Water Temperature and Coldwater Refuges in the Willamette River Basin

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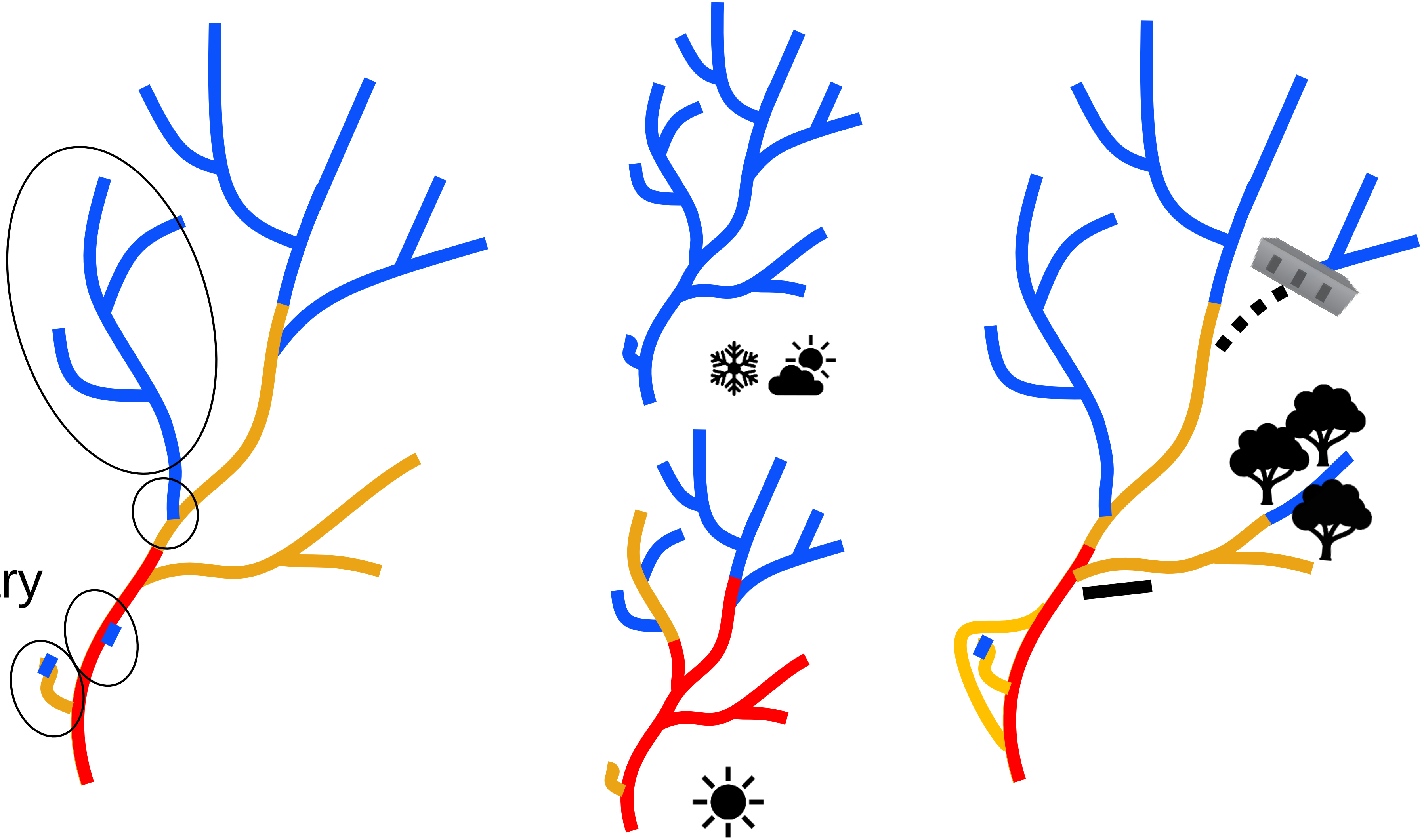
State of the Willamette Workshop
January 15, 2020

USGS photograph

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

Water temperature conditions vary…

Along a river network | **Over time** | **With human actions**



Coldwater refuges (CWRs) include sub-basins, tributary mouths, and off-channel features

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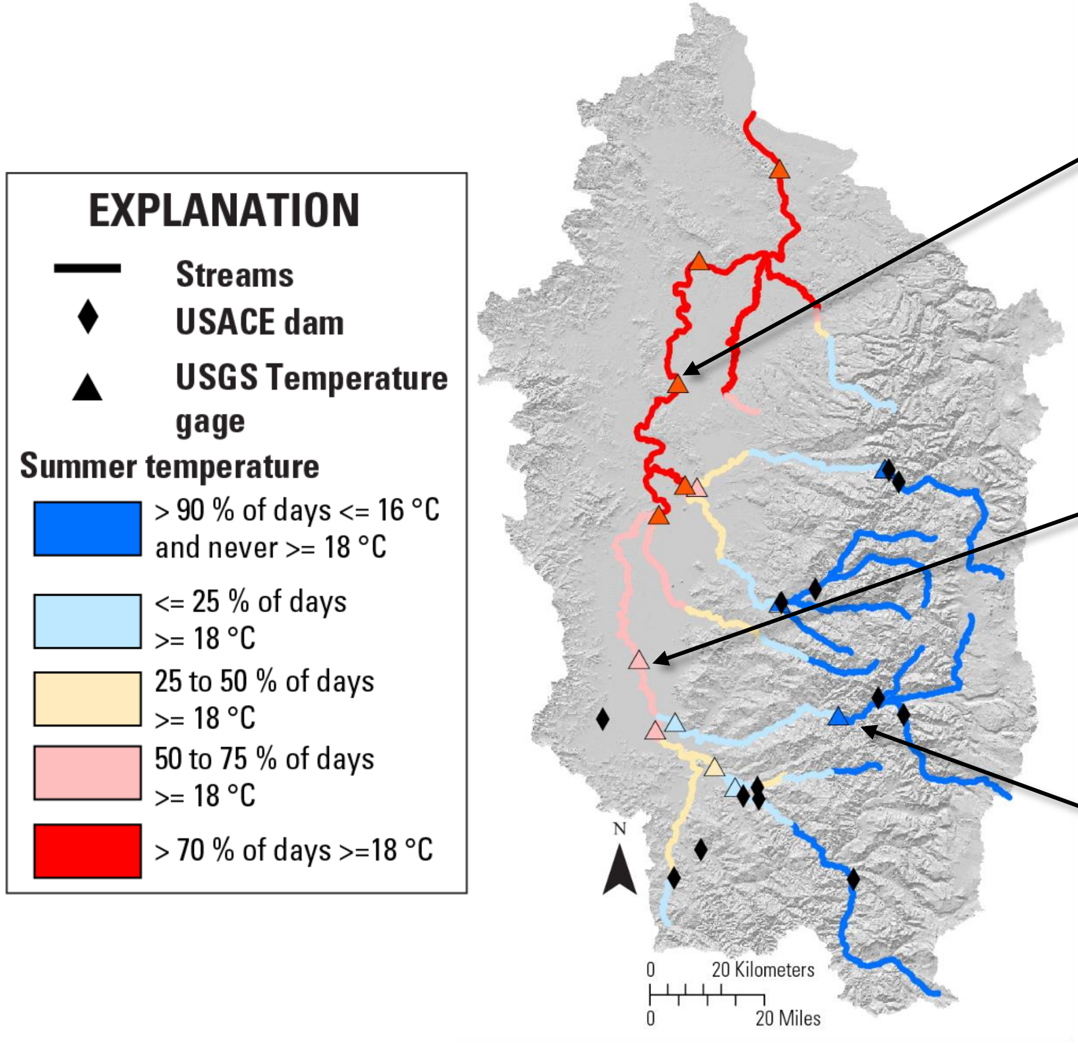
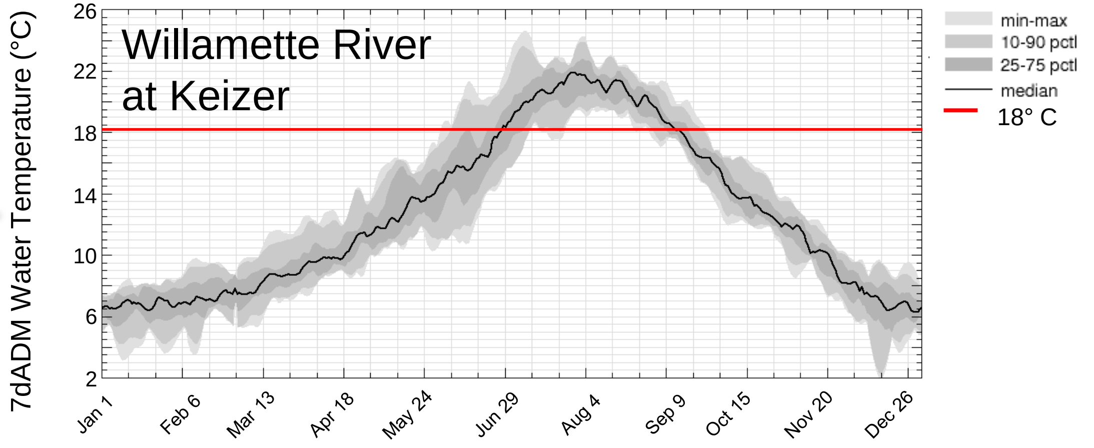
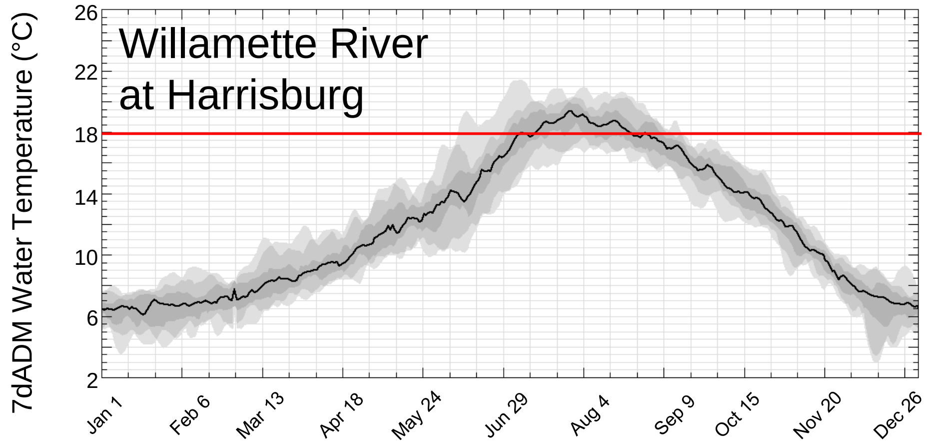
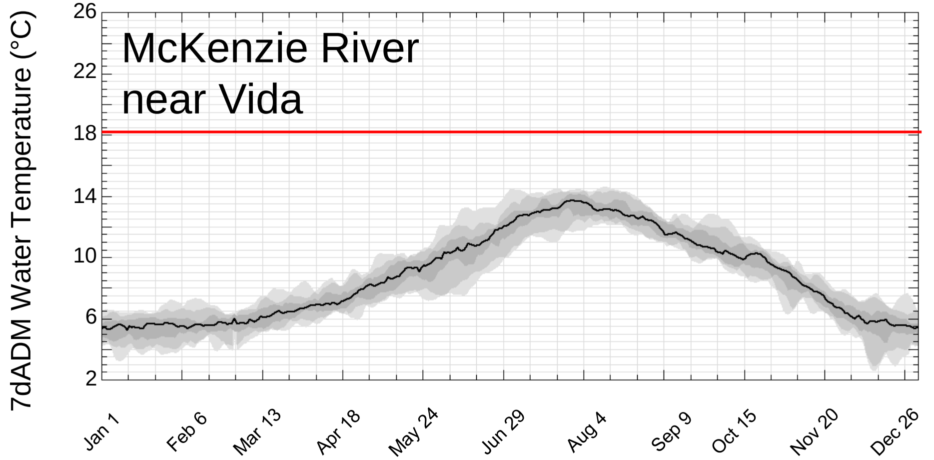
Willamette River Thermal Conditions









