Dams in Oregon: impacts, opportunities and future directions

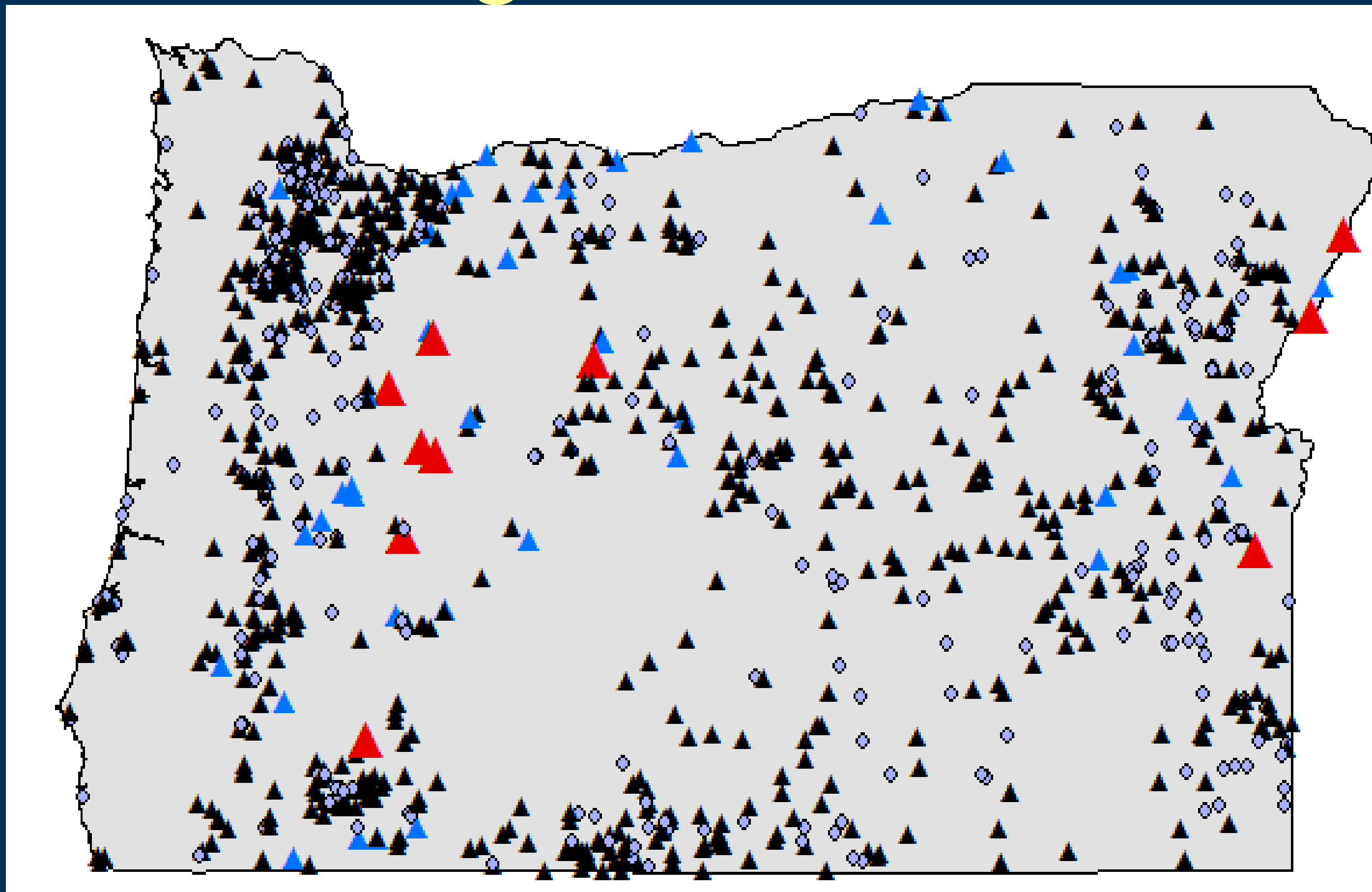
Rose Wallick

Chauncey Anderson, Stewart Rounds, Mackenzie Keith, Krista Jones

USGS Oregon Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

Dams in Oregon



More than 1,100 dams in state dam inventory

48 dams more than 100ft tall
10 dams more than 300 ft tall
Cougar Dam is tallest – 519 ft

Dam Height

USGS

Overview

Purpose and environmental impacts of dams

Strategies to address impacts

- *Removal, infrastructure modifications, operations*

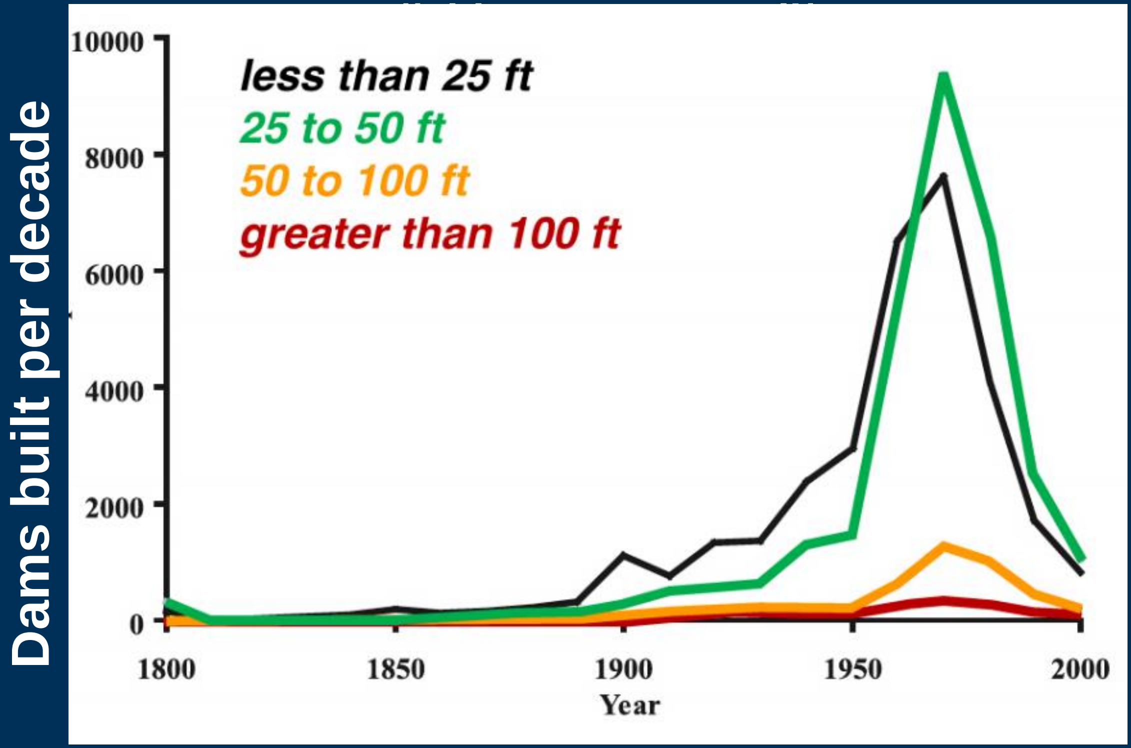
Science insights from USGS studies

Future directions

USGS

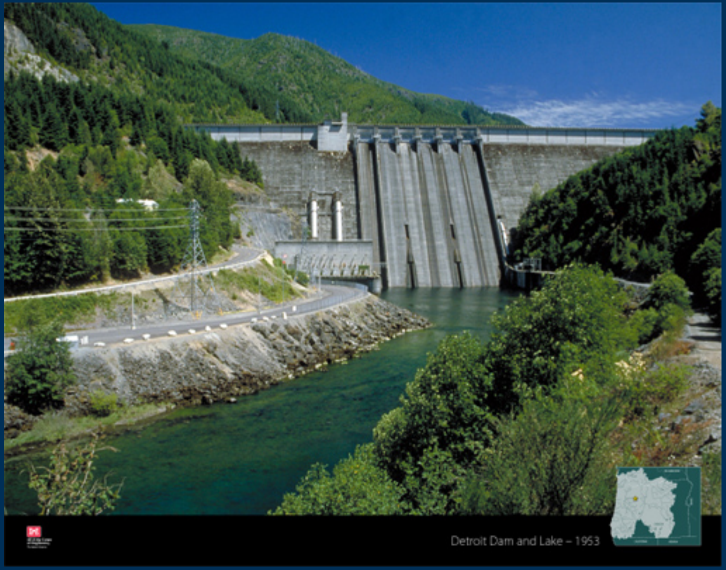
U.S. has more than 87,000 documented dams

Source: National Inventory of Dams,



After Doyle et al. (2003)

USGS



Detroit Dam, completed 1953, 463 ft

Cougar Dam, completed 1963, 519 ft

Photographs courtesy USACE

Purpose of dams

Dams provide:

- Hydropower
- Flood control
- Water storage
- Navigation
- Recreation
- Other benefits

Middle Fork Willamette, USGS photo

Detroit Lake, Photo courtesy: https://www.detroitlakeoregon.org/

USGS

Environmental impacts of dams

- Alter river flows, water temperature, water quality, trap sediment, carbon, nutrients in reservoirs
- Block fish passage
- Change ecosystems above and below dams
- Support conditions that can lead to harmful algae blooms

Cougar Reservoir, South Fork McKenzie, USGS photo

USGS

Middle Fork Willamette River below Dexter Dam, USGS photo

Motivating factors for removing, upgrading or re-operating dams

Examples include:

- Dams age, expensive to maintain safely
- Facilities may not work as initially intended
- Reservoirs fill with sediment
- Regulatory requirements
  - Fish passage
  - Water quality

Iron Gate Dam and Reservoir, Klamath River, Photograph by C. Anderson, USGS

USGS

Management strategies

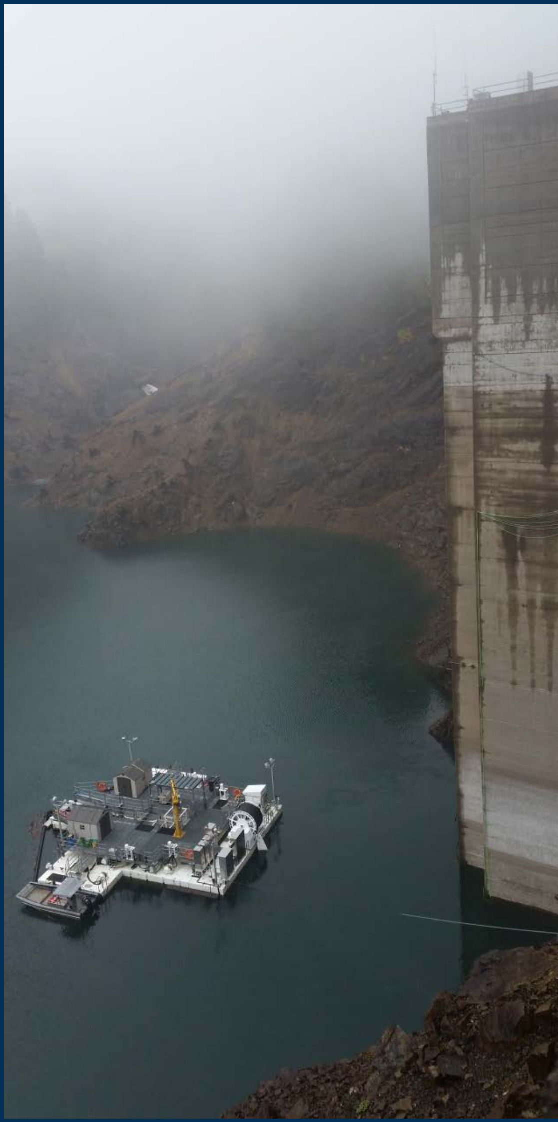
Obsolete or unsafe dams are candidates for removal

Upgrade facilities

- Fish passage
- Temperature control
- Total dissolved gas

Modify operations of existing facilities

- Environmental flows for habitats
- Flow management to address temperature
- Drawdowns to flush sediment or pass fish



Portable Floating Fish Collector, Cougar Reservoir, photo by R. Wallick, USGS

USGS

Dam removal reasons

Ecosystem restoration

- Fish passage and habit
- Upstream / downstream
- Water temperature char absolute temperatures)

Safety

- Many old facilities expe
- Earthquakes

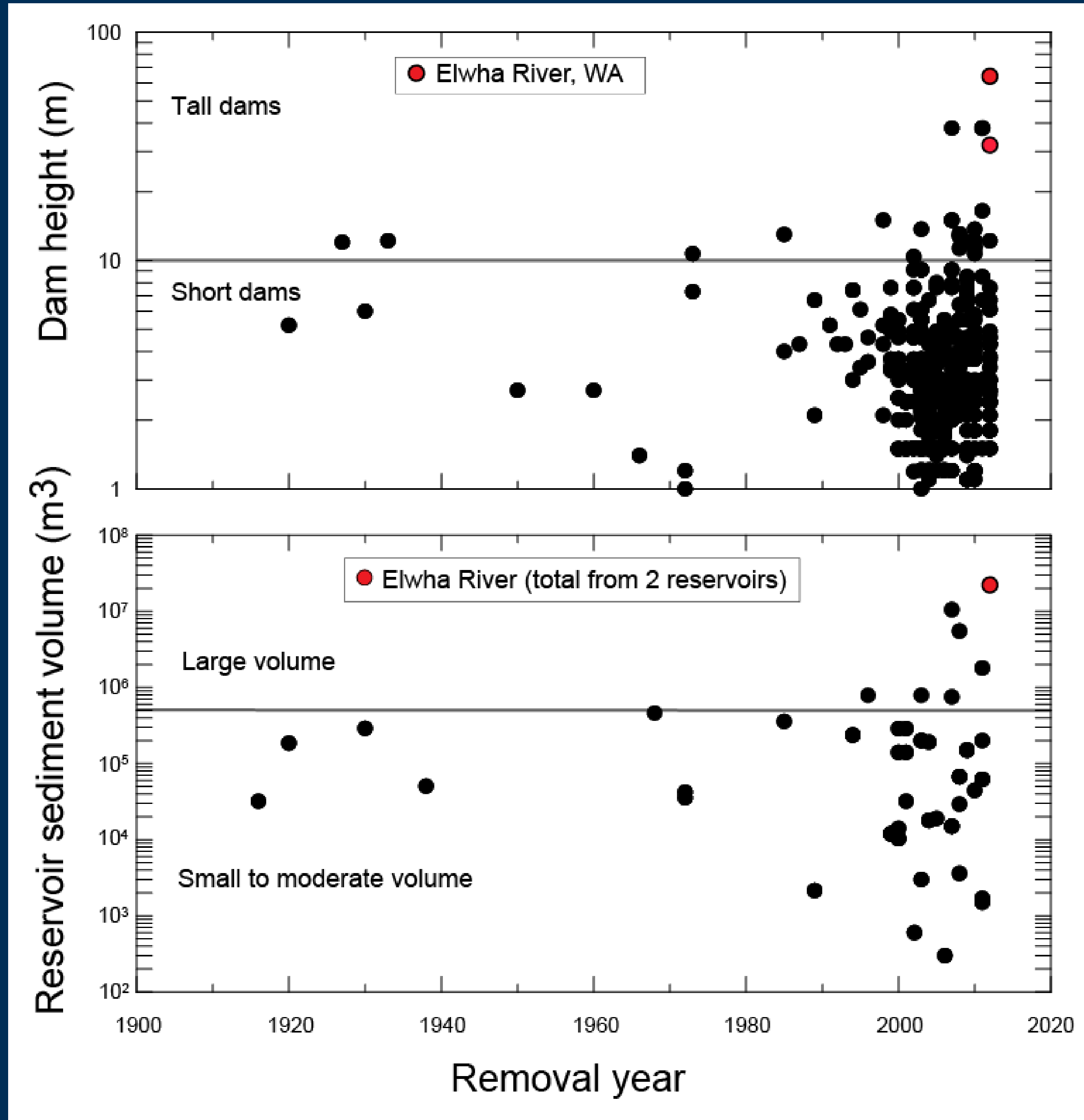
Economic

- FERC relicensing
- Costs of retrofitting or m ESA or other requiremer

Elwha Dam, 108 ft, removed in 2011
Photo by C. Magirl, USGS

New York Times article on risks of Lake Isabella dam failure

Dam removal in the U.S.



