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Developing and modeling the relations between flow management and water temperature in the Willamette River and its major tributaries

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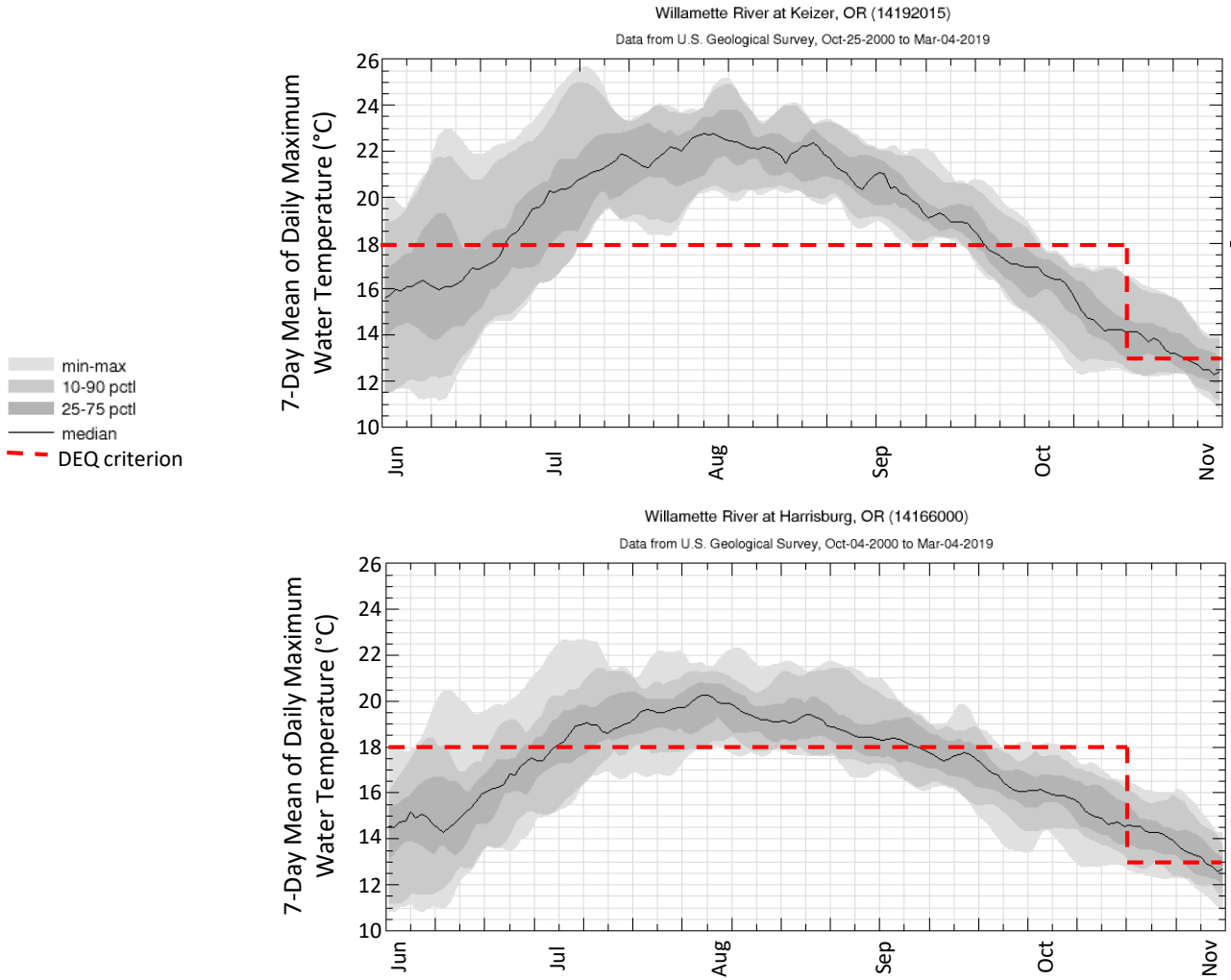
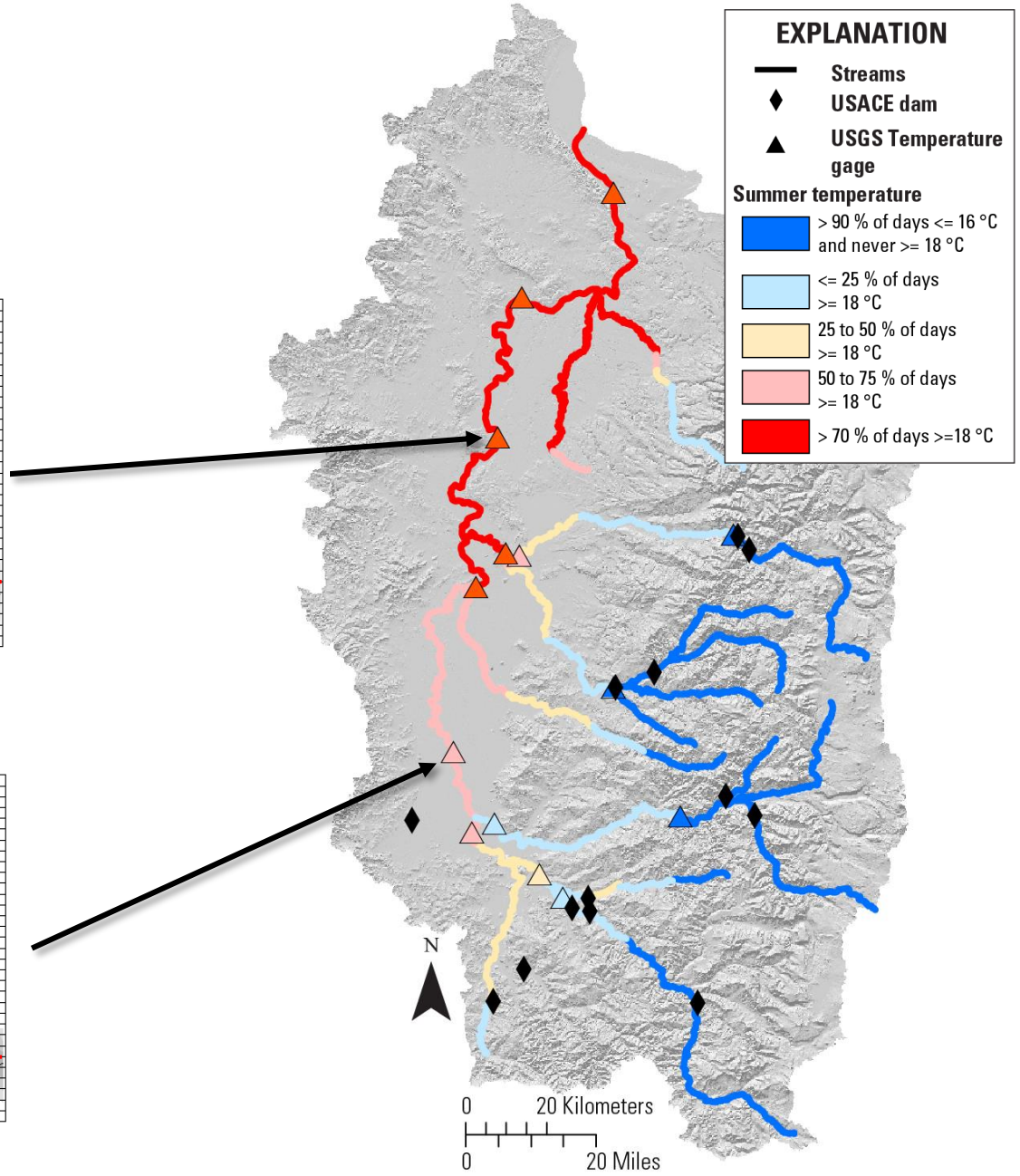
Willamette Fisheries Science Review
February 11, 2020

Willamette River thermal conditions:

Seasonally challenging for cold-water adapted species





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USGS map by Gabe Gordon
Temperature plots from USGS Data Grapher


Photo by USGS

USGS Temperature Program

Developing models and tools to predict stream temperature under different climatic and flow-management conditions

GOALS

1. Better understand primary controls on stream temperature, and spatial and temporal patterns and variability across the Willamette River and key tributaries
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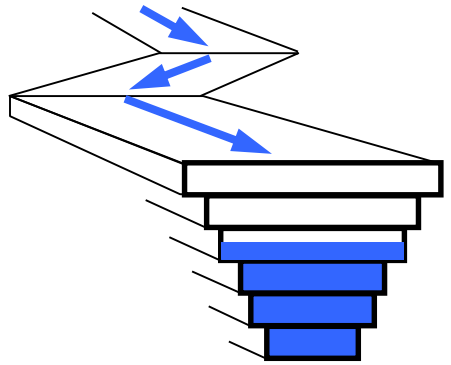
Approaches

Statistical

- Regression-based approach utilizing relations between streamflow, air temperature, and water temperature
  - **Pros**: quick, simple implementation possible across broad range of climate and flow conditions
  - **Cons**: limited to specific gage locations; not valid where release temperatures influential; limited extrapolation

Mechanistic

- Depth-discrete, hydrodynamic and water quality model with full heat budget
  - **Pros:** detailed, spatially-discrete analysis; useful for evaluating specific management actions including temperature management actions at individual dams
  - **Cons:** data intensive; limited to range of climate conditions in current set-up of models



CE-QUAL-W2

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Photo by USGS

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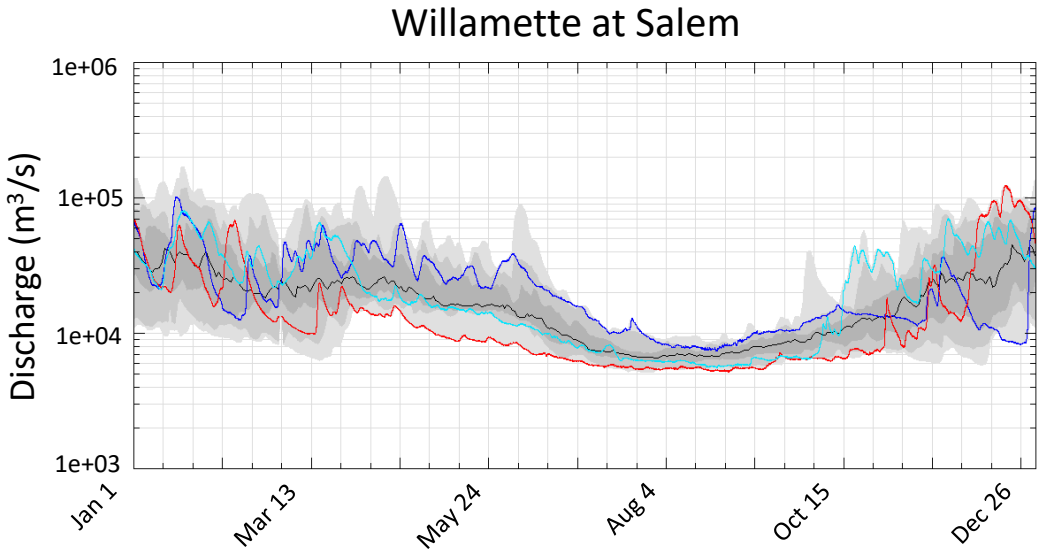
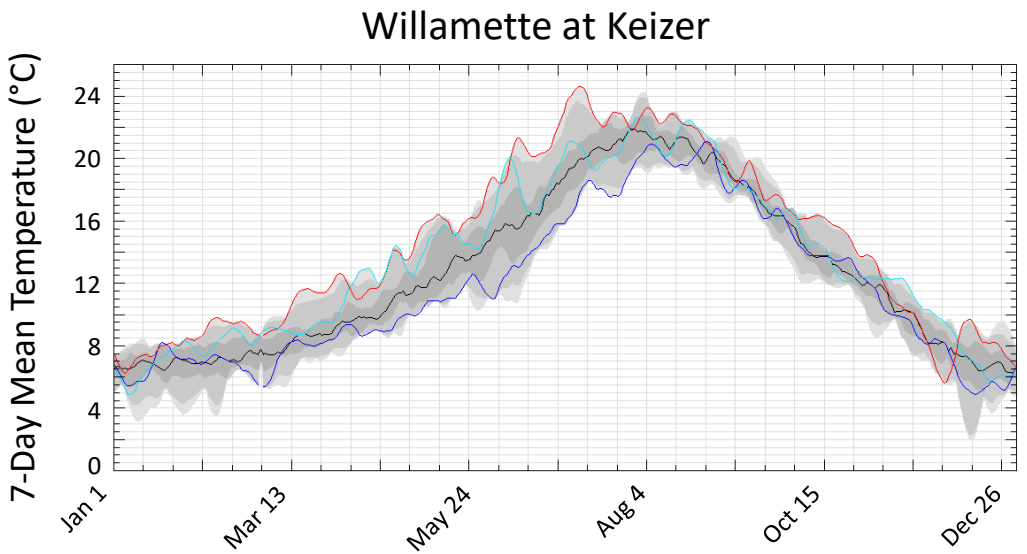
Investigating the ‘thermal mosaic’ of the Willamette River system

