2019 Study). An expansion project of this magnitude would have large

implications on the capital investment program during the construction phase. In addition to representing a large portion of the capital budget while being constructed, it is also thought to carry more execution risk than other projects in the capital investment portfolio. Further analysis will determine the best time to potentially build Dworshak Unit 4 in the broader context of upcoming reliability improvement needs on Units 1-3. The costs, risks and benefits then need to be weighed against the other reliability improvement projects in the capital portfolio. Given the number of upcoming large reliability improvement projects (e.g. at Grand Coulee, Chief Joseph, McNary and John Day), the ability to sustain and execute upon the capital program levels identified in the IPR is critical for this project to move forward. Proceeding with design and construction on this project remains under consideration by BPA executives.

10.2.2.3 Other Expansion Projects

The addition of a third unit was also considered at Reclamation's Black Canyon dam in the past but has been on hold as there is not a need or financial justification for proceeding with the project.

10.2.3 Strategy for Managing Technological Change and Resiliency

Power Services engages in many areas that serve to promote and integrate technological changes. Collaboration and knowledge sharing is an important strategy to adapt to these changes. Key collaborations enable BPA to keep abreast of the latest technological changes affecting the industry. They provide forums for addressing upcoming challenges and opportunities associated with new technologies. Power Services collaborates with CEATI interest groups, Reclamation Research and Development Group, the Corps' Hydroelectric Design Center, DOE Water Power Technologies office, and EPRI. BPA's Technology Innovation office has aided Power Services to develop roadmaps for technology innovation. These roadmaps steer our efforts toward the most beneficial innovations. They include three main categories pertinent to hydro assets:

10.2.3.1 Hydropower Reliability and Life Extension

1. **Machine condition monitoring**: Aimed at improving asset condition information to avoid damaging operations and to extend equipment life.
2. **Oil analysis advancements**: Aimed at improving oil testing technologies to provide better information about the condition of oil filled equipment.
3. **Predictive Analytics**: Systems that integrate machine condition monitoring and other operational information to predict when failures might occur, when maintenance or repair interventions will be necessary, and the optimal type of intervention. This information could be used to extend equipment life, reduce routine maintenance outages, and reduce routine maintenance costs. It would enable an informed transition to condition-based maintenance.
4. **Repair and life extension technology improvements**: One example is the development of cold-spray technology to allow longer lasting repairs of water passageway surfaces that have been damaged by cavitation.

10.2.3.2 Hydropower Equipment Environmental Risk Reduction

1. **Oil-free Kaplan turbine technology**: Aimed at reducing oil leaks into the river that result from leaking Kaplan turbines while assuring good asset life. BPA TI supported a project (TIP 213) to design a test stand for oil-less Kaplan bushing materials in collaboration with HDC and PNNL. BPA-PGA is now direct funding HDC to build the test stand with PNNL and for PNNL to conduct the testing.

2. **Environmentally acceptable lubricants (EALs)**: Aimed at developing EALs that are more specifically tailored to various hydropower applications.
    a. BPA is participating in a CEATI HPLIG Project #03/110 - Environmentally Acceptable Oil Test Program, which aims to identify, collect, and test EALs for performance characteristics that relate to hydroelectric and dam equipment.
    b. Building on the CEATI work, the HDC is planning further study to include specific considerations and recommendations for selecting and deploying EALs to Corps FCRPS dams.
3. **Oil accountability projects:** Power Services is direct funding HDC to develop equipment and methodologies to both measure and track oil within the facilities. The work includes modern sensors to measure oil levels and oil leaks as well as dovetailing with oil tracking and accounting systems, all with the aim of early detection and action to minimize oil leaks.
4. **Improved fish passage turbine and associated testing technology:** Aimed at reducing fish mortality through turbines and more effectively testing improvements.

10.2.3.3 Hydropower Facility Optimization

1. **Hydropower facility optimization**: Aimed at maximizing plant generation efficiency within operational constraints and providing actionable information to operators to assure non-damaging turbine operations in support of the Grid Modernization Federal Data Modernization project.

10.2.3.4 Technological Change

A long developing issue within the hydro industry is the adoption of digital control systems to replace analog control systems. This technological change has resulted in new equipment that offers advantages over the old, but is expected to have a shorter life. Asset management tools are being adapted to properly reflect expected replacement cycles and build them into the plans. Since condition scores are integral to the asset management process, Power Services and CEATI collaborate to improve the hydroAMP condition assessment methodology to differentiate between analog and digital equipment. Examples include:

1. Development of the hydroAMP Generic Equipment List that defines design lives for different assets, with attention paid to digital vs. analog asset types.
2. Modifications to the guides for Governors and Miscellaneous Electrical equipment to improve condition assessment of digital equipment.
3. Improvements to the hydroAMP condition assessment tools will continue into the foreseeable future, to assure they reflect current technologies as shown in the example above.

Data acquisition and control systems, known as SCADA or DACS, have been prone to short life expectancies. The Corps has developed a Generic Data Acquisition and Control System (GDACS) that is intended to extend the life expectancy of this asset type by incorporating components that use industry standard protocols and design (i.e. generic) and therefore could be replaced in the future without full system replacement. GDACS systems have been utilized in the FCRPS for over a decade with success, and their deployment will continue at facilities with aging SCADA systems. Deployment is expanding to Reclamation facilities as well.

Turbine replacements with improved fish passage turbines have been identified as important improvements to the lower Columbia and Snake River dams because of their fish passage and efficiency benefits. These projects have been studied at the system level in the Turbine Replacement Strategy, with the recommendation to

prioritize these projects and to perform refined studies for each facility to determine optimal investment design. Refined studies have been performed for McNary and John Day and others are on the horizon. These studies result in better identification of costs and benefits and facilitate planning and programming of turbine replacements.

CO2 generator fire-suppression systems are being re-assessed within the hydro industry for several reasons, including life safety concerns of CO2 and newer technologies that reduce fire risk, such as modern fast-acting generator protective relays, and modern low-flammability winding systems. BPA Power Services is direct funding a comprehensive study, coordinated by HDC, and executed by a consultant (HDR Engineering) with the goal of thoroughly analyzing the economics and life safety implications of various options, to determine if generator fire suppression is necessary and economical at specific facilities, and if so, which type of system is recommended. These options include replacement with modern CO2 systems, replacement with safer suppression media, and removal of the systems.

10.2.3.5 Resiliency

Resiliency is managed in an ad-hoc manner and strategies are not formally defined. Indefinite Delivery Indefinite Quantity Multiple Award Task Order Contracts are in place to allow more rapid response to equipment failures for critical equipment. Reclamation also has a joint process developed with BPA Transmission to promptly respond to emergencies in Reclamation operated switchyard and substation equipment.

Station service equipment serves an important function to keep equipment running during normal operations and allow it to operate during a grid outage. The FCRPS has developed a station service equipment design philosophy that aims to provide sufficient redundancy, which has led to an overall increase in redundancy at the plants to which it has been applied. As station service equipment replacements continue, each system will be evaluated and likely improved.

For power system level events, BPA has black start agreements with each Corps district and Reclamation that identifies black start plants and units. The agreements require testing every three years. These tests involve starting units and energizing a dead powerhouse line or bus to ensure that the operations can be performed if called upon. Corps and Reclamation also have various Emergency Action Plans that describe how project operations would continue in an emergency situation such as floods, earthquakes or terrorism. These plans provide courses of action to ensure project missions are restored as quickly as possible.

10.3 Planned Future Investments/Spend Levels

This SAMP is based on the capital investment levels derived from the methodology described in 10.2 and shown in Table 10.3-1. The recommended capital investment strategy remains to ramp up the combined expand and sustain budget to $300 million in 2024 and then increases at the rate of inflation. Forecasts for Libby Unit 6 and Dworshak Unit 4 are shown in the Capital Expand line items for Corps of Engineers. Note that these projects are optimized in the same portfolio as sustain investments and project timing is subject to change pending executive approval. Any changes in timing or forecasts would result in shifts between the capital and expand forecasts, but the total capital amounts will remain unchanged. Expense levels have held flat or decreased since 2018, absorbing the impacts of inflation. The previous SAMP identified the intent to return to capturing inflation after the BP22 rate period. For the Corps, expense levels are escalated at 2% per year starting in 2024. For Reclamation, expense levels also begin escalating at approximately 2% per year in 2024, but there is an $8 million reduction in the non-routine expense budget in 2026. This results in a slight decrease in total expense

between 2025 and 2026. After 2026, Reclamation's budget is escalated at 2% per year. Near-term budget increases are still expected to be less than inflation, which has been significantly higher than 2% in 2021. Note that expense levels may change between the development of the SAMP and the IPR initial proposal.

