Adaptation and Resilience to Climate Change of Hydropower Water Services and Climate Changes

Energy Optimization and
Environment Department - DEA

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CONTEXT

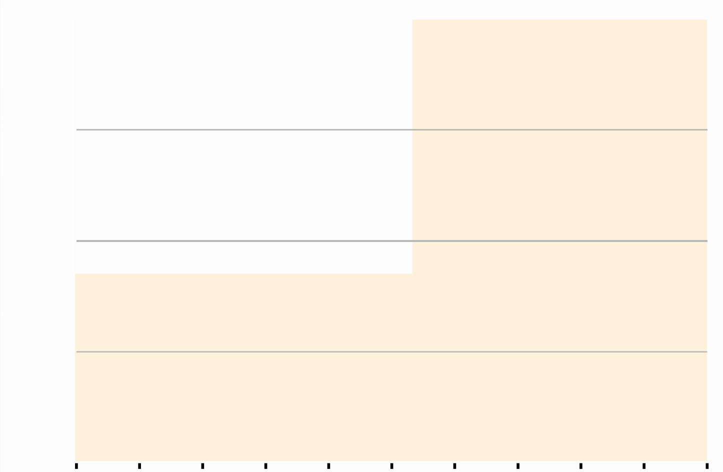
- **HPPs provide services related to water resources (**for example: floods and droughts prevention, ecological flow, navigation, human water demand etc.)
- These services:
  - **may be affected by climate change**,
  - on the other hand, **else may help to mitigate climate change effects on:**
    - **the surrounding ecosystems and communities and**
    - **the HPP energy service itself**

CONTEXT

- **Flood Control and Drought Management Activities at Annex XII**

- **Annex XII activities** addresses issues in the **interface Hydropower and Environment** which are **relevant for the hydropower industry**.

- Recently **climate change prognostics** resulted in an **increasing interest** on hydropower due to its **intrinsic mitigation and adaptation capability**.



CONTEXT

- **[Flood Control and Drought Management Activities at Annex XII]**

- *But CC effects in hydrologic extremes intensity and frequency had also put an extra uncertainty in the reliability of services provided by hydropower plants*

- *New eligibility criteria for financing hydropower projects are being developed in several institutions.*

A Pesquisa que constrói o futuro

CONTEXT

- <u>**Flood Control and Drought Management Activities at Annex XII**</u>

- Annex XII will occupy of **processes for preparing assessments of A&R to CC** of hydropower **with regard to its floods and drought management services**.

CONTEXT

- **Flood Control and Drought Management Activities at Annex XII**

- The activities in Annex XII have the intent of **identifying criteria and indicators** which can be used by **government agencies, multilateral banks, private financial sector** when **analyzing flood and drought services provided** by hydropower projects **considering climate change**.

CONTEXT

- Flood Control and Drought Management Activities at Annex XII

- **How HPP and its environment characteristics affect the flood and drought services provided by a hydro plant.**

- **How climate change influences the effectiveness and efficiency of these services.**

GOAL

A Pesquisa que constrói o futuro

- Assessments procedures **should enable to verify whether the HPP Flood and Drought services planned are ensured <u>even in the context of climate change</u>**.
- To do this it is necessary:
  - Identify Flood and Drought services considered in HPP planning;
  - Verify the performance of these services in a climate change context;
  - Set the accepted non-service limit; and
  - What should be the action if this limit is not met.

Referencies

- Some **bibliographic references on resilience indicators of HPP and Water Infrastructure** can be used as a basis for the discussion of Flood and Drougth Assessment Procedures, particularly:

  - **CBI Documents (Hydropower Criteria, Water infrastructure Criteria)**

  - **IHA Hydropower Sustainability Assessment Protocol**

  - **IHA ESG Gap Analysis Tool**

  - **Reservoir operations under climate change: Storage capacity options to mitigate risk,** *Nima Ehsani, Charles J. Vörösmarty, Balázs M. Fekete, Eugene Z. Stakhiv,* ***Journal of Hydrology****, 555 (2017) 435–446*

Optimized Flood...