Major et al., *Gravel-Bed Rivers* v. 8, in press, based on American Rivers database

Dam removal –technical concerns

- Hydrologic Changes – Flooding, channel changes
- Sediment Erosion / Transport / Deposition
  - Reservoir erosion
  - Downstream deposition
  - Impacts to habitats
  - Debris
  - Contaminants
- Water quality
- Invasive aquatic species & plants
- Loss of fish collection facilities
- Decreased groundwater levels
- Impacts on infrastructure (WTPs, pumps, pipelines…)

Potential benefits include: improvements to habitat, fish passage, water quality, removal of non-native reservoir fish…

USGS

Effects of dam removal proportional to dam size and operation

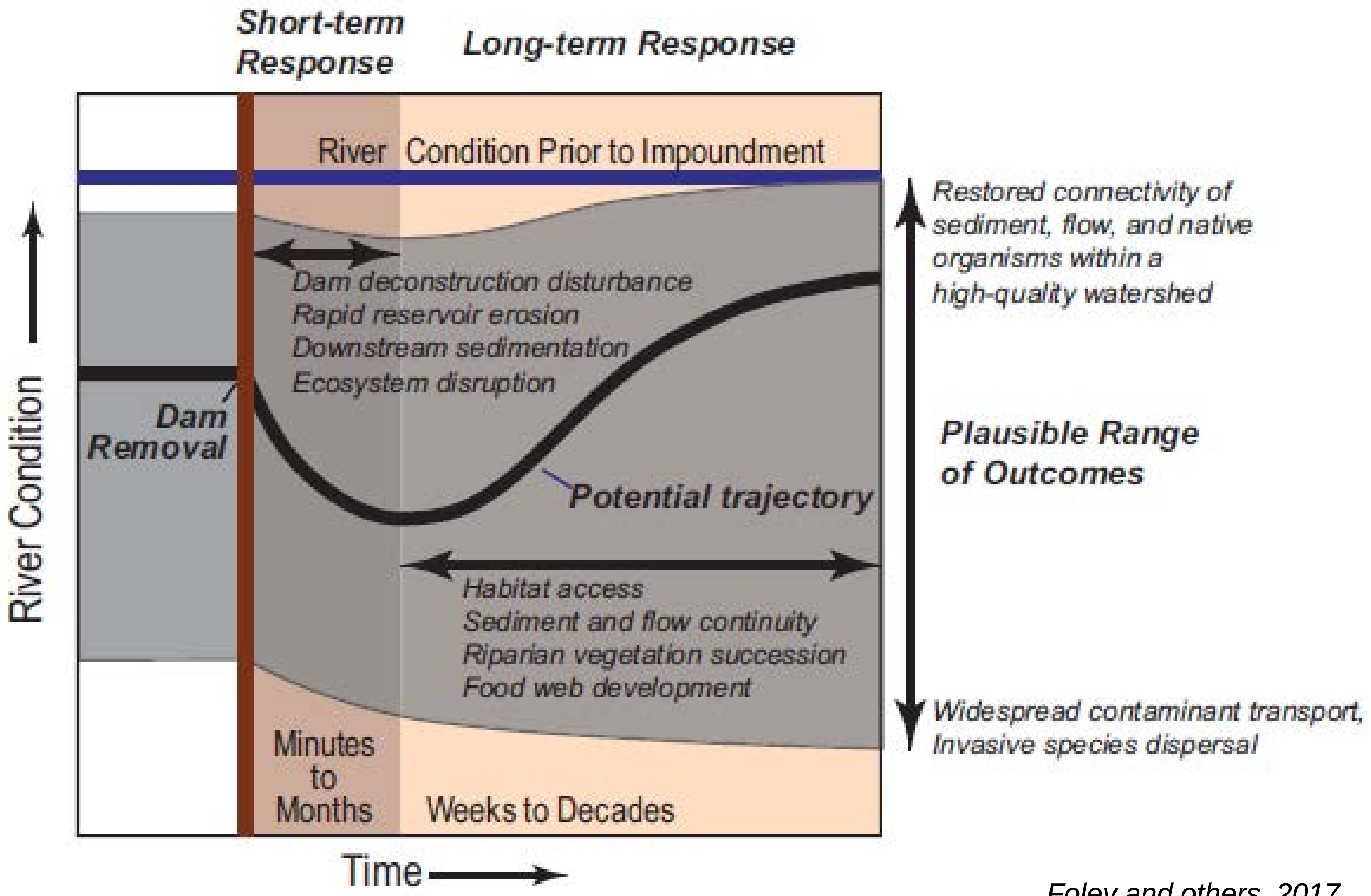
- Dam's effects on flow and sediment transport (dam presence and operations both matter)
- Dam height, and pace of removal
- Reservoir sediment volume, composition

Homestead Dam, Ashuelot River, NH (Gartner et al., 2015)

Glines Canyon Dam, Elwha River, WA

USGS photographs

Overarching conceptual model



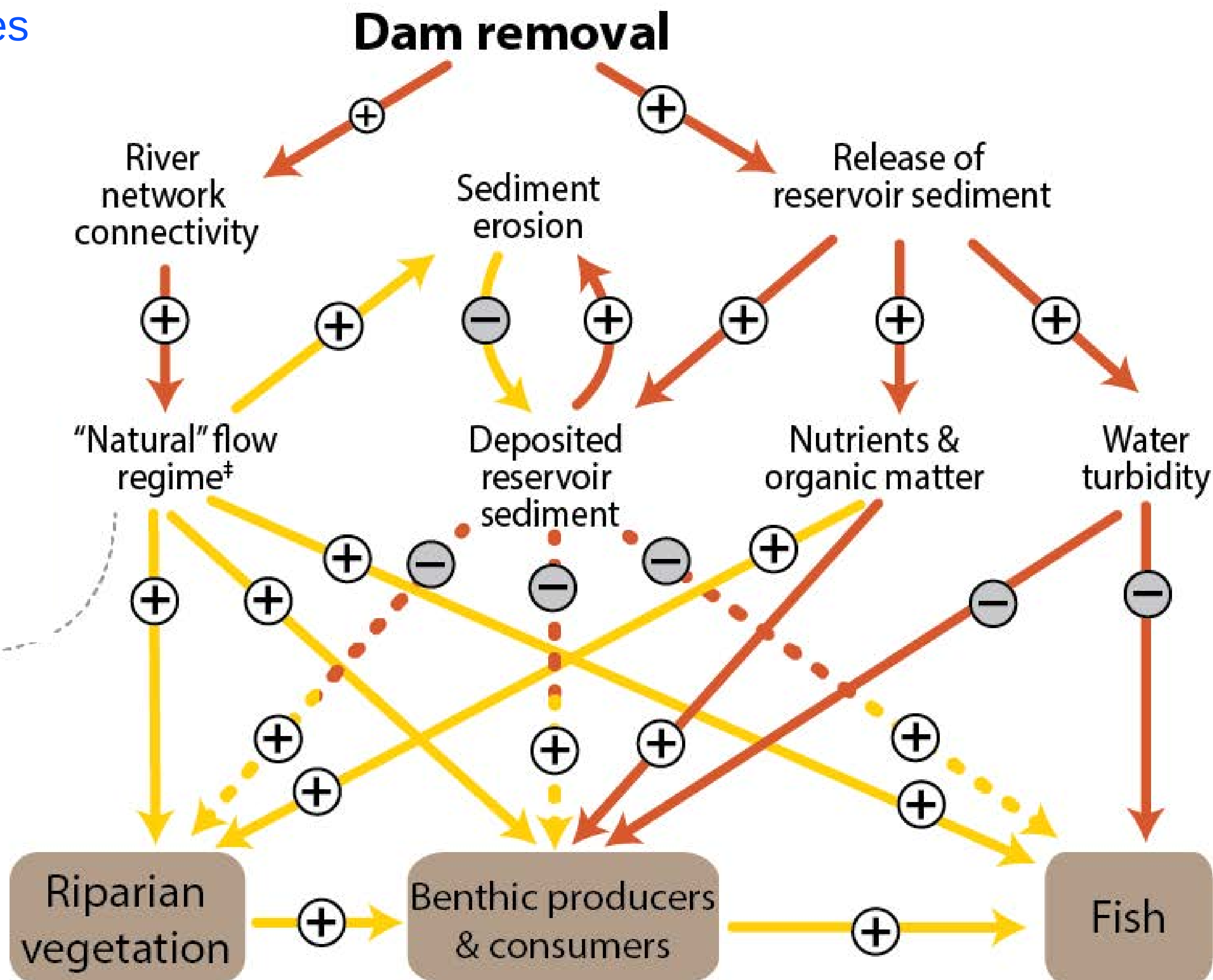
Foley and others, 2017

Ecosystem impacts, benefits from dam removal

Much still to learn about ecosystem responses, but making progress.

1. Ecosystem responses mediated through bio-physical processes

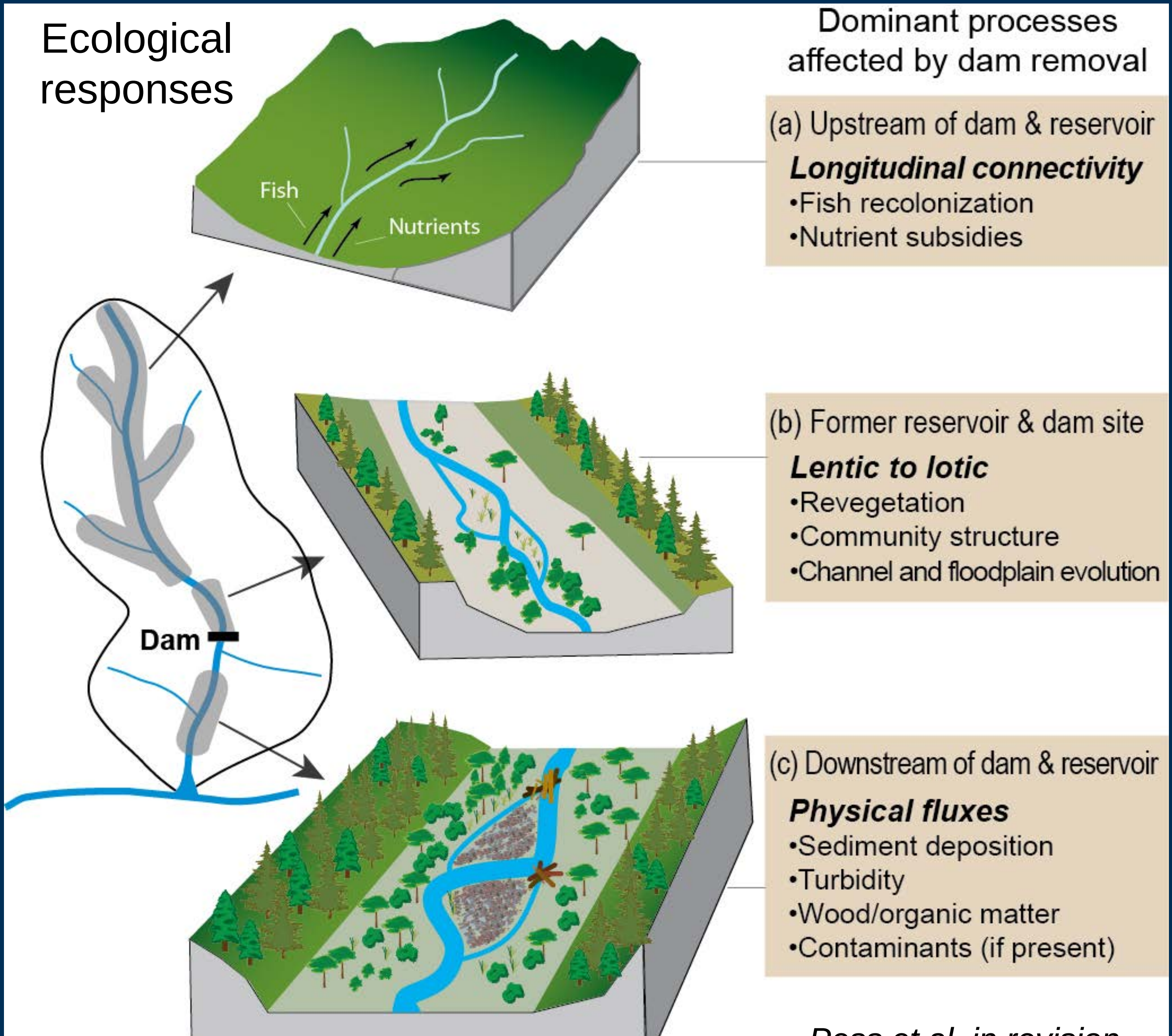
2. Many complex relationships, feedbacks



‡Includes temperature, sediment, and nutrient regimes

Pess et al., in revision

Coupled upstream-downstream system



Pess et al, in revision.