Table 10.3-1 Future Expenditures (in thousands)

Program	Rate Case FY's		Future Fiscal Years							
Capital Expand (CapEx)	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033
Corps of Engineers	12,906	4,834	25	0	0	505	2,264	4,031	4,037	2,509
Bureau of Reclamation										
Total Capital Expand	12,906	4,834	25	0	0	505	2,264	4,031	4,037	2,509
Capital Sustain										
Corps of Engineers	210,511	248,565	287,321	297,705	306,881	301,131	301,358	304,250	292,614	291,088
Bureau of Reclamation	76,583	52,906	25,564	22,295	20,668	33,733	39,801	43,142	62,829	74,093
Total Capital Sustain	287,094	301,471	312,885	320,000	327,549	334,864	341,159	347,392	355,443	365,181
Expense (OpEx)										
Corps of Engineers	257,608	262,760	268,016	273,376	278,843	284,420	290,109	295,911	301,829	307,866
Bureau of Reclamation	153,864	156,718	156,141	159,264	162,449	165,698	169,012	172,329	175,840	179,357
Total Expense	411,472	419,478	424,157	432,640	441,292	450,118	459,121	468,303	477,669	487,223

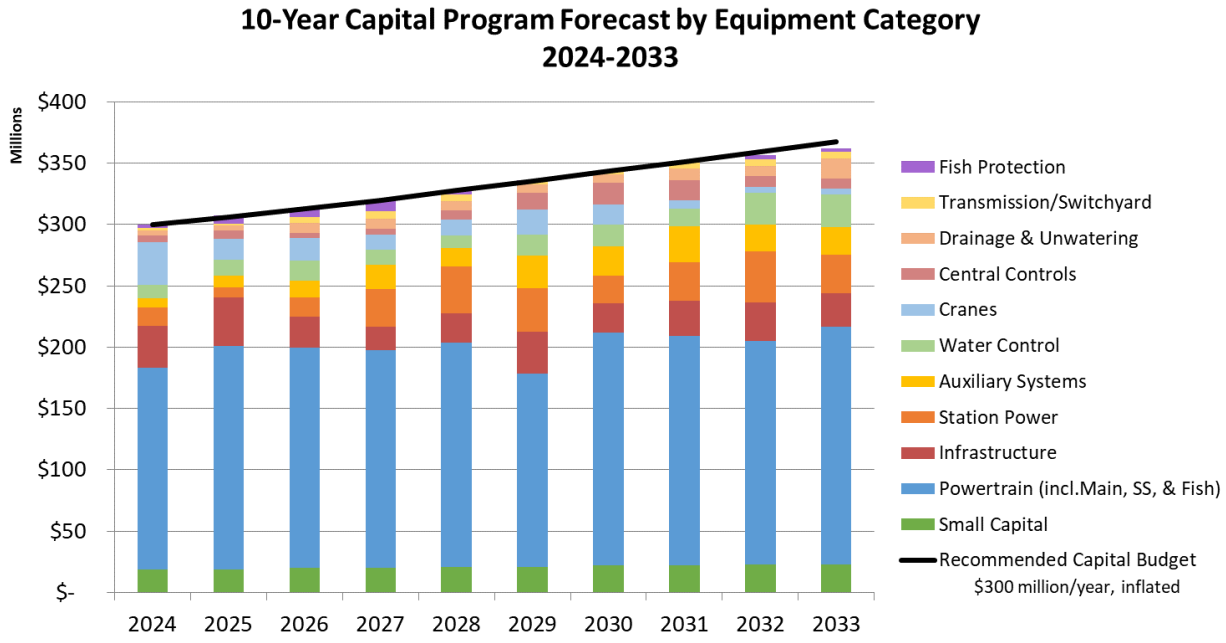
To accommodate for risks and uncertainties around execution, BPA used a midpoint for projected future Capital Expenditures shown in Table 10.3-2 below for BP-24 IPR and rate case processes only.

Table 10.3-2 Midpoint for Future Capital Expenditures used in IPR (in thousands)

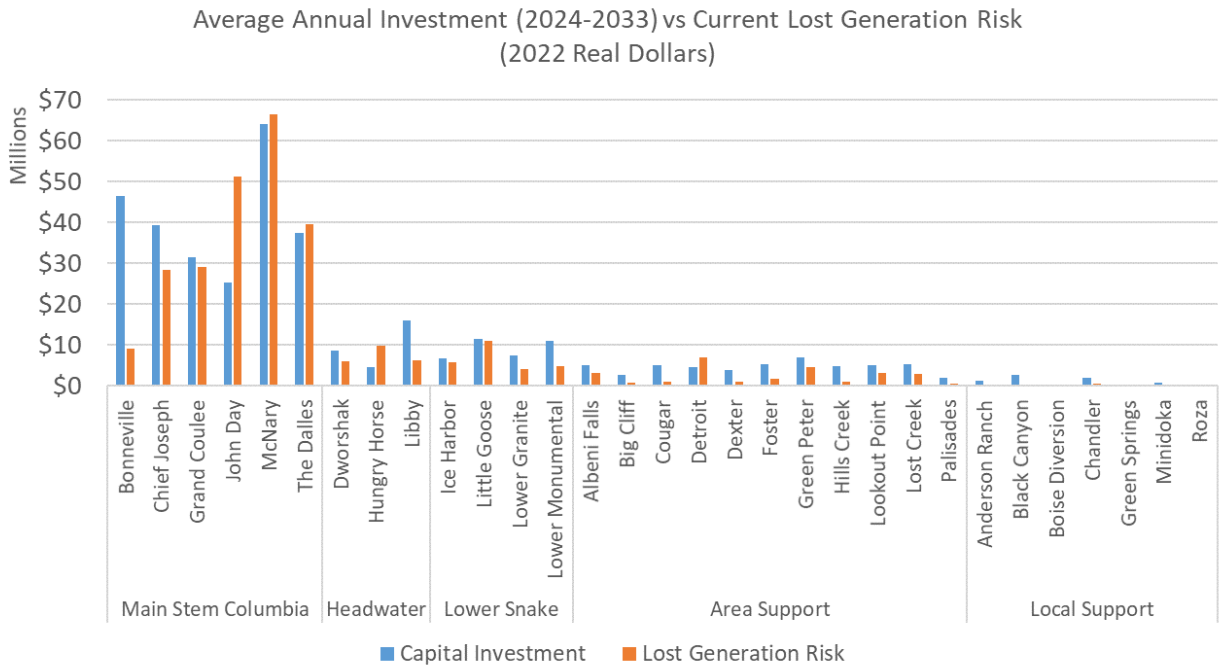
$ in Thousands	Federal Hydro Direct Capital Midpoint for IPR/BP-24									
Capital Sub-Categories	FY 2024	FY 2025	`FY 2026	FY 2027	FY 2028	FY 2029	`FY 2030	FY 2031	FY 2032	FY 2033
Expand										
Corps of Engineers	11,615	4,351	23	-	-	455	2,038	3,628	3,633	2,258
Bureau of Reclamation	-	-	-	-	-	-	-	-	-	-
Total Expand	11,615	4,351	23	-	-	455	2,038	3,628	3,633	2,258
Sustain										
Corps of Engineers	189,460	223,709	258,589	267,935	276,193	271,018	271,222	273,825	263,353	261,979
Bureau of Reclamation	68,925	47,615	23,008	20,066	18,601	30,360	35,821	38,828	56,546	66,684
Total Sustain	258,385	271,324	281,597	288,000	294,794	301,378	307,043	312,653	319,899	328,663
Fed Hydro Total	270,000	275,675	281,619	288,000	294,794	301,832	309,081	316,281	323,532	330,921

10.3.1 10-Year Capital Program Forecast

Investment in powertrain equipment is forecast to represent roughly half of the annual capital budget over the next 10-year period beginning in 2024. Crane replacements and modernizations, which have been quite common in the recent years ahead of powertrain projects, are forecast to decline from 2024 to 2033. Investment in infrastructure, station power, auxiliary system and water control assets increase slightly over this period as a result.



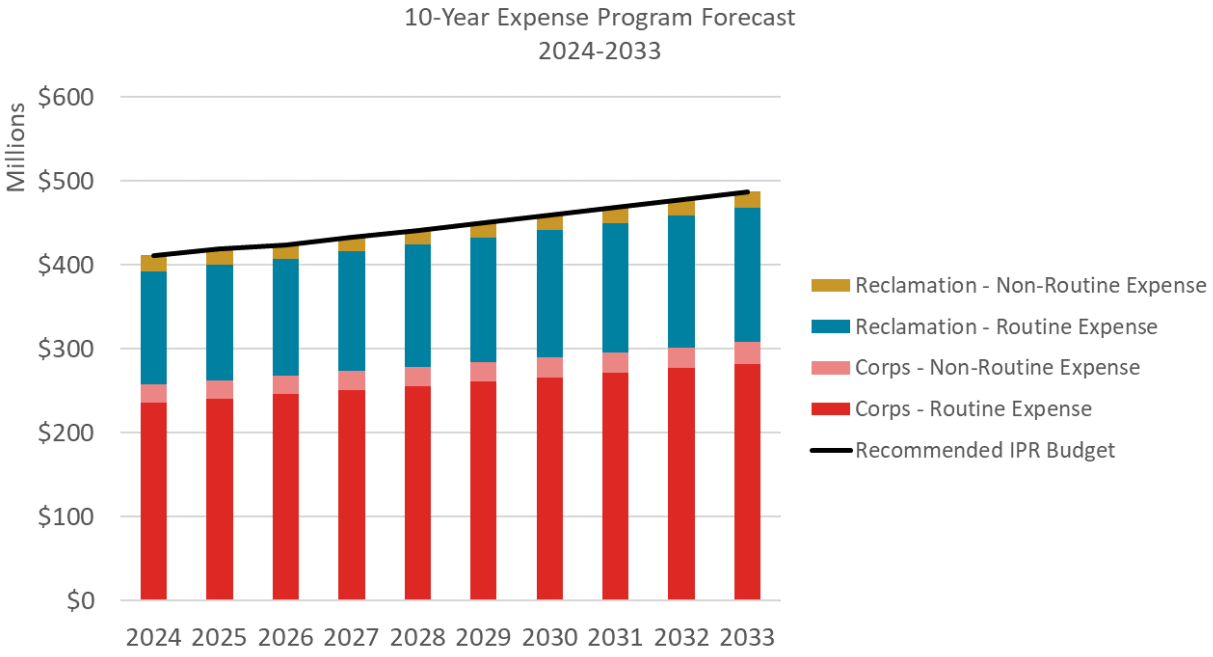
The chart below shows the average annual capital investment forecast at each plant from 2024-2033 versus the current level of Lost Generation Risk. Blue bars represent planned projects that are either in scoping, design, or construction. Orange bars show the current level of Lost Generation Risk based on asset condition, probability of failure, and failure consequences. As Lost Generation Risk is the primary driver for replacement in most powertrain assets, the FCRPS strategic approach tends to drive investments to be proportional to the lost generation at most plants.