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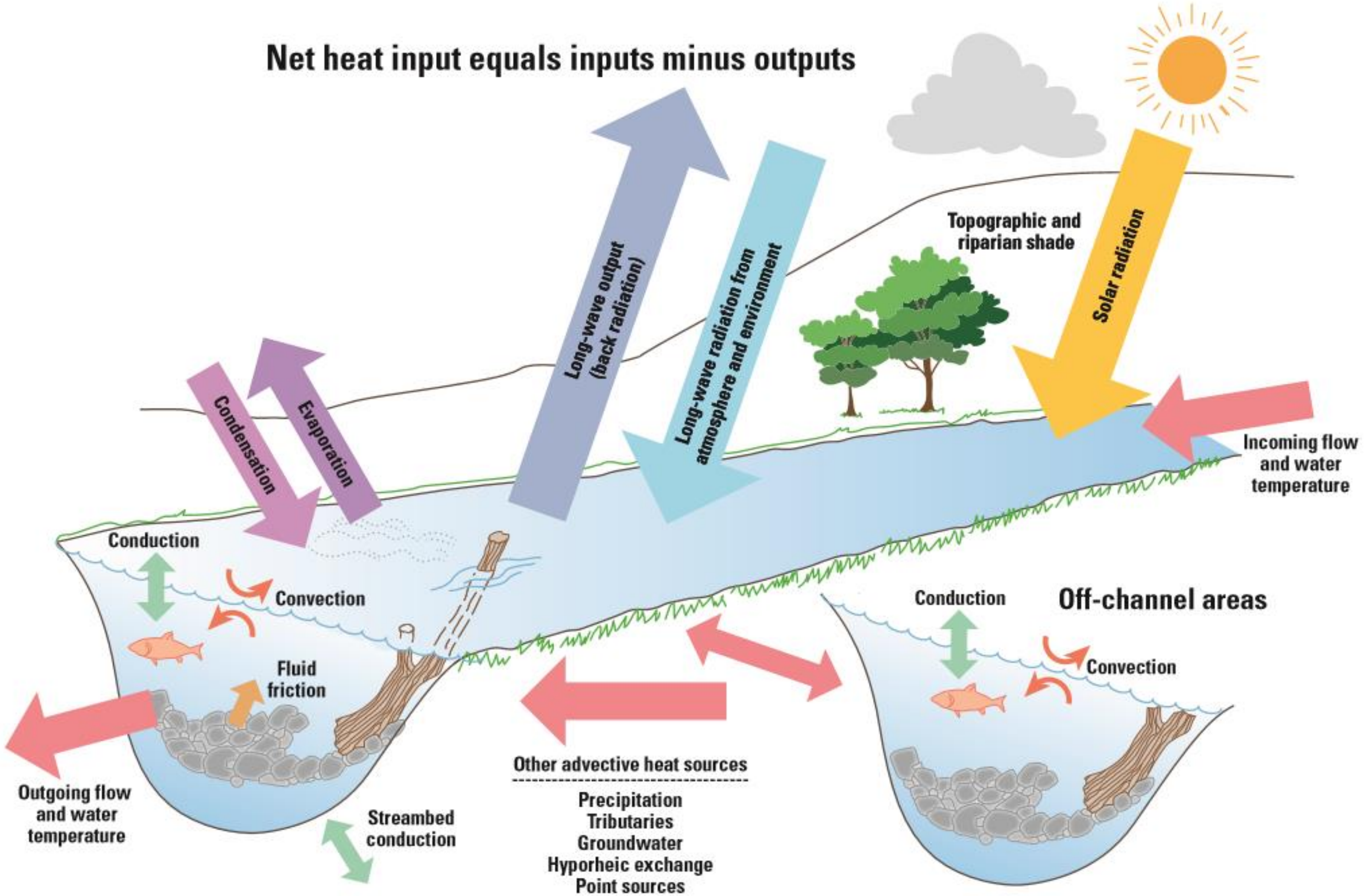
USGS map by Gabe Gordon
Temperature plots from USGS Data Grapher

Controls on Stream Temperature

$$water\ temperature \propto \frac{heat\ load}{discharge}$$

$$\Delta T \propto \frac{q}{mC}$$

q = amount of heat added or removed from the system
m = mass of water
C = specific heat of water (approximately constant)



Adapted from Bartholow (2000)

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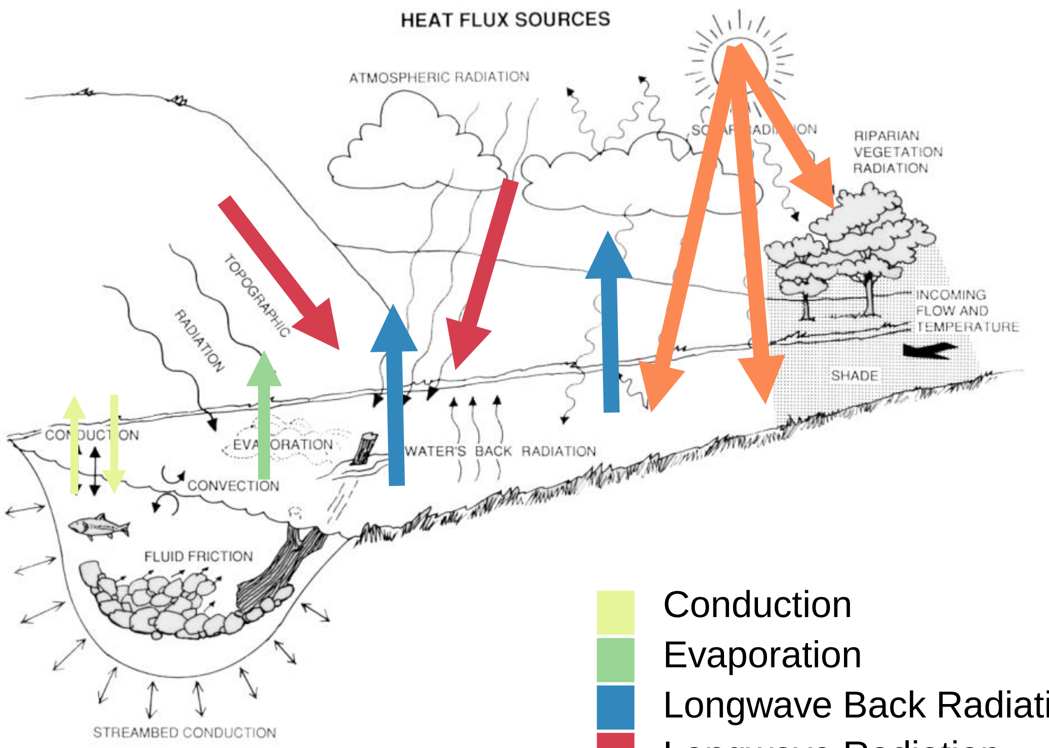
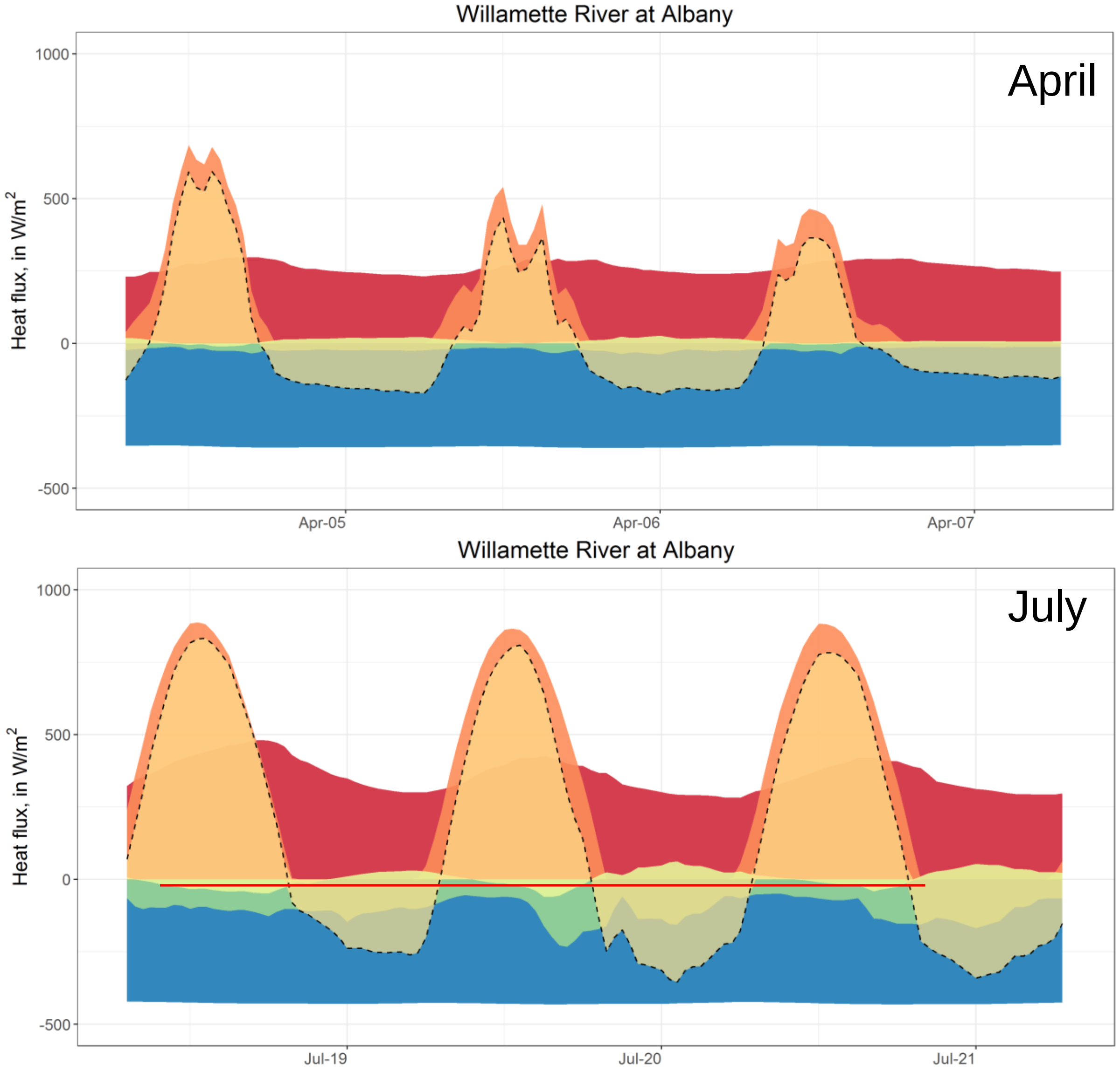
Heat Load to the Willamette River:

Comparing Flux Source and Magnitude



Adapted from Bartholow (2000)

- Conduction
- Evaporation
- Longwave Back Radiation
- Longwave Radiation
- Net Heat Flux
- Shortwave Solar



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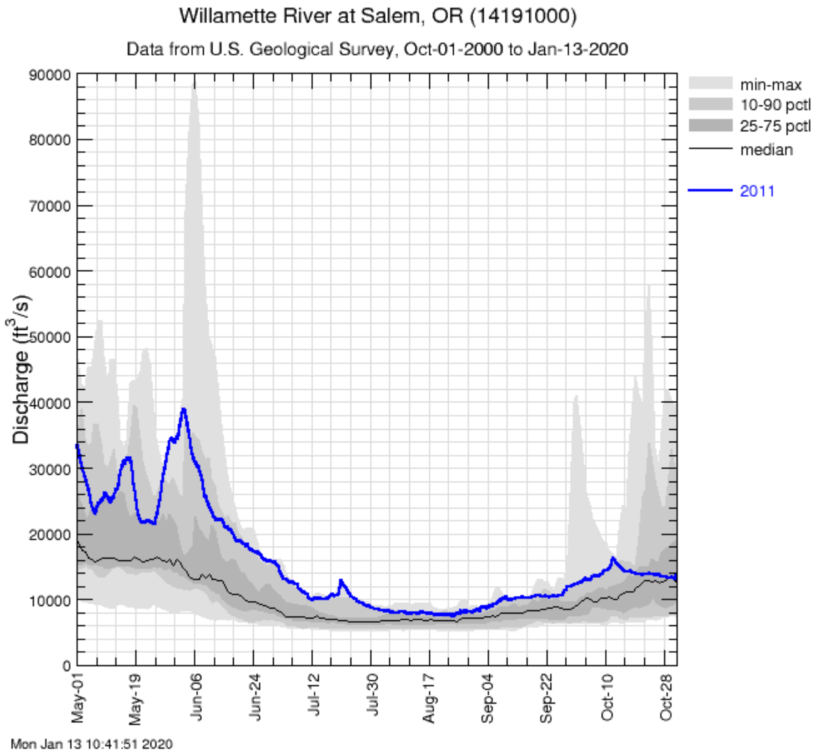
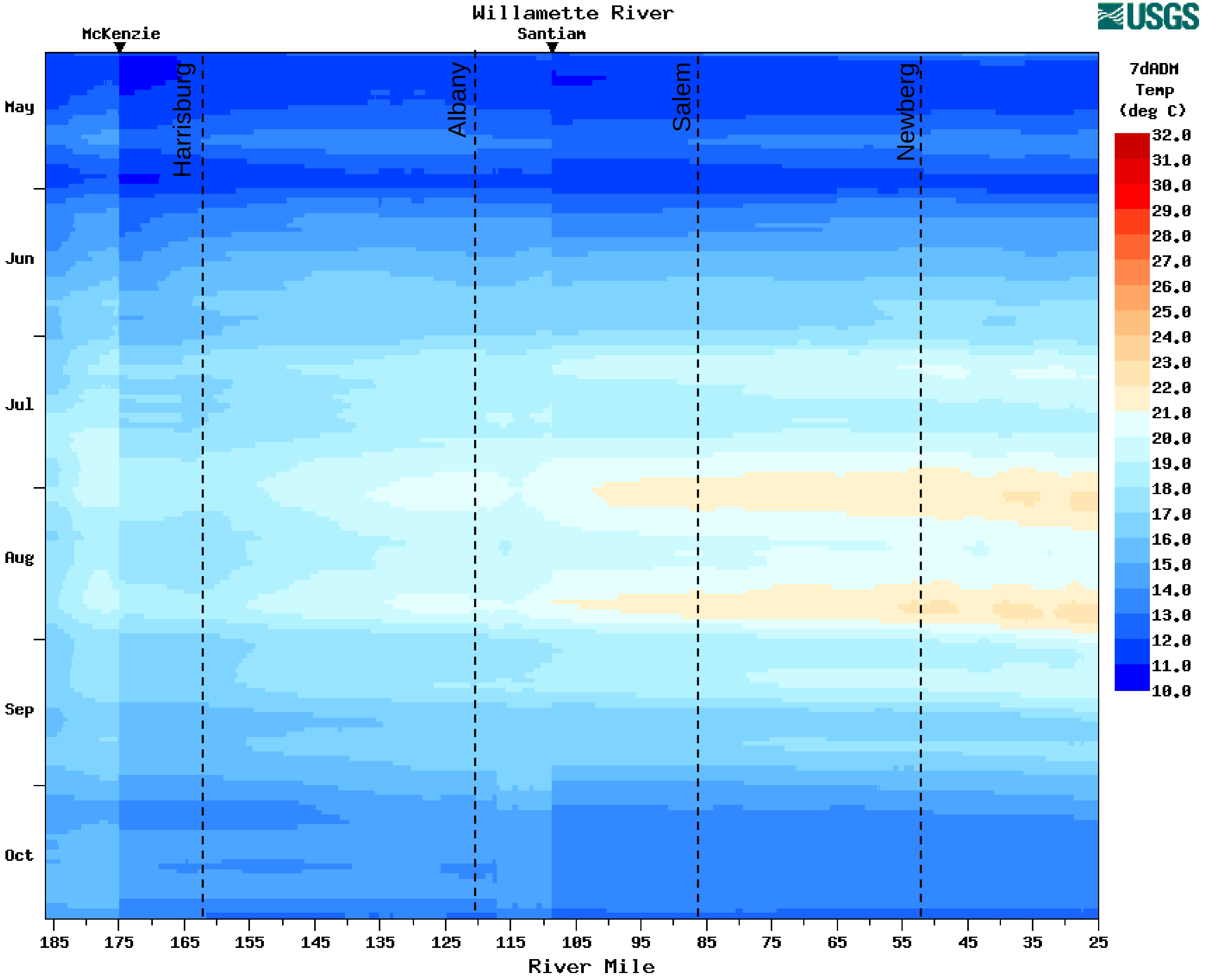
provisional results; subject to revision