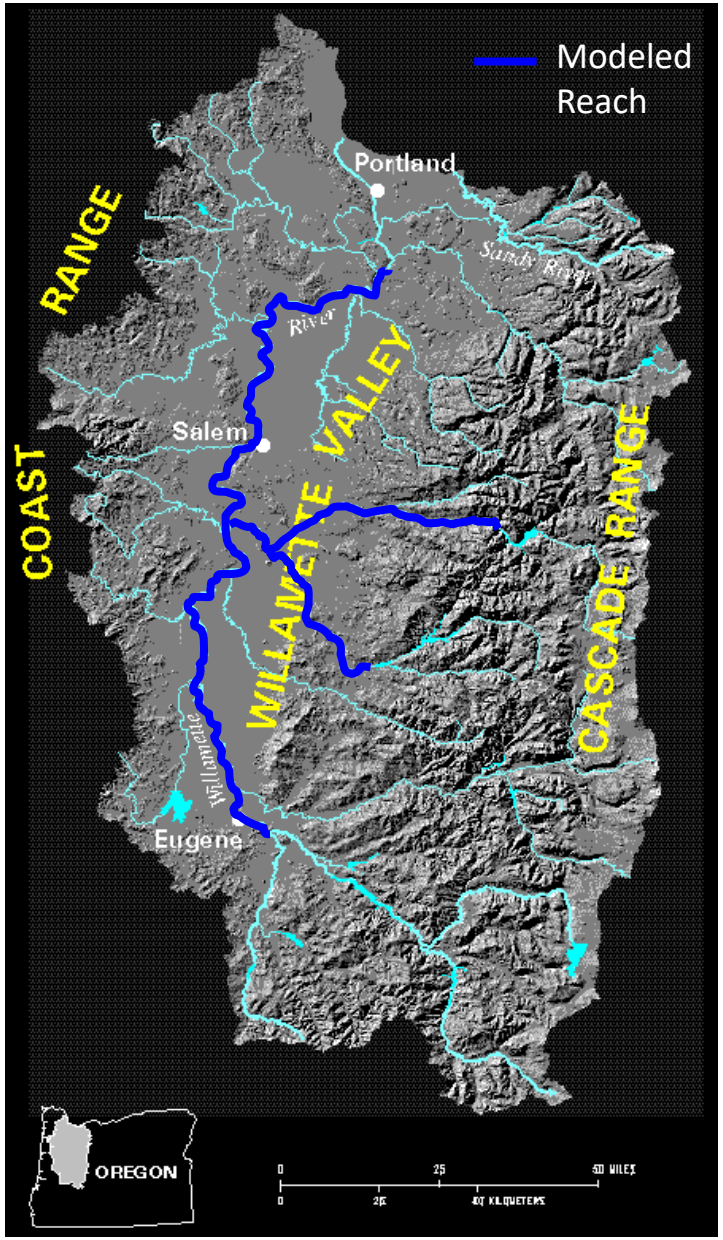
Modeled years

- 2011: “cool/wet” year
- 2015: “hot/dry” year
- 2016: “normal” year

- Min-Max
- 10-90 percentile
- 25-75 percentile
- Median







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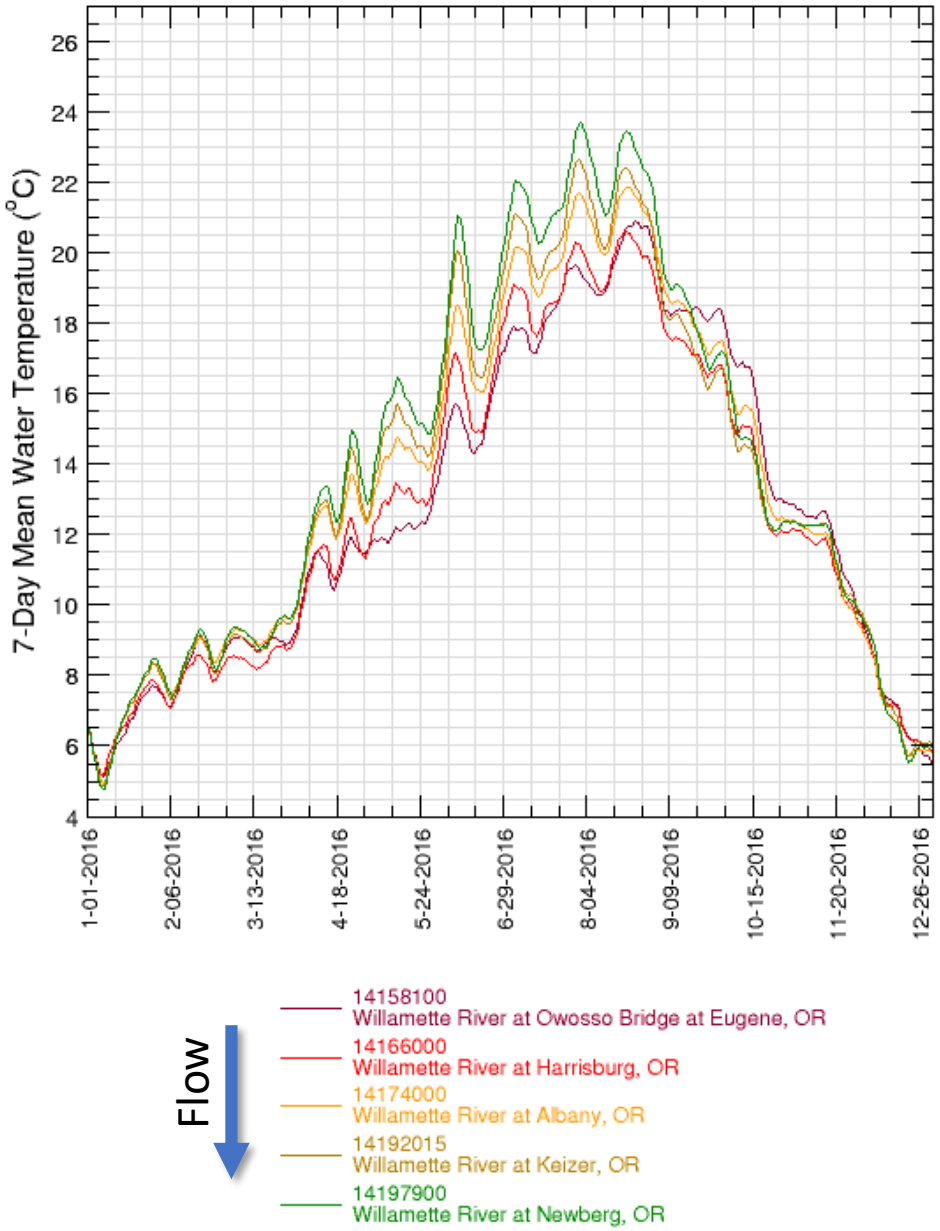
Data from USGS Data Grapher

Investigating the ‘thermal mosaic’ of the Willamette River system

- Stream temperature is balance between advective heat, heat budget, and stream flow
- ‘Thermal template’ varies with geology, geomorphology, climate, anthropogenic influence
  - Close to dam releases, temperature directly controlled by outflow temperatures
  - With distance, influence of weather conditions prevail
- General understanding is that river warms downstream, but patterns complex