Compared to the previous SAMP, there is a notable difference in investment forecast at Grand Coulee over the next 10 years. After analyzing their investment program, Reclamation determined that the amount of work in the queue for Grand Coulee between the modernization of Washington Powerplant units G19-21 and the electrical modernization of G1-18 was impractical. They elected to defer the electrical modernization on G1-18 until after the G19-21 modernization is complete. In addition, Reclamation, BPA, and the Corps have partnered on a new alternatives analysis for G19-21. This analysis uses the same approach that BPA and the Corps developed for analyzing optimal alternatives for the John Day, McNary and Libby modernization projects. The modernization of G19-21 will likely be one of the largest investments undertaken in FCRPS history, so extra time is being taken to ensure that an optimal path forward is selected. These shifts have resulted in existing budgets being reoptimized to other high value investments primarily at Bonneville, The Dalles and Libby dams.

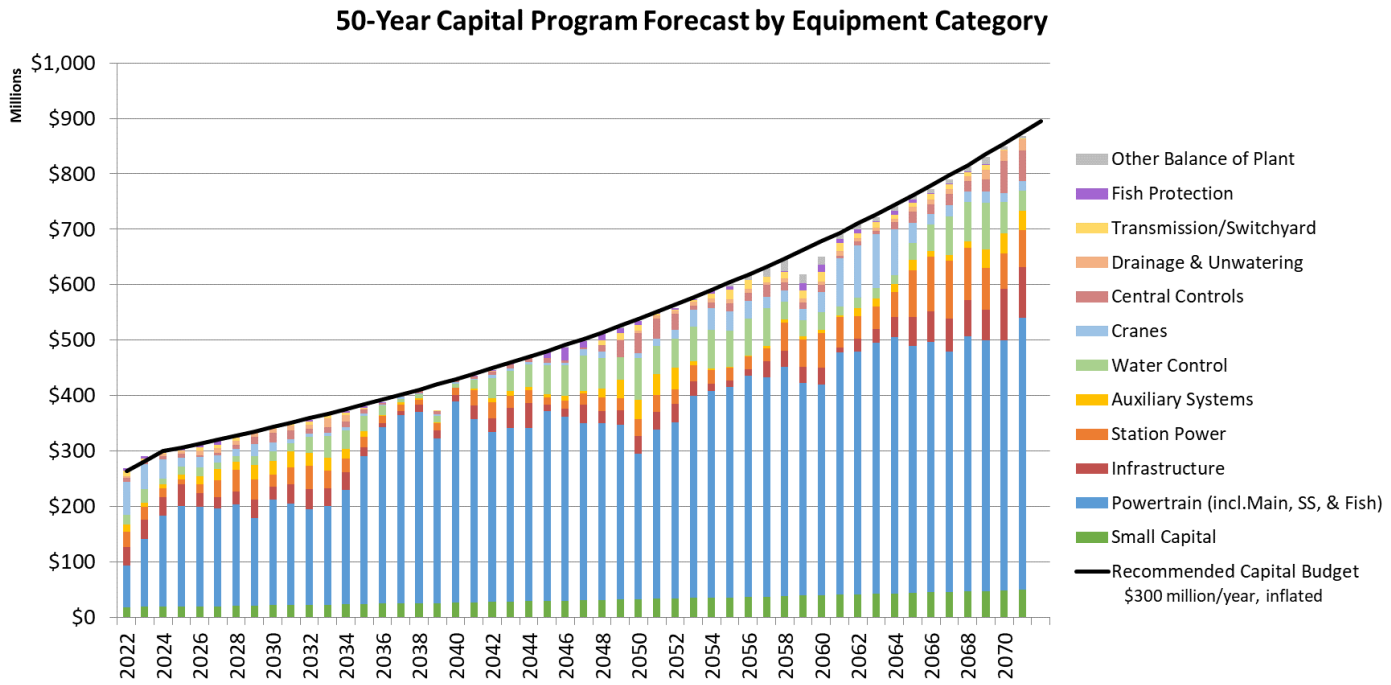
10.3.2 10-year Expense Program Forecast

Expense program budgets have not increased and have been absorbing inflation since 2018. Wages, which represent the majority of the routine expense budget, have historically risen at a rate that is even higher than inflation. Holding the expense program flat in nominal terms has been achieved through deferring non-routine expense projects, eliminating or consolidating positions through attrition, and cutting back in various areas of the operations and maintenance program. Holding budgets flat cannot continue indefinitely as the effect is a reduction in budget in real terms. This has been heightened by recent inflationary pressures influenced by global supply chain and labor shortages. The 10-year expense program forecasts assume roughly a 2% per year increase to lessen the impact of inflation over the time period.



10.3.3 Long-term Capital Outlook

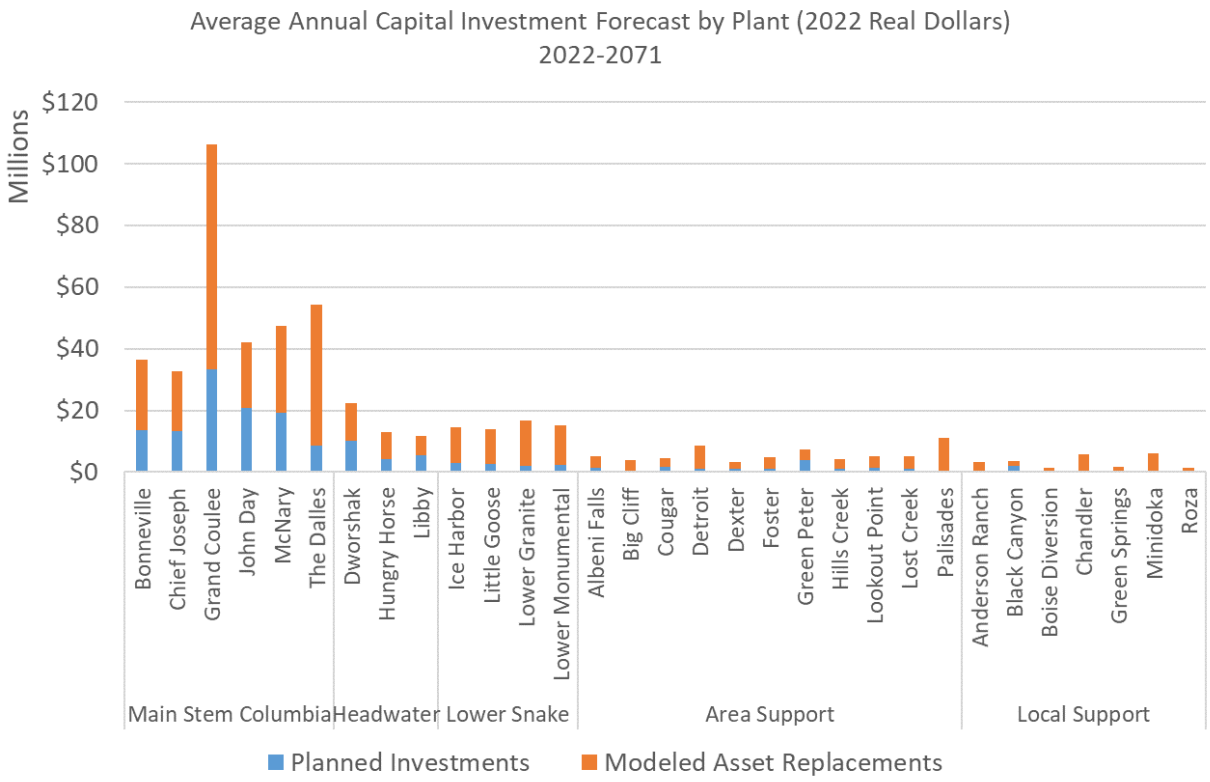
Beginning in the mid-2020s, investment in powertrain components will represent the majority of capital investments. This is a significant change from recent years in which much of the program has been focused on pre-modernization work. By 2025, powertrain investment will represent close to 60% of the budget compared to about 30% today. Investment in powertrain equipment is expected to increase further in the early 2030s when John Day Turbine and Generator replacements and GCL G19-21 modernization are in construction concurrently. In the mid-2030s, powertrain investments represent more than 80% of the budget. FCRPS asset management staff are continuing to discuss and evaluate the risks of deferring non-powertrain equipment in those years. Future revisions to the capital investment strategy may evaluate the benefits of a temporary increase in the capital program above the rate of inflation if those years prove to remain overly constrained.



The level of investment by strategic class over the 50-year study period is highly correlated with the amount of generation provided by each strategic class. Main Stem Columbia plants are planned to receive the vast majority of investment, consistent with the relative risk of lost generation and direct costs of failure posed by those plants. Investment in the Area Support plants is high relative to their contribution to the FCRPS generation portfolio; however, less investment is targeted at powertrain equipment. Only 50% of the total investments in Area Support facilities address powertrain components compared to about 70% for other strategic classes. Much of the investment in these facilities support their other authorized purposes.

Strategic Class	% of Average Annual Generation	% of 50-Year Capital Forecast
Main Stem Columbia	77%	63%
Lower Snake	12%	12%
Headwater	6%	9%
Area Support	4%	12%
Local Support	1%	4%

Unlike the 10-year forecast, which primarily consists of projects that are in planning and execution, the 50-year forecast mostly consists of modeled asset replacements derived from the optimal replacement timing methodology described in Section 10.2. This 50-year outlook gives a sense of the average annual investment priorities over the long term. In general, this long-term outlook looks very similar to the 2024-2033 snapshot presented in Section 10.3.1. However, additional investment needs at Grand Coulee beginning in the 2030s and beyond are captured.