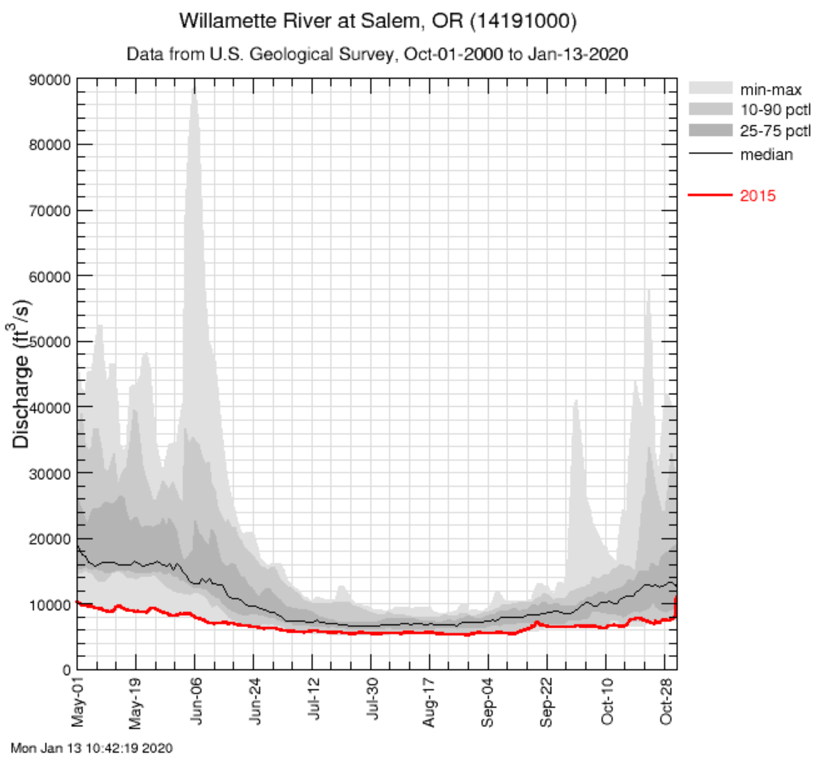
Willamette River Temperature 2011

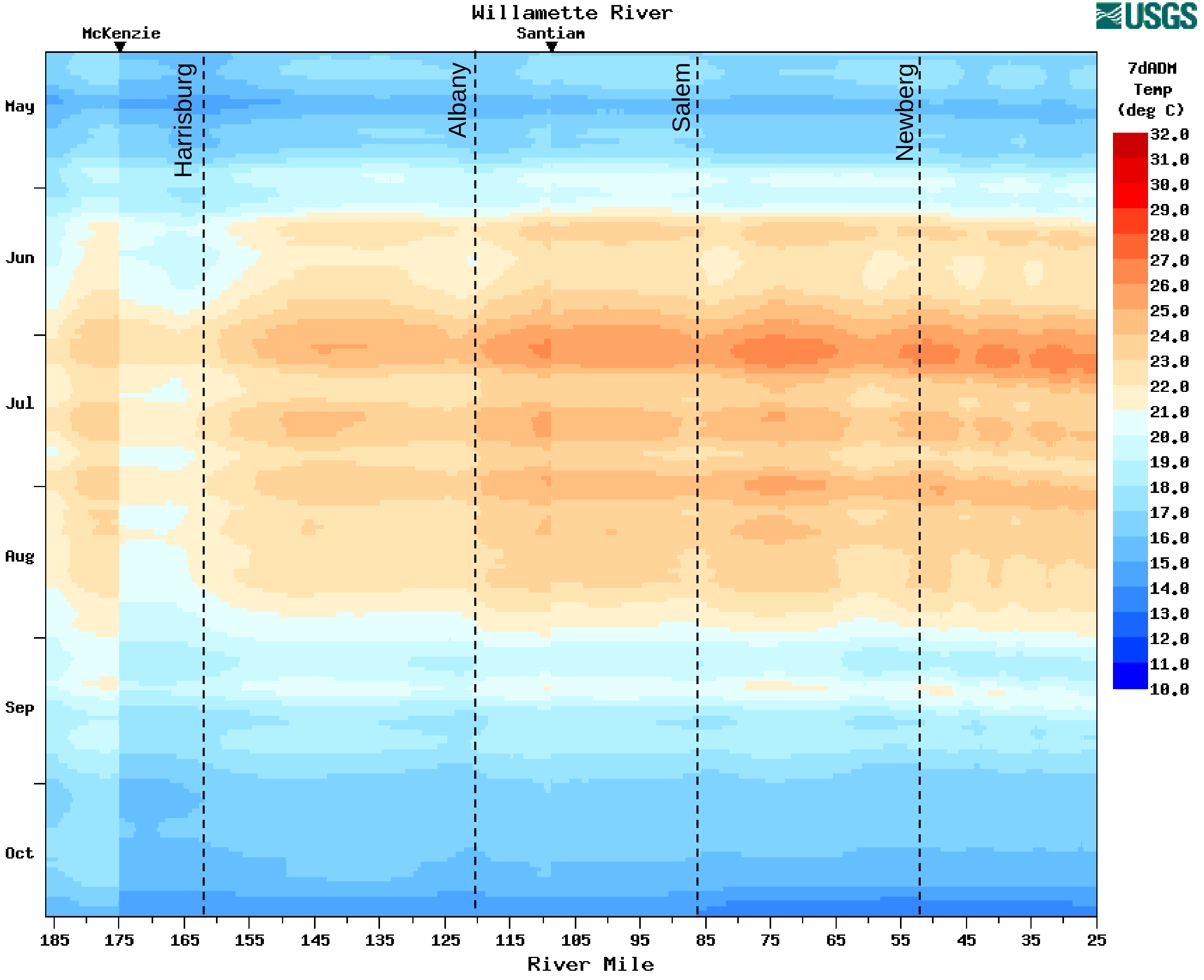




provisional results; subject to revision
discharge plot from USGS Data Grapher

Willamette River Temperature 2015

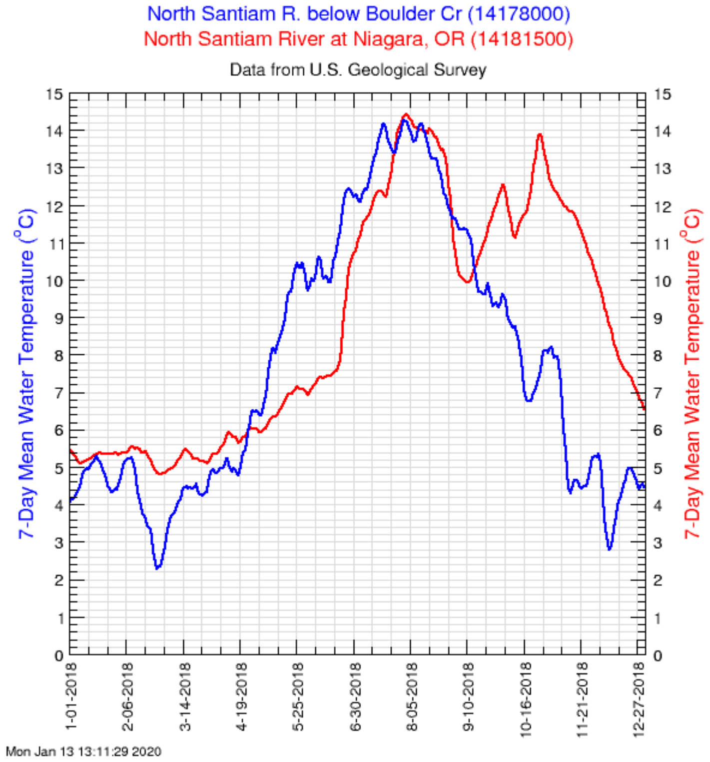


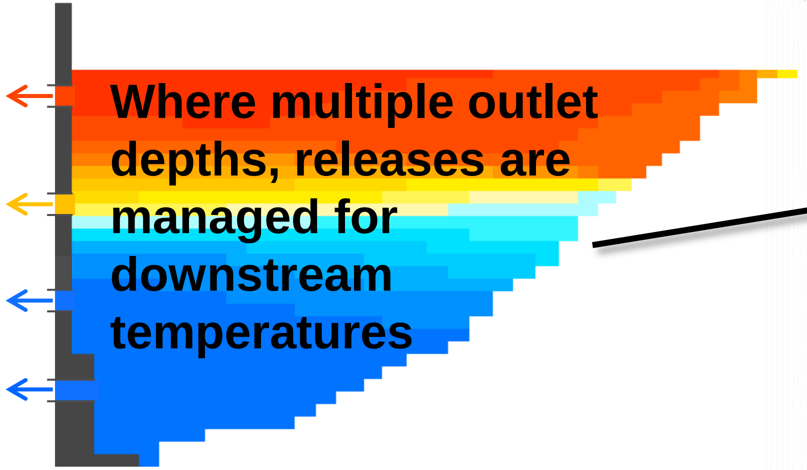


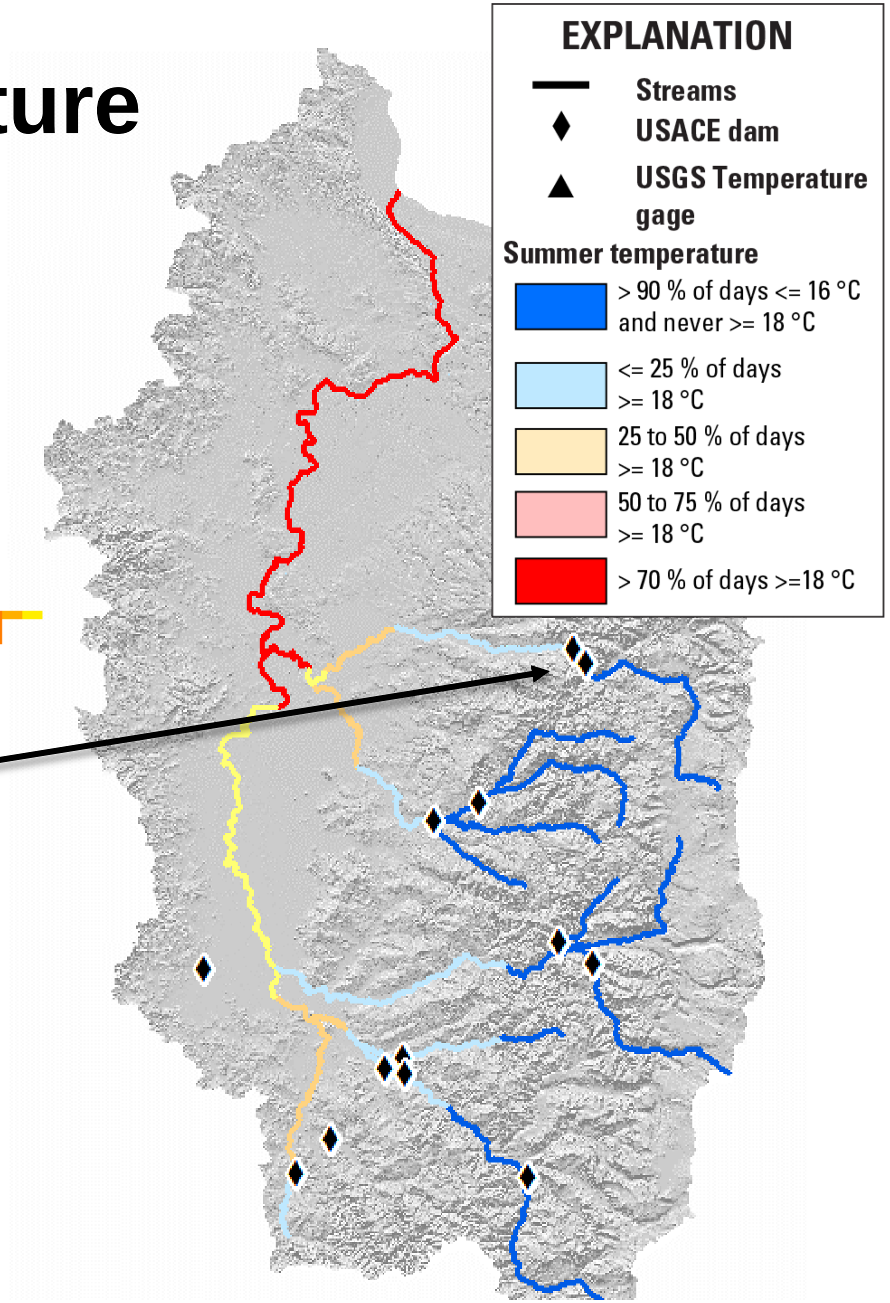
provisional results; subject to revision
discharge plot from USGS Data Grapher

