Incorporating Climate Change into Temperature TMDLs: S.F. Nooksack River Case Study

DEPARTMENT OF ECOLOGY
State of Washington

James Kardouni
WA State Dept. of Ecology Bellingham Field Office
Water Quality Program TMDL Lead

06/02/2022

for ELI: Modeling Approaches for Considering Climate Change

Presentation Overview

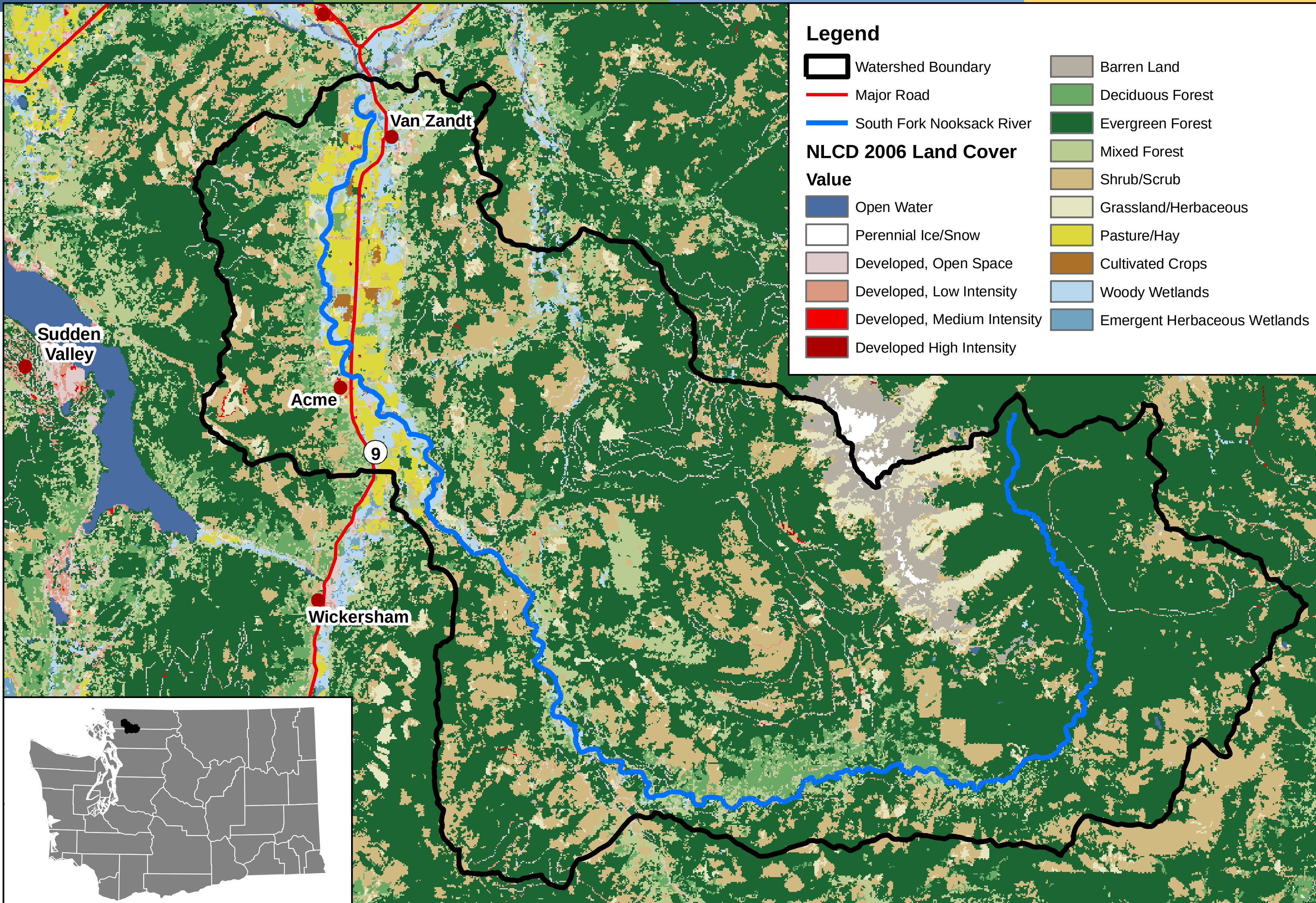
1. Project setting
2. Temperature TMDL
3. Climate change
4. TMDL & Climate Change
5. River and Habitat Restoration