10.4 Implementation Risks

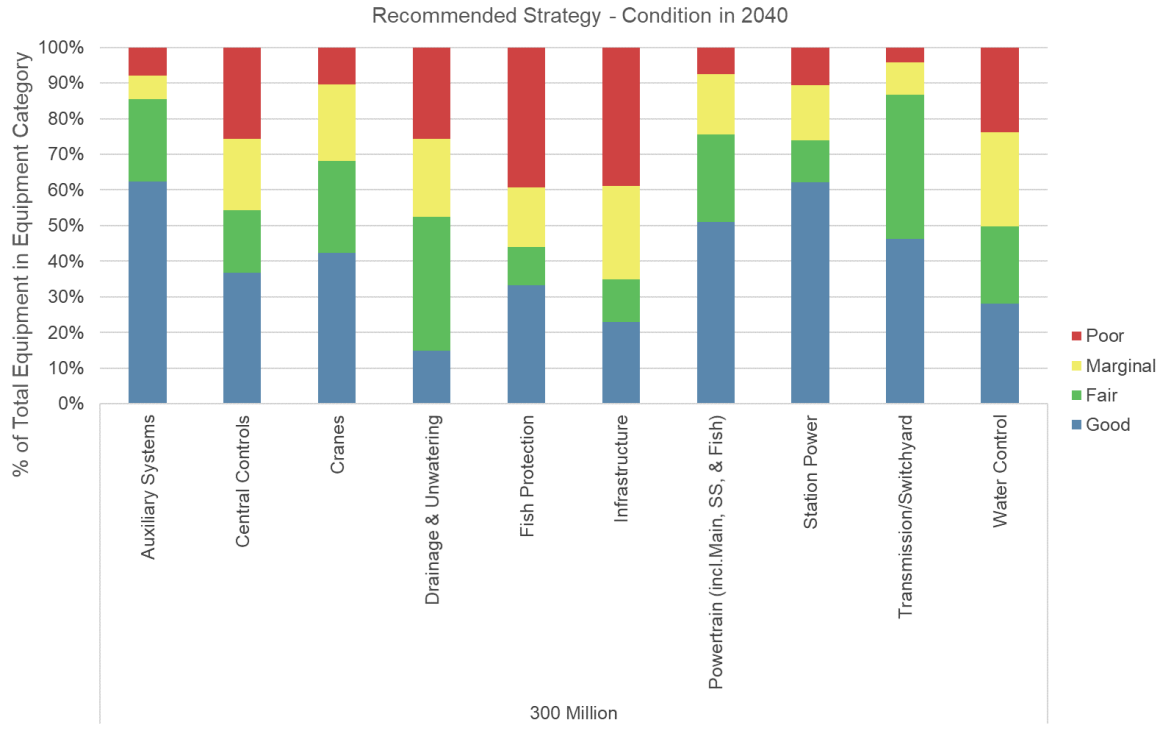
Table 10.4-1, Implementation Risks

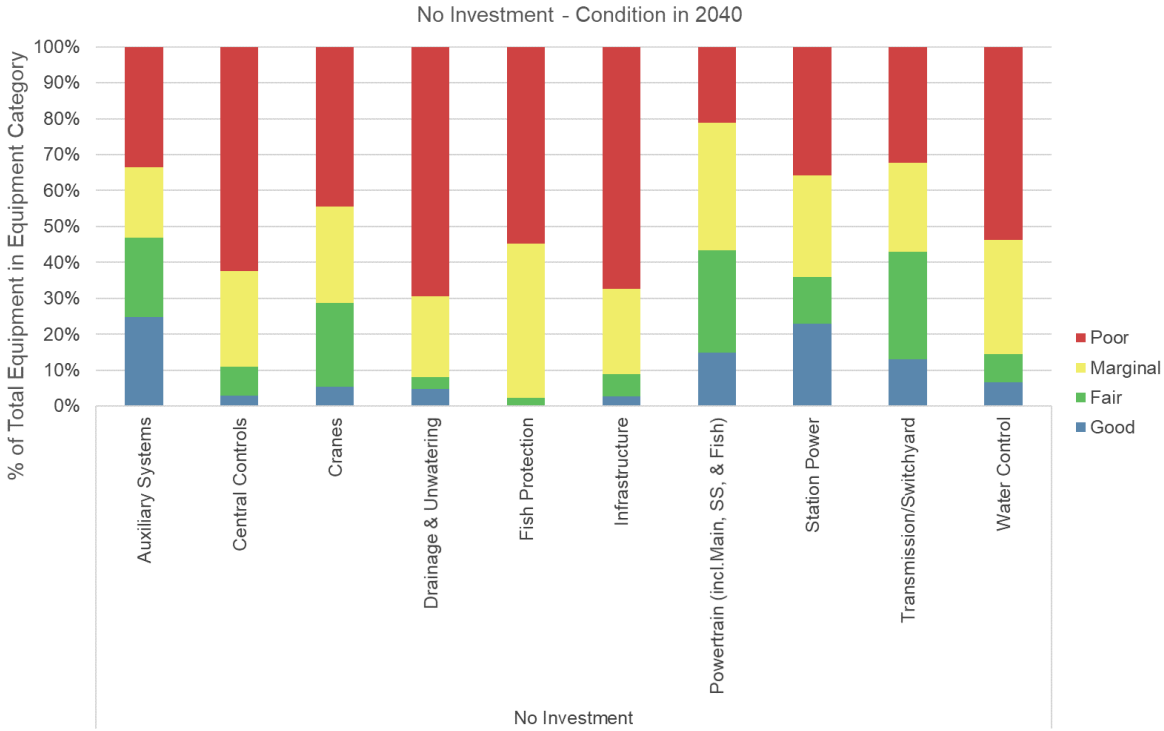
Risk	Impact	Mitigation Plan
Global supply chain constraints, labor shortages and material cost increases lead to project delays and project cost increases	The on-going impacts of the pandemic on supply chain, labor shortages and material costs result in an extended period of project cost increases and delays in project execution.	At present, project cost increases are being absorbed within existing program levels and budgets are re-optimized. FCRPS leadership continues to monitor this emerging risk as it develops.
Bids received are higher than government estimates causing reevaluation of priorities	Higher than expected bids can result in the need to reevaluate the timing and merits of a project. Some changes may result in deferring projects if the business case is severely impacted. The additional time to review can affect budget execution. Delays are compounded if bids received for joint assets require requesting additional federal appropriations.	Walla Walla District is the center of expertise for cost estimation at the Corps. For major projects, a cost and schedule risk analysis is employed to produce a risk-informed estimate for the cost and schedule of a project. The Corps is looking to adapt this to more projects as the majority are single point estimates.

Risk	Impact	Mitigation Plan
Decisions on Dworshak Unit 4 and Libby Unit 6 are not made in a timely-manner causing delays to other investments	The construction of Dworshak Unit 4 and the completion of Libby Unit 6 represent significant portions of the Walla Walla and Seattle district investment programs. The optimal timing of investments in existing units at those facilities are impacted by these decisions. Dworshak Unit 4, with a significantly higher cost than Libby Unit 6, poses the highest risk.	Proceeding with Phase 1 design on both projects will provide increased certainty around the costs and benefits of the respective projects so that they can be adequately evaluated within the investment portfolio. It also keeps the projects moving while the Phase 2 construction phase remains under consideration. Phase 1 design at Libby is ongoing but design for Dworshak Unit 4 is still pending approval.
Annual re-optimization of Asset Plan results in shifting resource requirements for Corps districts and Reclamation from year-to-year	Any perceived or real uncertainty in work ramping up or down at a given district or plant makes it difficult for the districts to adjust and plan resources. This is especially true at more remote facilities.	The Asset Planning Team will take the level of investment and number of projects by district into account when developing the System Asset Plan. More modest changes over time are easier to resource and plan for than having large shifts from district-to-district. Earlier collaboration between the agencies on business cases will result in improved alignment and streamlined approval of projects. This will lend more certainty to future investments and less shifting in each revision of the plan.
Optimistic project schedules result in under-execution of capital budget	Projects could take longer to execute than expected due to as-found conditions, contractor performance, outage scheduling or other factors. Without "shelf-ready" projects that resources can be shifted to, budget execution will be impacted.	Corps and Reclamation capital program managers provide 3-point estimates by project for the current year and the next fiscal year. A Monte Carlo simulation is run to produce a distribution of potential outcomes. Corps and Reclamation SOY budget requests are based on the results of this analysis. Although this captures some risk for near term budgets, a mitigation strategy still needs to be developed for the long-term portfolio.
Project complexity results in longer scoping and study than anticipated	Project schedules can be impacted when more studies or scoping are required than anticipated. Project justification for complex projects has taken more time than expected as our analyses and requirements evolve. This can also arise from disagreements in priorities or recommended project alternatives between BPA, the Corps, and Reclamation.	The Business Process Improvement Taskforce developed a project lifecycle map that outlines the process from project identification to approval and the requirements to pass each stage gate. Early collaboration via more interagency involvement in project delivery teams during the scoping of a project between the agencies reduces disagreements and ensures requirements for approval are agreed upon early in the process.
Regional strategies for prioritization are currently in development in order to ensure a consistent approach	Regional strategies and design philosophies for non-powertrain equipment are under development. These strategies are meant to improve alignment between the agencies on investments where benefits have been difficult to quantify and FCRPS-wide priorities have not been clear. If there is not Three Agency alignment on the completed strategies, timing and scope of related investments identified by the plants and districts will remain uncertain.	Regional strategy teams have representation from each agency to ensure that coordination happens during development.

10.5 Asset Condition and Trends

Condition over the next 20 years is expected to remain relatively stable under the recommended strategy compared to today. Investments made across the system are expected to prevent significant declines in availability that would be seen absent investment. By 2040, the vast majority of FCRPS assets would be expected to be in marginal or poor condition without investment, including almost 60% of the powertrain assets.





10.6 Performance and Risk Impact

Over time, the recommended plan will reduce the number of high-risk assets or limit increases to a manageable level. It is not expected that high-risk assets will be reduced to zero, nor is it the strategy. In some cases, the optimal intervention timing results in an asset remaining in the high-risk category for a number of years. Overall, assets that enter the high-risk category remain in the high-risk category for an average of 9 years in the recommended plan.