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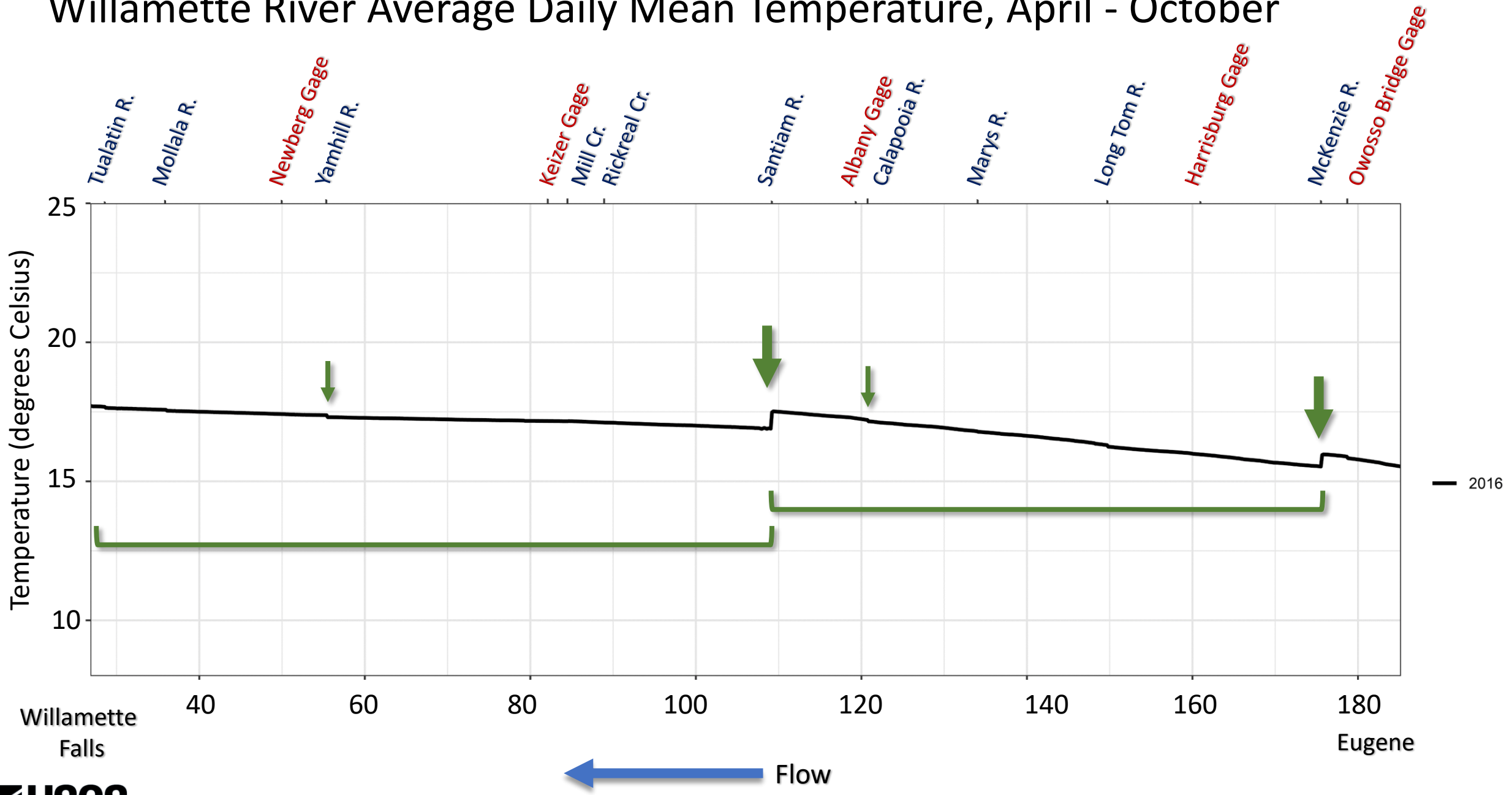
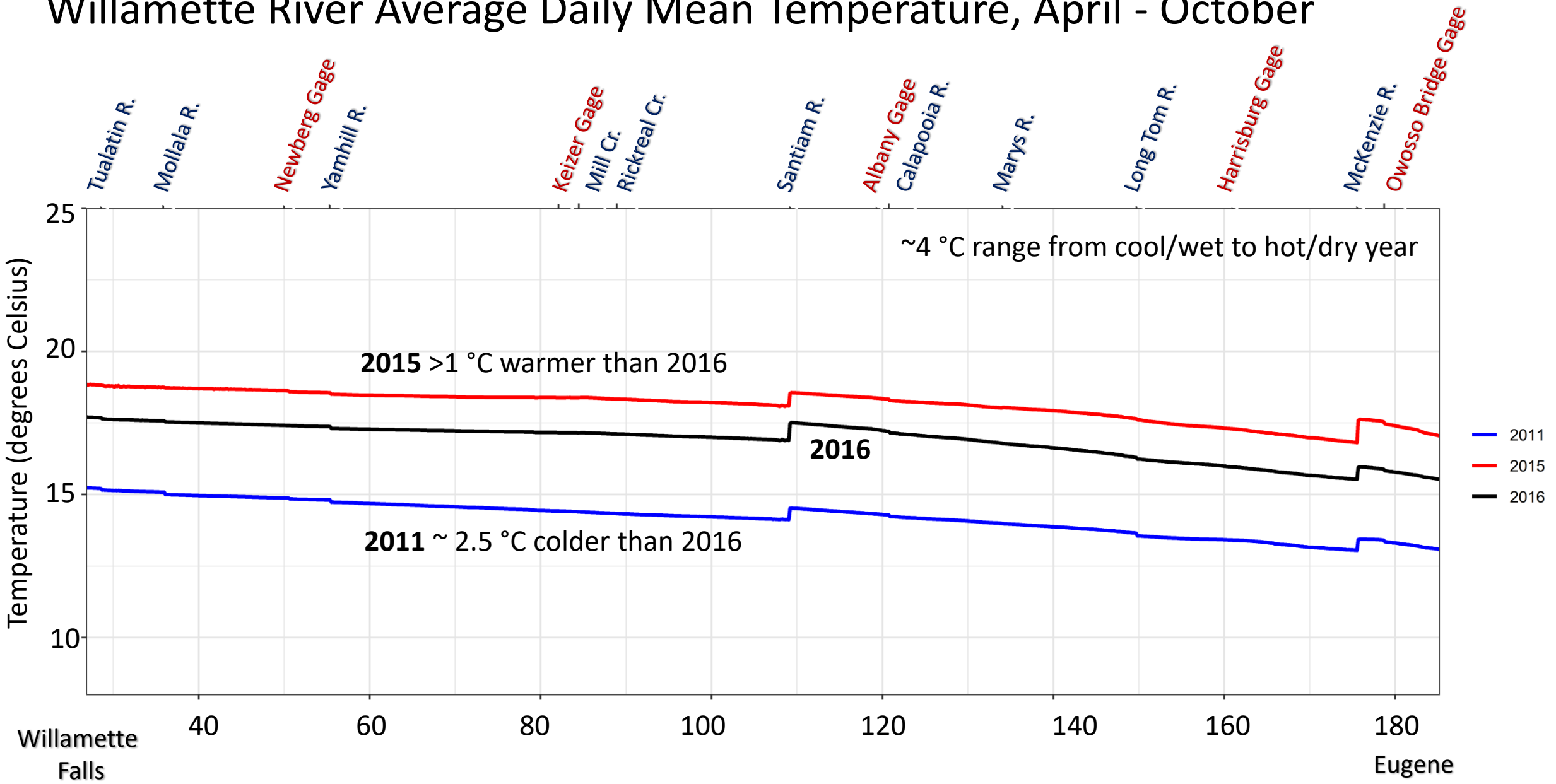
Willamette River Average Daily Mean Temperature, April - October



USGS

Provisional data; subject to revision

Willamette River Average Daily Mean Temperature, April - October



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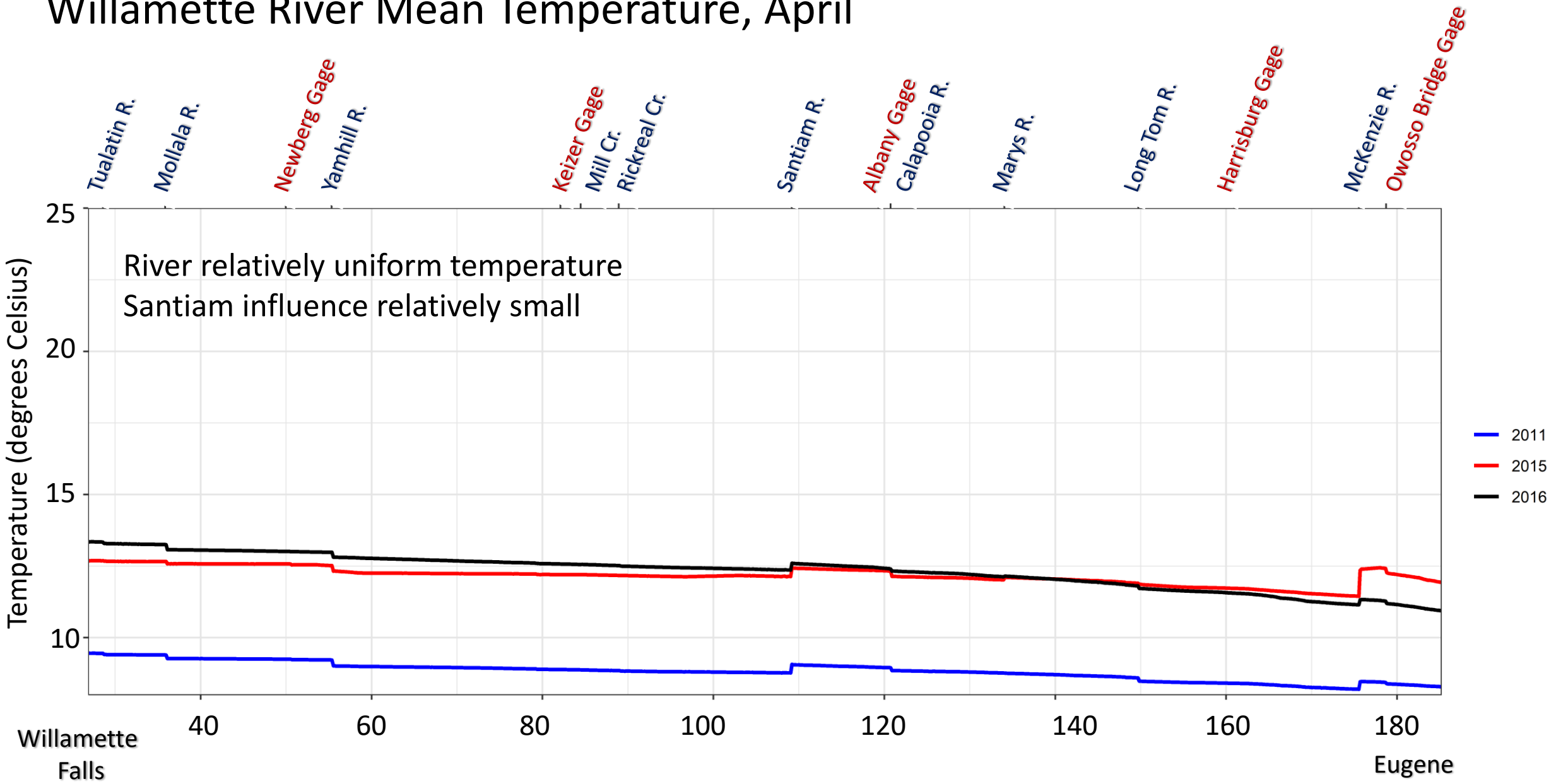
Provisional data; subject to revision

Willamette River Mean Temperature, April



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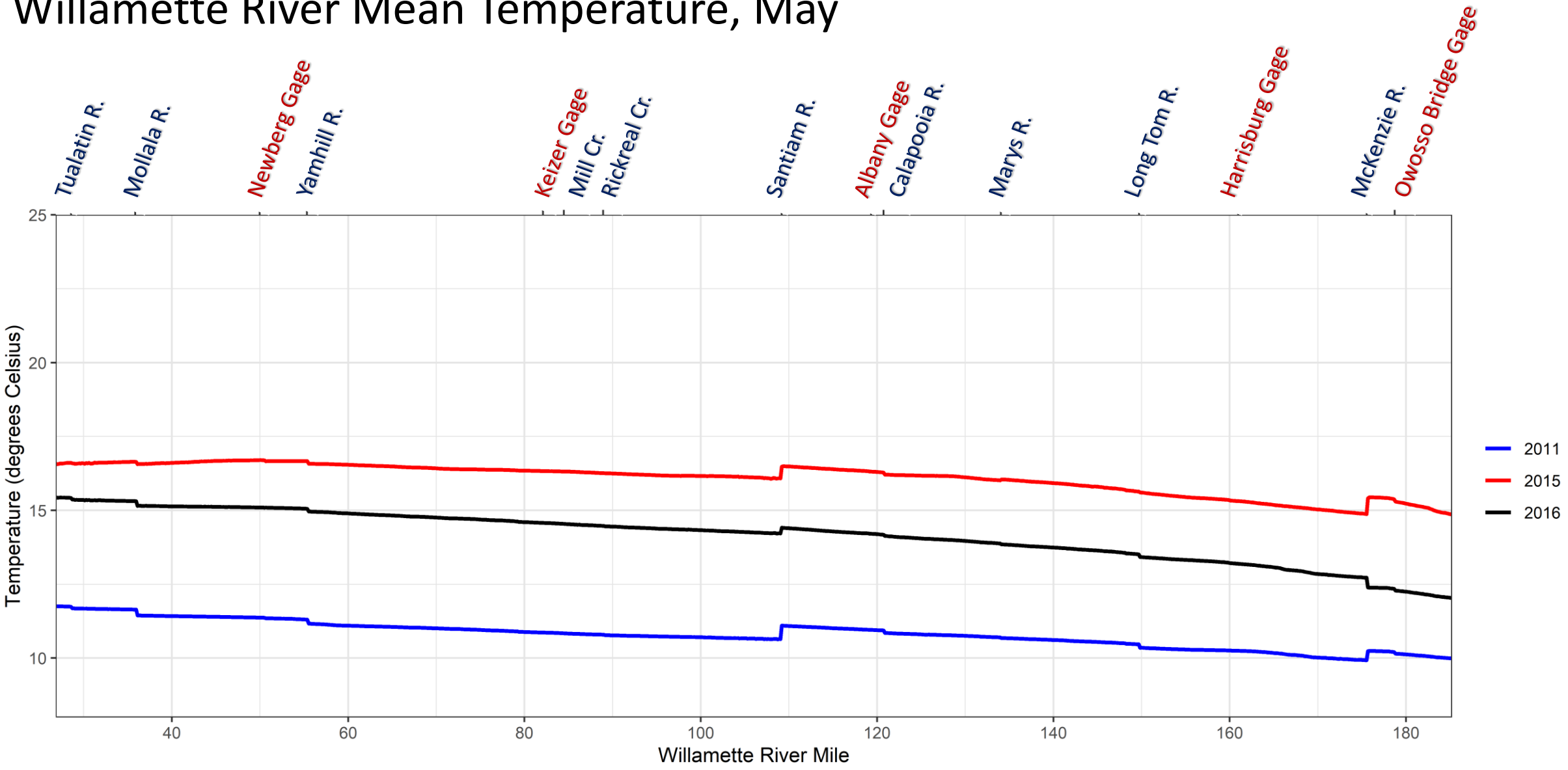
Willamette River Mean Temperature, May