Eletrobras Cepel
45 anos
A Pesquisa que constrói o futuro

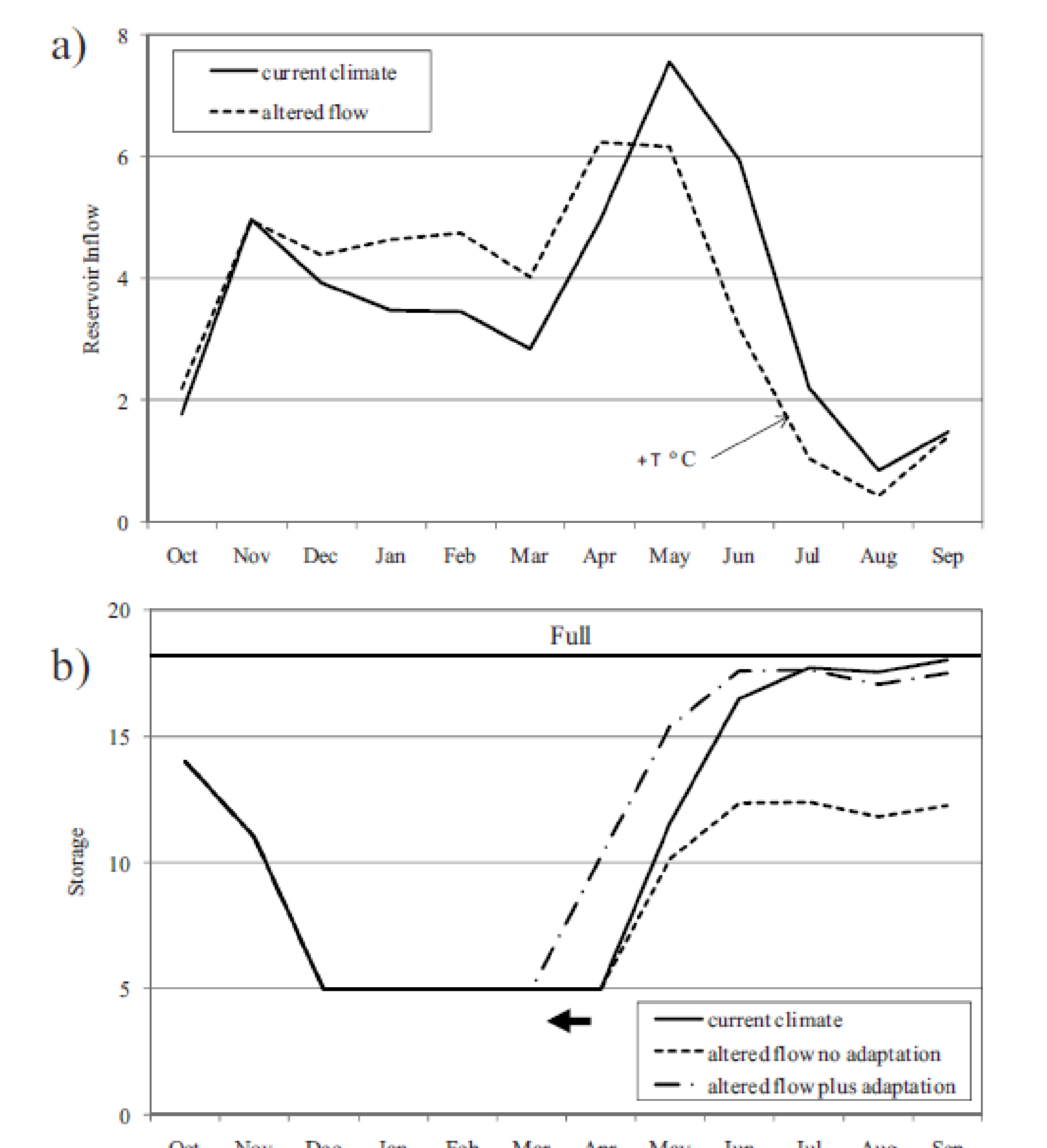
Optimized Flood Control in the Columbia River Basin for a Global Warming Scenario

Se-Yeun Lee[1]; Alan F. Hamlet, M.ASCE[2]; Carolyn J. Fitzgerald[3]; and Stephen J. Burges, F.ASCE[4]

Abstract: Anticipated future temperature changes in the mountainous U.S. Pacific Northwest will cause reduced spring snow pack, earlier melt, earlier spring peak flow and lower summer flow in transient rain-snow and snowmelt dominant river basins. In the context of managed flood control, these systematic changes are likely to disrupt the balance between flood control and reservoir refill in existing reservoir systems. To adapt to these hydrologic changes, refill timing and evacuation requirements for flood control need to be modified. This work poses a significant systems engineering problem, especially for large, multiobjective water systems. An existing optimization/simulation procedure is refined for rebalancing flood control and refill objectives for the Columbia River Basin for anticipated global warming. To calibrate the optimization model for the 20th century flow, the objective function is tuned to reproduce the current reliability of reservoir refill, while providing comparable levels of flood control to those produced by current flood control practices. After the optimization model is calibrated using the 20th century flow the same objective function is used to develop flood control curves for a global warming scenario which assumes an approximately 2 °C increase in air temperature. Robust decreases in system storage deficits are simulated for the climate change scenario when optimized flood rule curves replace the current flood control curves, without increasing monthly flood risks.