The following risk maps compare risk in 2040 under the recommended plan versus a no investment scenario.

10.6.1 Safety Risk

In 20 years, the number of high safety risk assets is expected to fall from 178 to 156. Without investment, the number would rise to 517. Assets that pass into the high safety risk category remain for an average of 10 years before replacement. In practice, operational procedures reduce these risks until the equipment is replaced.

Recommended Strategy - Safety Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	323	13	46	31	2
Likely	399	33	70	74	3
Possible	1053	136	150	213	4
Unlikely	1303	158	362	155	30
Rare	3823	289	438	426	123

Consequence

No Investment - Safety Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	714	82	180	87	65
Likely	901	90	246	162	23
Possible	2107	256	302	352	5
Unlikely	1539	129	265	168	30
Rare	1645	72	73	130	39

Consequence

10.6.2 Lost Generation Risk

In 20 years, the number of high lost generation risk assets is expected to fall from 238 to 155. Without investment, the number would rise to 1,121. Assets that pass into the high lost generation risk category remain for an average of seven years before replacement.

Recommended Strategy - Lost Generation Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	23	18	50	11	5
Likely	19	26	152	81	8
Possible	52	106	366	513	39
Unlikely	73	111	294	1045	84
Rare	44	137	800	3117	427

Consequence

No Investment - Lost Generation Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	29	41	132	298	18
Likely	23	39	290	606	67
Possible	55	107	553	1669	99
Unlikely	70	106	300	1129	199
Rare	34	105	387	1070	180

Consequence

10.6.3 Direct Cost Risk

In 20 years, the number of high direct cost risk assets is expected to increase from 402 to 443. Without investment, the number would be even higher at 1,118. Assets that pass into the high direct cost risk category remain for an average of 11 years before replacement.

Recommended Strategy - Direct Cost Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	6	76	276	58	1
Likely	8	83	381	105	3
Possible	8	318	998	230	6
Unlikely	36	467	1317	277	3
Rare	28	1293	3075	706	9

Consequence

No Investment - Direct Cost Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	26	237	692	184	3
Likely	31	314	860	235	4
Possible	17	767	1888	367	8
Unlikely	8	576	1317	275	5
Rare	4	345	1293	315	2

Consequence

10.6.4 Environmental Risk

In 20 years, the number of high environmental risk assets is expected to increase from 103 to 125. Without investment, the number would rise to 261. Assets that pass into the high environmental risk category remain for an average of 12 years before replacement.

Recommended Strategy - Environmental Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	321	26	9	59	
Likely	383	88	51	57	
Possible	976	263	223	94	
Unlikely	1555	236	140	77	
Rare	3567	665	354	513	

Consequence

No Investment - Environmental Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	789	198	39	102	
Likely	922	254	126	120	
Possible	1864	437	430	291	
Unlikely	1658	218	127	128	
Rare	1574	171	55	159	

Consequence

10.6.5 Compliance Risk

In 20 years, the number of high compliance risk assets is expected to increase from 11 to 15. Without investment, the number would rise to 94. Assets that pass into the high compliance risk category remain for an average of eight years before replacement.

Recommended Strategy - Compliance Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	313	21	12		
Likely	495	41	23		
Possible	1345	69	47		
Unlikely	1658	228	46		
Rare	4979	187	193		

Consequence

No Investment - Compliance Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	894	140	94		
Likely	1191	179	52		
Possible	2855	90	77		
Unlikely	1972	115	44		
Rare	1883	22	54		

Consequence

10.6.6 Public Perception Risk

In 20 years, the number of high public perception risk assets is expected to increase from zero to one. Without investment, the number would rise to seven. Assets that pass into the high public perception risk category remain for an average of five years before replacement.

Recommended Strategy - Compliance Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	312	33	1		
Likely	519	36	4		
Possible	1296	81	80	4	
Unlikely	1811	57	60	4	
Rare	5014	261	67	17	

Consequence

No Investment - Public Perception Risk in 20 years

Likelihood	Insignificant	Minor	Moderate	Major	Extreme
Almost Certain	1045	76	7		
Likely	1341	77	4		
Possible	2748	148	120	6	
Unlikely	1988	78	60	5	
Rare	1835	89	21	14	

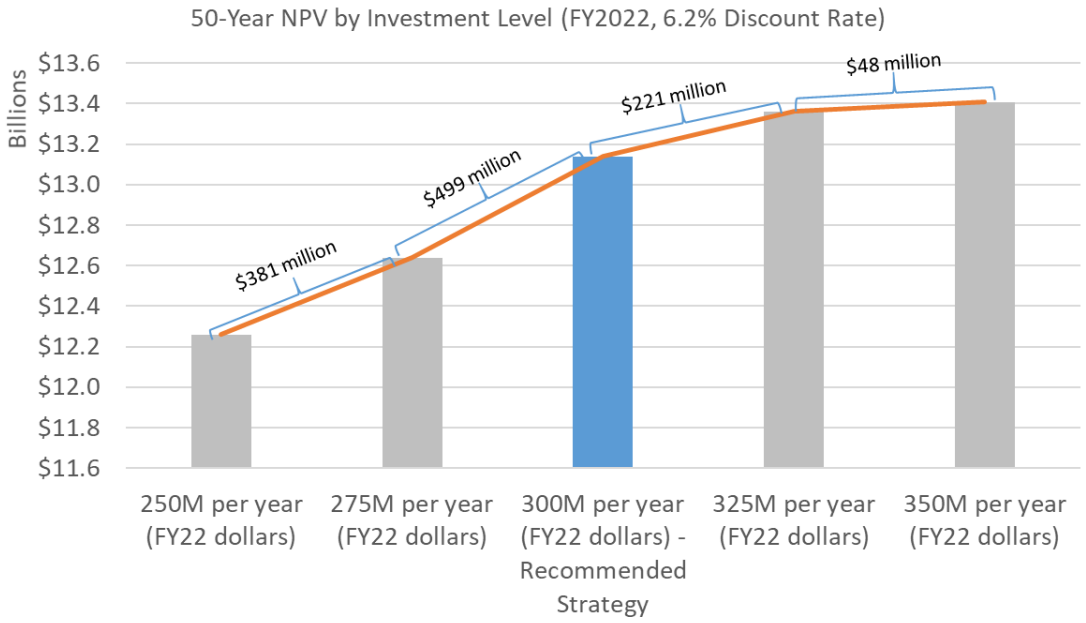
Consequence

10.6.7 Economics of the Strategy

Arriving at a recommended investment level involves performing sensitivity analysis to understand the cost and risk tradeoffs of different levels of capital investment. Five levels of investment were studied ranging from $250 million per year to $350 million per year, escalating at the rate of inflation. The model will identify investments up to these budget constraints if it is optimal to do so but will leave budget on the table if there are no remaining assets at or past their optimal replacement dates that minimize lifecycle cost. In this year's analysis of investment level over multiple years, the budget was fully consumed in most years for each investment level.

10.6.7.1 Net Present Value of Investment

Compared to a no investment alternative, all budget levels analyzed produce a Net Present Value between $12.2 and $13.4 billion through risk mitigation and efficiency benefits. Higher levels of investment over the recommended strategy produce incrementally smaller benefits and are less logistically feasible to execute. Lower levels of investment are significantly more costly from a risk perspective. The recommended investment level is expected to deliver a $13.1 billion NPV over the 50-year period of study.

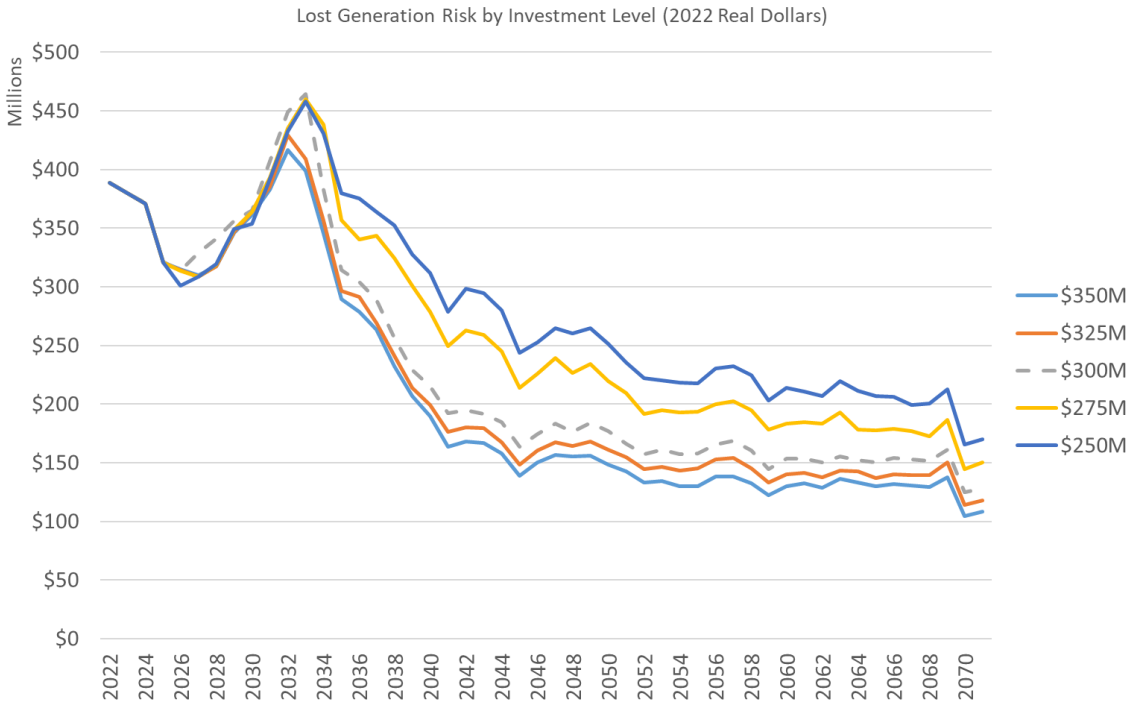


10.6.7.2 Long-term Risk Profiles

The following charts illustrate the risk profiles and lost efficiency opportunities associated with each capital investment level. Differences in funding levels begin in 2021 and reach their stated target by 2024. It is assumed that, on average, it takes four years from the start of a project before the construction phase begins. This means that the first year in which impacts of the different budget levels can be seen is 2025. Refer to Section 10.2 for how Lost Generation Risk, Direct Cost Risk and Lost Efficiency Opportunity are defined and calculated.