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Case study: Marmot Dam, Sandy River

Photos by J. Major, USGS

<u>Lessons learned (Foley and others, 2017)</u>

- Physical responses typically fast
- Ecological responses differ longitudinally
- Connectivity quickly restored
- Geomorphic context matters
- Quantitative models useful for predicting effects
- Fish respond rapidly

USGS





Using science and engineering to inform dam operations

Examples from Willamette and Columbia









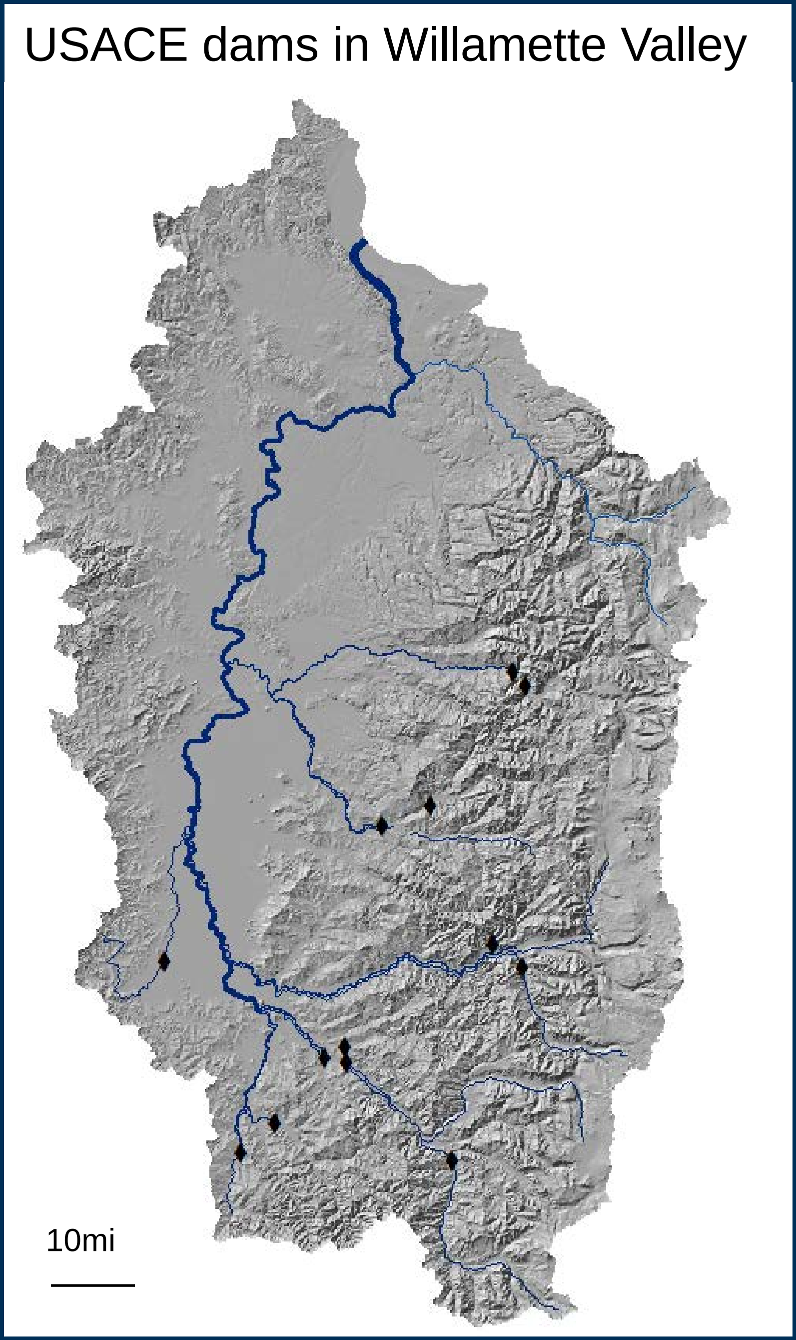
(photos from Corps of Engineers and PGE)

Willamette Basin

- 13 USACE dams
- ESA-listed fish
  - Chinook salmon
  - Steelhead salmon
  - Bull trout

Operations consider

- Flood control, hydropower, downstream water users, recreation
- Temperature management
- Seasonal flow requirements for listed fish



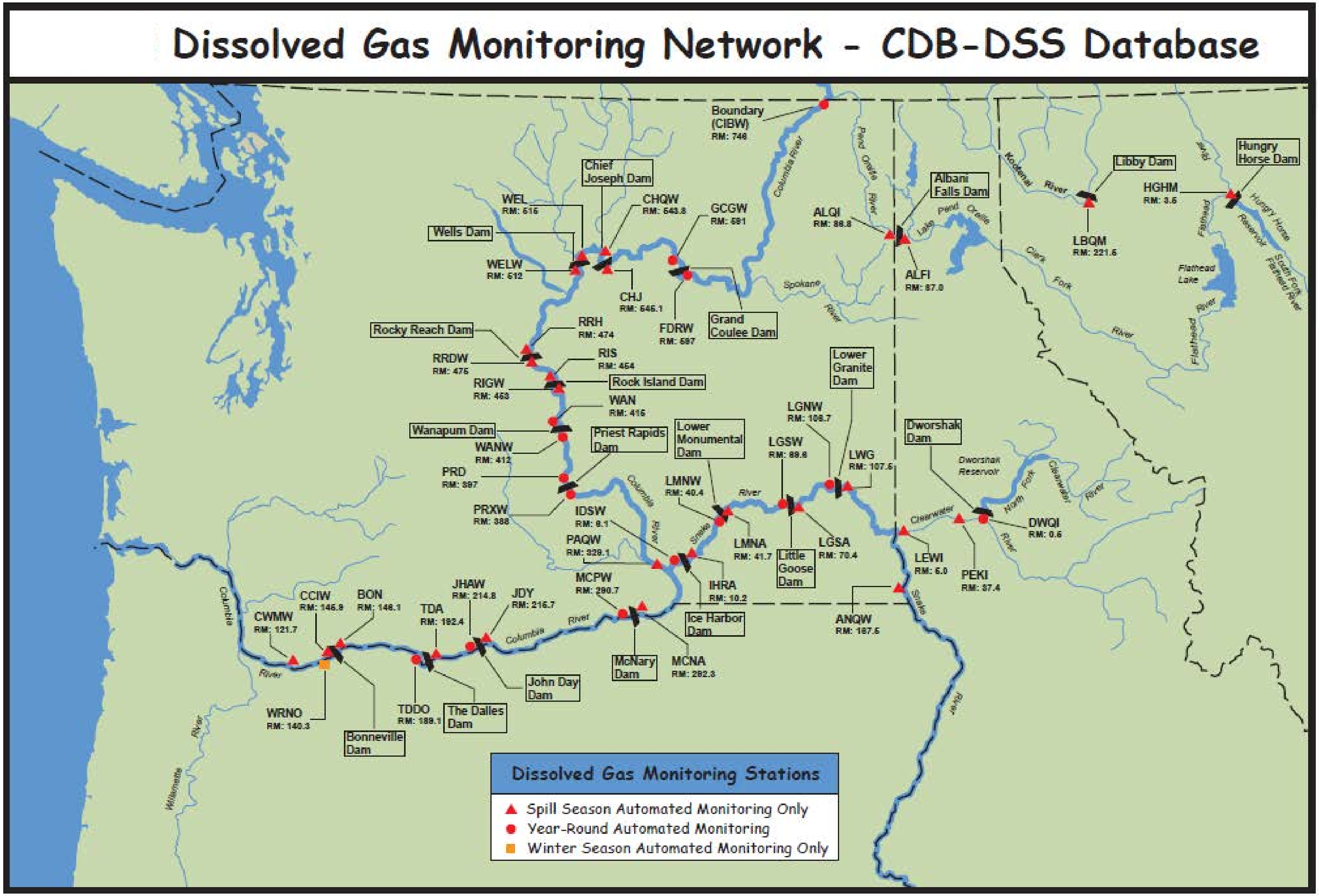
Total Dissolved Gas

Critical regulatory metric for dam operations

  - **Goal: Minimize gas bubble trauma for outmigrating juvenile salmonids**
- **Real time decisions regarding spill and power generation**
- **Infrastructure improvements**

Lower Granite Dam, Snake River. Photo credit: E. Glisch, USACE

Total Dissolved Gas Monitoring



http://www.nwd.usace.army.mil/Missions/Water/Columbia/Water-Quality/

Downstream Temperatures

Temperature affects fish habitat and the timing of migration, spawning, egg incubation and emergence, etc.

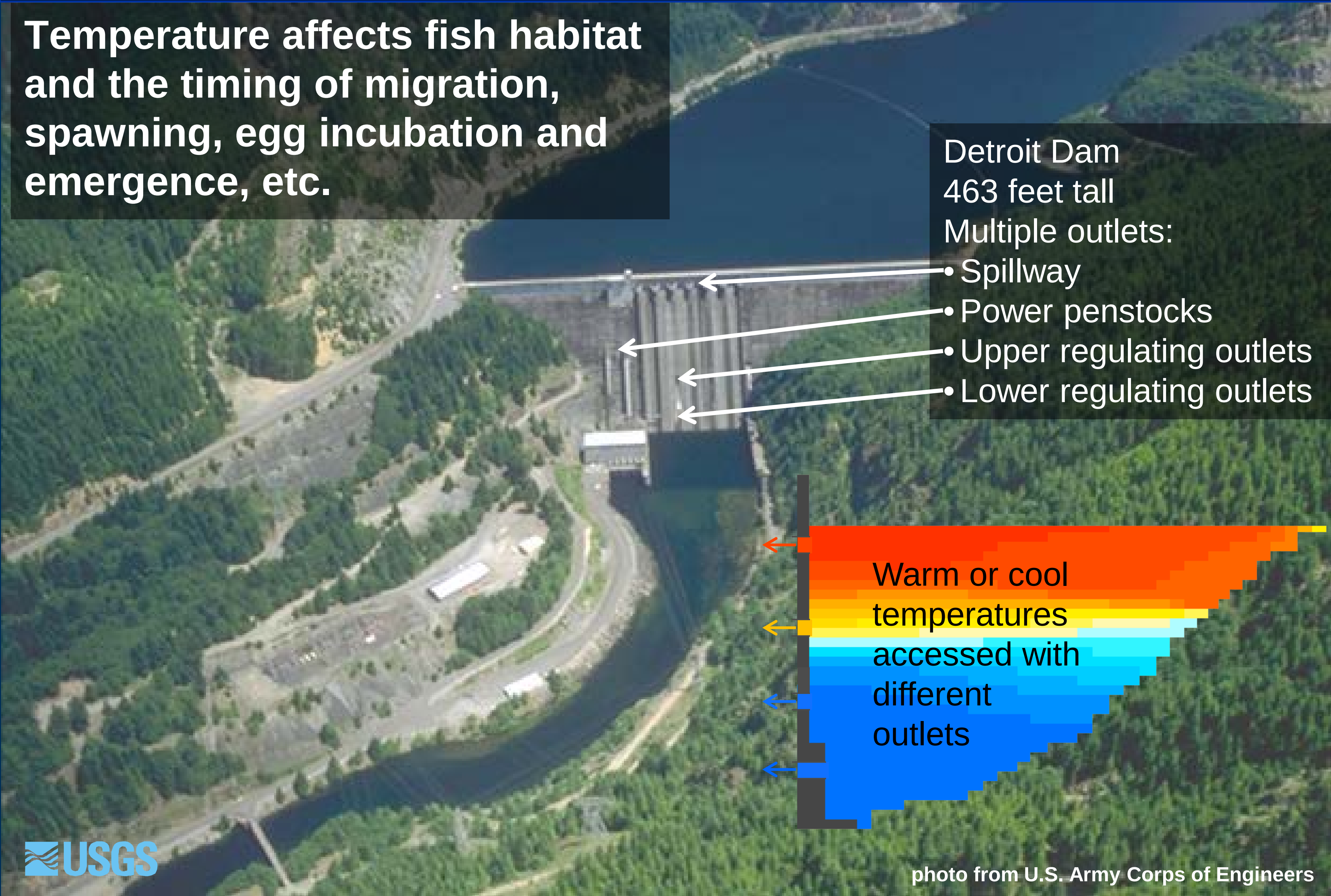
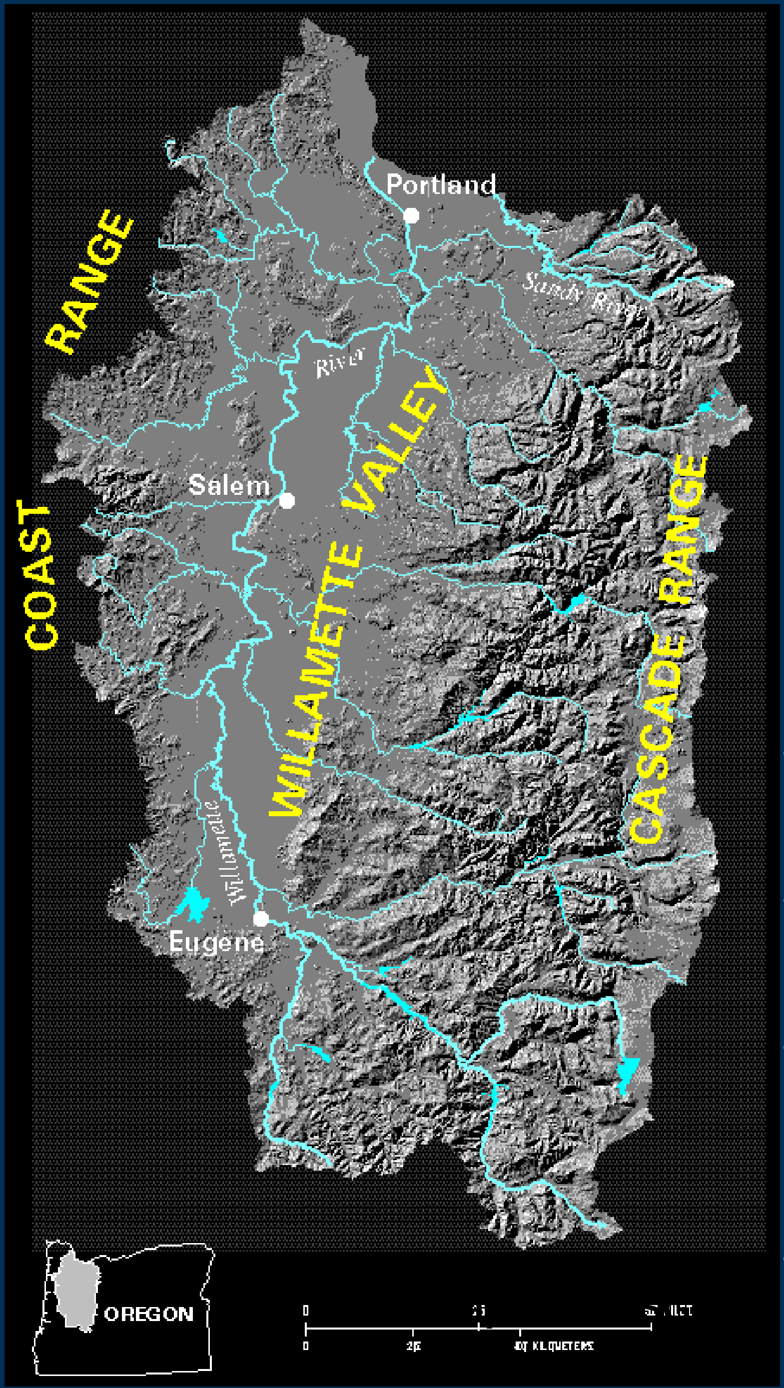
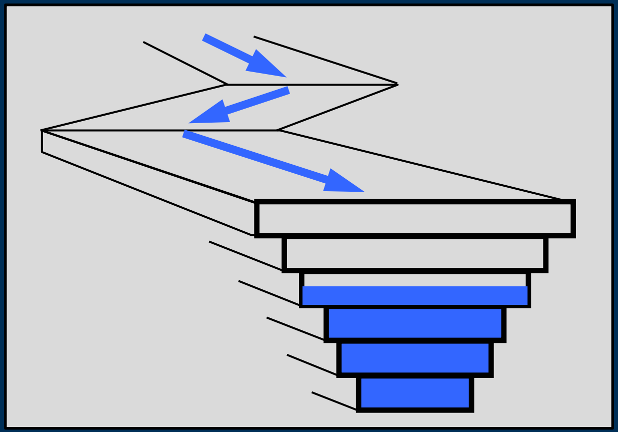