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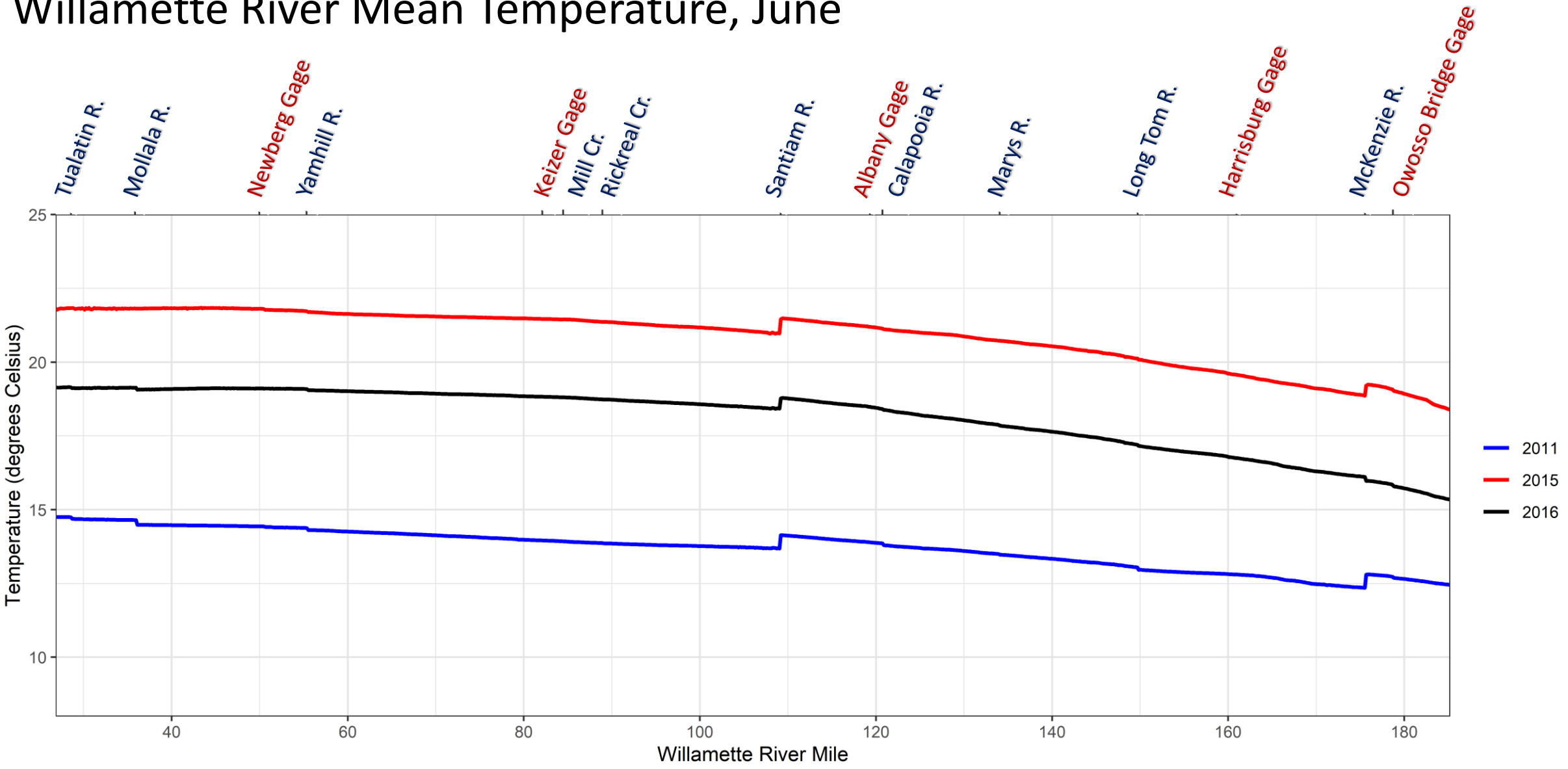
Provisional data; subject to revision

Willamette River Mean Temperature, June



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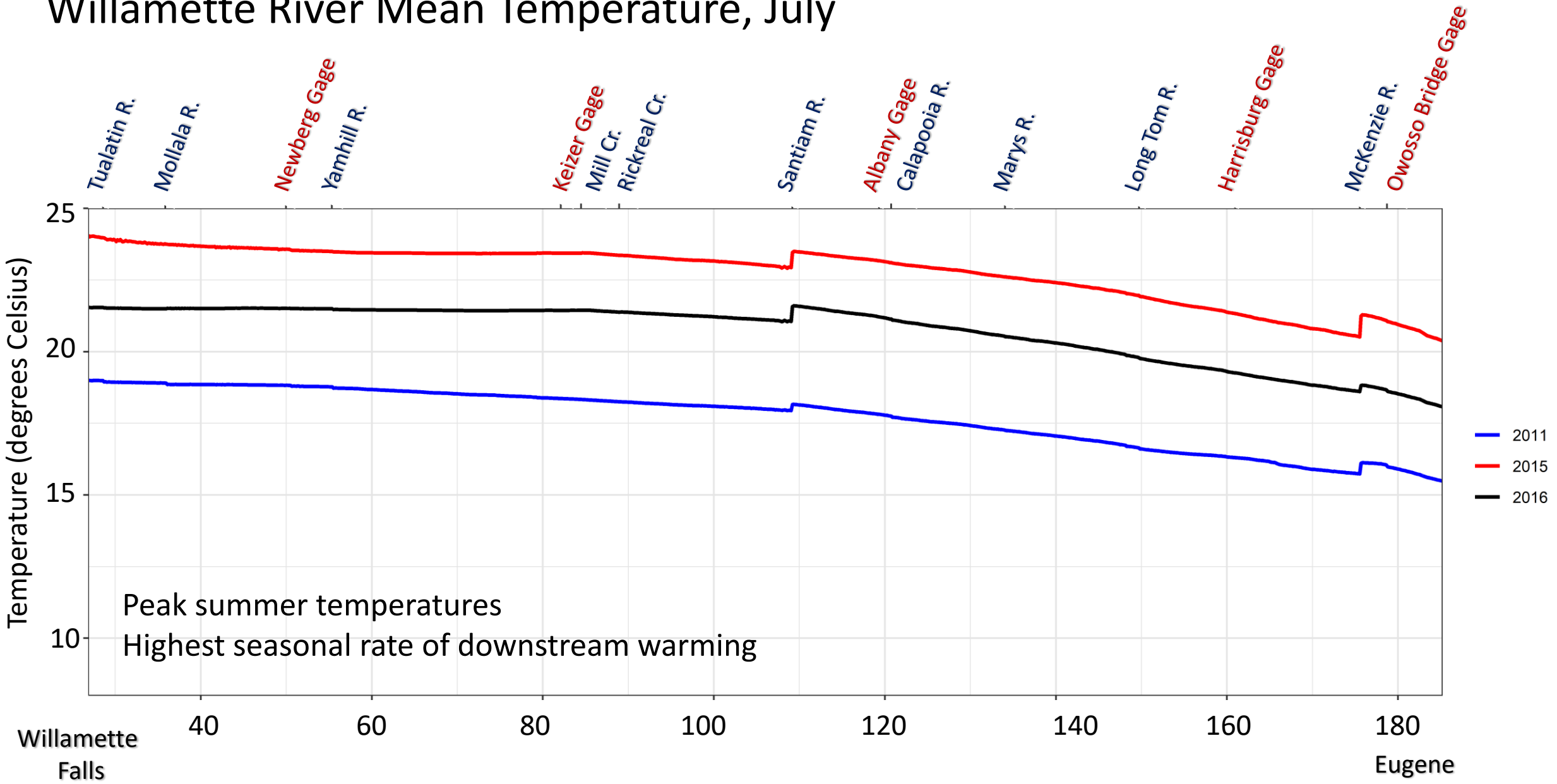
Provisional data; subject to revision

Willamette River Mean Temperature, July



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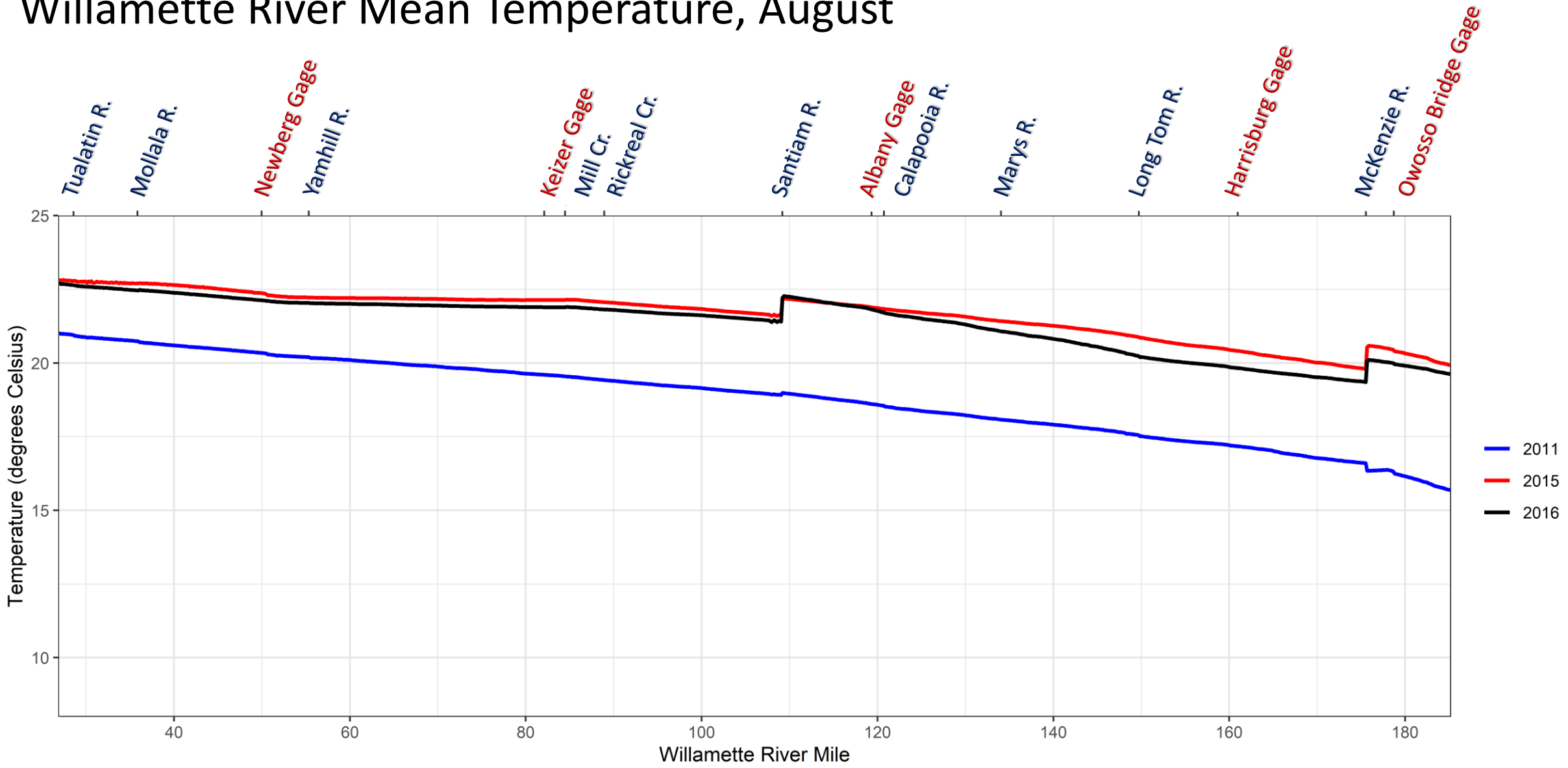
Provisional data; subject to revision