Influence of Dams on Stream Temperature

Close to the dams, stream temperature is controlled by the temperature of released water







USGS Data Grapher; Rounds (2010);
Temperature map by Gabe Gordon, USGS; based on 7day average of daily maximum stream temperatures 2010-2017; https://waterdata.usgs.gov/nwis

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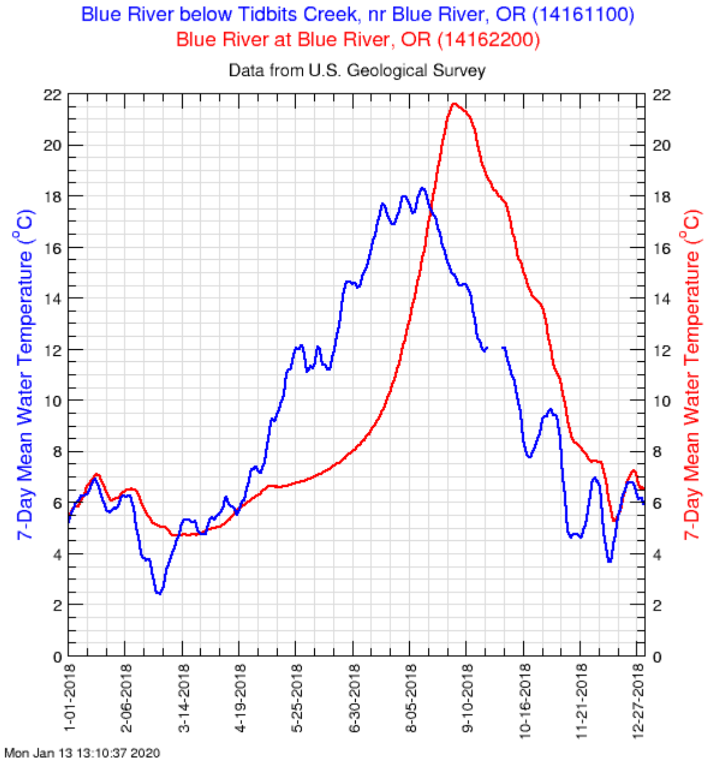

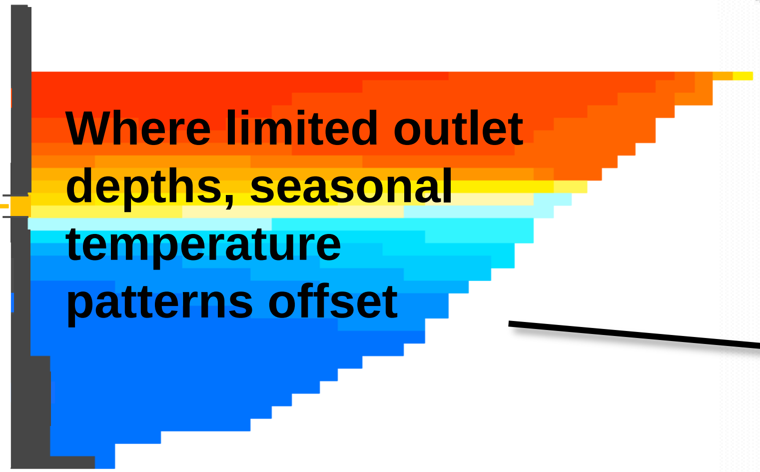

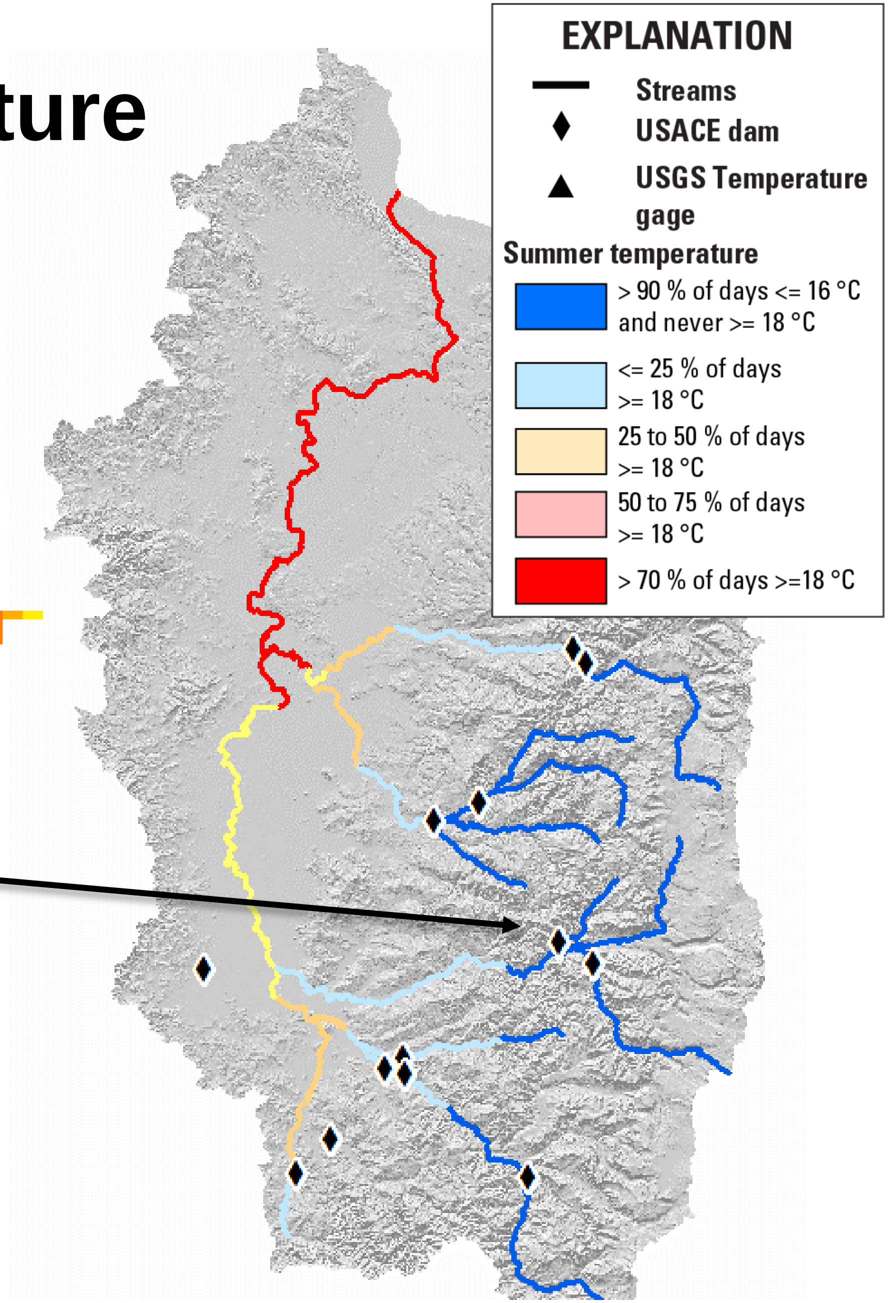

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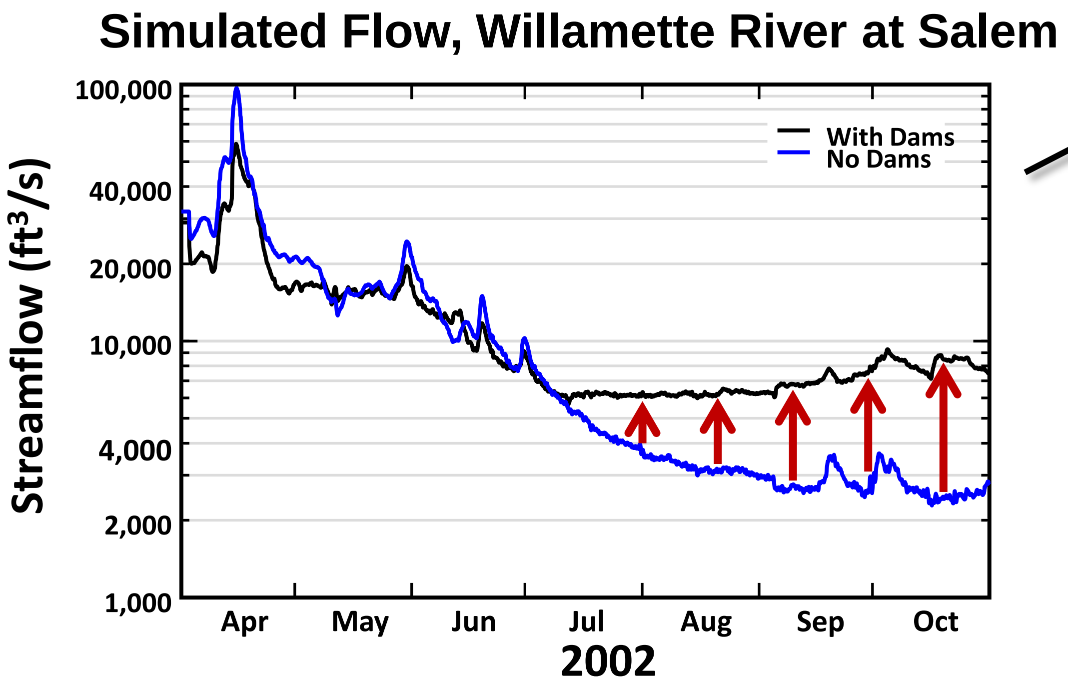
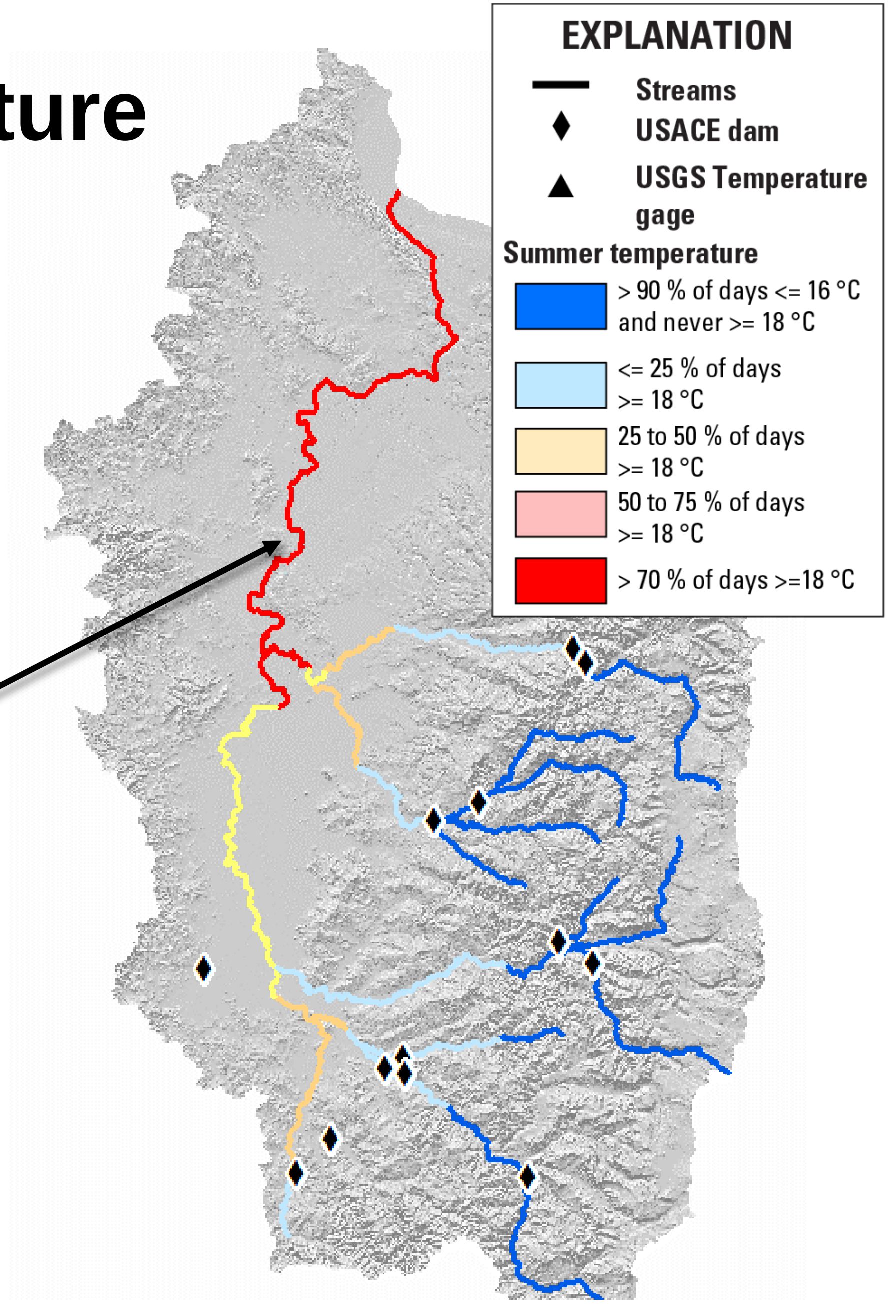
Influence of Dams on Stream Temperature