photo from U.S. Army Corps of Engineers

Willamette River Models

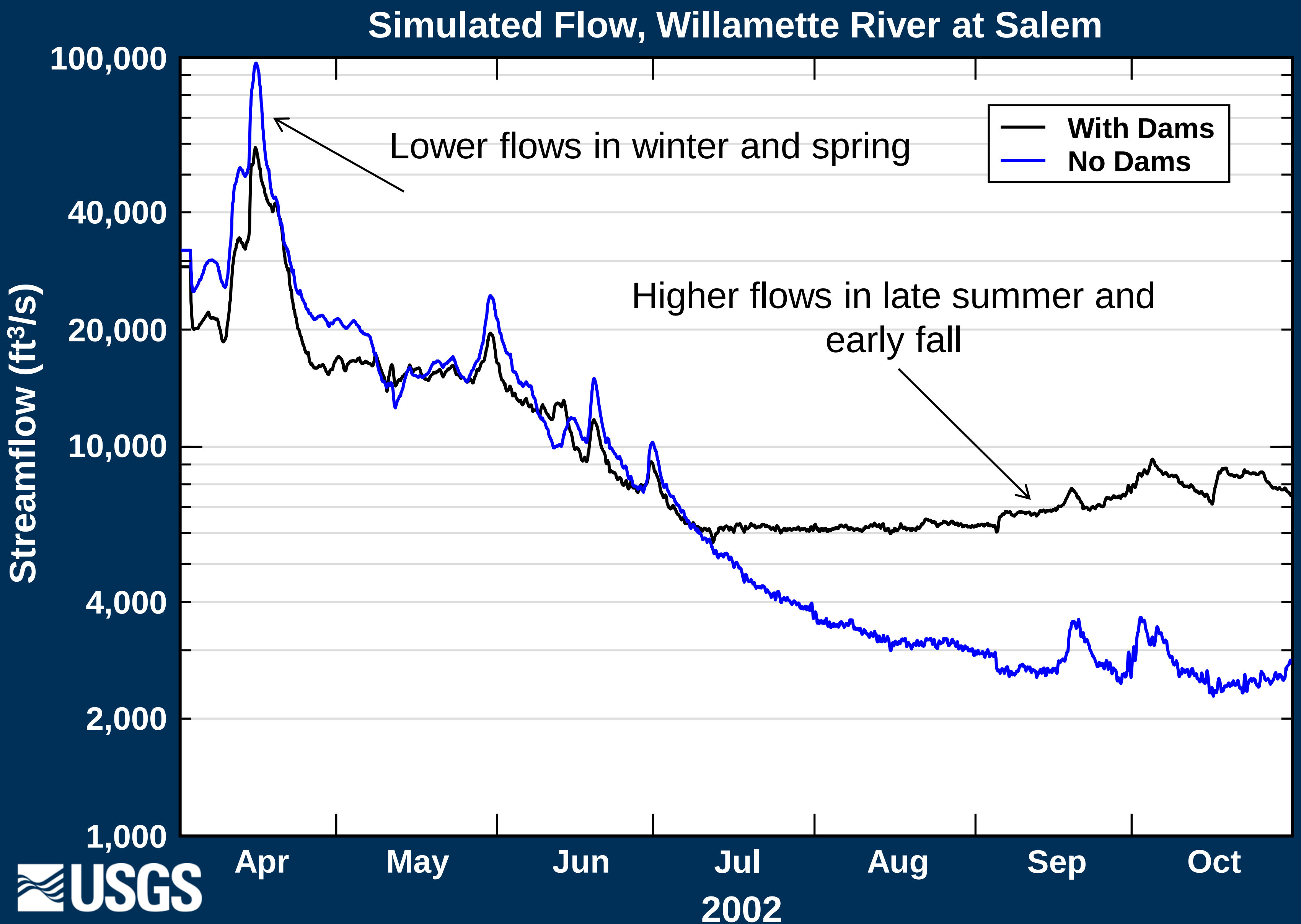


CE-QUAL-W2
444 river miles



- Calibrated for 2001 and 2002 for temperature TMDL.
- Used to assess effects of upstream dams.
- Used to evaluate 2011 (cool/wet) and 2015 (hot/dry) conditions and aid in evaluations of flow management
- Used to help quantify a *Thermal Mosaic* of the river.

Flow Comparison, With and Without Dams



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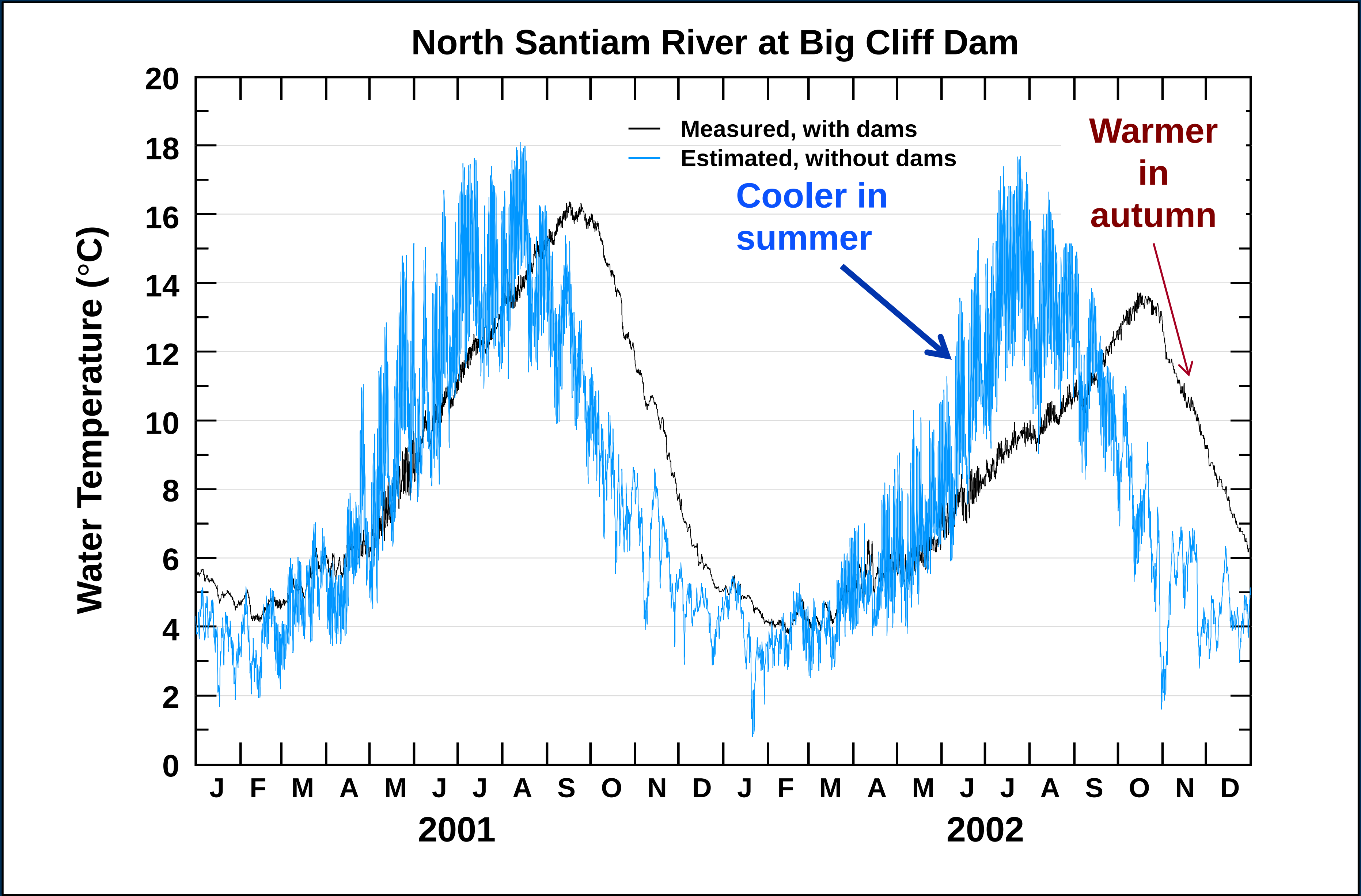
See http://pubs.usgs.gov/sir/2010/5153/

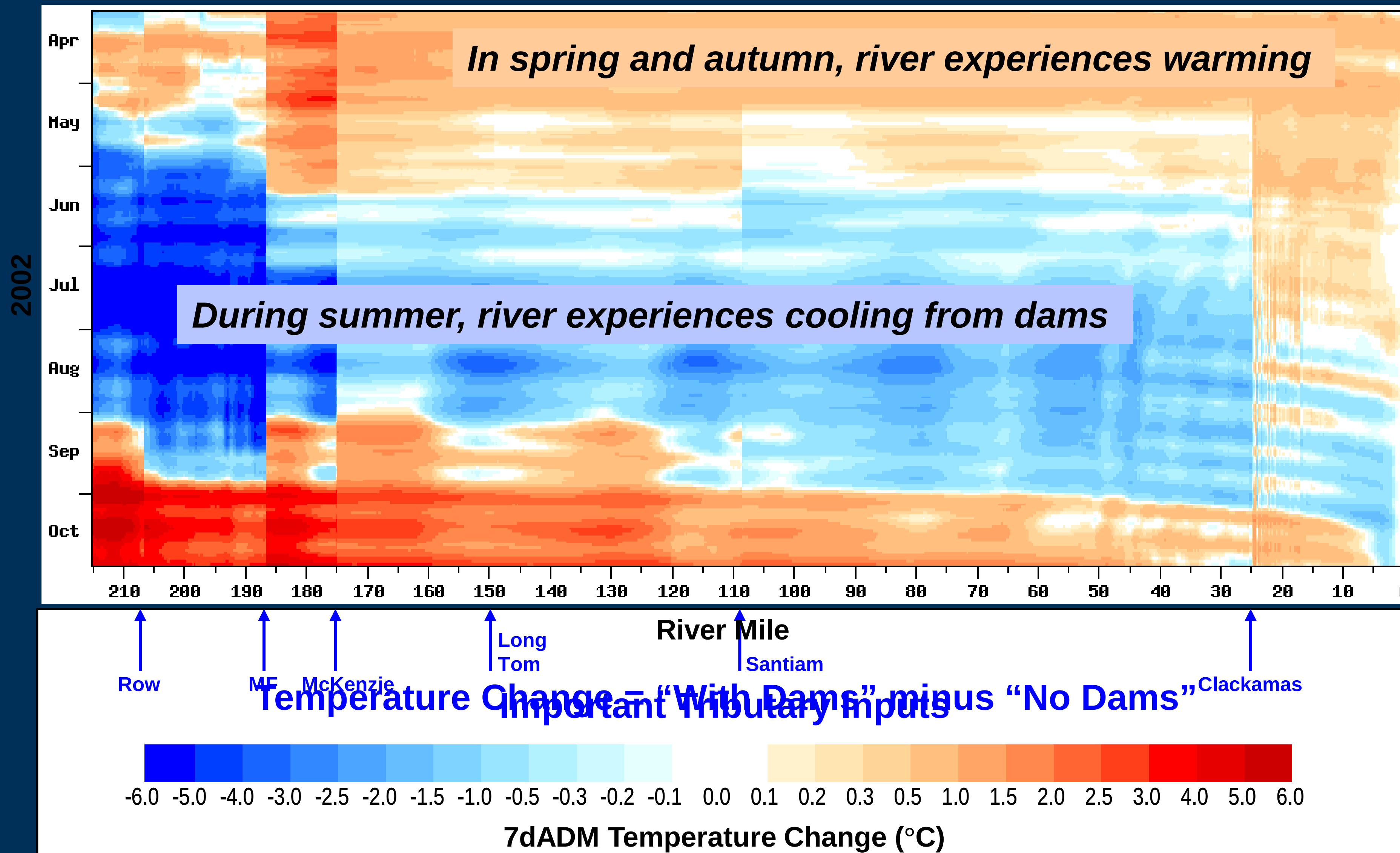
Temperature Comparison, With and Without Dams