Willamette River Mean Temperature, August



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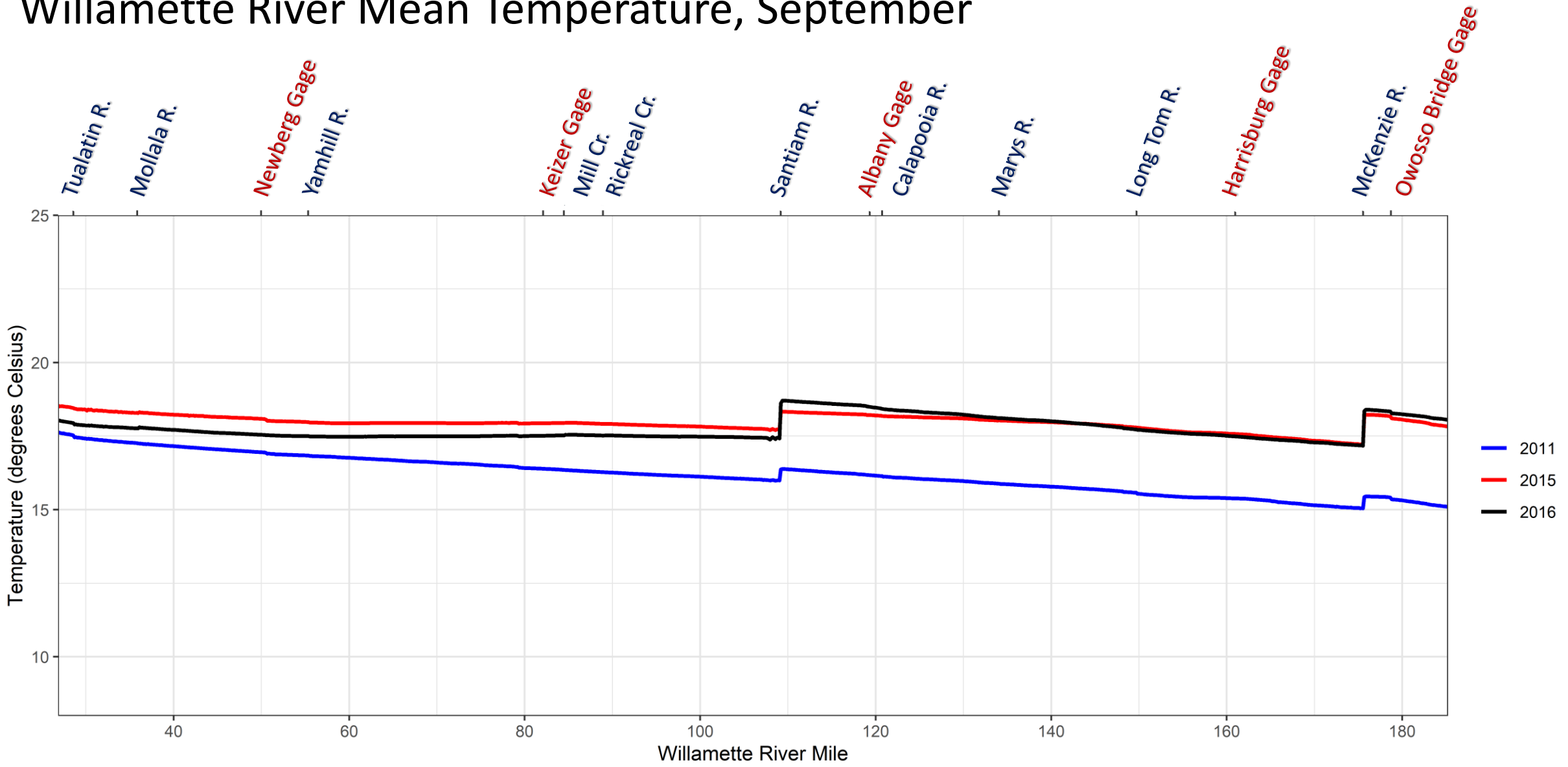
Provisional data; subject to revision

Willamette River Mean Temperature, September



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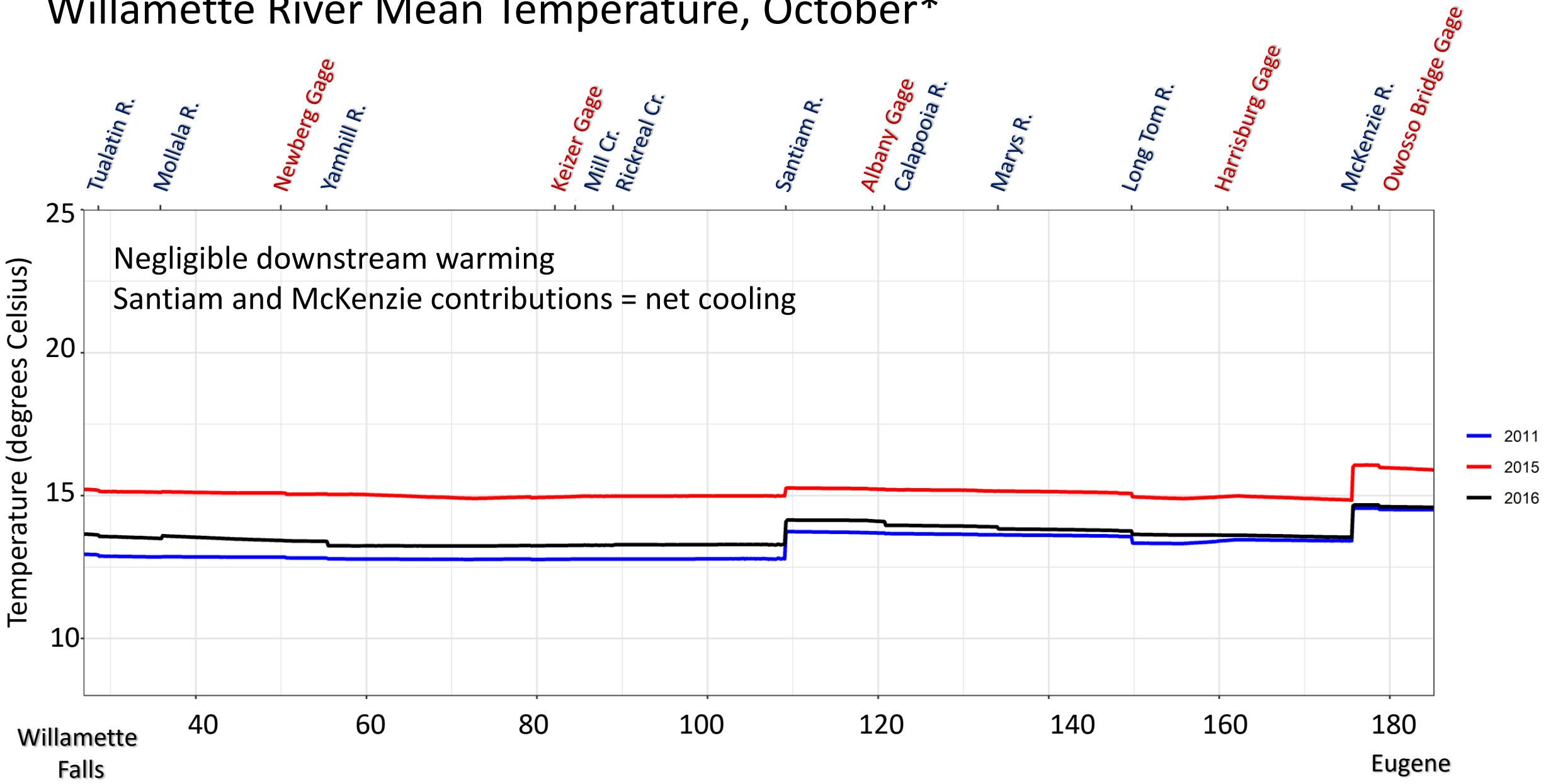
Provisional data; subject to revision