- With distance and travel time, direct temperature influence decreases
  - Primary dam influence on temperature is flow augmentation





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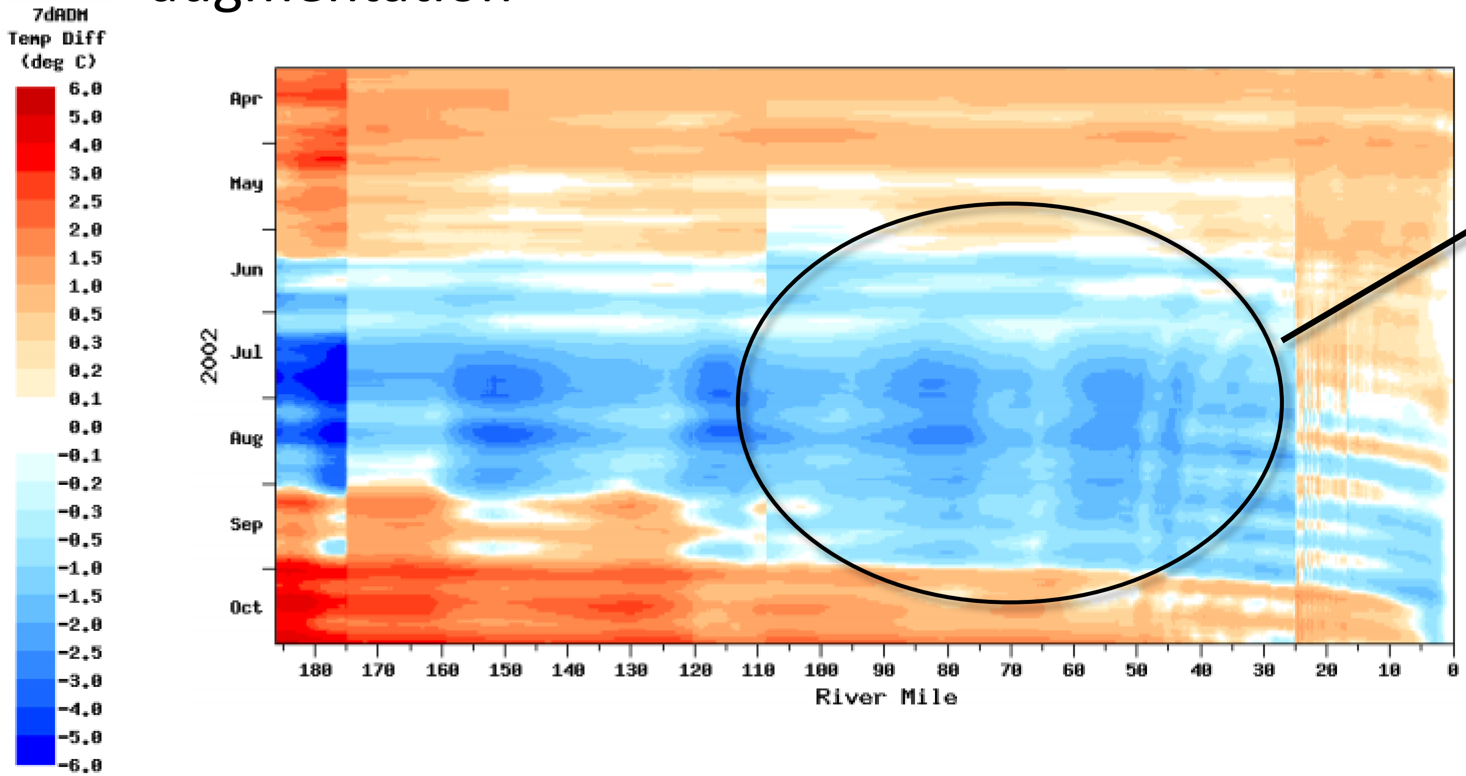

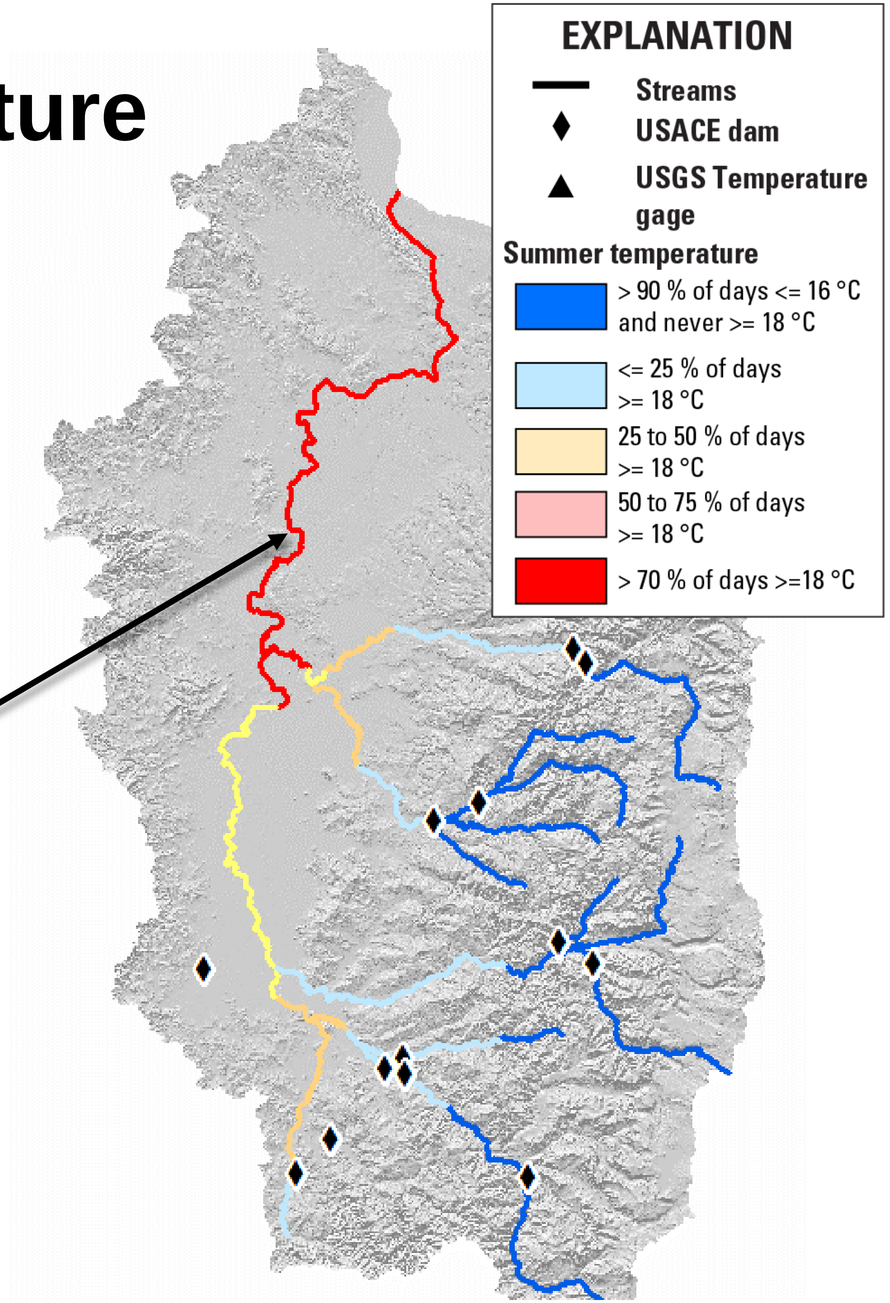

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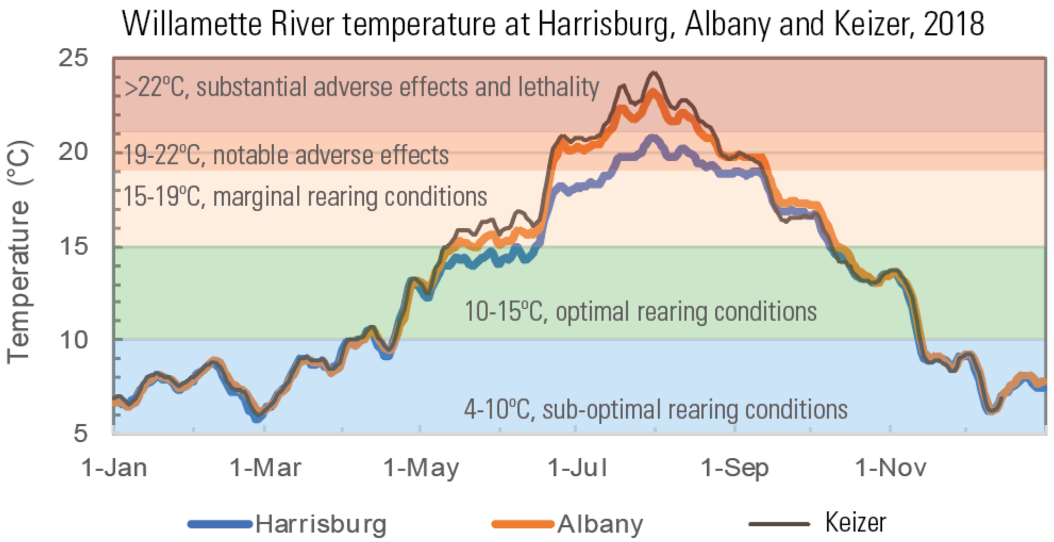
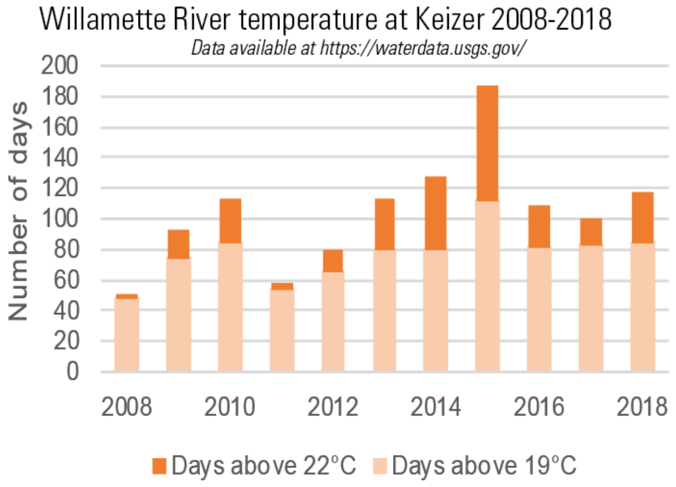
Rounds (2010); temperature map by Gabe Gordon, USGS; based on 7day average of daily maximum stream temperatures 2010-2017; https://waterdata.usgs.gov/nwis



Temperature summary from 7-day average of daily maximum data in 2018 at each gage



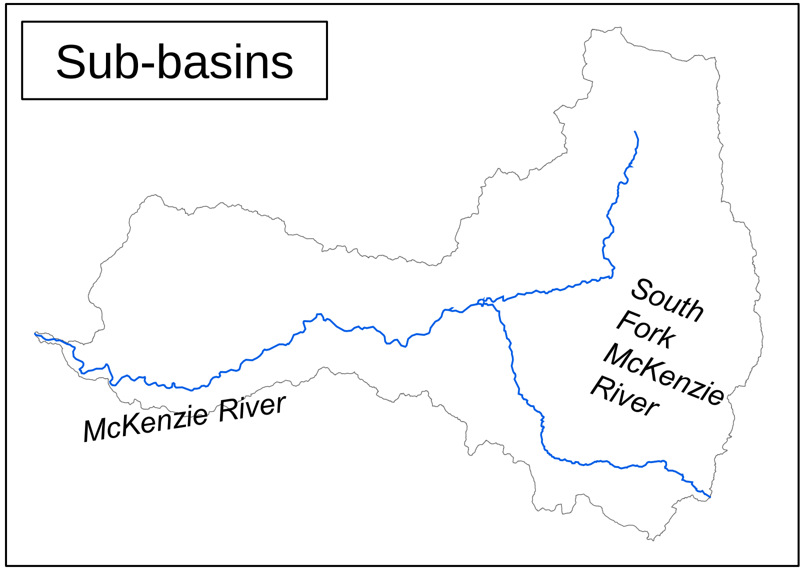
Temperature summary from 7-day average of daily maximum data in each year

Provisional data; subject to revision
Stream temperature data available from https://waterdata.usgs.gov
Preliminary temperature thresholds for juvenile Chinook Salmon based on literature review by G. Hansen, T. Kock, and R. Perry (USGS)

- Winter stream temperatures cold and relatively uniform across the basin
- Systematic downstream warming in summer
  - Elevated stream temperatures represent challenge to cold water-adapted species in summer
    - Degree of summer heating varies annually and spatially
- Primary mainstem influences are solar heat flux and streamflow
  - Dam release temperatures influence upper reaches of major tributaries

REST AREA AHEAD
Coldwater refuge!