DOI: 10.1061/(ASCE)0733-9496(2009)135:6(440)

CE Database subject headings: Climate changes; Floods; Reservoir operation; Columbia River; Optimization; Simulation; Hydrologic models; Global warming.



Reservoir operations under climate change: Storage capacity …

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Research papers

Reservoir operations under climate change: Storage capacity options to mitigate risk

Nima Ehsani [a,*], Charles J. Vörösmarty [a], Balázs M. Fekete [a], Eugene Z. Stakhiv [b]

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[b] Johns Hopkins University, Visiting Scholar, US Army Institute for Water Resources, Alexandria, VA,

ing water management strategies. The hydrological implications of future climate will affect the design capacity and operating characteristics of dams. The vulnerability of water resources systems to floods and droughts will increase, and the trade-offs between reservoir releases to maintain flood control storage, drought resilience, ecological flow, human water demand, and energy production should be reconsidered. We used a Neural Networks based General Reservoir Operation Scheme to estimate the implications of climate change for dams on a regional scale. This dynamic daily reservoir module automatically adapts to changes in climate and re-adjusts the operation of dams based on water storage level, timing, and magnitude of incoming flows. Our findings suggest that the importance of dams in providing water security in the region will increase. We create an indicator of the Effective Degree of Regulation (EDR) by dams on water resources and show that it is expected to increase, particularly during drier

Dam construction is a long-standing strategy to reduce the spatiotemporal variability of natural water supply. By regulating the flow of water, dams alter the natural hydrograph to secure a reliable source of water for a wide variety of human and environmental needs. The suite of undesirable environmental impacts of dams and reservoirs (Baker et al., 2011; McCully, 1996; Mirchi et al., 2014; Poff et al., 2007; Poff and Schmidt, 2016) make the construction of new dams socially and politically controversial. Nevertheless, the role of dams and conveyance facilities is indisputable in achieving water security and providing the economic services required for development (Goldsmith and Hildyard, 1984; Khagram, 2004).

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Reservoir operations under climate change: Storage capacity ...

Effective Degree of Regulation

$$EDR_m = \frac{|TAW_{d,m} - TAW_{n,m}|}{TAW_{n,m}}$$

TAW: **Total Available Water**

d: with Dams

n: without Dams

m: month

Effects of Climate Change on the Operation of Dams

$$\Delta EDR_t = \frac{EDR_t - EDR_{avg}}{EDR_{avg}} \times 100$$

EDR_{avg}: EDR mean contemporary

EDR_t: EDR in the future time

Reservoir operations under climate change: Storage capacity ...

Effects of Climate Change on the Water Availability

$$\Delta TAW_t = \frac{TAW_{F,t} - TAW_{C,avg}}{TAW_{C,avg}} \times 100$$

TAW: Total Available Water

$TAW_{F,t}$: Total Available Water in the Future in time t

$TAW_{C,avg}$: Total Available Water Contemporary average

Climate Change Effect on water availability due to the number of reservoirs and/or capacity in the future