Project Team

- Nooksack Tribe
- Lummi Nation
- EPA Office of Research & Development
- EPA Region 10
- Washington State Department of Ecology
- Tetra Tech (contractor)
- UW Climate Impacts Group
- USFS

S.F. Nooksack River Study Area

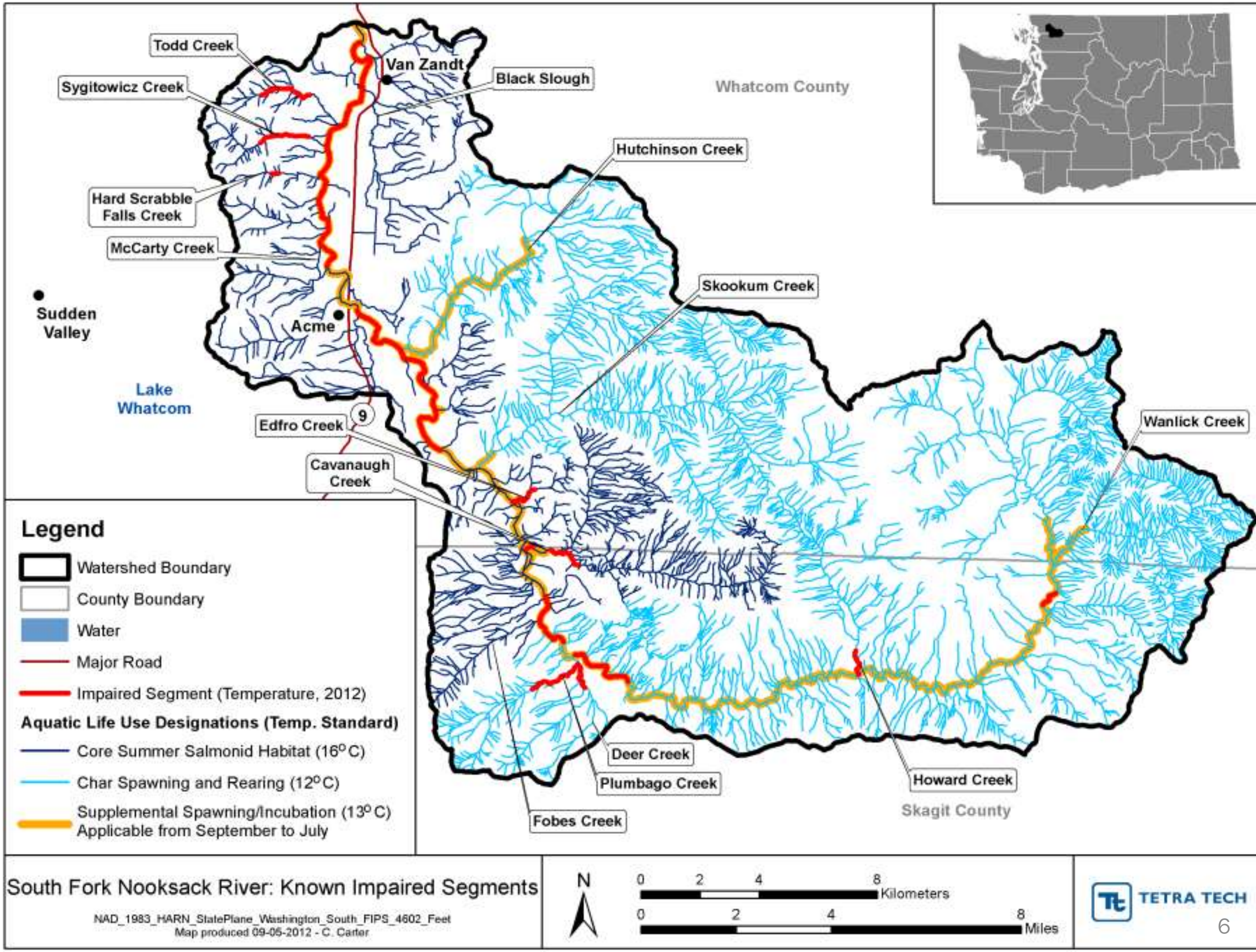
- Temperature impairments requiring Total Maximum Daily Loads (TMDLs)
- 36 mainstem RM with 186 mi^2 watershed
- Average annual discharge 1,032 cfs
- Temperate climate, mountain snow, no glaciers
- Land Uses
  - Forestry
  - Agriculture
  - Minimal rural development