Potential coldwater refuges (CWRs) include sub-basins, tributary mouths, and off-channel features



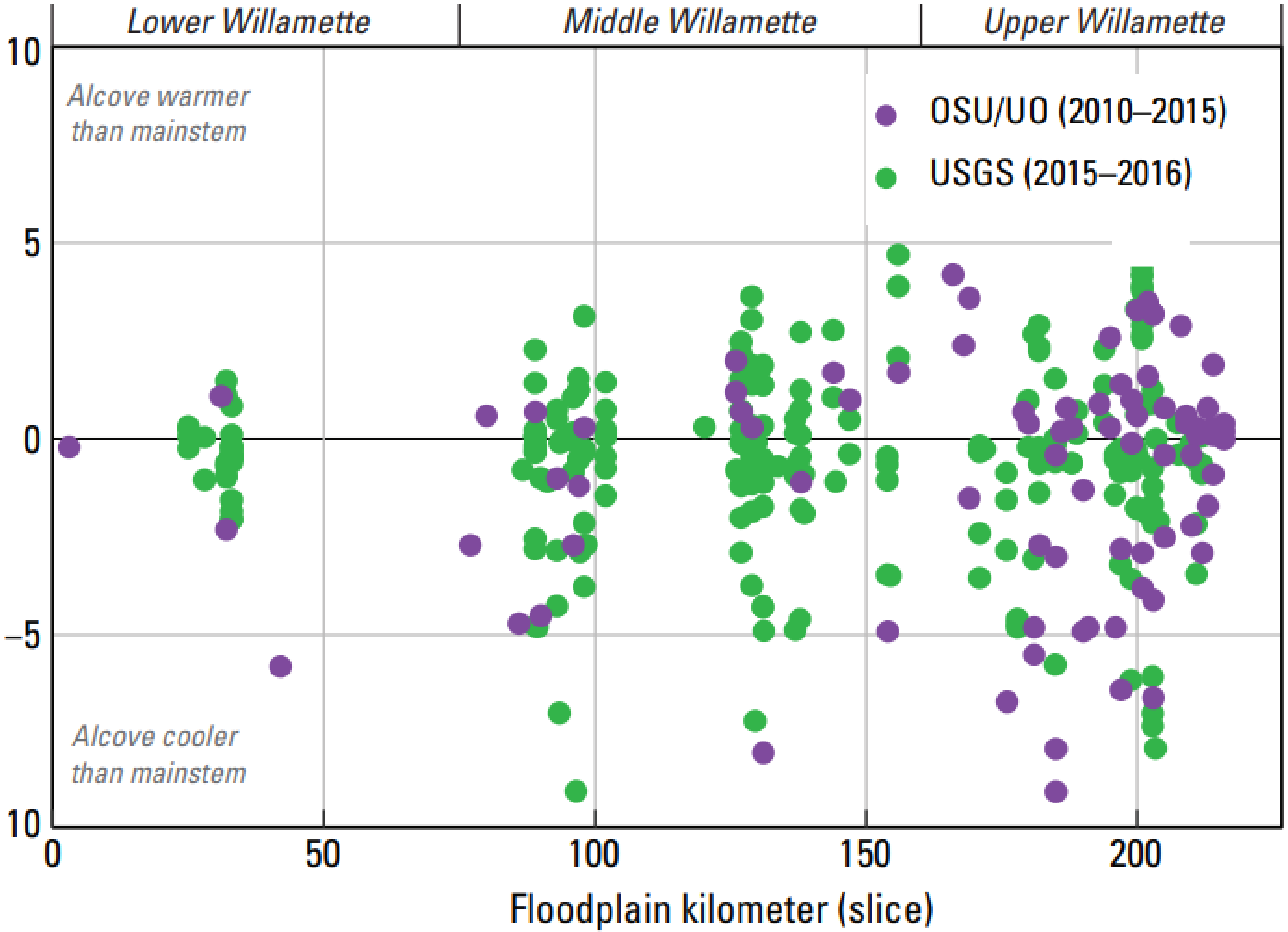
Johnson Creek; USGS photograph

Alcove on mainstem Willamette River downstream of Santiam River; USGS photograph

Water temperature (and dissolved oxygen) vary greatly in off-channel features.

Warmer than main channel

Cooler than main channel



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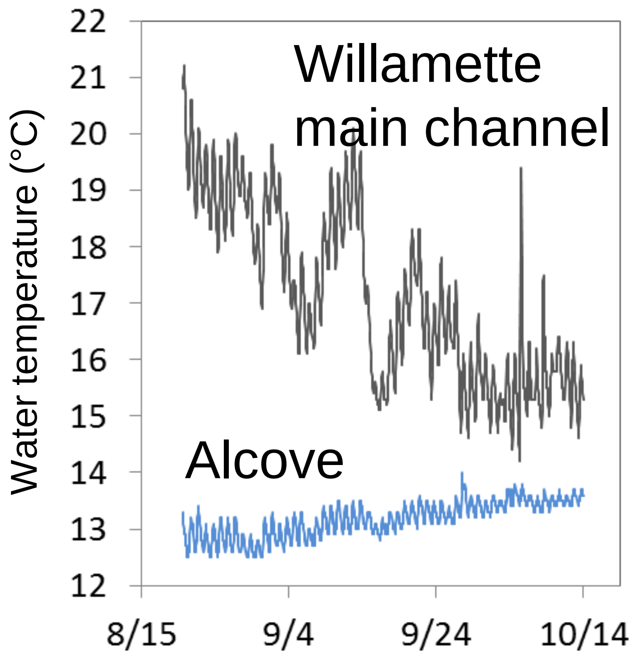
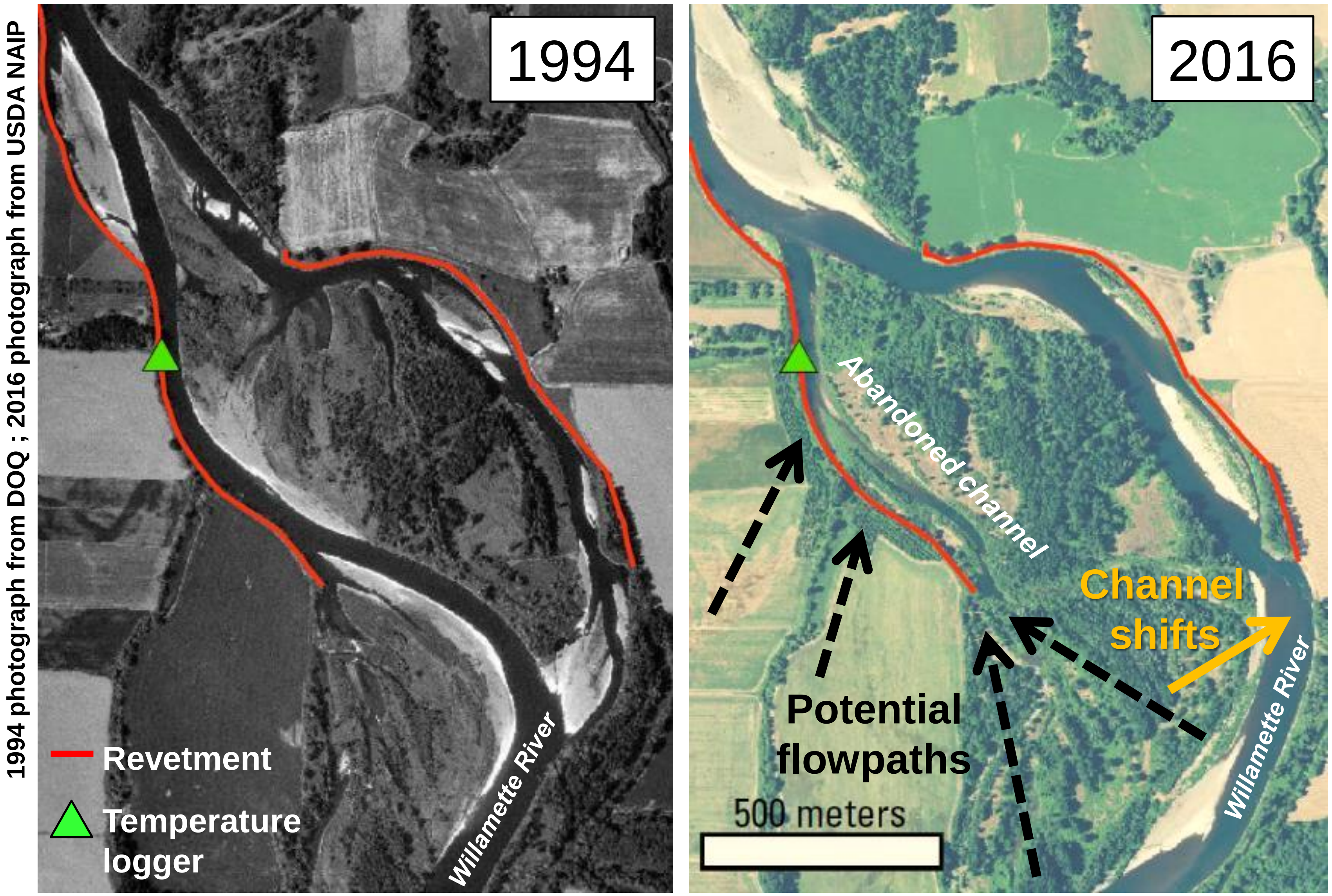
Blue Ruin Alcove in the Upper Willamette above Harrisburg



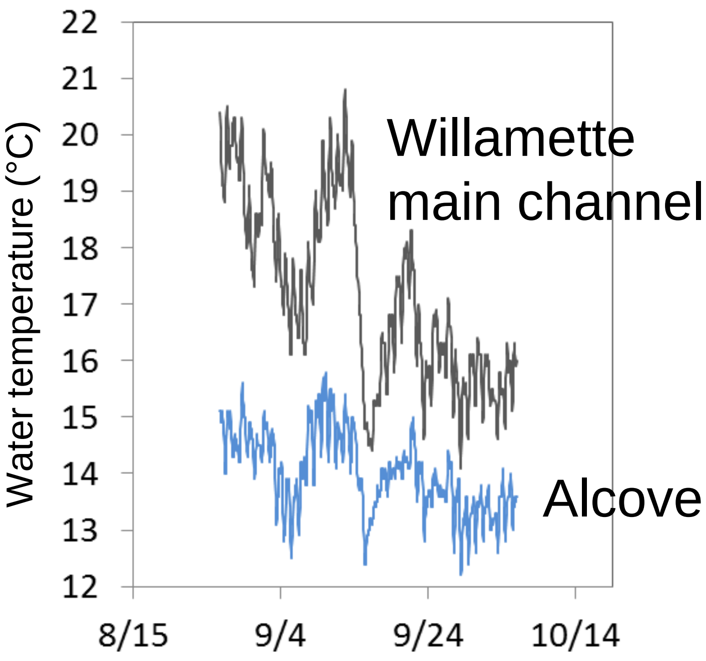
Channel abandonment and gravel deposition → alcove receiving water with long flowpaths



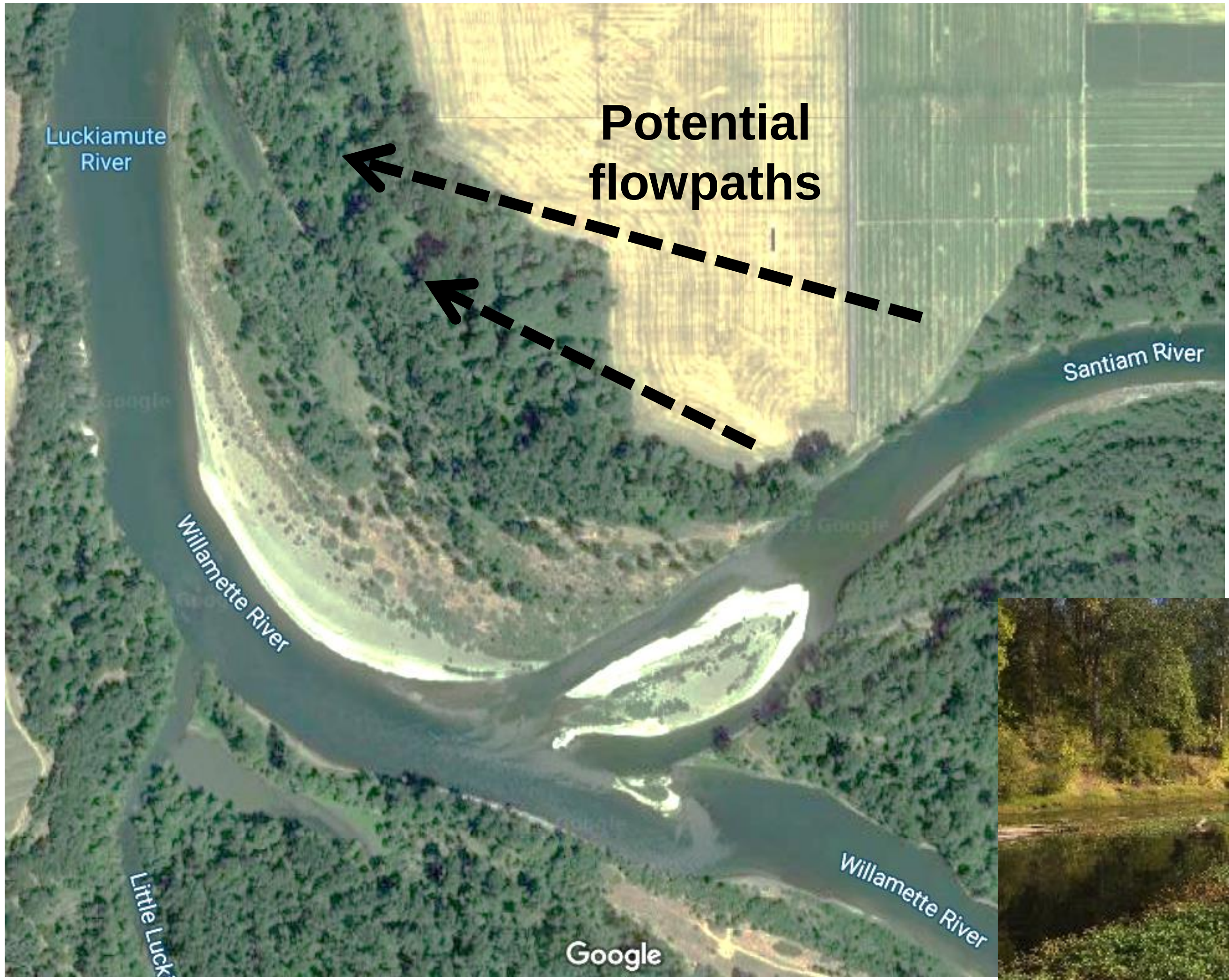
Smith, Mangano, and Rounds (In review)