See http://pubs.usgs.gov/sir/2010/5153/

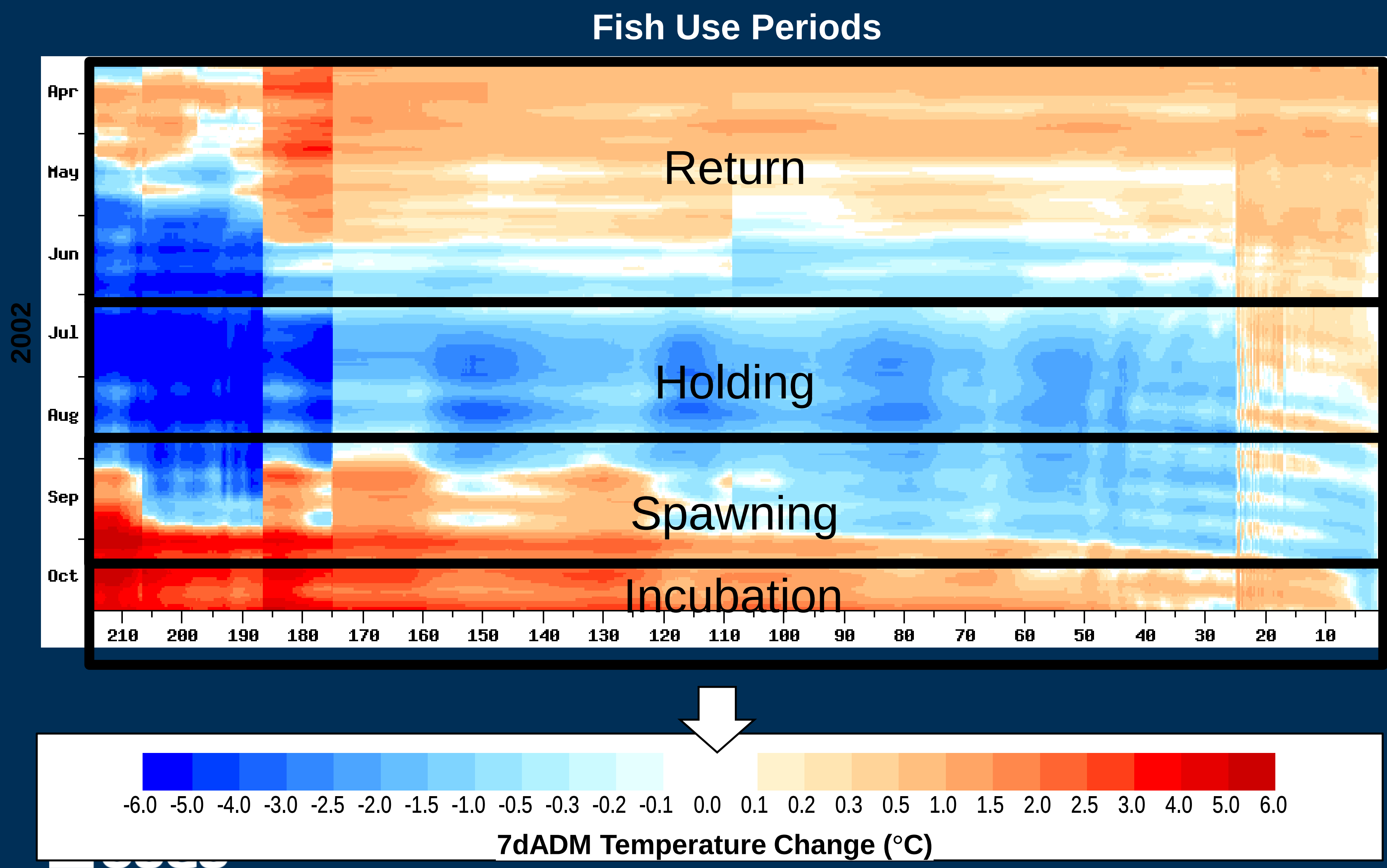
Thermal Effect of Dams on River Network

Coast Fork Willamette and Willamette Rivers

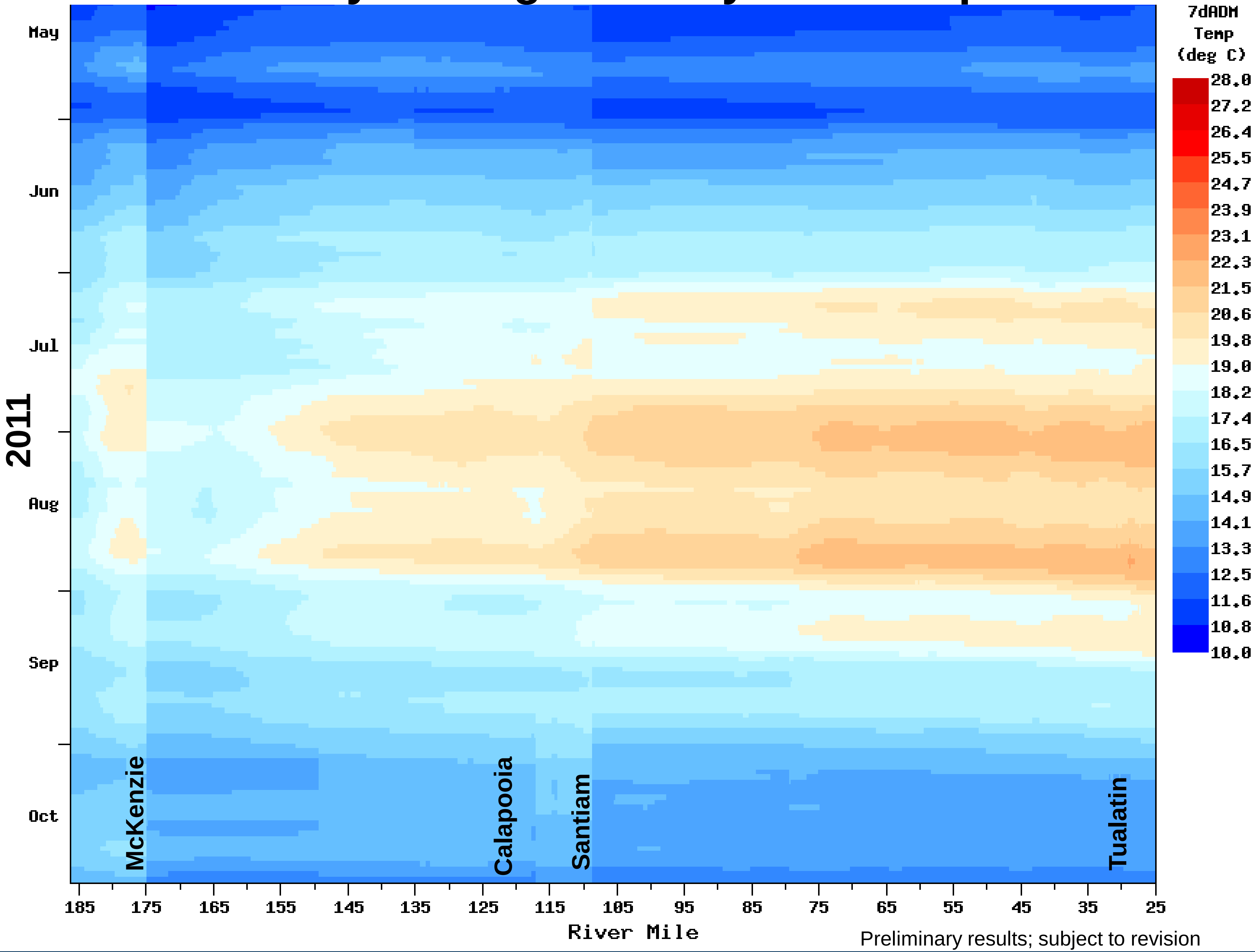


See http://pubs.usgs.gov/sir/2010/5153/

Downstream Thermal Effect of Dams on Fish

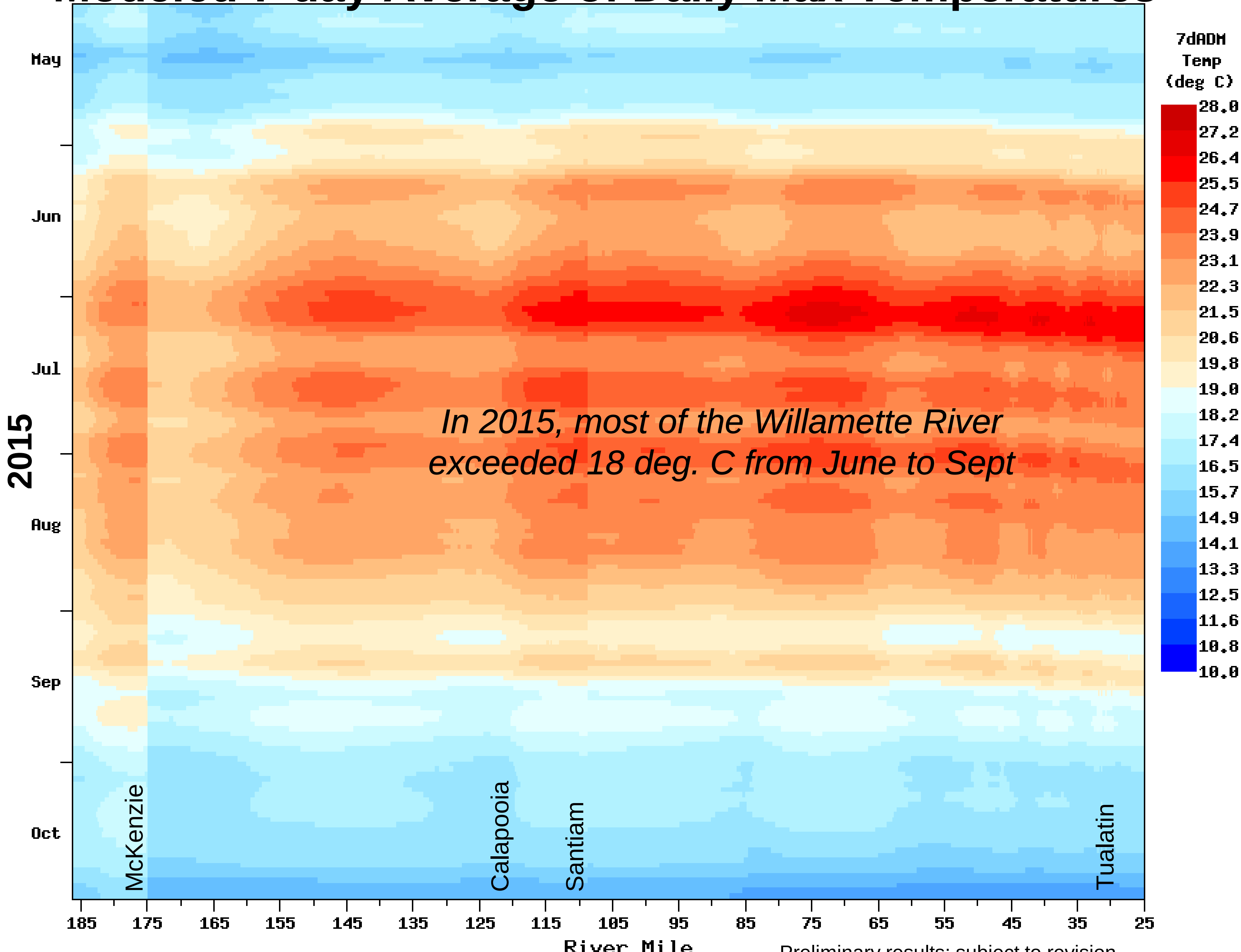


Modeled 7-day Average of Daily Max Temperatures



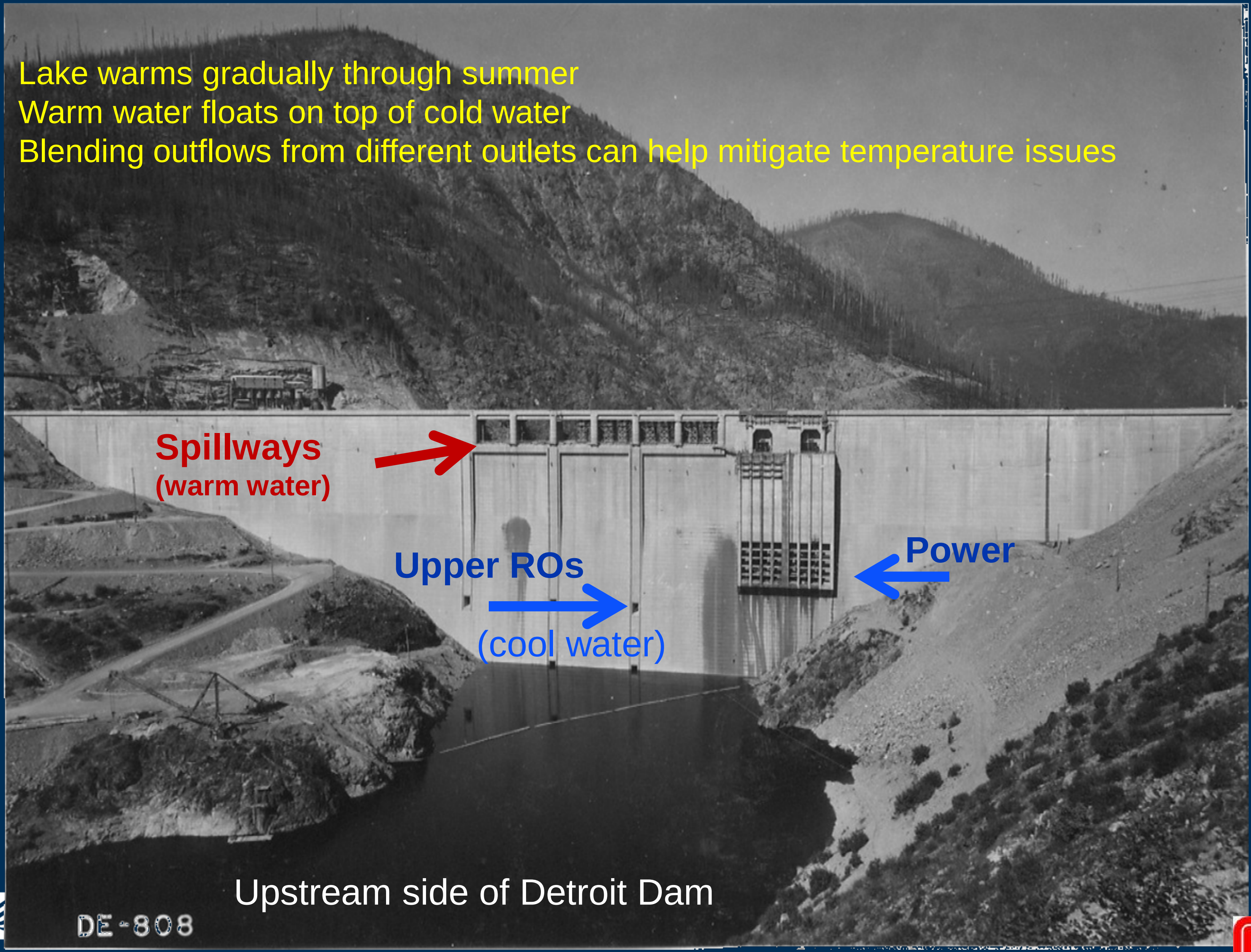
Preliminary results; subject to revision