South Fork Nooksack River: NLCD 2006 Land Cover

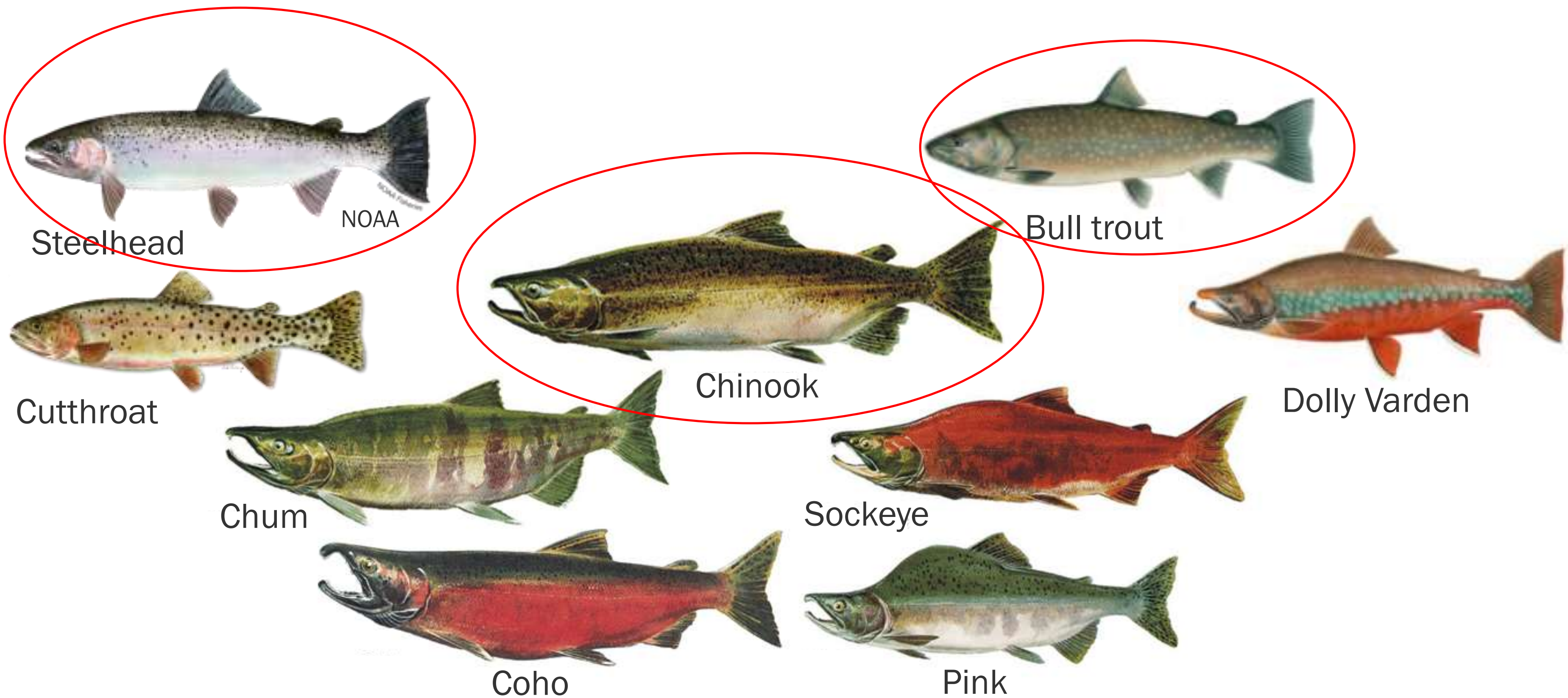
NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet
Map produced 04-10-2012 - S. Job