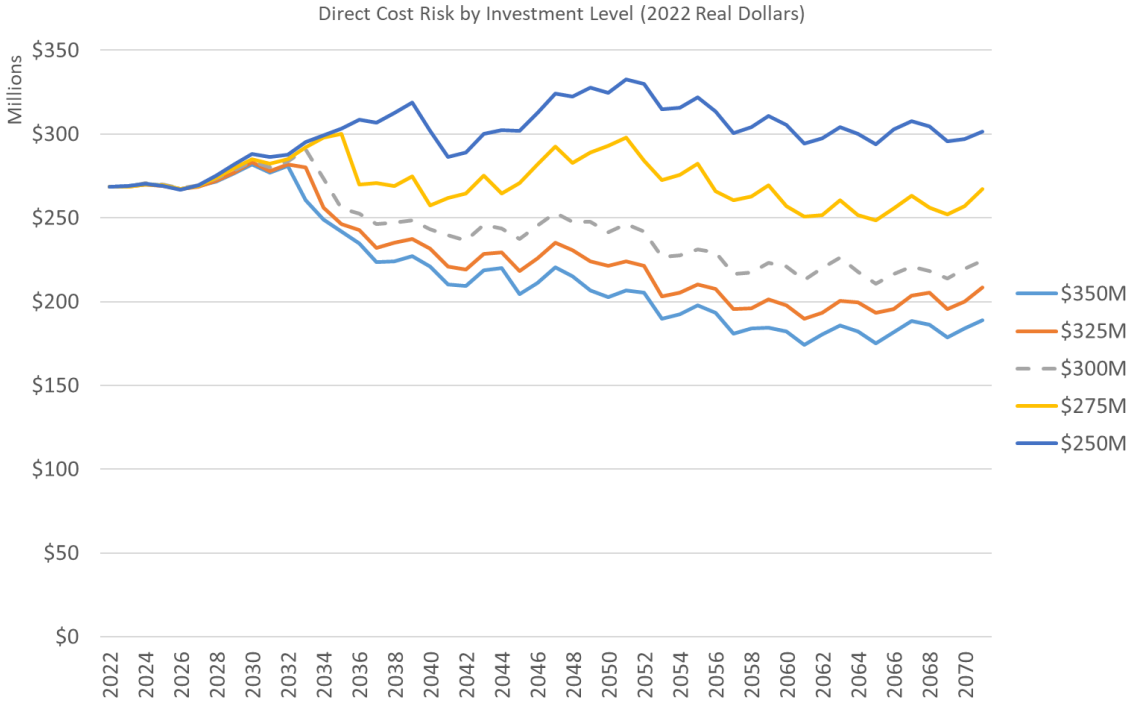
10.6.7.3 Lost Generation Risk

Under investment levels less than $300 million, a more significant portion of the capital budget is devoted to non-power generation assets that improve safety, maintain day-to-day operations or support the multipurpose missions of the dams. Beyond a $300 million program, the incremental reductions in lost generation risk are marginal.



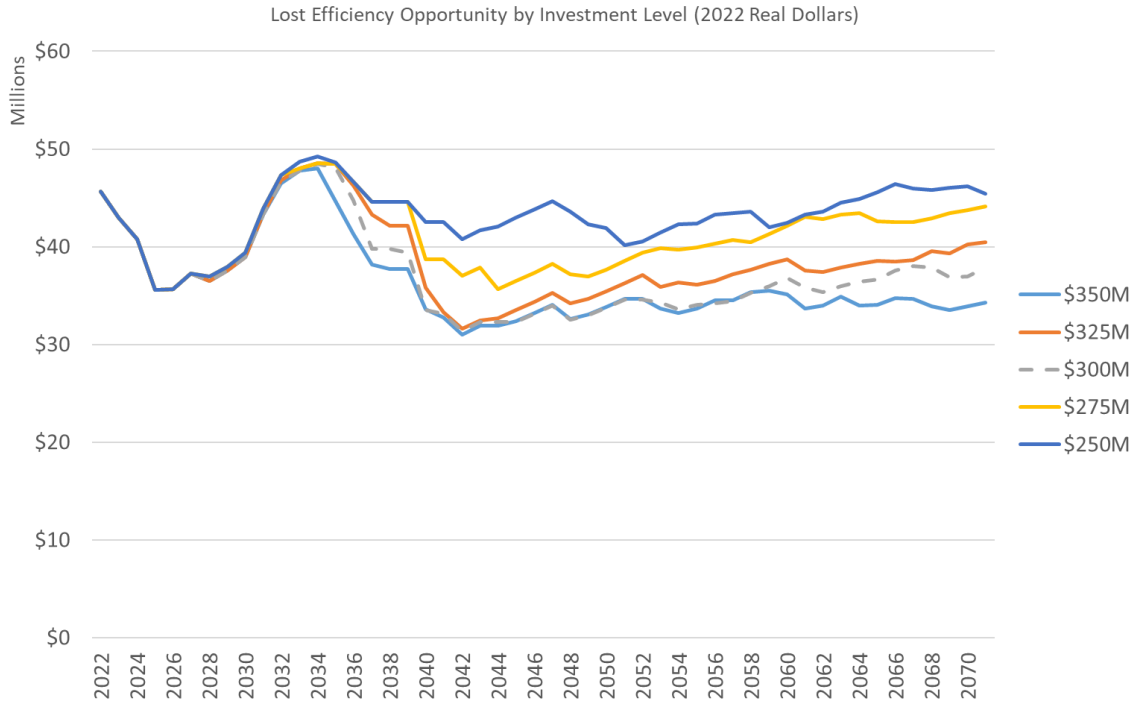
10.6.7.4 Direct Cost Risk

A $300 million investment level is expected to essentially maintain the current level of direct cost risk over the study period. Higher levels of investment can achieve modest decreases over time. Lower levels of investment show slight increases.



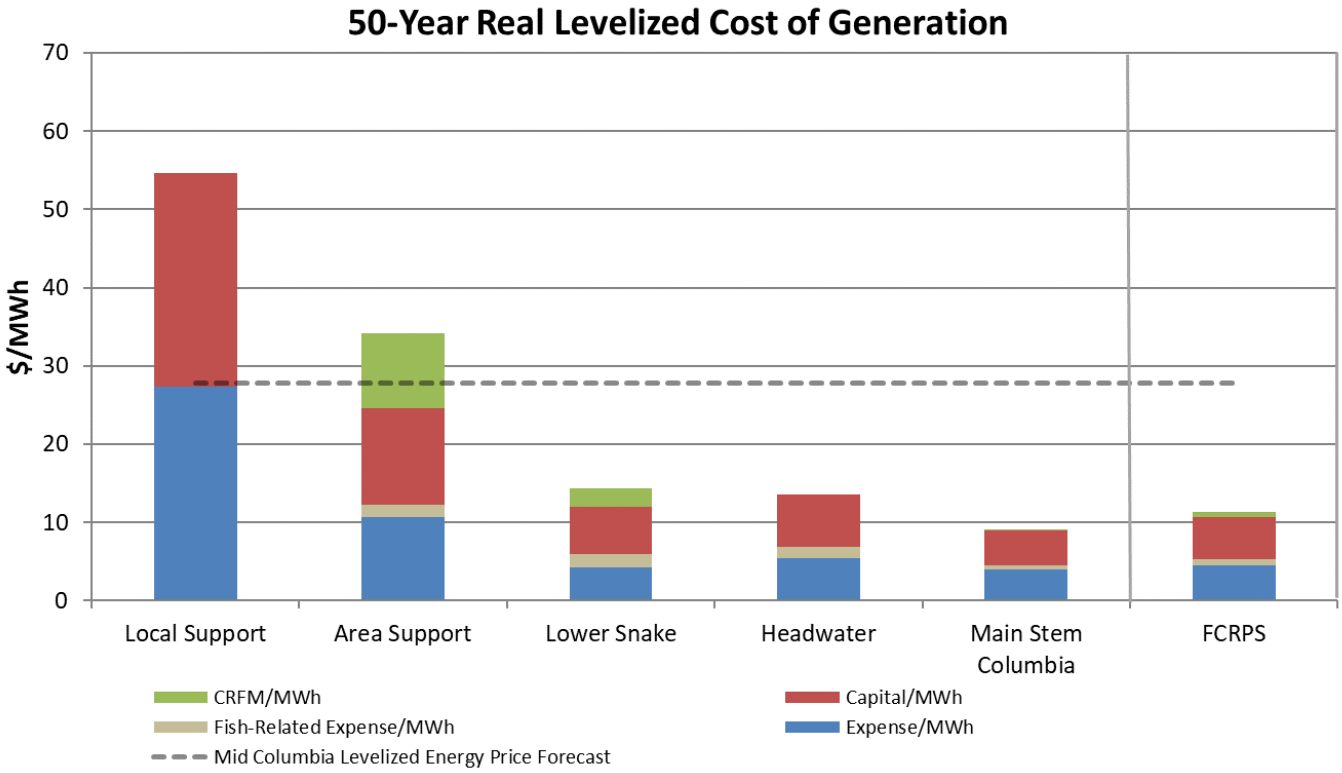
10.6.7.5 Lost Efficiency Opportunity

Similar to Lost Generation Risk, there is a higher lost efficiency opportunity at investment levels below $300 million per year. This is again because there is proportionately less budget available for powertrain components, resulting in fewer turbine replacements that provide generation efficiency benefits. Due to constraints on how many concurrent turbine replacement projects can be supported across the system, higher levels of investment than $300 million per year are not expected to result in a significant reduction in the Lost Efficiency Opportunity.