Modeled 7-day Average of Daily Max Temperatures



Preliminary results; subject to revision

Example of temperature blending: Detroit Dam, Oregon



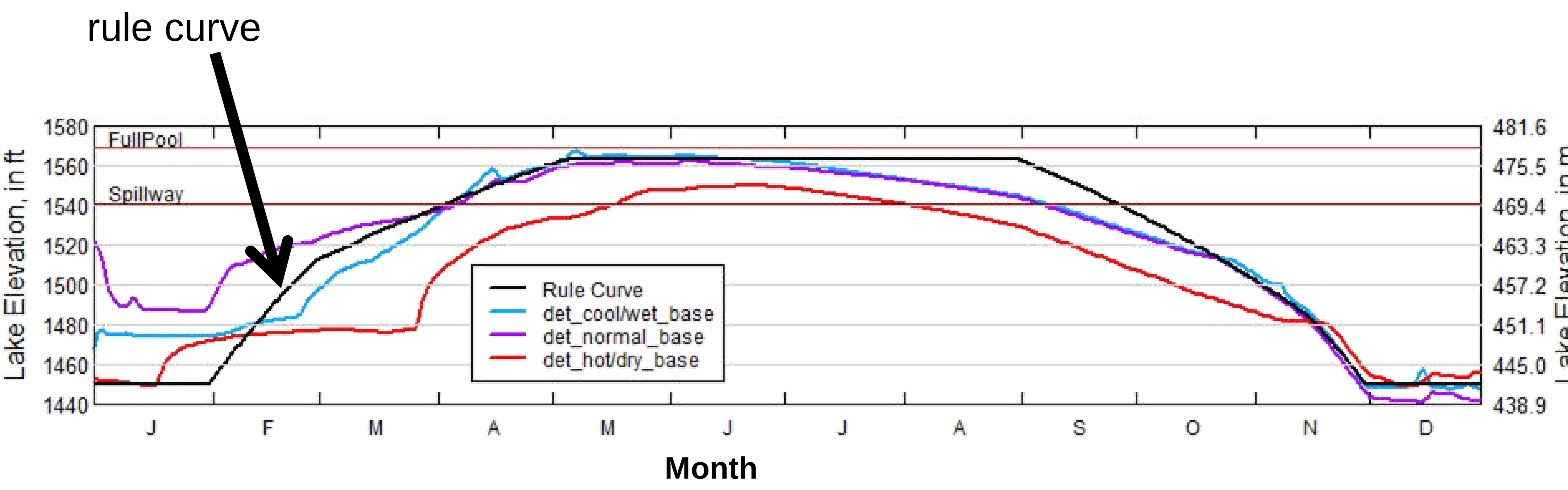
Upstream side of Detroit Dam

Image from Corps of Engineers

Detroit Lake water levels for different scenarios

In all years, lake level above spillway, but duration varies

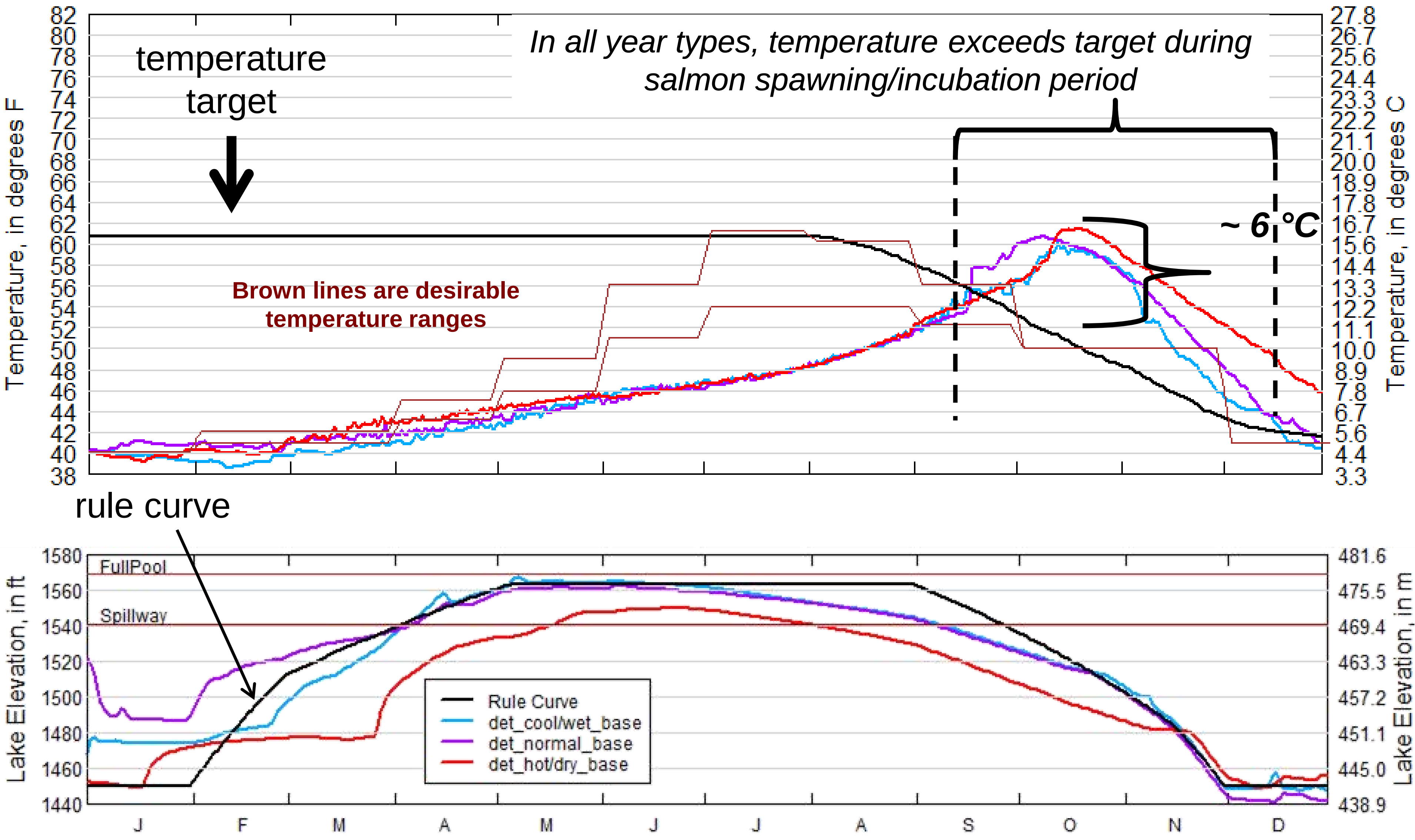
- In dry year, water level drops below spillway August 1
- In cool/wet years and normal year, below spillway early September



See http://dx.doi.org/10.3133/ofr20151012

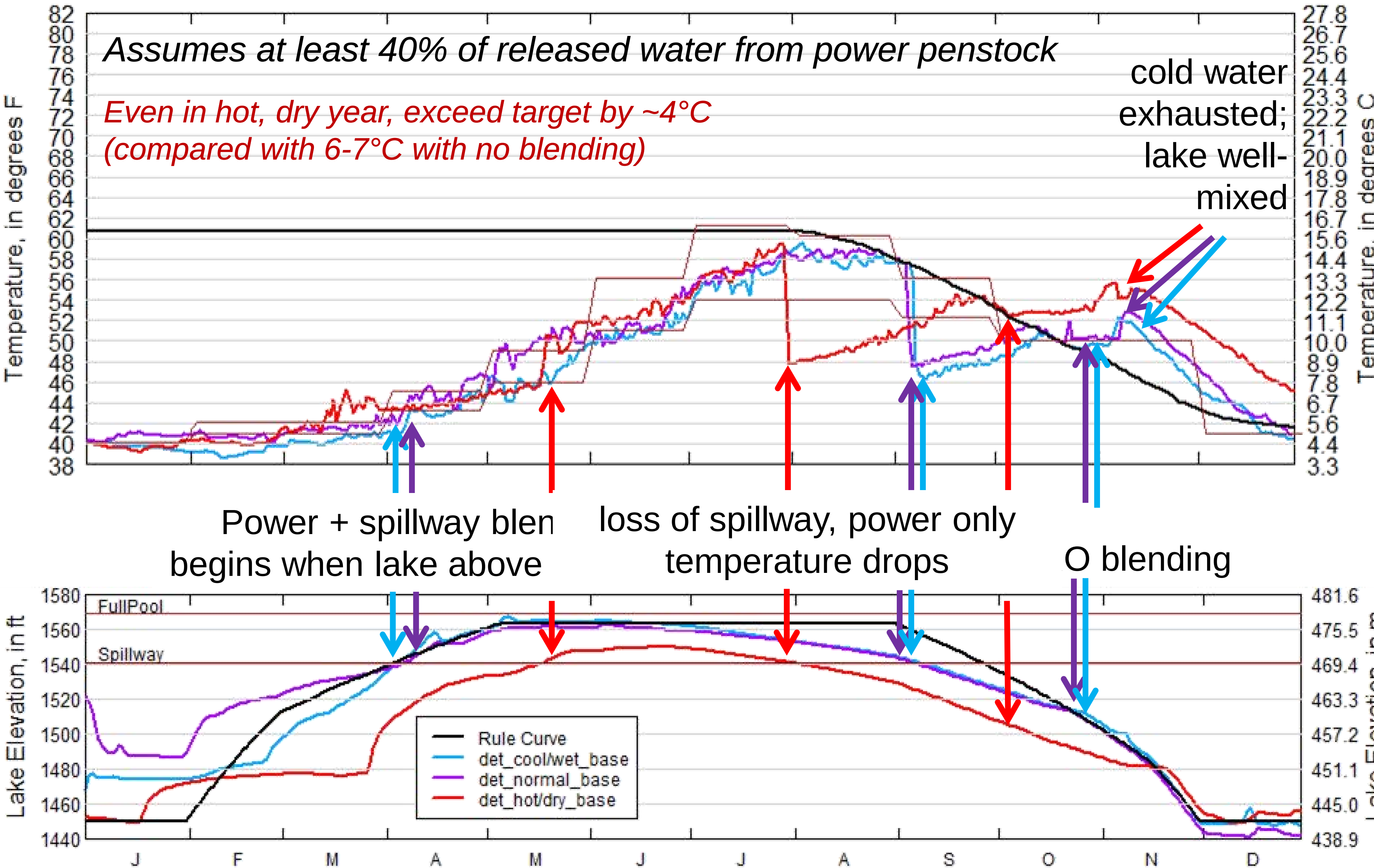
Detroit Modeled Temperatures, Without Blending

When releasing cool water from power penstock, temperatures are below target most of summer. Water remaining in the fall is warm, resulting in releases that exceed targets for spawning and incubation.



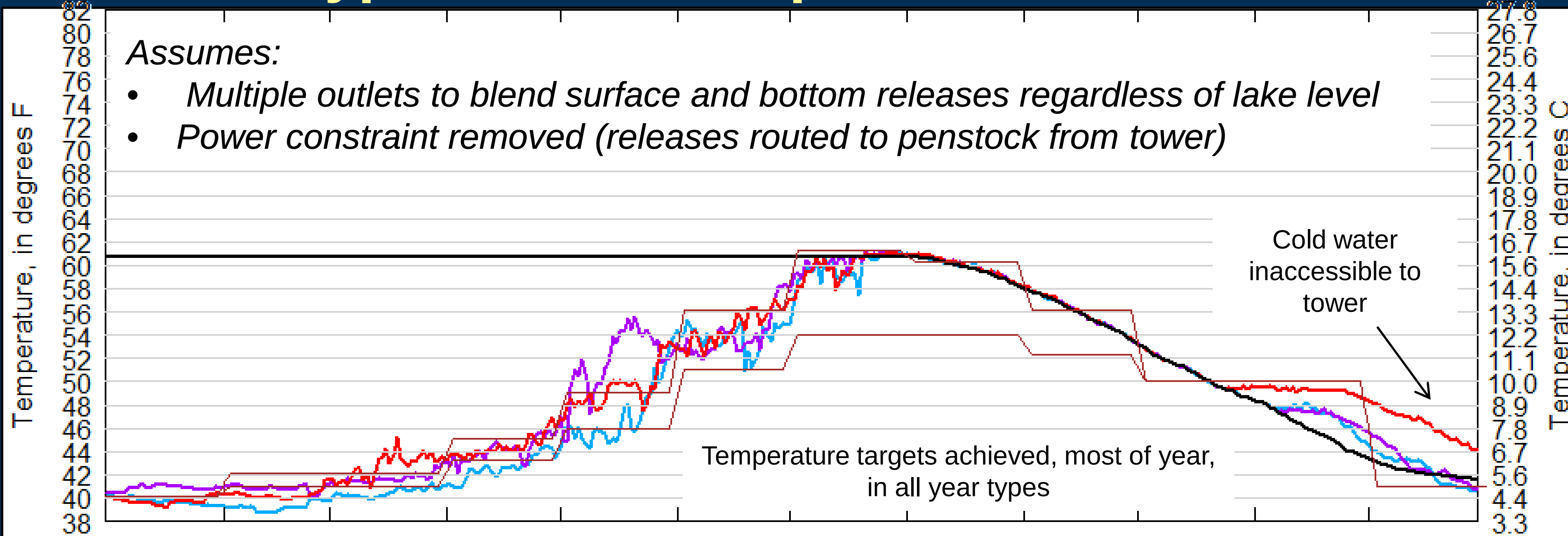
See http://dx.doi.org/10.3133/ofr20151012

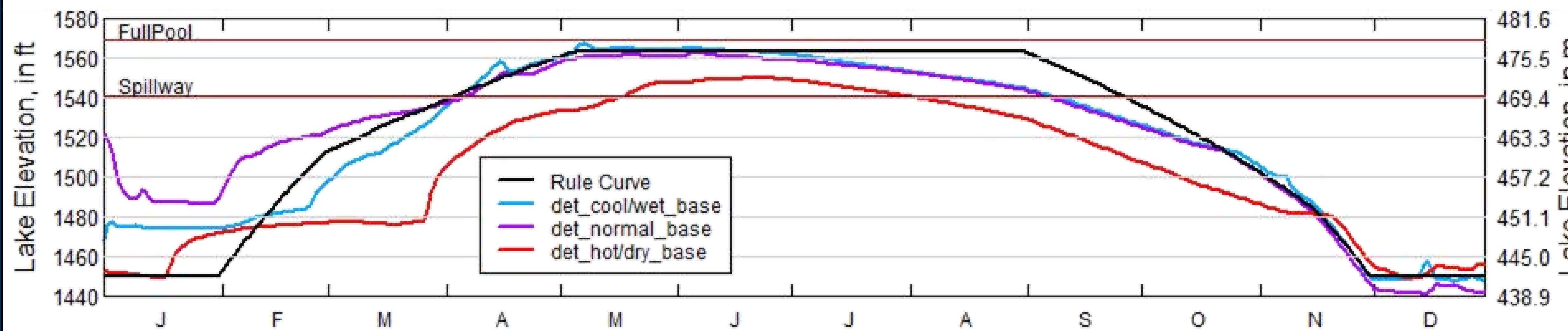
Blending Releases from Multiple Outlets to Manage Temperature



See http://dx.doi.org/10.3133/ofr20151012

With Hypothetical Temperature Control Tower





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Summary of Temperature Management

- Temperature is a major influence on fish
- Monitoring needed for understanding effect of flow, operation, and other factors
- Modification of seasonal temperatures impacts multiple life stages of anadromous fish
- Mitigation
  - With blending from multiple existing outlets
  - With temperature towers
  - Accompanied with reduced power generation
- Models can inform real-time operations and design of new structures.