TETRA TECH


Todd Creek
Van Zandt
Black Slough
Sygitowicz Creek
Whatcom County
Hutchinson Creek
Hard Scrabble Falls Creek
McCarty Creek
Skookum Creek
Sudden Valley
Acme
Lake Whatcom
9
Edfro Creek
Cavanaugh Creek
Wanlick Creek
Legend
Watershed Boundary
County Boundary
Water
Major Road
Impaired Segment (Temperature, 2012)
Aquatic Life Use Designations (Temp. Standard)
Core Summer Salmonid Habitat (16°C)
Char Spawning and Rearing (12°C)
Supplemental Spawning/Incubation (13°C) Applicable from September to July
Deer Creek
Plumbago Creek
Howard Creek
Skagit County
Fobes Creek
South Fork Nooksack River: Known Impaired Segments
NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet
Map produced 09-06-2012 - C. Carter
N
0 2 4 8 Kilometers
0 2 4 8 Miles
TETRA TECH

S.F. Nooksack River Study Area

- Home to 9 salmonid species, 3 of which are threatened
- Local Tribes rely on healthy salmonid populations
- Low summer flow and high temperatures have negative impacts



TMDL & Climate Change Impetus

We know that…

- Climate change will affect freshwater ecosystems
- The TMDL program is the primary framework to achieve healthy water bodies as per the CWA

But…

- Majority of TMDLs assume a 'stationary climate'

So…

- **EPA Region 10 and Office of R&D** interested in how projected climate change impacts can be incorporated into a TMDL and influence restoration plans

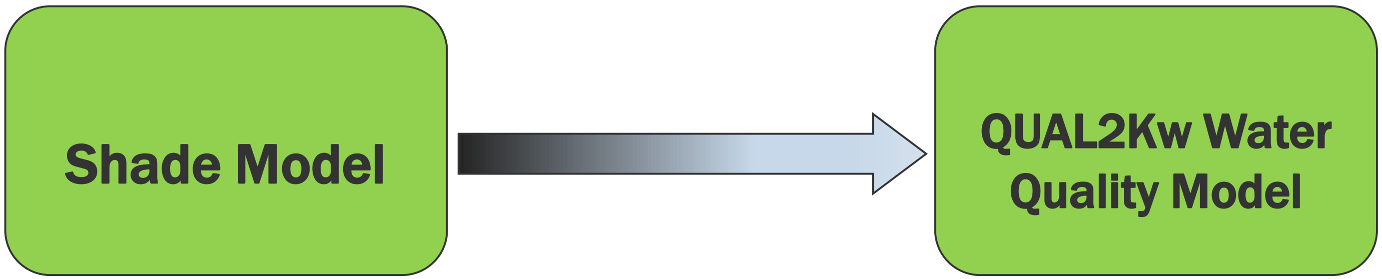
Stream Temperature… Why Model?

Fulfill objectives:

- Characterize temps and governing processes
- Simulate existing conditions
- Determine TMDL
- Evaluate different scenarios e.g.
  - Natural conditions
  - Climate change
  - Explore options for reducing temperature
- Support recovery efforts
- Understand possible outcomes
- Identify data gaps
- Adaptive management

