A Comprehensive Approach to Assess Current and Future Vulnerabilities in the Columbia River Reservoir System under Climate Change

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Extended Abstract

The water resources of the Columbia River Reservoir System sustain an economically critical food-energy-water nexus. Across the system, long-term water management planning is challenged by future hydrologic variability associated with climate change. The U.S. Army Corps of Engineers (USACE) has established climate policy aimed to reduce operational vulnerabilities to the effects of climate change and variability; however, the use of climate information in policy and planning continues to be developed and is typically limited to qualitative assessments due to large uncertainties associated with projected outcomes. Here, we present a novel approach for demonstrating the performance of current operating criteria of the Columba River Reservoir System under a wide range of historical and future hydrological conditions and further attributing shifts in performance to underlying hydrologic and operational conditions.

Integration of climate change into long-term planning studies has been a priority of USACE Northwestern Division, Seattle, Portland, and Walla Walla districts and our federal partners for more than 15 years. USACE has partnered with the Bonneville Power Administration, U.S. Bureau of Reclamation (USBR), and several academic and research institutions to evaluate the effects of climate change in the Columbia River Basin (RMJOC 2011; RMJOC 2018; RMJOC 2020). Through these efforts, datasets and modeling tools have been continuously developed toward applications that are relevant and reliable for decision making frameworks. The USACE climate change team has taken the modeling results from the recent studies (RMJOC 2018; RMJOC 2020) and applied them in a comprehensive operational vulnerability assessment for the Columbia River Reservoir System. This work represents one step along a development pathway for supporting adaptive management planning to foster resilience in the face of hydroclimatic change (Figure 1).

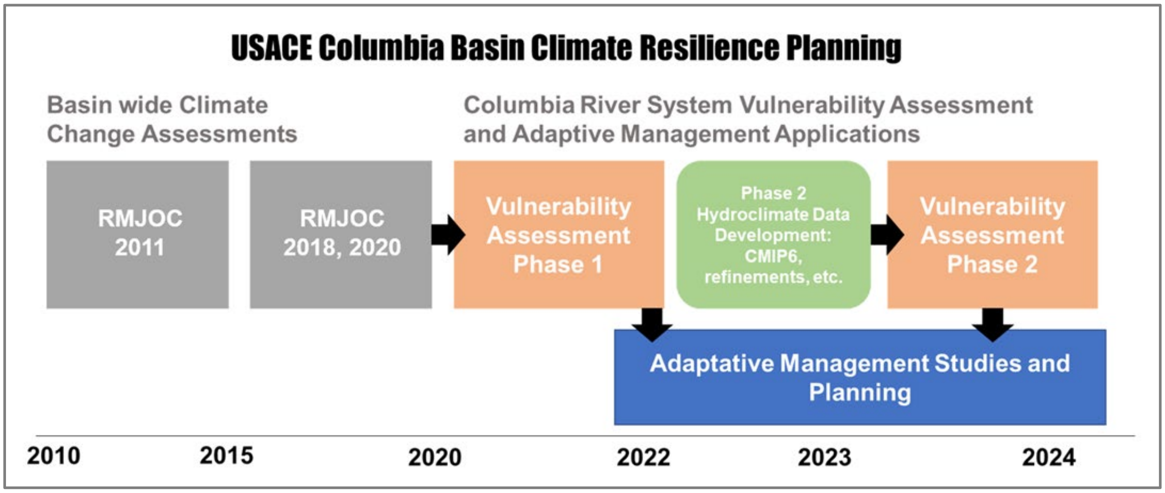

Figure 1. Long term development, modeling, and planning studies that support resilience of the Columbia River Reservoir System.

The vulnerability assessment methodology uses a multistep approach (Figure 2) to:

1) Characterize operational vulnerabilities across the Columbia River Reservoir System.
2) Attribute underlying hydrologic and operational mechanisms driving vulnerable outcomes.
3) Quantify how vulnerabilities and driving mechanisms are projected to change in time through the end of the 21st century.

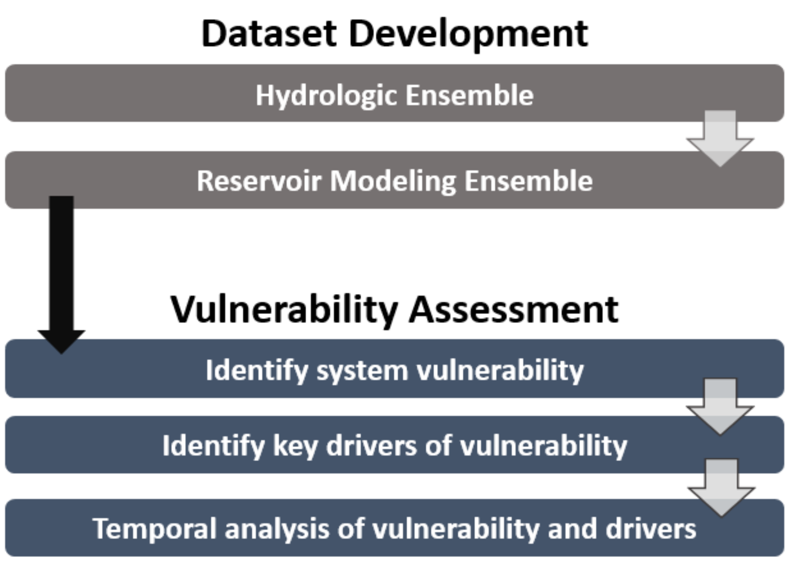

Figure 2. Flowchart of data development and analysis for the vulnerability assessment.