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Reservoir Operations for Fish Passage:
Fall Creek Lake Drawdowns

Photo courtesy USGS Western Fisheries Research Center, Columbia River Research Laboratory

Fall Creek Lake, photo courtesy USACE

Fall Creek Lake during 2016 drawdown, photo by M. Keith (USGS)

USGS

Fall Creek Lake

Fall Creek Lake during 2016 drawdown, photo by M. Keith (USGS)

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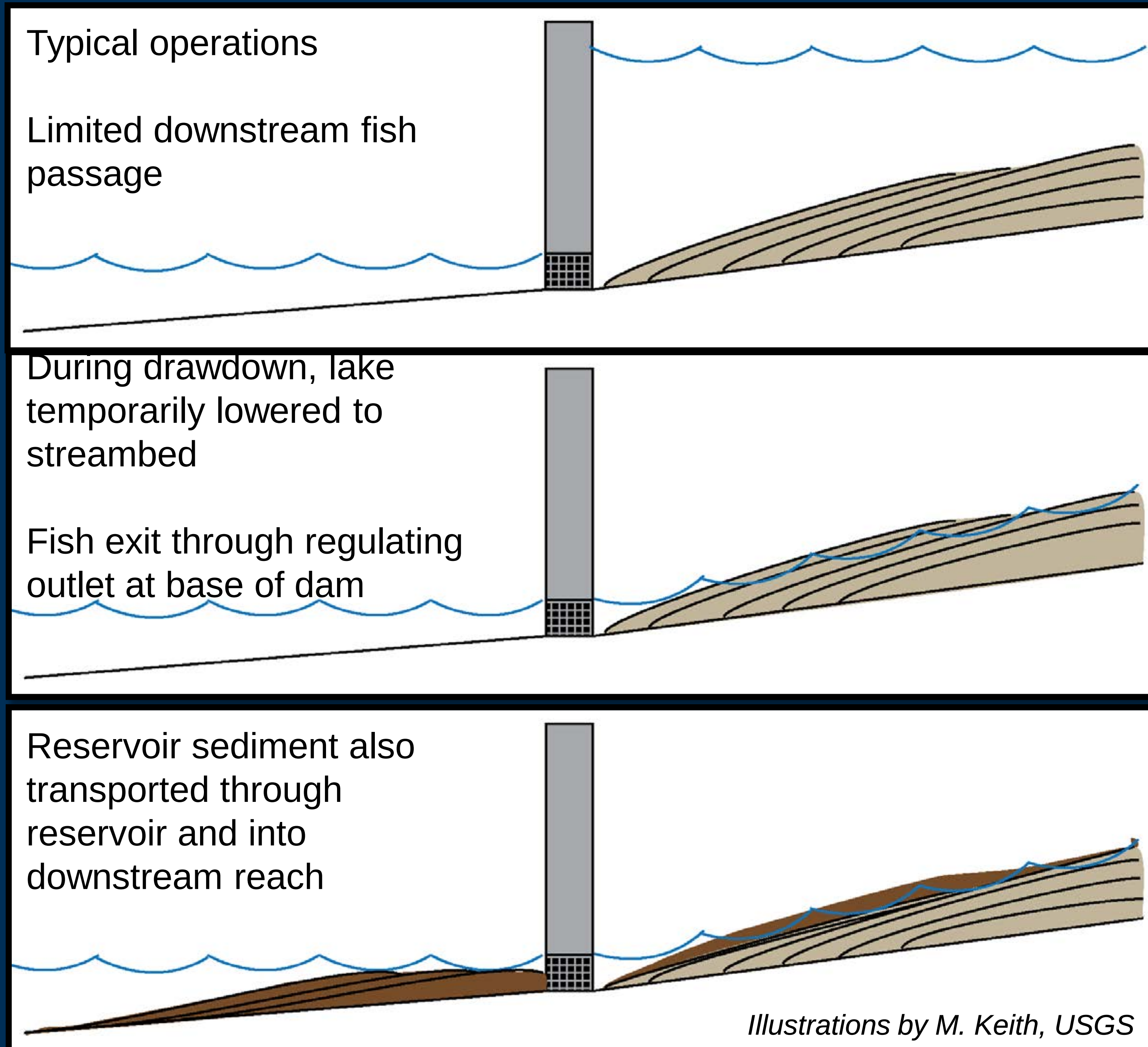
Typical operations
Limited downstream fish passage
During drawdown, lake temporarily lowered to streambed
Fish exit through regulating outlet at base of dam
Reservoir sediment also transported through reservoir and into downstream reach
Illustrations by M. Keith, USGS

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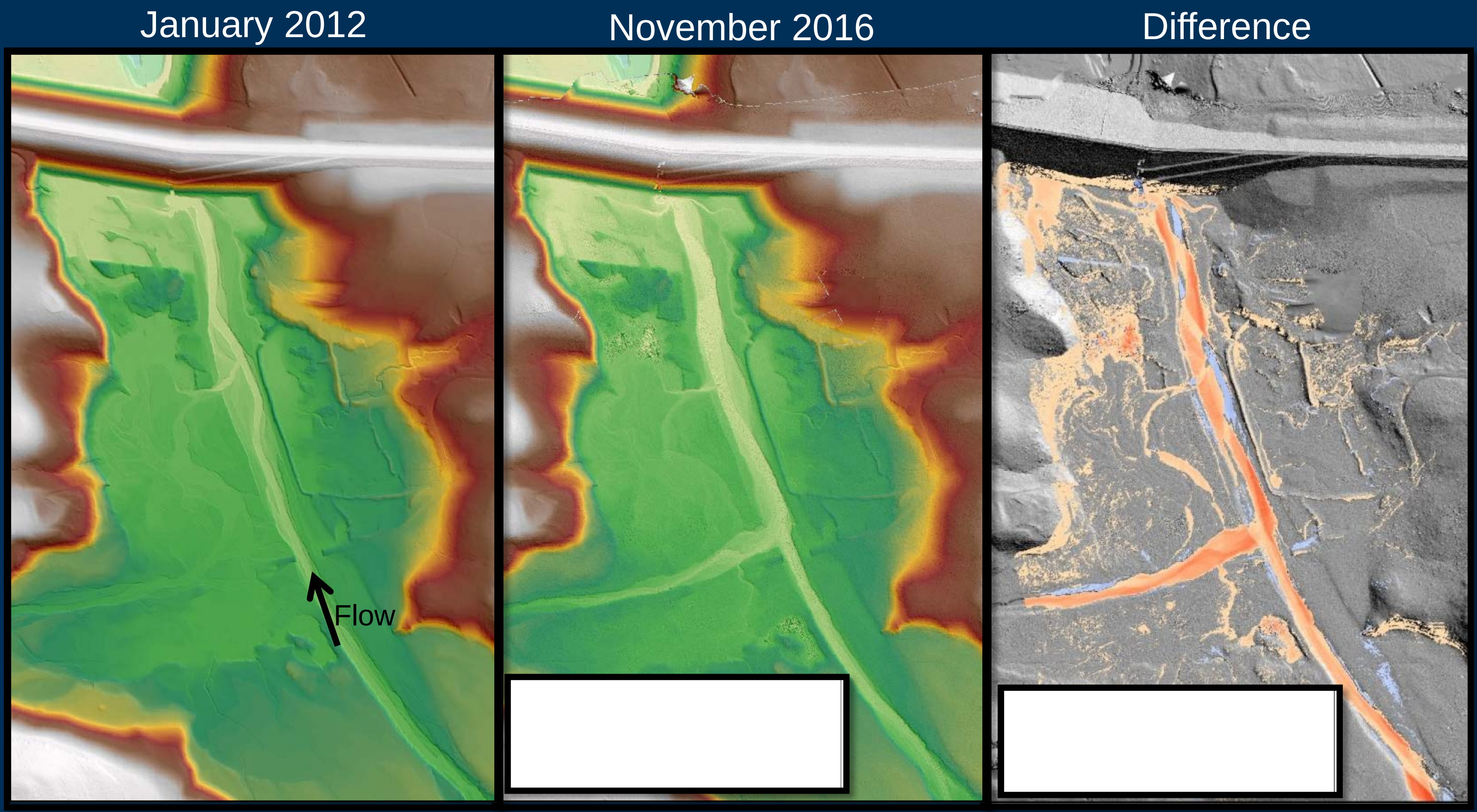
High Resolution Mapping to Track Reservoir Erosion



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Unpublished data subject to revision. Photo credit: M. Keith, USGS, ORWSC

Downstream sediment deposition from drawdown of Fall Creek Lake

Study in progress: modeling and analyses to identify flow management strategies with potential to reduce sediment impacts

USGS

Photo credit: M. Keith, USGS

Dam Releases to Meet Ecological Objectives

Examples of environmental flow objectives:

Inundate existing habitats

- Support spawning and incubation
- Optimize high or low flow rearing

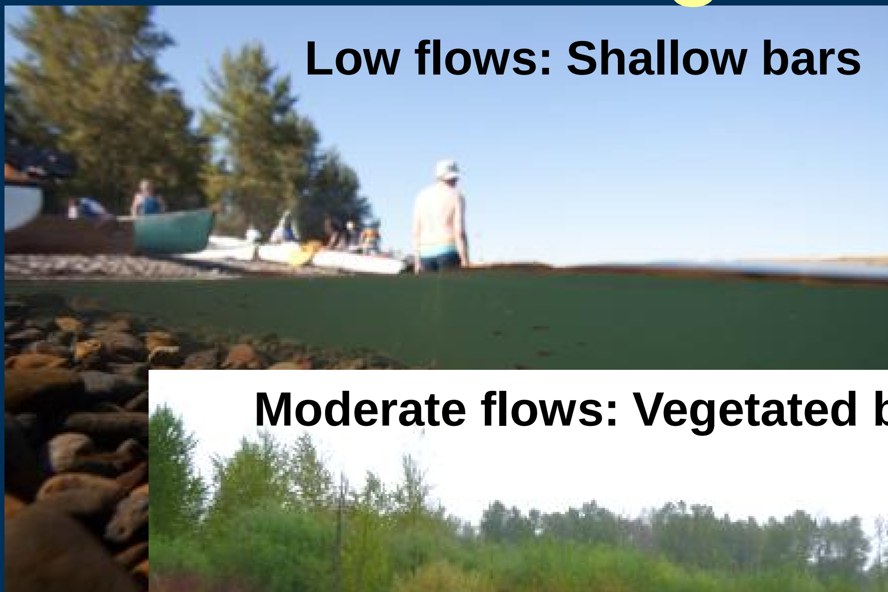
Maintain or create habitats

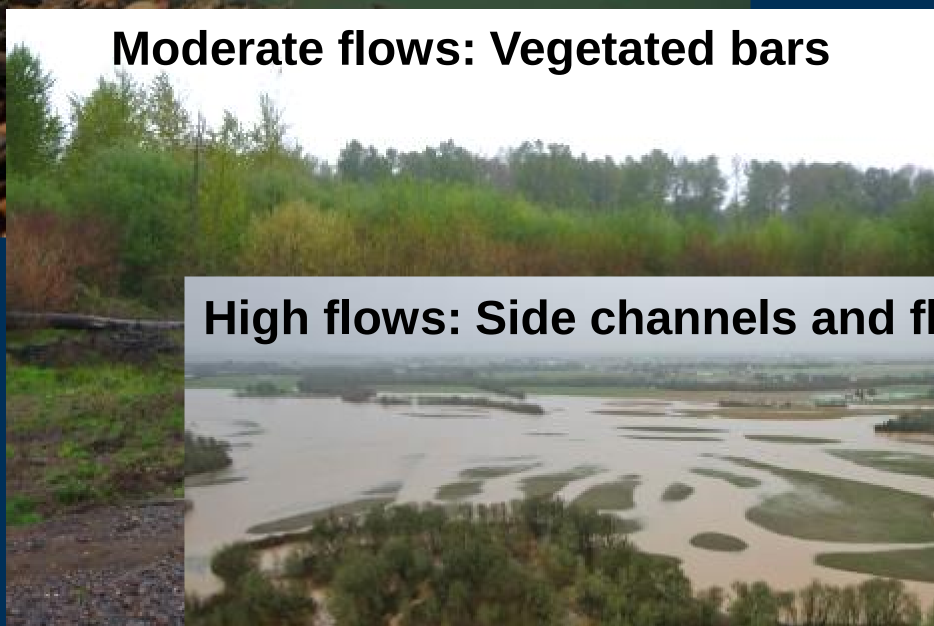
- Move sediment or create and maintain side channels