TMDL Temperature Models

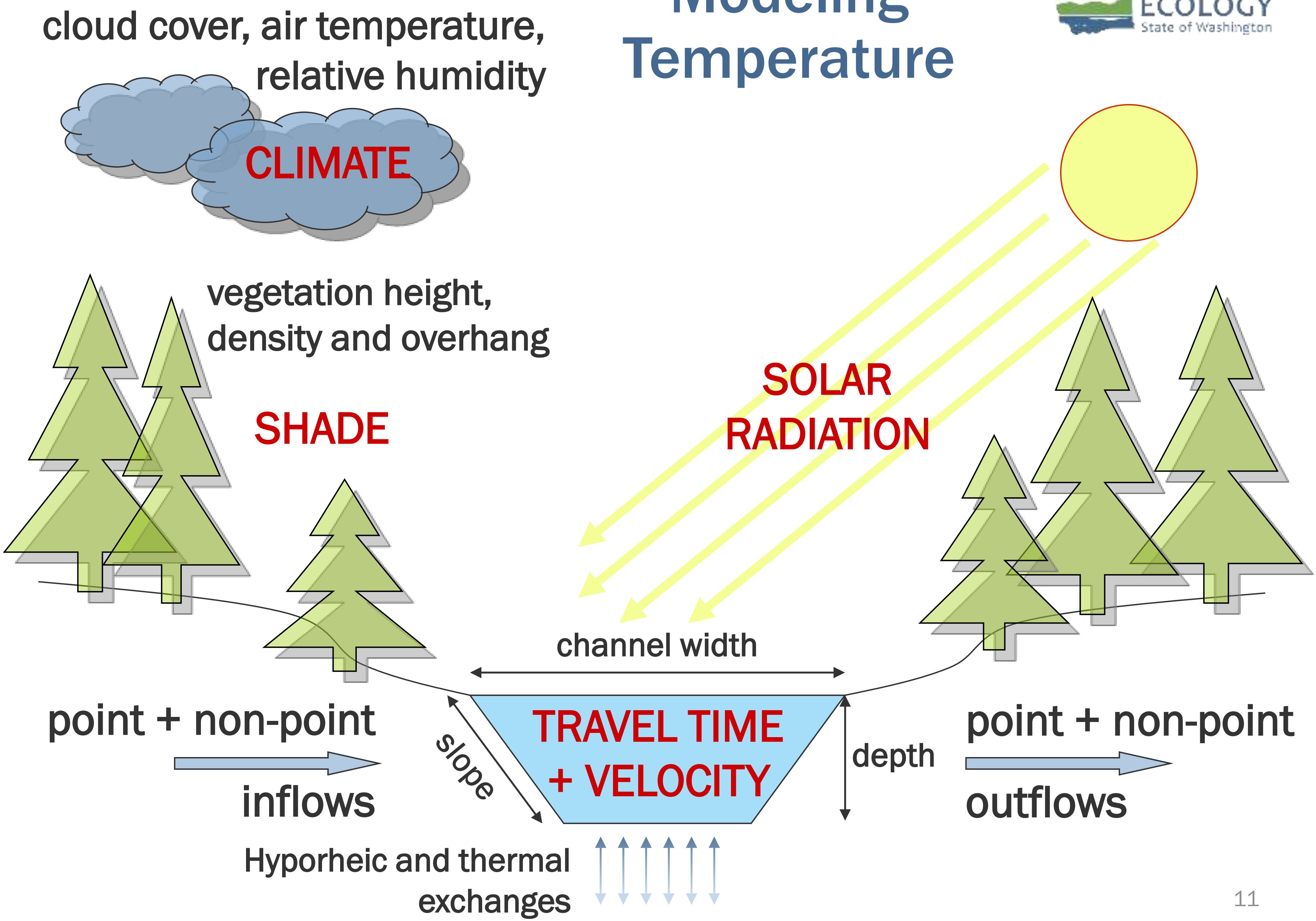
- **Shade:** Calculates effective shade based on channel geometry, riparian veg. and topography, and provides shade as input to QUAL2Kw stream model
- **QUAL2Kw:** Simulates in-stream temps. Under low flow and high temperature steady state critical conditions