To accomplish these objectives, a 160-member ensemble of hydrologic projections derived from Coupled Model Intercomparison Project version 5 Global Climate Models (GCMs) for representative concentration pathway (RCP) 4.5 and RCP 8.5 emission scenarios is used to derive ensembles of hydro-regulated flow conditions and a suite of hydrologic and operational metrics that could explain performance degradation. The ensemble consists of 160 different combinations of GCMs, hydrology models, emission scenarios, and statistical downscaling techniques. Each unique combination results in continuous daily unregulated streamflow and meteorology throughout the basin spanning water years 1951 through 2099. The ensemble of potential historical and future hydrological conditions is translated to a regulated condition with reservoir modeling using hydro-regulation models that are used by USACE and USBR to support federal water management planning.

Forty-four operational vulnerabilities across multiple business lines were identified by a regional team of modelers and impact assessment leads (Figure 3). Years in the reservoir modeling ensemble that include an event with negative consequences are identified. The hydrological and reservoir modeling ensembles are processed into a dataset of metrics that could explain operational vulnerabilities. A machine learning algorithm, Random Forest (Breimen et al. 2001), is then applied to attribute the most influential drivers of vulnerability. Finally, the relative frequency of events where vulnerabilities occur and key influential drivers are analyzed temporally to characterize vulnerability over the course of 1951-2099.

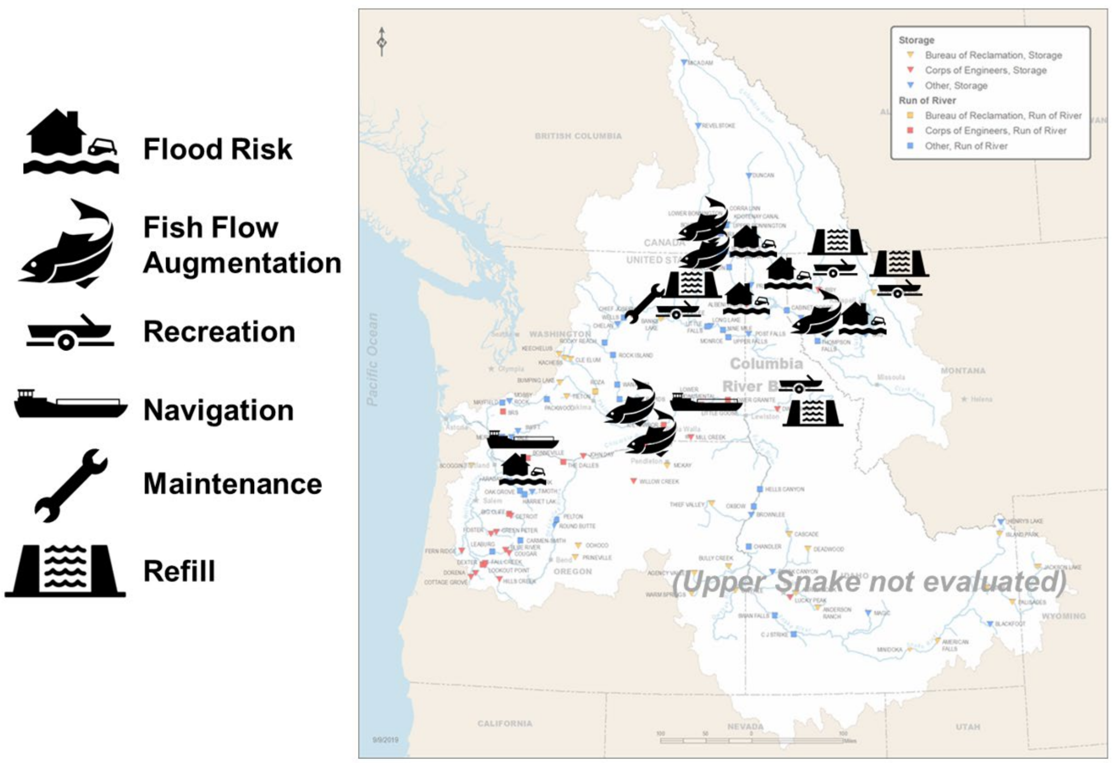

Figure 3. Map of the Columbia Reservoir System and vulnerabilities evaluated across 6 business lines.

The Columbia River Reservoir System Vulnerability Assessment quantifies the relative frequency at which the system can meet operational objectives and further identifies the underlying hydrological and operational conditions that lead to changes in performance. This comprehensive analysis and methodology will be used to inform adaptive management planning. Future work will include reservoir modeling analysis to assess how operations could be altered to maintain or decrease the frequency for which the system cannot meet operational objectives or provide beneficial conditions for other resources. The methodology developed for this effort provides an example of decision-support products that can be used to anticipate potential hydroclimatic change and begin planning for preparedness and increased resilience for water resource infrastructure.

References

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