USGS NWIS Data for Station 441355123094600 and 441155123091900
https://waterdata.usgs.gov/usa/nwis/uv?site_no=441355123094600
https://waterdata.usgs.gov/usa/nwis/uv?site_no=441155123091900

Alcove at the Santiam Confluence in Middle Willamette



Alcove receiving water from the Santiam River



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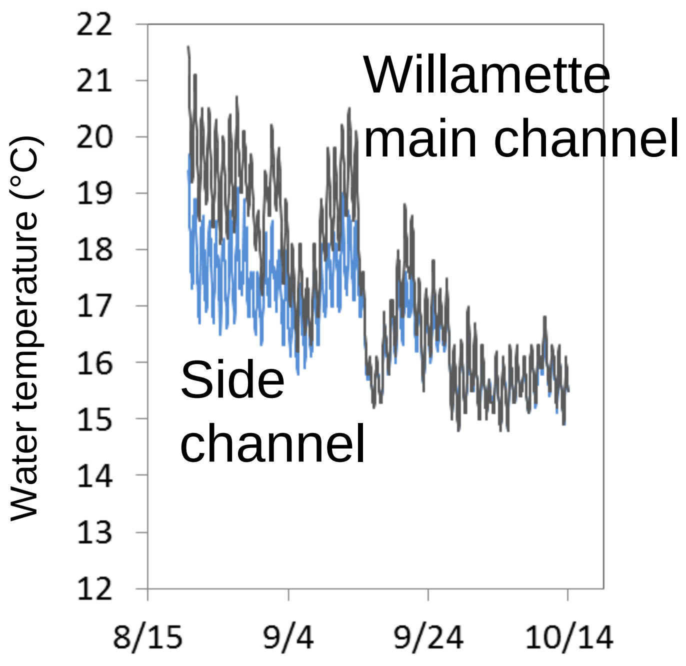
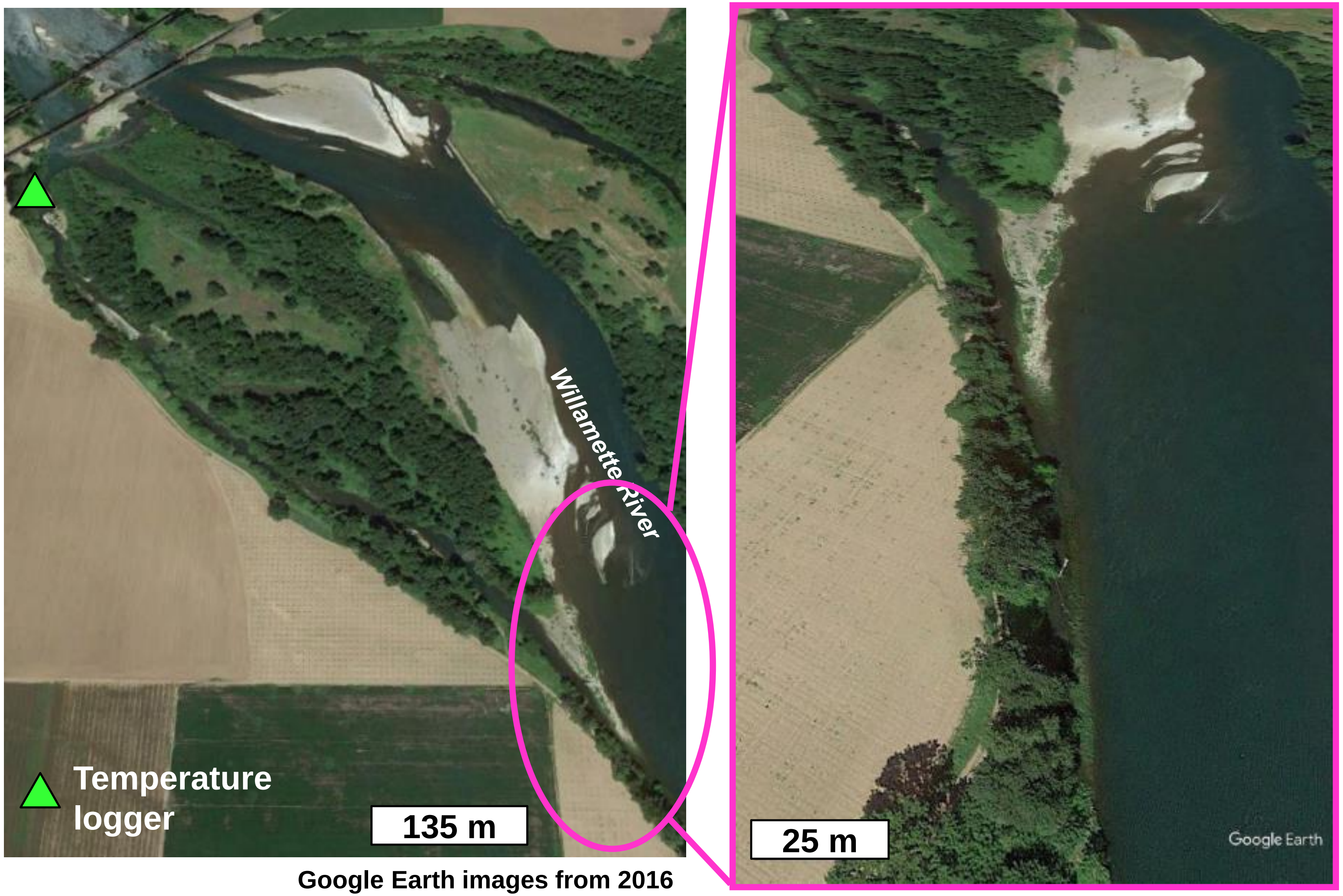
Side Channel in the Upper Willamette above Harrisburg



Side channel disconnects from the mainstem at its upstream end when flows are low



Google Earth images from 2016

Smith, Mangano, and Rounds (In review)

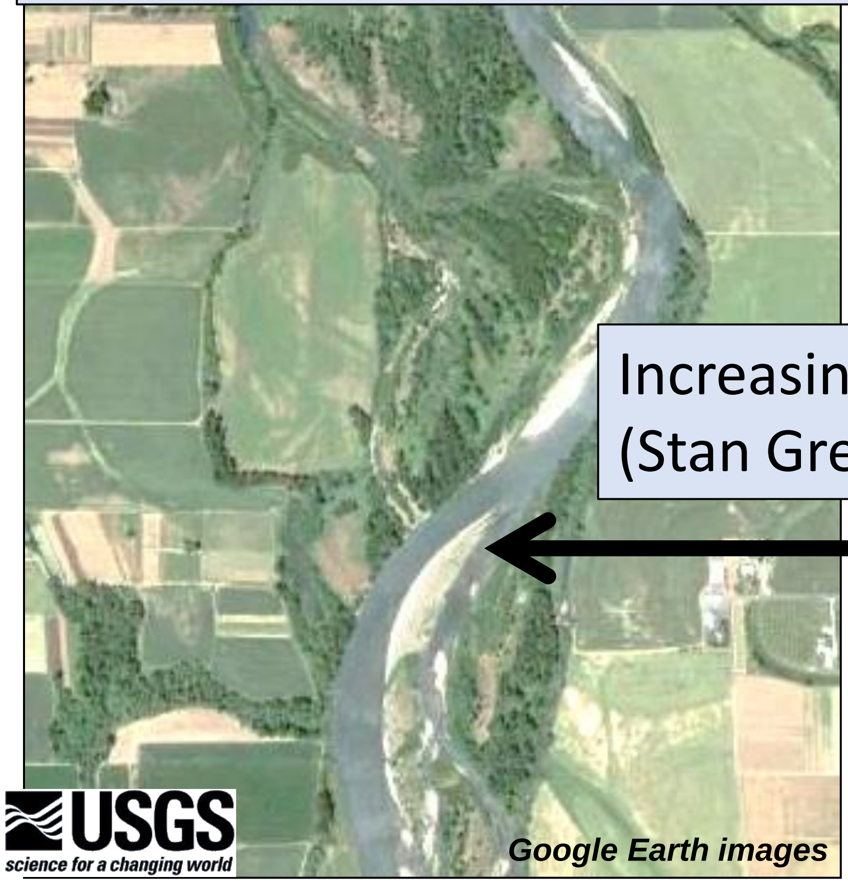
USGS NWIS Data for Station 441355123094600 and 441613123102600
https://waterdata.usgs.gov/usa/nwis/uv?site_no=441613123102600
https://waterdata.usgs.gov/usa/nwis/uv?site_no=441155123091900

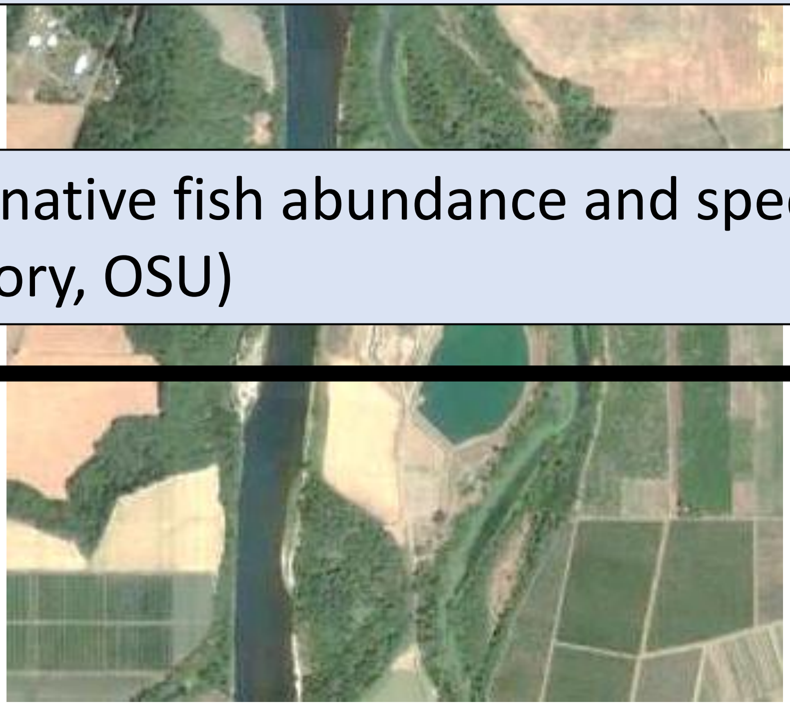
Types and numbers of potential CWRs vary along the main channel

<u>Upper Willamette (Eugene to Corvallis)</u>
- Historically, lateral mobility created off-channel features and multiple channels; some mobility today as well as revetments
- Greatest number of potential CWRs

<u>Middle Willamette (Corvallis to Newberg)</u>
- Single thread channel
- Historically more stable than the upper Willamette
- Short dynamic reaches stabilized with revetments and vegetation
- Fewer off-channel features than Upper Willamette

<u>Lower Willamette(Newberg to the Columbia River)</u>
- Single thread channel
- Constrained by bedrock and revetments
- Potential CWRs are mostly tributaries (Mangano and others, 2018)





Increasing native fish abundance and species richness (Stan Gregory, OSU)

Google Earth images

Key Science Message

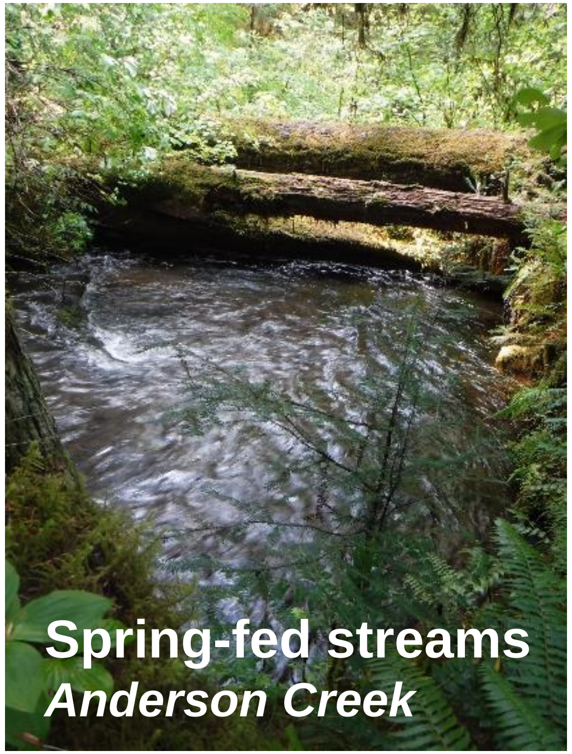
Water temperature and types of potential CWRs differ for places (locations) along the river network, owing to changes in the processes influencing water temperature conditions and heterogeneity.