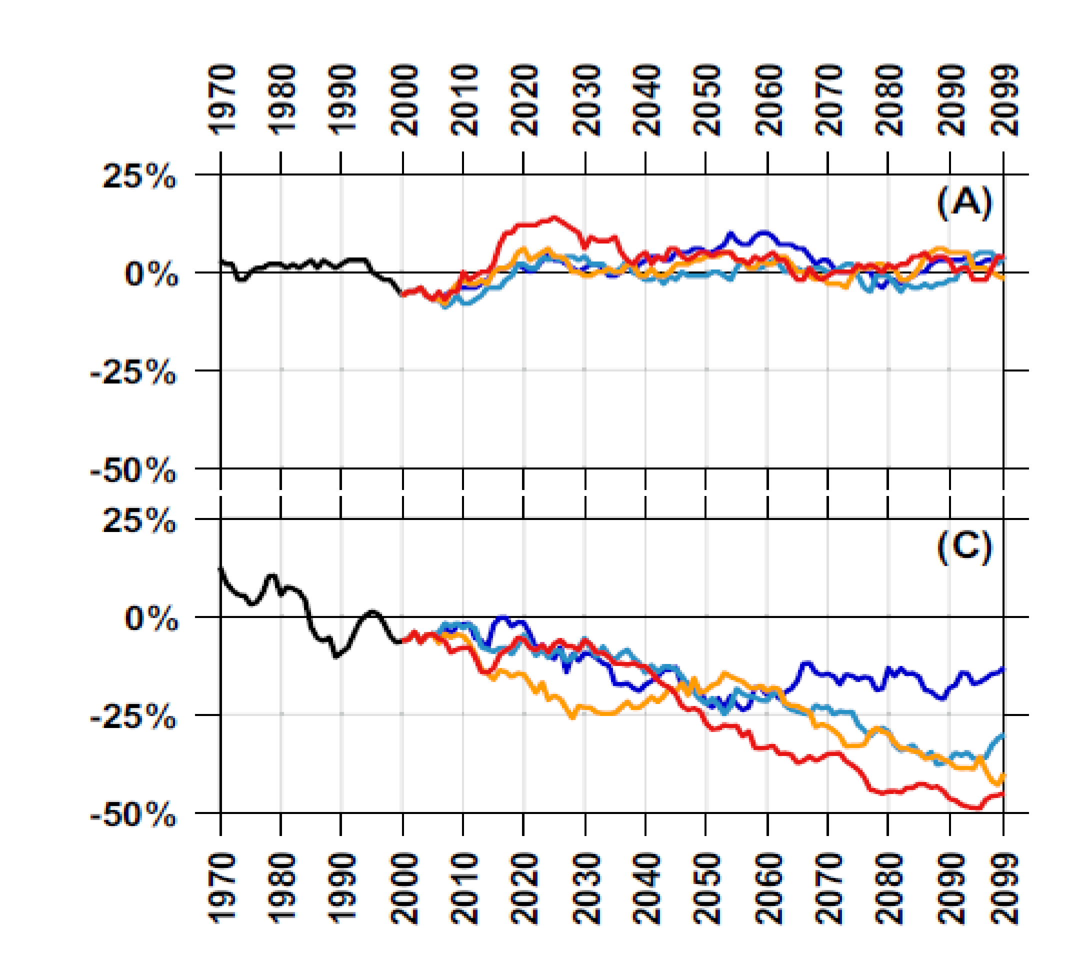
$$CEA_t = \frac{\Delta TAW_{(DS-s,t)} - \Delta TAW_{(DS-0,t)}}{\Delta TAW_{(DS-0,t)}} \qquad s = 1, 2 \text{ or } 3$$

$\Delta TAW_{(DS-s,t)}$: Effects of CC on Water Availability considering DS-s set of dams in the future time t