10.6.7.6 Real Levelized Cost of Generation

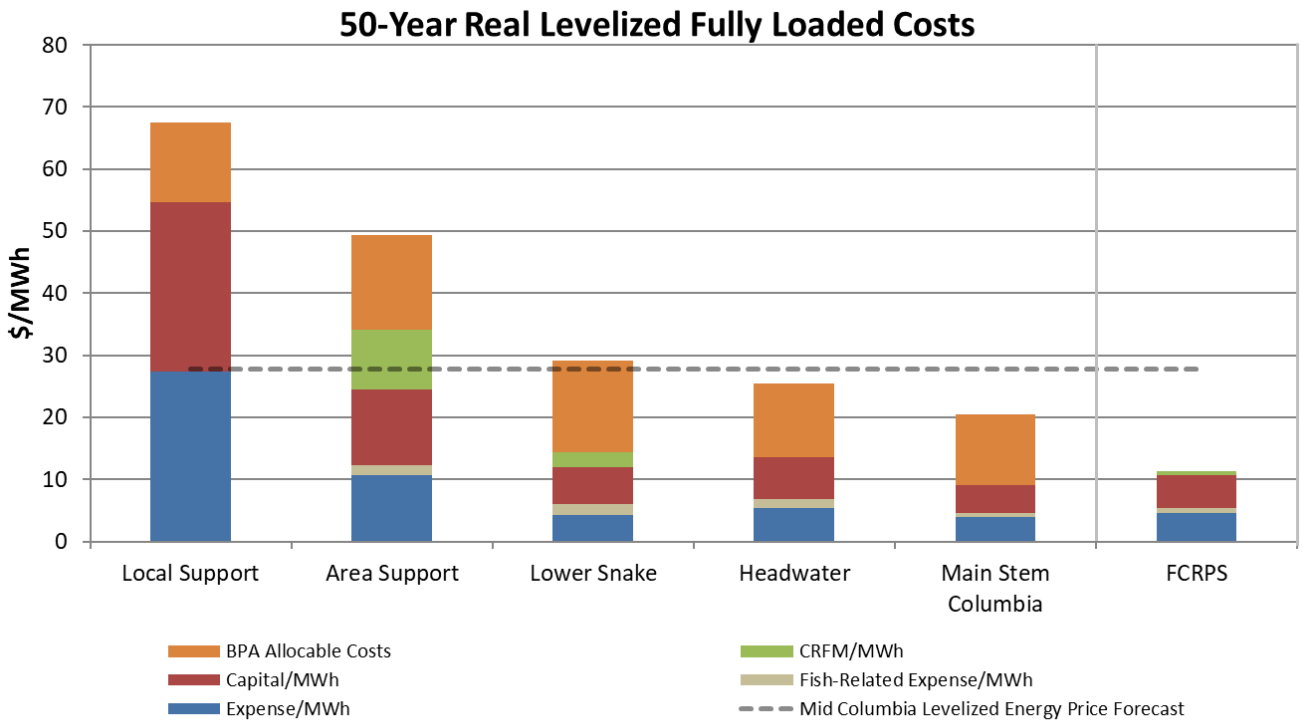
The Levelized Cost of Generation is a forward look at the Cost of Generation metric described in Section 8.3.6. It takes the capital and expense programs outlined in the recommended strategy and levelizes them over a 50-year period to give a representative annual capital and expense value. Plant generation is also modified based on the changes in the lost generation risk profiles to recognize difference from current conditions. For purposes of this analysis, financing is not considered for capital expenditures. As the Willamette Valley EIS is currently on-going at the time of writing for this SAMP, levelized costs of generation are reflective of pre-EIS and pre-injunction operations and structural measures. A levelized cost analysis will be included in the Willamette Valley EIS, incorporating the impacts of operational changes, and structural measure costs. These measures are expected to significantly increase the cost of generation above the pre-EIS and pre-injunction levels shown below. Outcomes from the EIS will be captured in in the 2024 FCRPS SAMP. Note that the "Area Support" strategic class is primarily made up of Willamette Valley plants.



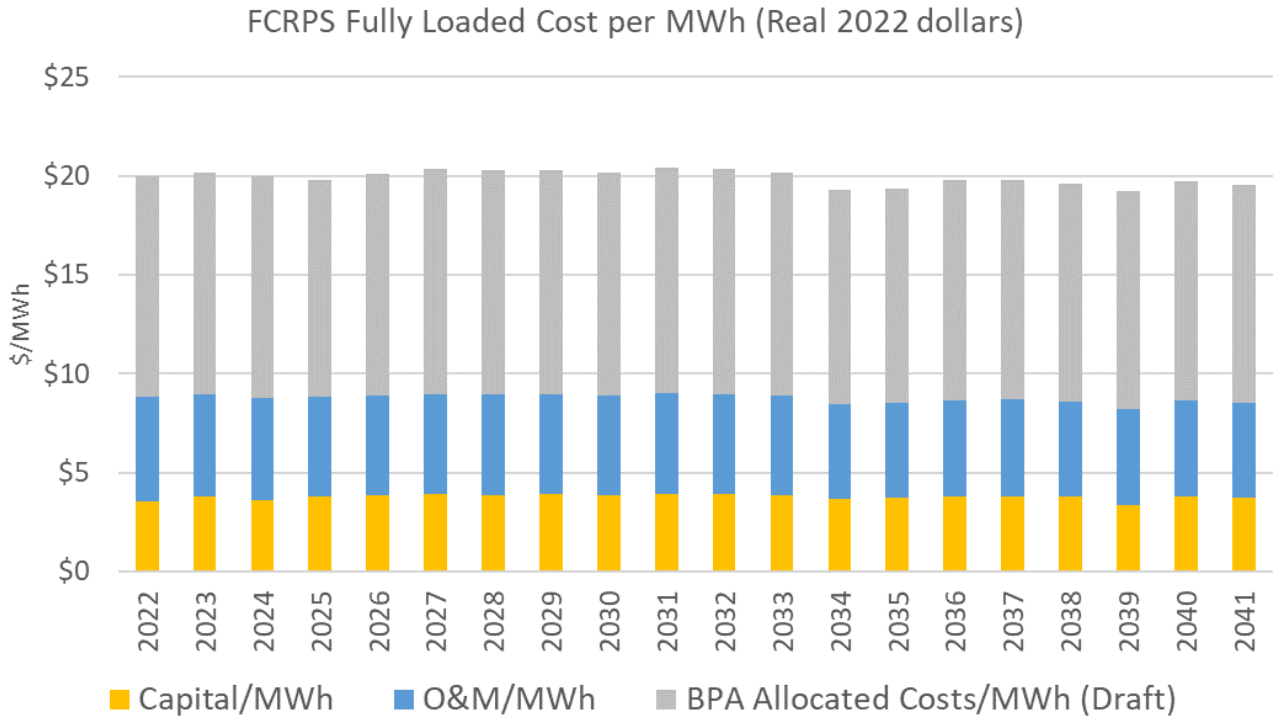
As a whole, the FCRPS has a 50-Year Real Levelized Cost of Generation of $10.14/MWh compared to a real levelized energy price forecast of $28/MWh for the Mid-Columbia. All plants in the Main Stem Columbia, Headwater and Lower Snake strategic classes are expected to produce power at or below the real levelized energy price. This means that 84% of the capital investment program over the next 50 years is targeted at plants producing power at a cost below the expected spot market energy price. Note that, like the Cost of Generation metric, this is not an "all-in" cost and only considers the incremental costs of generation.

10.6.7.7 Real Levelized Fully Loaded Cost

The Real Levelized Fully Loaded Cost includes allocations for all costs that can be attributed to the FCRPS. This includes BPA's Fish and Wildlife Program, Residential Exchange and other BPA overheads. Future BPA allocable costs are assumed to increase at the rate of inflation for the purpose of this analysis. The strategy outlined in this SAMP is expected to result in a Real Levelized Fully Loaded Cost of $22.13/MWh for the 50-year study period. Thus, planned investments over the next 50 years are forecasted to result in only a minor increase over the system's current Fully Loaded Cost of $20.70/MWh shown in Table 8.3.6-1 over FY18-FY20. Additionally, the 2022 SAMP forecasted Levelized Fully Loaded Cost of $22.13/MWh is only slightly higher than the 2020 SAMP forecast of $22.00/MWh.



At the FCRPS system level, Fully Loaded Costs are expected to remain relatively stable over the next 20 years under the capital and expense programs outlined in this SAMP. In real dollars, there is potential for a slight reduction in fully loaded costs in future years due to increased average annual generation from higher reliability and unit efficiency improvements.



10.6.7.8 Summary of Results

To summarize, over 60% of the capital and expense programs in this SAMP are targeted at the Main Stem Columbia, which has a 50-year incremental cost of generation of $8.08/MWh and a fully loaded cost of $19.46/MWh. Budgets for the Lower Snake and Headwater strategic classes are proportional to the amount of generation they contribute to the system. Multipurpose activities represent a larger portion of the budgets for Area Support and Local Support facilities, resulting in budgets proportionately higher than the amount of FCRPS generation they represent. In total, the 50-year levelized Cost of Generation for the FCRPS is forecast to be $10.14/MWh and the 50-year levelized Fully Loaded Cost is $22.13/MWh. Both metrics are highly competitive with recent market prices and BPA's expectations for market prices in the future.