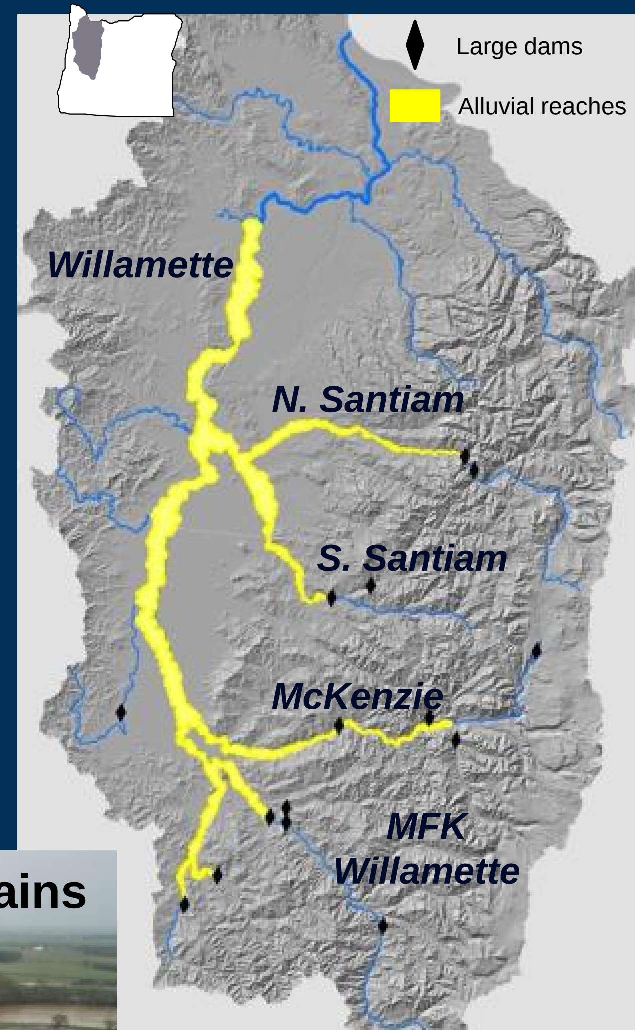
Minimize and manage fish disease

Willamette River side channel, photo by J. Mangano, USGS

Flows to support Spring Chinook rearing habitat



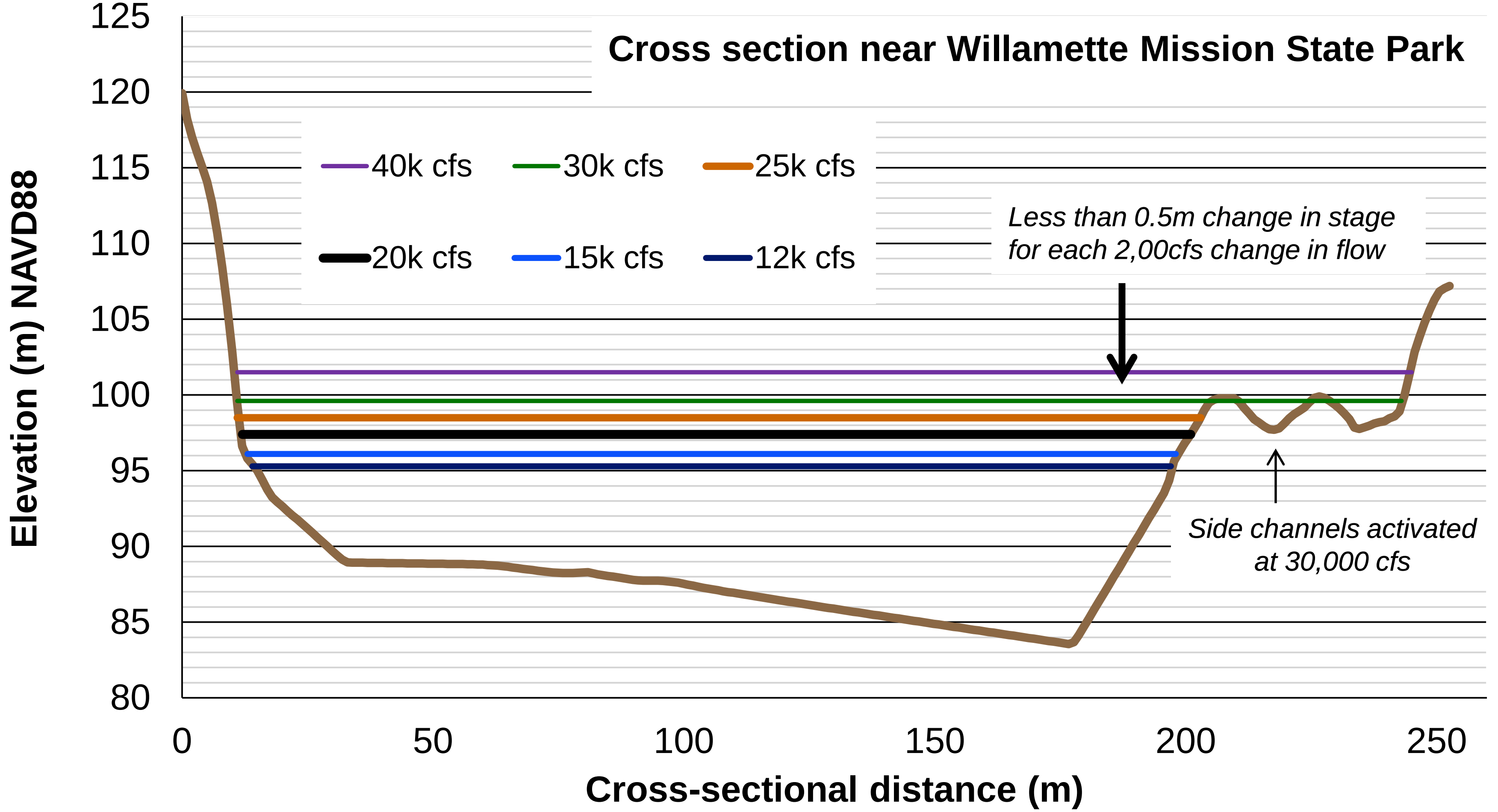




map by USGS

Flow Management to Inundate Existing Habitats: Willamette Mission Reach

Provisional stage and inundation extent determined for 12,000-40,000 ft³/s to inform flow management and reservoir allocation.



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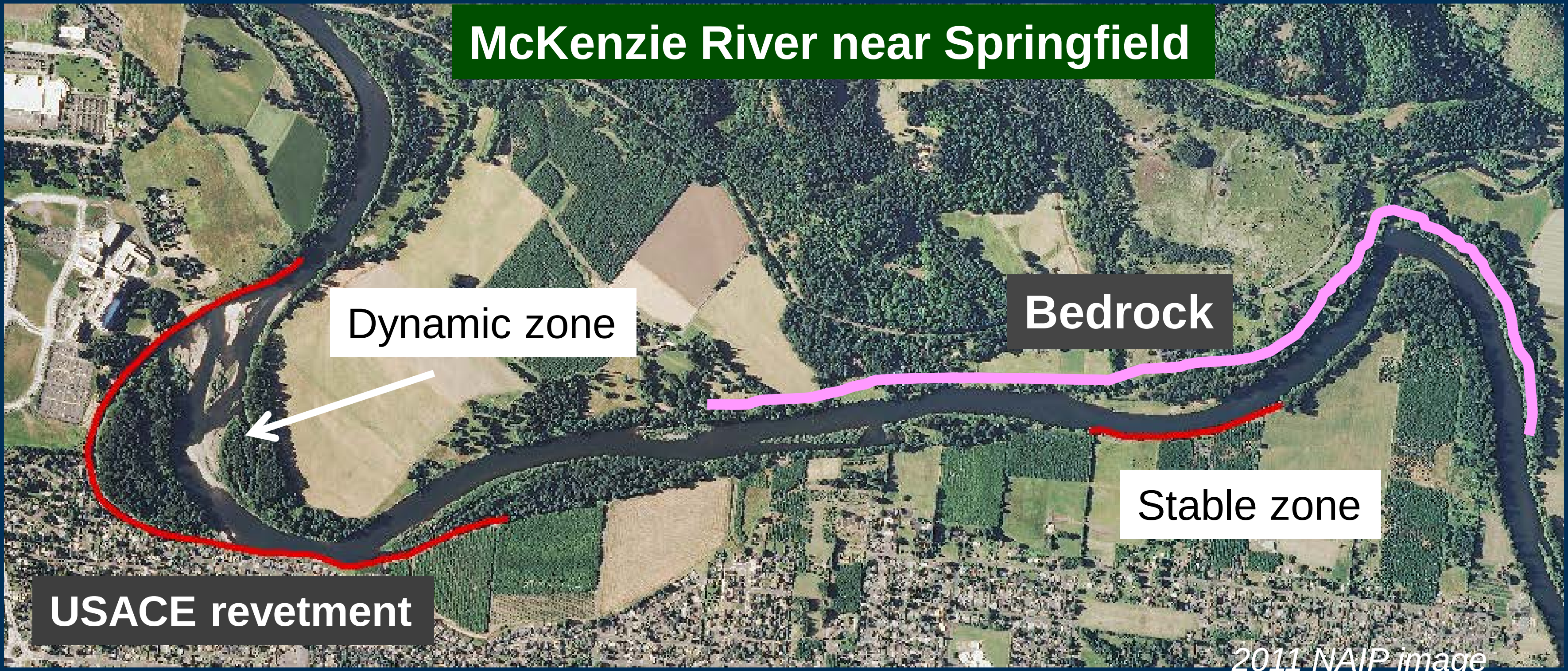
Provision results

Flow Management to Create and Enhance Habitats

- *Strategic flows can be used to refresh gravel bars and scour side channels*
- *Effectiveness depends on constraints like sediment supply, physiography, bank erodibility and infrastructure*



Considerations for Flow Management

- Realistic flow targets, aligned with geomorphic, biological factors
- Reach-specific flow targets for meeting hydraulic/inundation objectives
- Reach-specific targets for habitat forming processes
- Role of river restoration, floodplain managers, agriculture and others

Questions for Future Research

How can we optimize upgrades to benefit multiple purposes?

How can we maximize benefits of dams, minimize ecological impacts and do this cost-effectively?

How can we better anticipate societal values and needs 50 + years in future?

What can we learn now to better plan for future?

How can science community better support engineering community?

USGS

Summary

Dams provide critical societal services, but have environmental impacts

Small portion of dams may be removed for safety, cost or other reasons.

- *Science and engineering community can help managers better anticipate effects of dam removal.*

Many strategies to minimize ecological costs of large dams

- *Innovative science and engineering can address temperature issues, improve fish passage, develop environmental flows*

Lookout Point Dam, Photo courtesy USACE

USGS

References

Rose Wallick, rosewall@usgs.gov, 503-251-3219

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USGS

Extra slides

Examples of dam removal studies

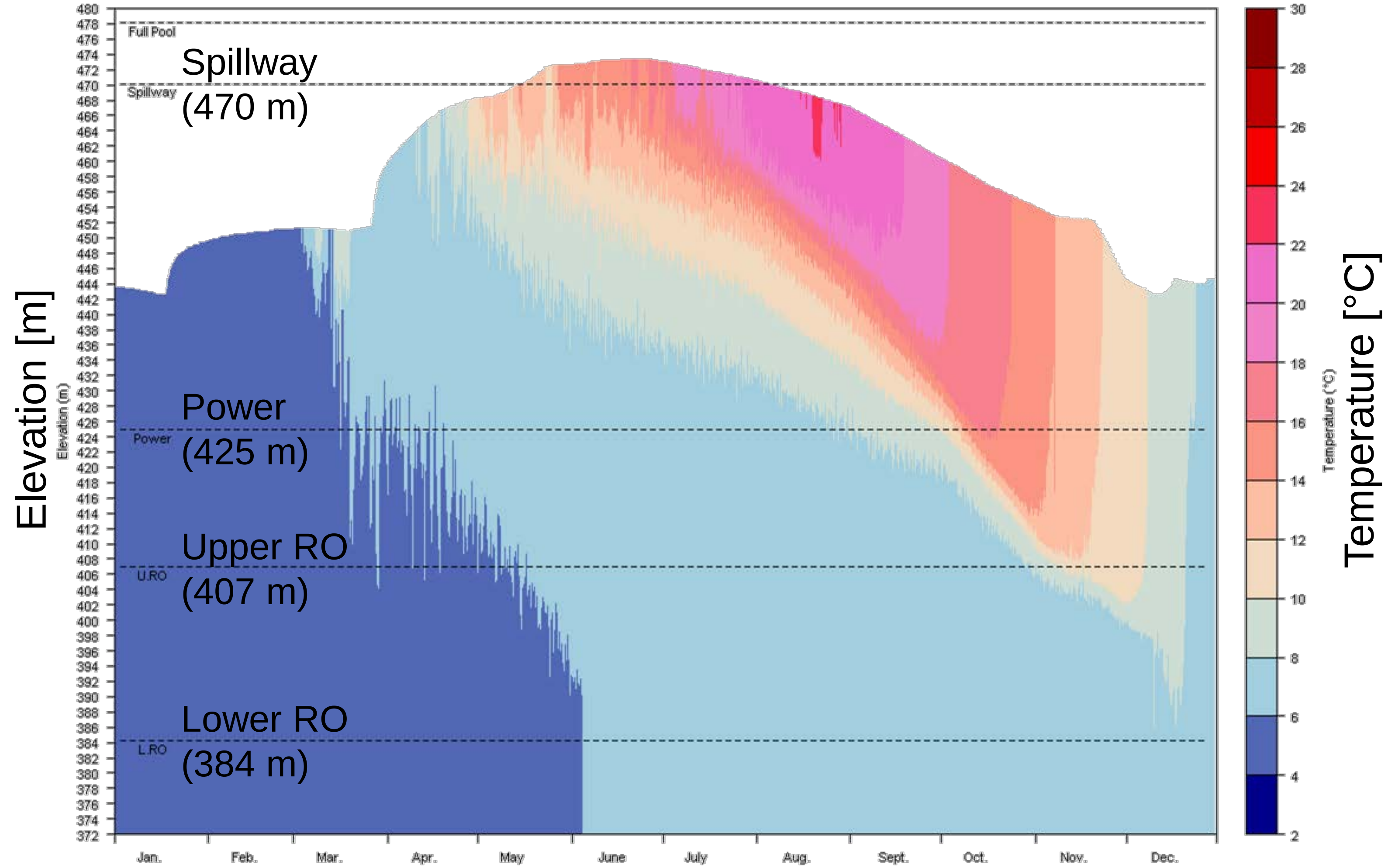
- Conceptual Models to Generate Hypothesis and Inform Adaptive Management

- Case studies Marmot, Condit, Elwha, others

Notching of coffer dam during Marmot Dam removal, Sandy River 2007. Photo by Jon Major, USGS

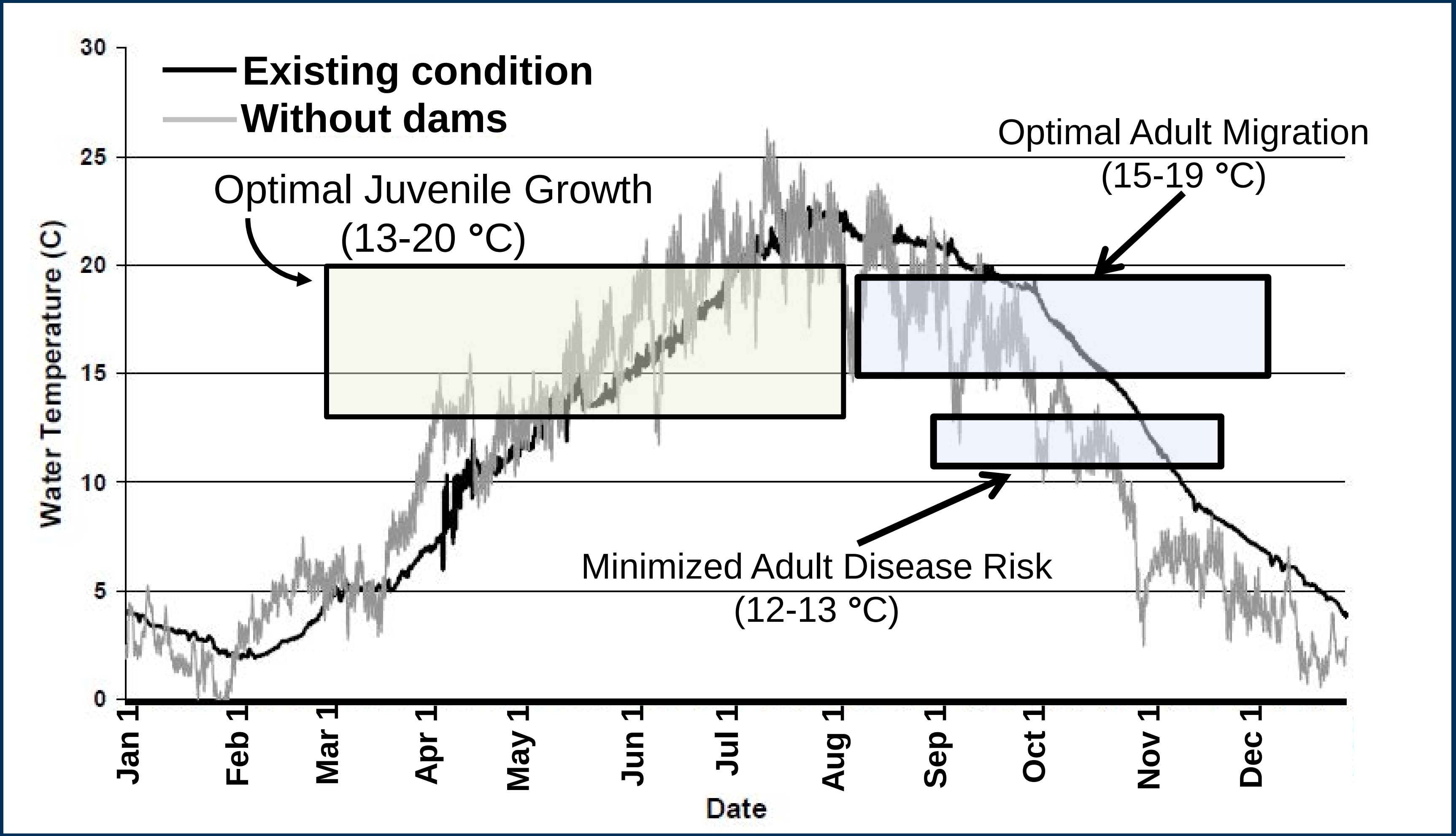
Factors affecting in-reservoir and release temperatures

- Residence time
- Depth, volume, surface area
- Climate and meteorology
- Stratification (depth/timing)
- Outlet depth
- Operations



The CE-QUAL-W2 model can simulate all of these factors

Flow comparison: Klamath River



Source: PacifiCorp 2005; Klamath SD EIS, 2012