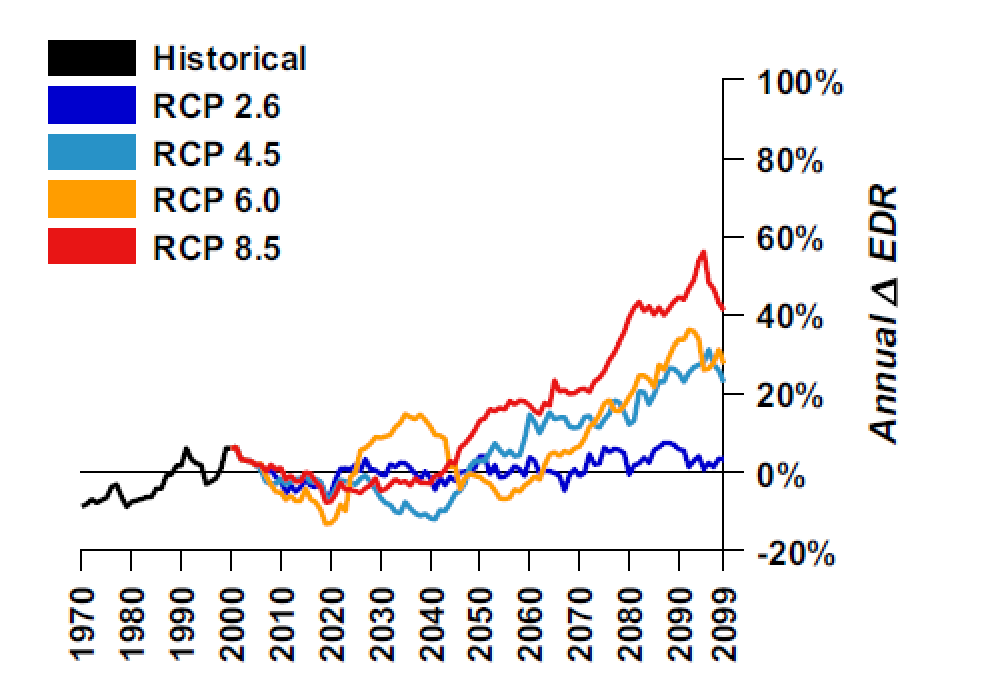
DS-0: original set of dams

DS-s: increase the storage capacity of the original set of dams by increase the number of dams or the capacity

Reservoir operations under climate change: Storage capacity ...



20-year moving average of **ΔTAW** in the Northeast for the most water-rich (A) and the most water-scarce (C) months of year.



20-year moving average of the change in annual **Effective Degree of Regulation** for the dams in the region.

Reservoir operations under climate change: Storage capacity …

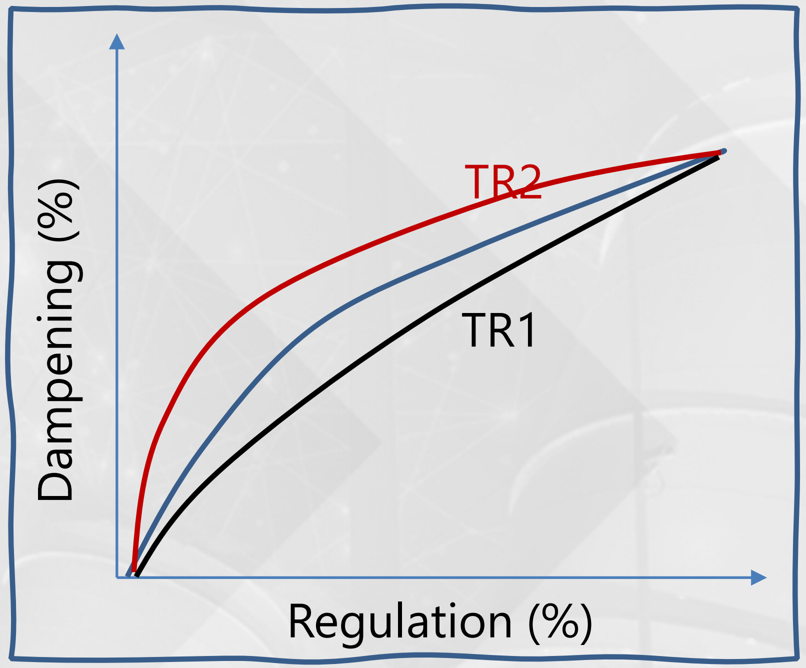
A Pesquisa que constrói o futuro

- To calculate these indices we need:
  - **The climate scenarios (GCM);**
  - **The hydrological scenarios associated to the climate scenario (hydrological model);**
  - **A simulation model (reservoirs operation simulation).**

Flood control services from reservoirs

- Simple screening approach can also be developed to **assess the flood protection capability of a reservoir or a set of reservoirs.**

- Example: **Curves of Available Degree of Regulation x Flood Dampening**, for several return periods.



- We need: **Annual inflow to reservoirs**; **regulated volume of reservoir**; **reservoir level for flood control**.

- It is possible to determine **the flood protection capability of the specific reservoir in the basin**.

- **We can calculate these indexes considering the <u>historical inflow</u> and the <u>future scenarios</u>.**

Contents of a White Paper...

- Simple screening methods, as in the last reference, to evaluate the performance of the Flood and Drought services of the HPP in the scenarios of climate changes

- More elaborated approaches

Contents of a White Paper...

Criteria for using climate change scenarios

Which time horizon ? 2040-2060 or 2080-2100

Which emissions scenarios ? RCP 4.5, RCP 6.5, RCP 8.5

Which GCM and downscaling models ?

Percentiles of entire ensemble ?

Models proven to perform well for the region?

Thank you

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