Strategic Class	% of FCRPS Average Annual Generation	% of 50-Year Capital Forecast	% of 50-Year Expense Forecast	50-Year Cost of Generation ($/MWh)	50-Year Fully Loaded Cost ($/MWh)
Main Stem Columbia	77%	63%	66%	$8.08	$19.46
Lower Snake	12%	12%	13%	$12.50	$27.22
Headwater	6%	9%	8%	$13.15	$24.97
Area Support	4%	12%	9%	$32.77	$47.87
Local Support	1%	4%	4%	$42.24	$55.17
FCRPS	100%	100%	100%	$10.14	$22.13

11.0 Addressing Barriers to Achieving Optimal Performance

11.1 Departmental Challenges

Due to the nature of having three separate government agencies collectively acting as a single hydropower utility, there are inherent challenges to achieving optimal performance. While BPA is focused on the generation and transmission of power, the Corps and Reclamation have a broader focus on the multipurpose missions of the dams. They also must comply with nationwide policies and procedures set within their respective departments. It is important to acknowledge that the Three Agencies have varying levels of influence over these nationwide policies and procedures established at the departmental level. In some cases, this means that there are aspects of the asset management process over which the Three Agencies have less control than a typical utility.

11.2 Hydropower Acquisition

Contracting and acquisition processes present ongoing challenges in the FCRPS that the Three Agencies are addressing. The FCRPS continues to prioritize improvement and growth in this area. With hydro equipment having so many unique and complex aspects, it is a regional priority to build more effective, efficient and optimal acquisition strategies and processes. Several steps are underway to accomplish this. For example, in the Corps, a team of experts began implementation of two courses of action (COAs) to improve hydro acquisition. One COA leads to improvement in standardizing acquisition source selection plans and evaluation criteria. The other COA leads to a cross-District sharing of hydro acquisition experts to assist with high-risk projects. In the FCRPS, the Corps and Reclamation are together revitalizing a cross-agency contracting team to align and communicate best practices, improve efficiencies, develop cross-agency acquisition training, and when feasible, develop cross-agency tools. These COAs look to mitigate the impacts of some of the inefficiencies that arise from disparate contracting requirements.

11.3 Differing Agency Missions and Joint Assets

Hydropower is just one of the missions that the Corps and Reclamation must balance for the dams on behalf of the region. Reclamation has a significant irrigation and water management mission and some Corps dams provide extensive navigation, flood risk mitigation, and water supply benefits. Differences in the understanding and definition of risk across the Three Agencies, especially for non-power generation assets, can occasionally be source of inefficiency in the asset management process.

One way that the Agencies are seeking to remedy this inefficiency is by improving the modeling of these assets in existing asset management processes. Modeling the benefits and risks of investment in joint assets is currently not as sophisticated as the modeling for powertrain assets. As a result, the value of joint assets often does not compare well with powertrain assets, resulting in joint investments being deferred in favor of powertrain investments. Recognizing that joint assets still must be invested in and that their risk and benefits are not fully captured, the Asset Planning Team currently reserves a percentage of the annual capital budget for joint assets. Joint investments are then optimized within this sub-portfolio and locked in place. This interim methodology ensures that a reasonable level of investment continues in joint assets. Although joint assets are not optimized with all other assets, the same optimization techniques used on the broader portfolio are used within the joint sub-portfolio to determine priorities. In FY22, FCRPS staff will investigate how to improve modeling for spillway gates. This will serve as a pilot for better capturing the value of joint assets so that they can be fairly traded off against power generation assets.

In FY21, FCRPS staff identified the need to capture and monetize irrigation impacts to improve discussions around Reclamation investments that affect irrigation. Reclamation developed a model to quantify how incremental unit outages, investment, operations and maintenance costs affect their Reserve Power Rate. As of early FY22, this model has been used in an ad hoc manner to inform investment decision making. Asset Management staff plan to further discuss how to implement these impacts consistently within standard asset management processes.

11.4 Alignment of Equipment Capabilities with Operational Needs

Historically, BPA Power products and services have been developed based on the capabilities and limitations of the existing assets. With major powerplant modernization projects on the horizon, there is an opportunity to shape the design of the assets around future needs. Increased collaboration between BPA operations, the trading floor and FCRPS asset management is critical to ensure these opportunities are realized. For the John Day Turbine and Generator replacement project, for example, there has been close coordination between the Corps design team, district and plant staff, BPA Power, BPA Fish and Wildlife, and BPA Transmission to ensure that the modernized units meet the needs of each party.

12.0 DEFINITIONS

Asset Investment Excellence Initiative (AIEI): A Federal Columbia River Power System initiative to improve long term capital investment planning capabilities and processes.

Asset Planning Team (APT): Federal Columbia River Power System long term planning team tasked with development of the System Asset Plan.

Bonneville Power Administration (BPA): Power Marketing Authority in the Pacific Northwest under the Department of Energy.

Copperleaf: Asset Investment Planning and Management Tool used by Federal Columbia River Power System long term planning staff.

Capital Workgroup (CWG): Federal Columbia River Power System technical and economic Capital Investment review team tasked with review and approval of all Large Capital investments.

CEATI: User-driven organization that facilitates electric utility information sharing and technical projects for its participants.

Columbia River Fish Mitigation (CRFM): A program to mitigate the impacts to fish posed by the dams primarily on the lower Columbia and lower Snake Rivers.

Days Away Restricted or Transferred (DART): The number of recordable non-fatal injuries and work-related illnesses resulting in lost time or days on restricted or transferred duty per 100 full-time workers.

Direct Cost Risk (DCR): A risk calculated in Predictive Analytics reflecting the incremental cost of equipment failure compared to planned replacement (not including lost generation).

Direct Funding Agreements: Memoranda of Agreement that establish the ability for BPA to directly fund the Capital and Operations & Maintenance programs of the Corps and Reclamation.

Executive Steering Committee (ESC): A Three Agency leadership team that develops long term goals and strategies for the FCRPS and provides guidance to the Joint Operating Committees.

Expenditure: Term used by the Capital Investment program to describe an investment activity.

EUCG: Member-based trade association comprised of professionals from utility companies that meets semi-annually to provide a forum and tools to exchange information, share lessons learned, and find solutions to industry issues.

Federal Columbia River Power System (FCRPS): The Three Agency partnership comprised of the United States Army Corps of Engineers, United States Bureau of Reclamation and Bonneville Power Administration tasked with delivering on the multipurpose missions of the 31 federal hydroelectric facilities in the Pacific Northwest.

Hydraulic Plant Life Interest Group (HPLIG): A CEATI interest group focused on hydropower technology, asset management, operations & maintenance and best practices sharing.

hydroAMP: Hydro industry equipment condition assessment framework.

Integrated Program Review (IPR): A BPA financial public process in which capital and expense programs are reviewed with customers, stakeholders and other interested parties.

ISO 55000: A series of three international standards for Asset Management.

Joint Operating Committee (JOC): A committee tasked with overseeing the implementation of the direct funding agreements.

Lost Efficiency Opportunity (LEO): An opportunity cost calculated in Predictive Analytics that is associated with deferral of investment in more efficient equipment.

Lost Generation Risk (LGR): A risk calculated in Predictive Analytics reflecting the incremental loss of generation resulting from forced outages due to equipment failure.

Lost Time Accident Rate (LTAR): The number of recordable non-fatal injuries and work-related illnesses resulting in lost time per 100 full-time workers. Restricted to hydro-related incidents and only counts hydropower labor hours. Calculated on a 365-day rolling window to provide an annual rate, using 100 FTE = 200,000 man-hours.

North American Electric Reliability Corporation (NERC): Nonprofit corporation that develops standards for power system operation, monitors and enforces compliance, assesses resource adequacy and provides power system operation education and training resources.

North American Electric Reliability Corporation Critical Infrastructure Protection (NERC CIP): A set of Cyber and Physical Security requirements designed to secure the assets required for operating North America's bulk electric system.

Non-Routine Expense (NREX): Investment projects or large, maintenance activities that are not regularly re-occurring and are not classified as a capital expenditure.

Operations and Maintenance (O&M): The routine activities performed by the Corps and Reclamation as operators of the 31 hydroelectric facilities.

Operations and Maintenance Optimization Initiative (OMOI): The Corps' initiative to improve O&M decision making through a better understanding of value and risk to all missions at the facilities.

PAS 55: The predecessor to ISO 55000 and the first publicly available specification for optimized management of physical assets.

Predictive Analytics (PA): Copperleaf asset lifecycle cost minimization module.

United States Army Corps of Engineers (Corps): Operator of 21 Federal Columbia River Power System plants under the Department of the Army.

United States Bureau of Reclamation (Reclamation): Operator of 10 Federal Columbia River Power System plants under the Department of the Interior.

Reliability Implementation & Technical Subcommittee (RITS): Subcommittee of the Joint Operating Committee that is tasked with providing direction to the FCRPS regarding matters dealing with reliability and compliance issues, managing

changes in Bulk Electric System Reliability Standards and requirements and managing interagency power generation/transmission technical issues.

Strategic Asset Management Plan (SAMP): A document specifying a long-term optimized approach to asset management, derived from, and consistent with, the organizational strategic plan and asset management policy.

Strengths, Weaknesses, Opportunities, and Threats (SWOT): A strategic planning and strategic management technique used to help an organization identify strengths, weaknesses, opportunities, and threats related to business competition or project planning.

System Asset Plan (SAP): A document specifying the projects, resources and timescales associated with achieving the goals described in the Strategic Asset Management Plan. Sometimes referred to as the "Asset Plan."

Three Agency: Refers to the partnership between Bonneville Power Administration, the United States Army Corps of Engineers and the United States Bureau of Reclamation.

Total Case Incident Rate (TCIR): The sum of all recordable non-fatal injuries and work-related illnesses per year per 200,000 labor hours.

Total Dissolved Gas (TDG): A measure of the concentration of dissolved gasses in water downstream of spillways resulting from spilled water at dams.

Value Framework: A module in Copperleaf that allows for the comparison and optimization of an investment portfolio.

Western Electricity Coordinating Council (WECC): The Regional Entity responsible for compliance monitoring and enforcement applicable to the Pacific Northwest.