Willamette River Mean Temperature, October*

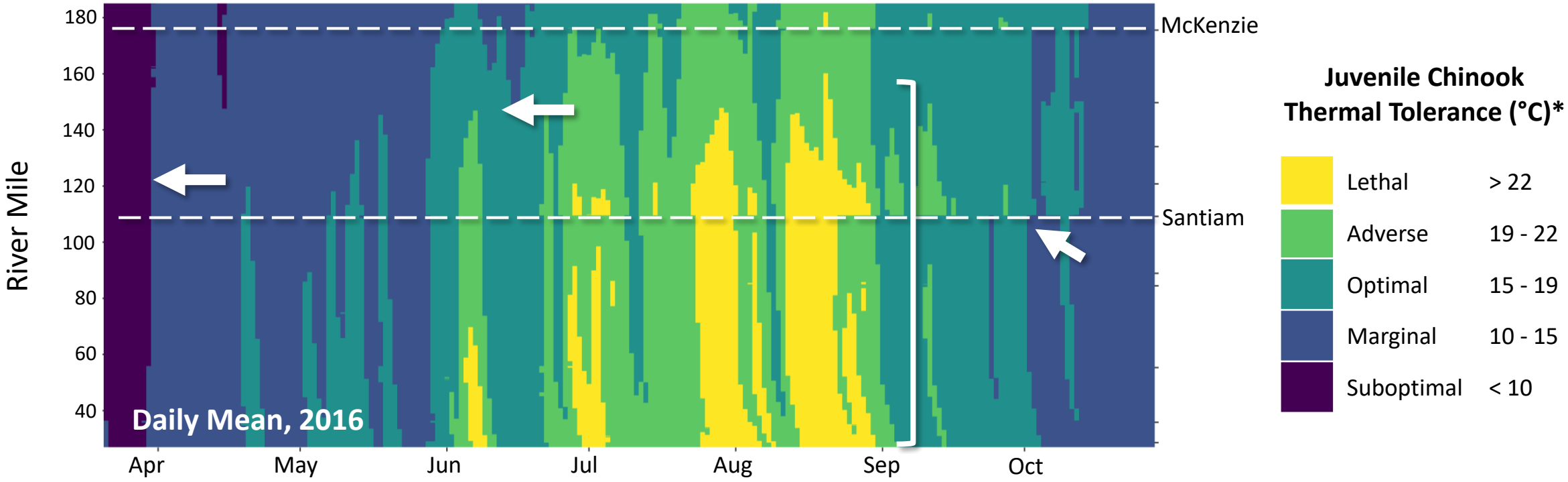


USGS *through October 29th

Provisional data; subject to revision

Visualizing the Thermal Mosaic of the Willamette River

Understanding temperature in relation to salmonid thermal tolerances



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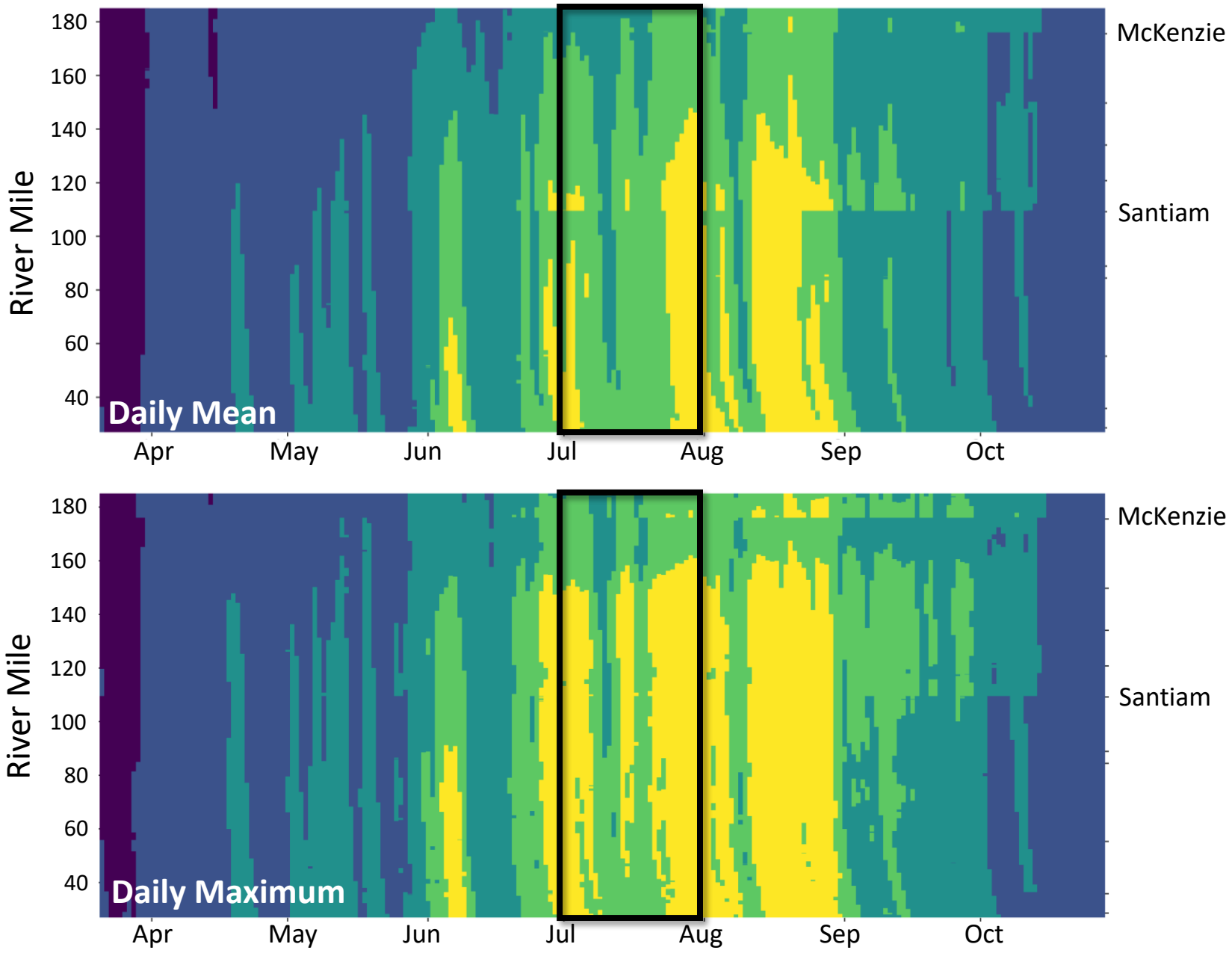
**Preliminary* temperature thresholds for juvenile Chinook Salmon based on literature review by G. Hansen, T. Kock, and R. Perry (USGS). Provisional data; subject to revision

2016 Willamette River Temperatures



Daily Mean Temperature

Percent of River Length in July:

- Lethal: 20%
- Adverse: 63%
- Optimal: 17%

Daily Maximum Temperature

Percent of River Length in July:

- Lethal: 49%
- Adverse: 43%
- Optimal: 7%

Suboptimal | Marginal | Optimal | Adverse | Lethal

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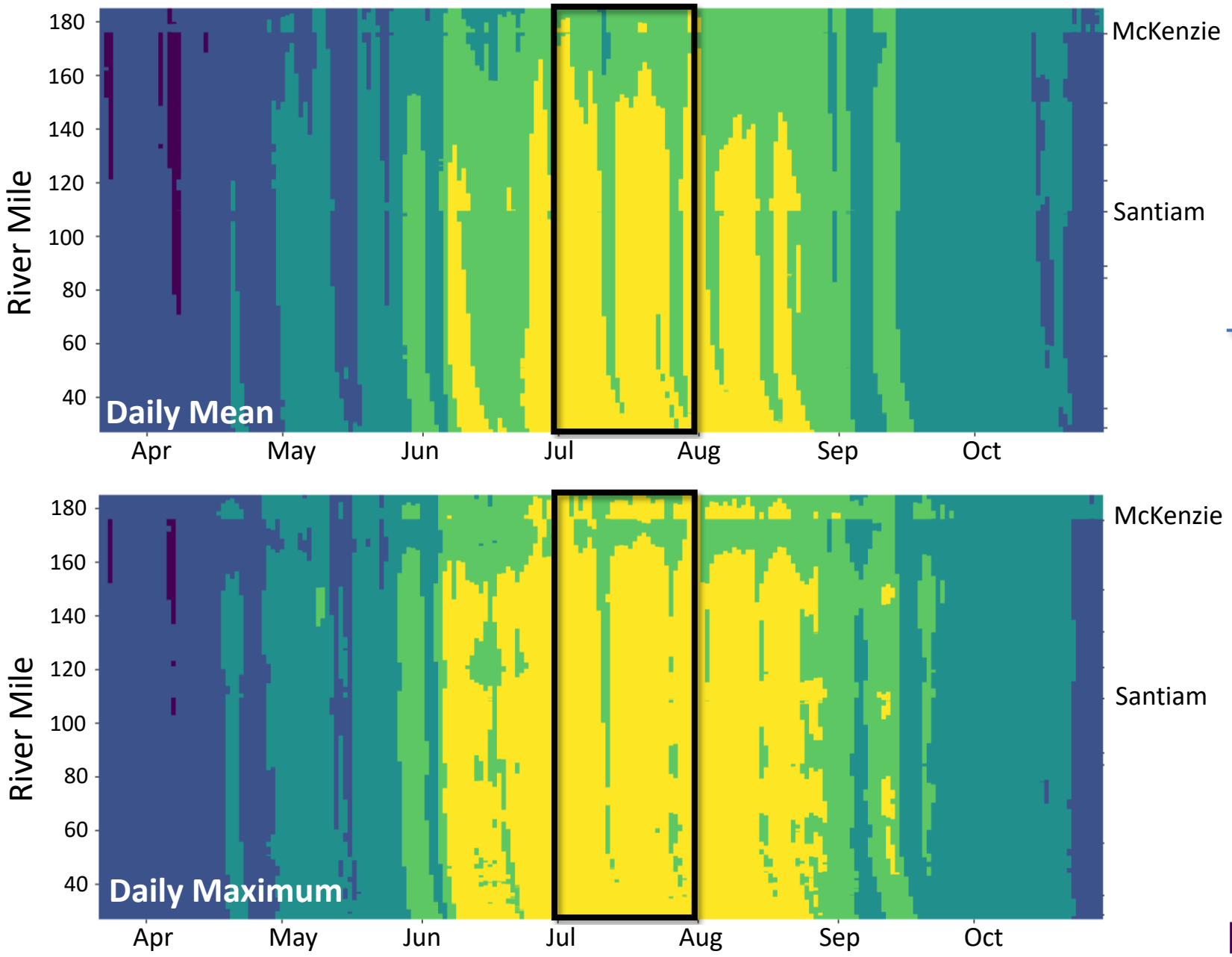
2015 Willamette River Temperatures



Daily Mean Temperature

Percent of River Length in July:

- Lethal: 67%
- Adverse: 32%
- Optimal: <1%

Daily Maximum Temperature

Percent of River Length in July:

- Lethal: 87%
- Adverse: 13%
- Optimal: 0%

Suboptimal | Marginal | Optimal | Adverse | Lethal

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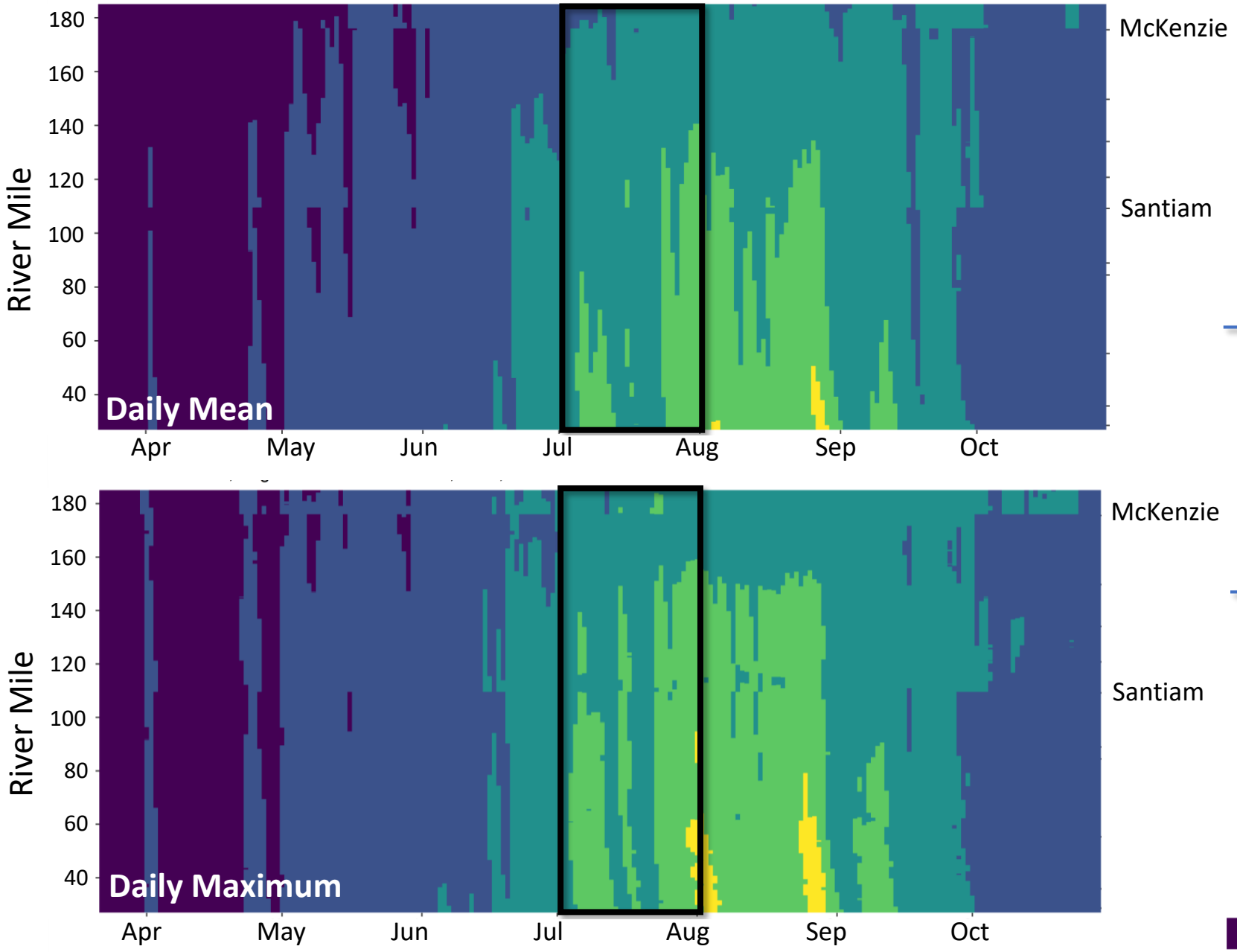
2011 Willamette River Temperatures



Daily Mean Temperature

Percent of River Length in July:

- Adverse: 21%
- Optimal: 75%
- Marginal: 4%

Daily Maximum Temperature

Percent of River Length in July:

- Lethal: <1%
- Adverse: 40%
- Optimal: 59%
- Marginal: <1%

Suboptimal | Marginal | Optimal | Adverse | Lethal

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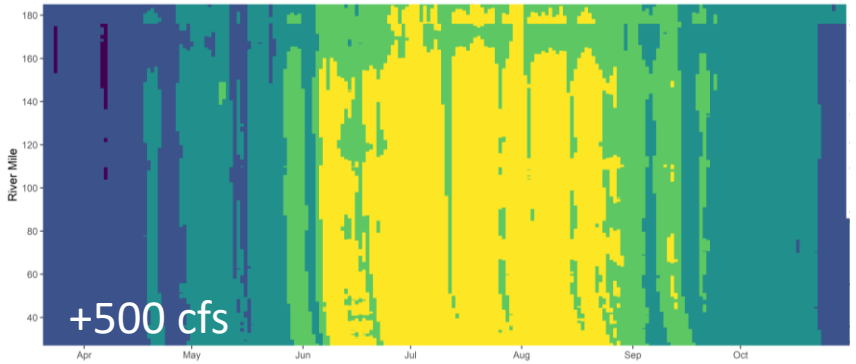
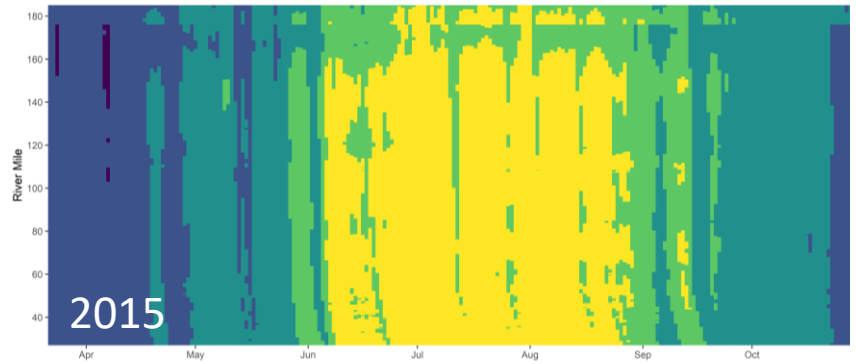
Flow Management Scenarios

Flow Volume



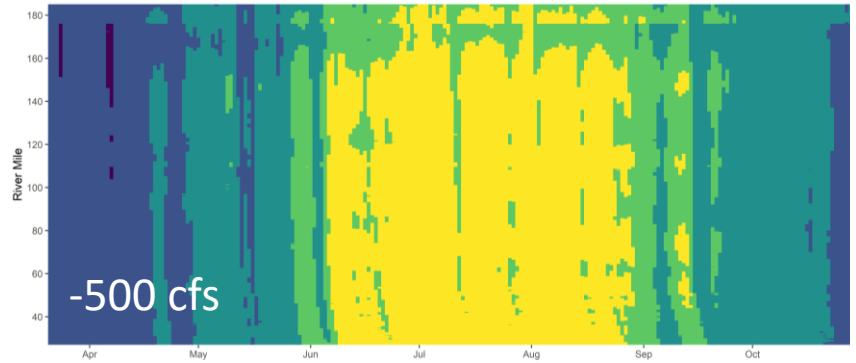
2015 + 500 cfs input to Upper Willamette

Percent of River Length in July:	Daily Mean Temperature	Daily Maximum Temperature
Lethal	66%	85%
Adverse	34%	15%
Optimal	<1%	0%



2015 Base Case

Lethal	67%	87%
Adverse	32%	13%
Optimal	<1%	0%



2015 - 500 cfs input to Upper Willamette

Lethal	69%	88%
Adverse	31%	12%
Optimal	<1%	0%

Preliminary thermal tolerance threshold. Provisional data; subject to revision

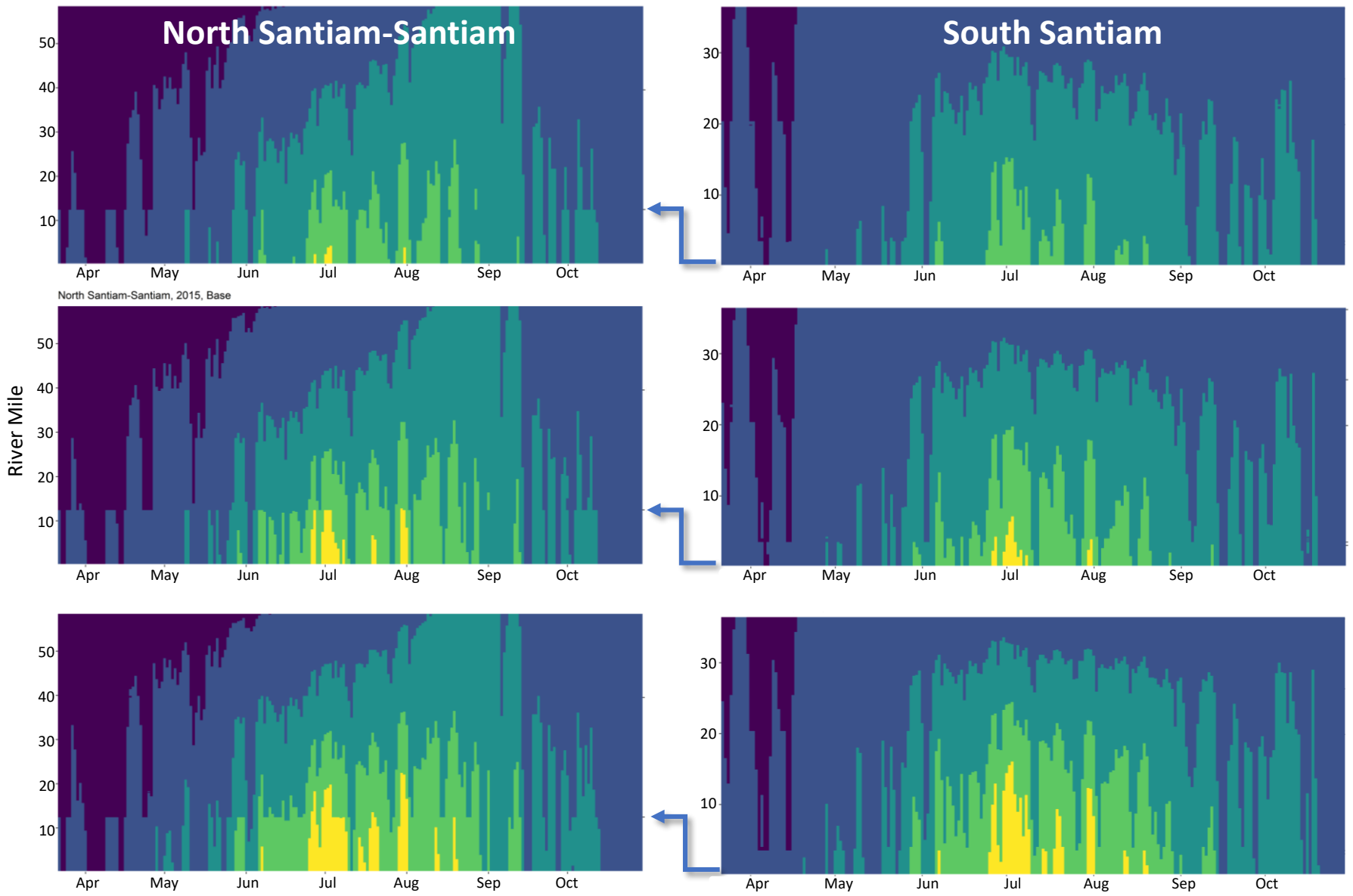
Flow Management Scenarios: Santiam Basin

Flow Volume

2015
+ 250 cfs input to North Santiam
+250 cfs input to South Santiam

2015 Base Case

2015
- 250 cfs input to North Santiam
- 250 cfs input to South Santiam



North Santiam-Santiam, 2015, Base

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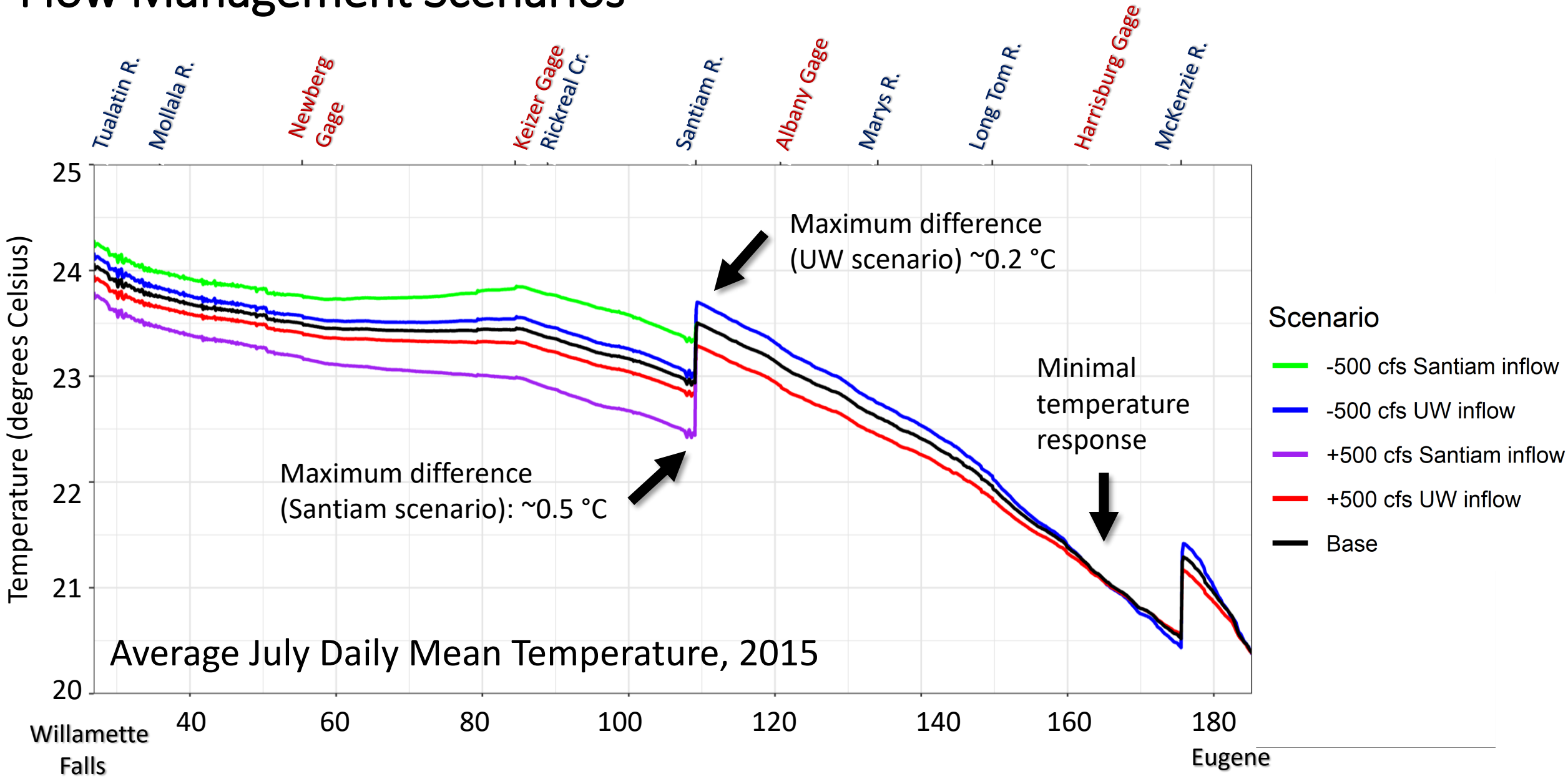
Preliminary thermal tolerance threshold. Provisional data; subject to revision

Flow Management Scenarios



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Provisional data; subject to revision