Implications for Habitat Conservation and Restoration

Strategies related to water temperature and CWRs will vary throughout the network.

The linkages between place, process, and strategy are important for developing realistic goals and expectations about the magnitude to which human actions can result in positive or negative changes in water temperature or create and enhance CWRs.

Conserving Existing Coldwater Habitats and Enhance Other Habitat Conditions Where Necessary



USGS photographs

Enhancing Existing Coldwater Habitats

Johnson Creek Confluence projects

South Fork Pedee Creek, proposed restoration site to enhance CWR
Luckiamute WSC photograph

Tryon Creek confluence project
Photographs courtesy of City of Portland BES

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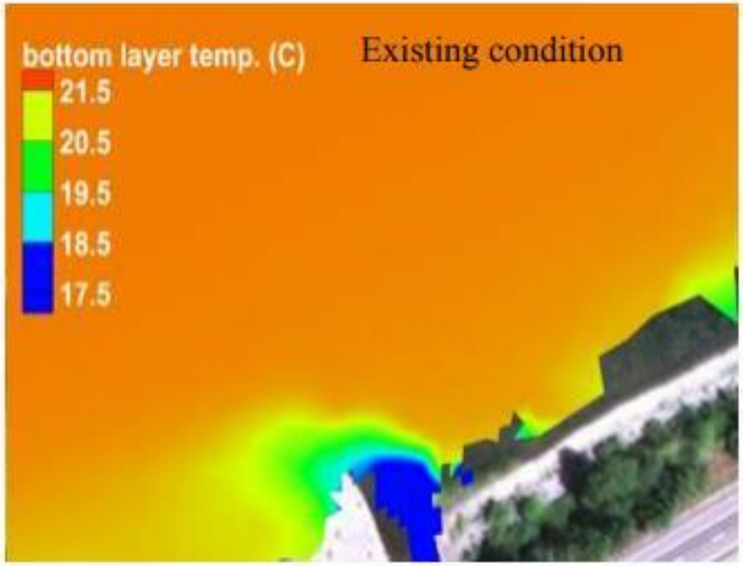
Experimental Strategies to Create Coldwater Habitats

Creating flow-through conditions at gravel pits

Revetment modification at TNC's Confluence Preserve, photograph by TNC

Expand coldwater plumes at tributary confluences (Marcoe and others, 2018)



Constructing lateral channels

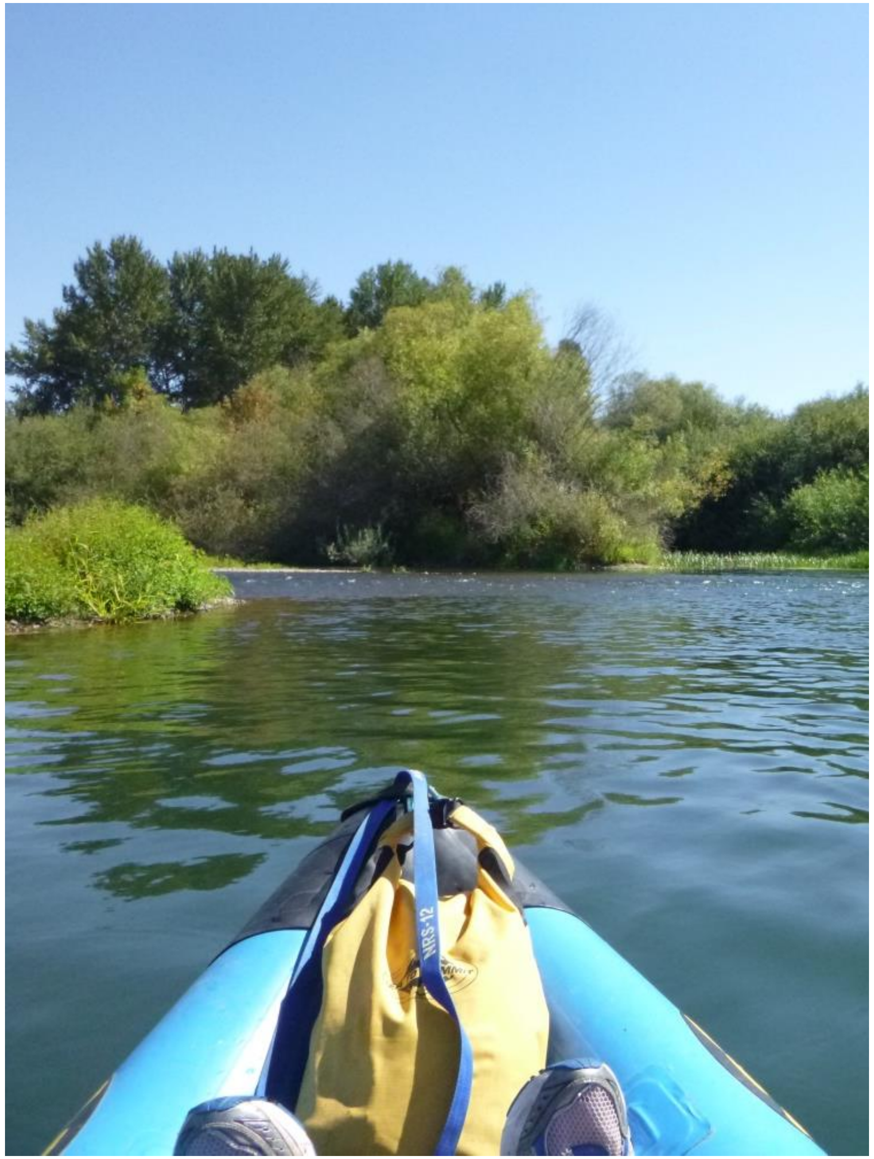
USGS

Examples of Considerations for Candidate Restoration Sites

Existing water temperature conditions	▪ What are the existing water temperature conditions at the site? ▪ Are water temperatures warm all summer and day? Or part of the summer or day? ▪ Are water temperatures consistent throughout the site or do they vary spatially and with depth?
Existing dissolved oxygen (DO) conditions	▪ What are the existing DO conditions? ▪ Are DO conditions suitable to provide temporary refuge (>4 mg/L) all or part of the summer? ▪ Are DO conditions consistent throughout the site or do they vary spatially and with depth?
Radiative heat fluxes	▪ What is the aspect of the site? ▪ Does the site have topographic and/or riparian shade? ▪ Are there locations of the site that lack shade? ▪ If riparian vegetation was planted, what is the potential area of the water surface that it could shade?

Summary

- Water temperature in the Willamette River is influenced largely by solar heat fluxes and streamflow.
- The types and numbers of potential CWRs vary along the Willamette River.
- Water temperature (and dissolved oxygen) in off-channel features are influenced by many factors, including solar heat fluxes, hyporheic exchange, and connections with the main channel.
- Understanding the processes shaping water temperature and CWRs for a specific place is key to developing strategies and realistic goals for water temperature and CWR improvements.



USGS photograph

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Benton

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MWSC: Jared Weybright

MMT: Allison Hensey, Kelly House, Cristina Watson

MRT: Joe Moll

NOAA: Anne Mullan

ODFW: Brian Bangs, Tom Friesen, Luke Whitman

ODEQ: Debra Sturdevant

OSU: Jonny Armstrong, Hannah Barrett, Carolyn Gombert, Stan Gregory, Stephen Lancaster

RDG: Troy Brandt

TNC: Melissa Olson

USACE: Norm Buccola, Kathryn Tackley, Jake Macdonald, Rich Piaskowski, Greg Taylor, Dan Turner

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USGS: Gabe Gordon, Gabe Hansen, Mackenzie Keith, Toby Kock, JoJo Mangano, R. Perry, David Piatt, Casie Smith, Christian Torgersen

UFL: David Hulse

WDFW: Nicole Czarnowski

WWR: Marjorie Wolfe (WWR)

References

Bartholow, J.M., 2000, The stream segment and stream network temperature models: a self-study course: U.S. Geological Survey Open-File Report 99-112, Portland, Oregon, 278 p., https://pubs.usgs.gov/of/1999/0112/report.pdf

Mangano, J.F., Piatt, D.R., Jones, K.L, and Rounds, S.A., 2018, Water temperature in tributaries, off-channel features, and main channel of the lower Willamette River, northwestern Oregon, summers 2016 and 2017: U.S. Geological Survey Open-File Report 2018-1184, 33 p., https://doi.org/10.3133/ofr20181184.

Marcoe, K., Collins, C., Corbett, C., Burke, M., Schwartz, M., Kolp, P., and Hanson, A. 2018. Lower Columbia River Thermal Refuge Study, 2015–2018. Final report to EPA. 105 p.

Rounds, S.A., 2010, Thermal effects of dams in the Willamette River basin, Oregon: U.S. Geological Survey Scientific Investigations Report 2010-5153, 64 p.

U.S. Geological Survey, 2020, USGS water data for Oregon: National Water Information System, Web Interface, accessed 1/13/2020, at https://waterdata.usgs.gov/or/nwis.

USGS photograph

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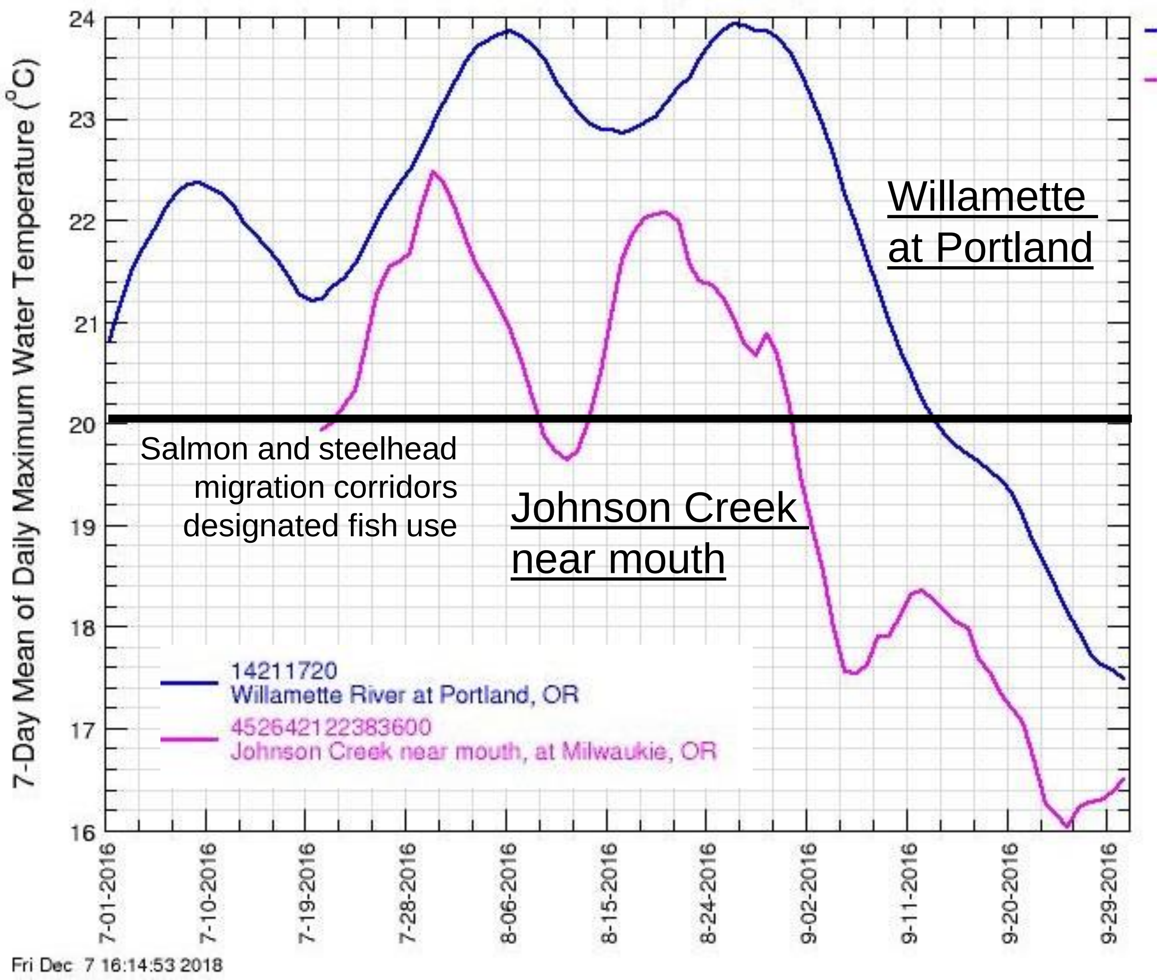

Johnson Creek; USGS

Mangano and others (2018)

Sub-basin CWR: McKenzie River sub-basin

Streamflow

Springs in the High Cascades provide cold flow; dams result in offset of water temperatures

Channel characteristics

The main channel has some laterally dynamic sections above Hayden Bridge; otherwise, largely stable because of geology and revetments

Biological relevance

Sub-basin has the coldest and most intact habitat for spring Chinook Salmon

Photos by Laurel Stratton-Garvin, USGS