Photo by USGS

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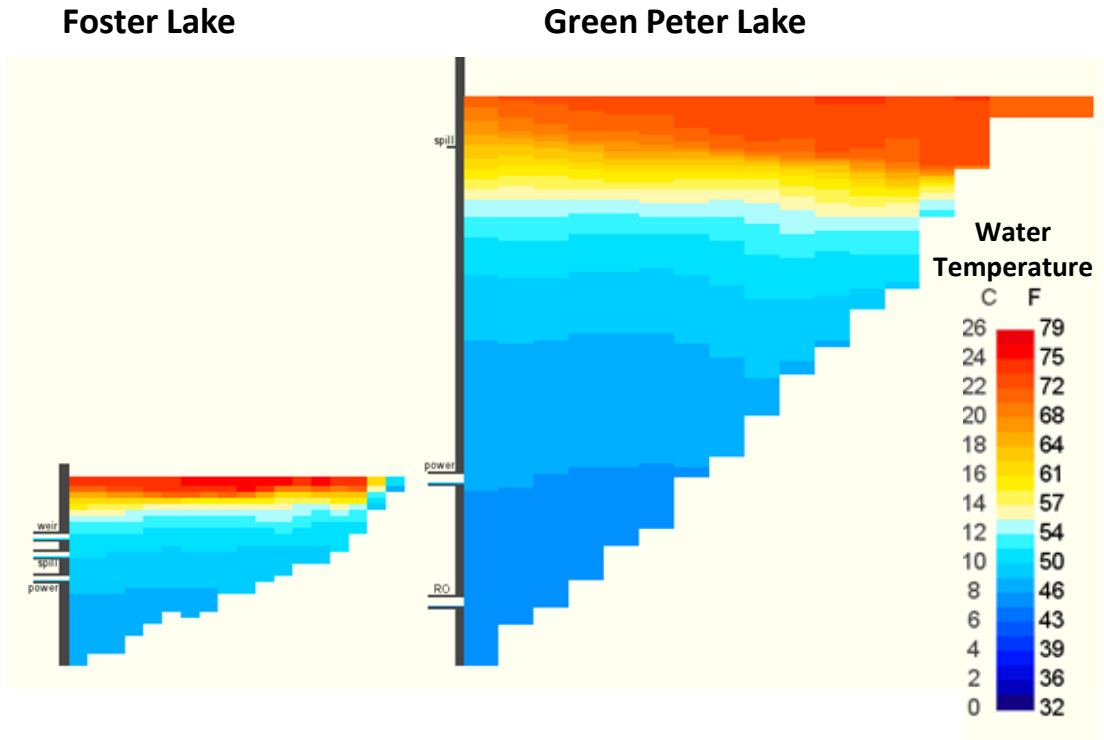
Modeling Temperature in Green Peter and Foster Lakes and the South Santiam River

- Model tracers examined mixing in Foster Lake
- Scenarios explored whether altered dam operation and water management could allow release of more-natural water temperatures downstream of the dams
- Do temperatures of water released from the dams persist in the South Santiam River?



US Army Corps of Engineers photos

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Provisional data; subject to revision

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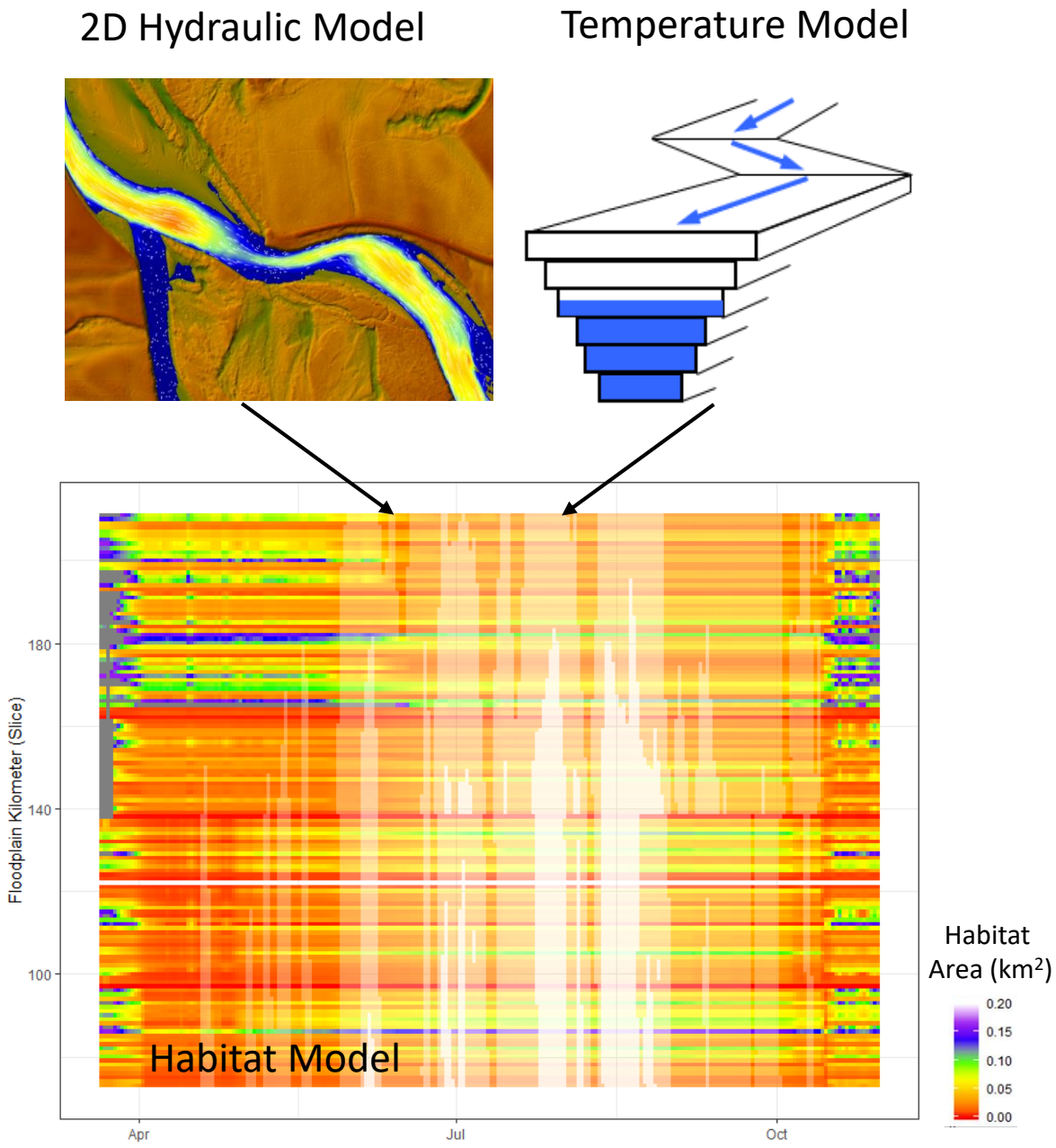
Tools to support other researchers

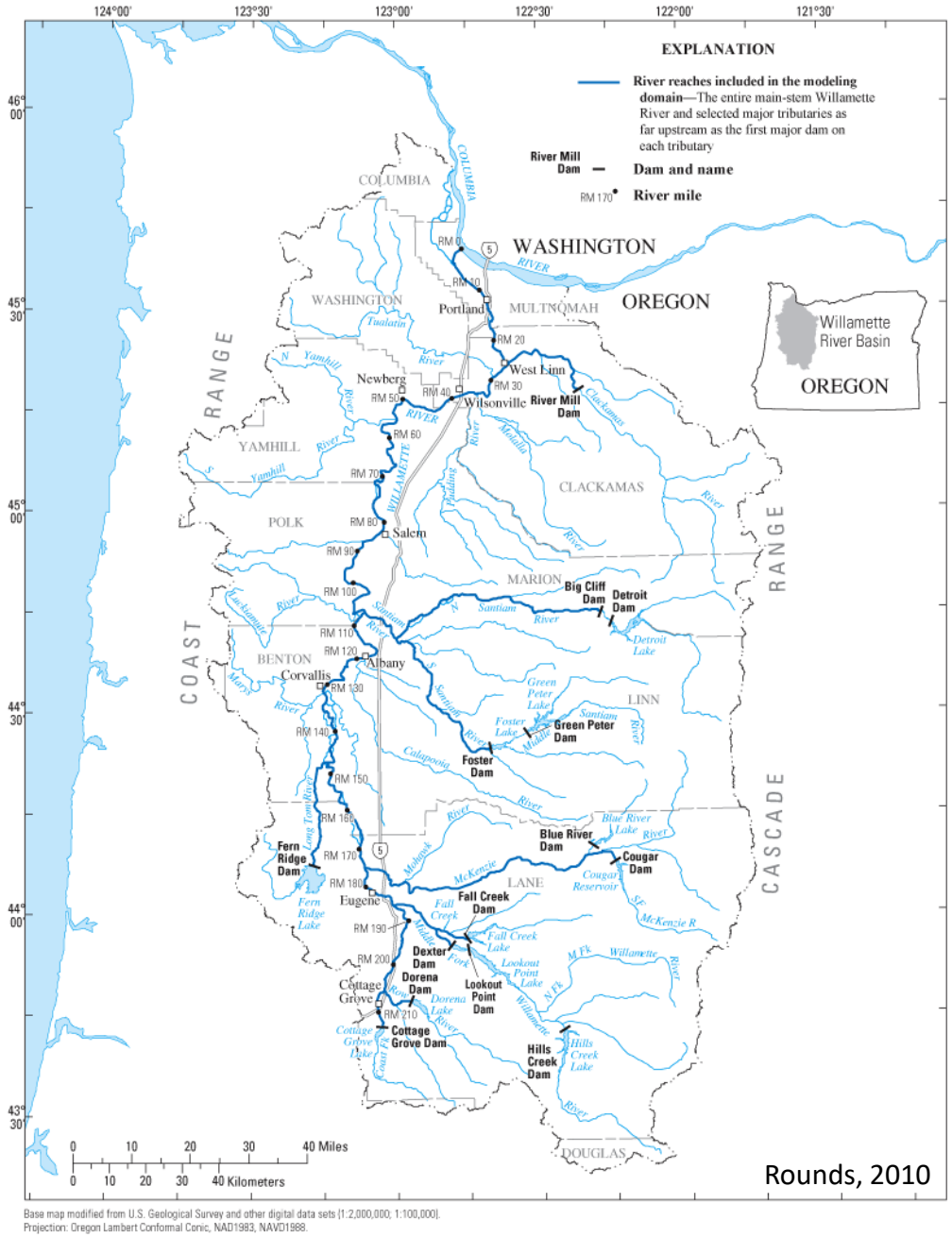
- Flow optimization model (Peterson, Pease, Deweber and others, *in progress*)
- Habitat capacity assessment (White and others, *in progress*



White and others, *in progress*

Willamette EIS Support

- Additional CE-QUAL-W2 models set-up:
  - Coast Fork-Middle Fork
  - McKenzie
  - Middle Fork between Hills Creek and Lookout Point
  - Lookout Point-Dexter
  - Hills Creek
  - Detroit-Big Cliff
  - Green Peter-Foster
  - Cougar
- All models set up for 2011, 2015, and 2016 and updated to version 4.2
- Spreadsheet-tool to run synchronous scenarios
- Support for EIS alternative model runs



Rounds, 2010

USGS


Photo by USGS

Summary and Key Findings

- Statistical and mechanistic modeling methods provide distinct approaches to understanding stream temperature in the Willamette, building tools to assess flow management operations
- River temperature varies seasonally and longitudinally
  - Warming rates from McKenzie to Santiam confluence generally higher than from Santiam confluence to Willamette Falls
  - Peak temperatures and peak downstream warming occurs in July; little downstream warming in spring and fall
- Flow management effect varies depending on location of additional inflow
- Further work will continue to develop tools and assess specific management scenarios

USGS

Provisional results; subject to revision

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References:

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

USGS Data Grapher: https://or.water.usgs.gov/grapher/

Photo: USGS