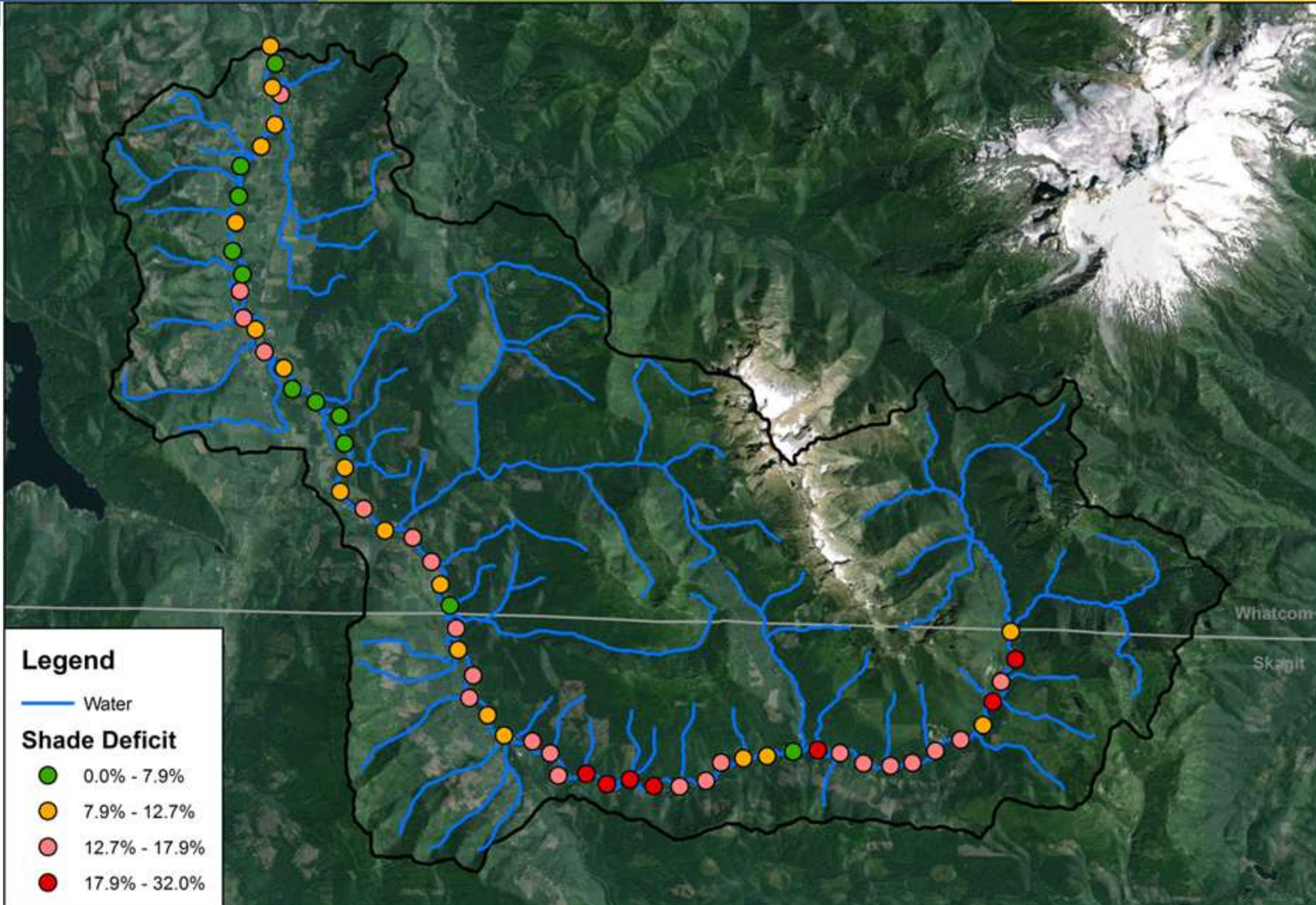


- Channel geometry
- Topography, elevation
- Aspect
- Riparian characteristics
- Solar radiation

- Headwater temperatures
- Tributary temperatures
- Flow and hydraulics
- Meteorology
- Channel geometry

Modeling Temperature





South Fork Nooksack River:
Shade Deficit

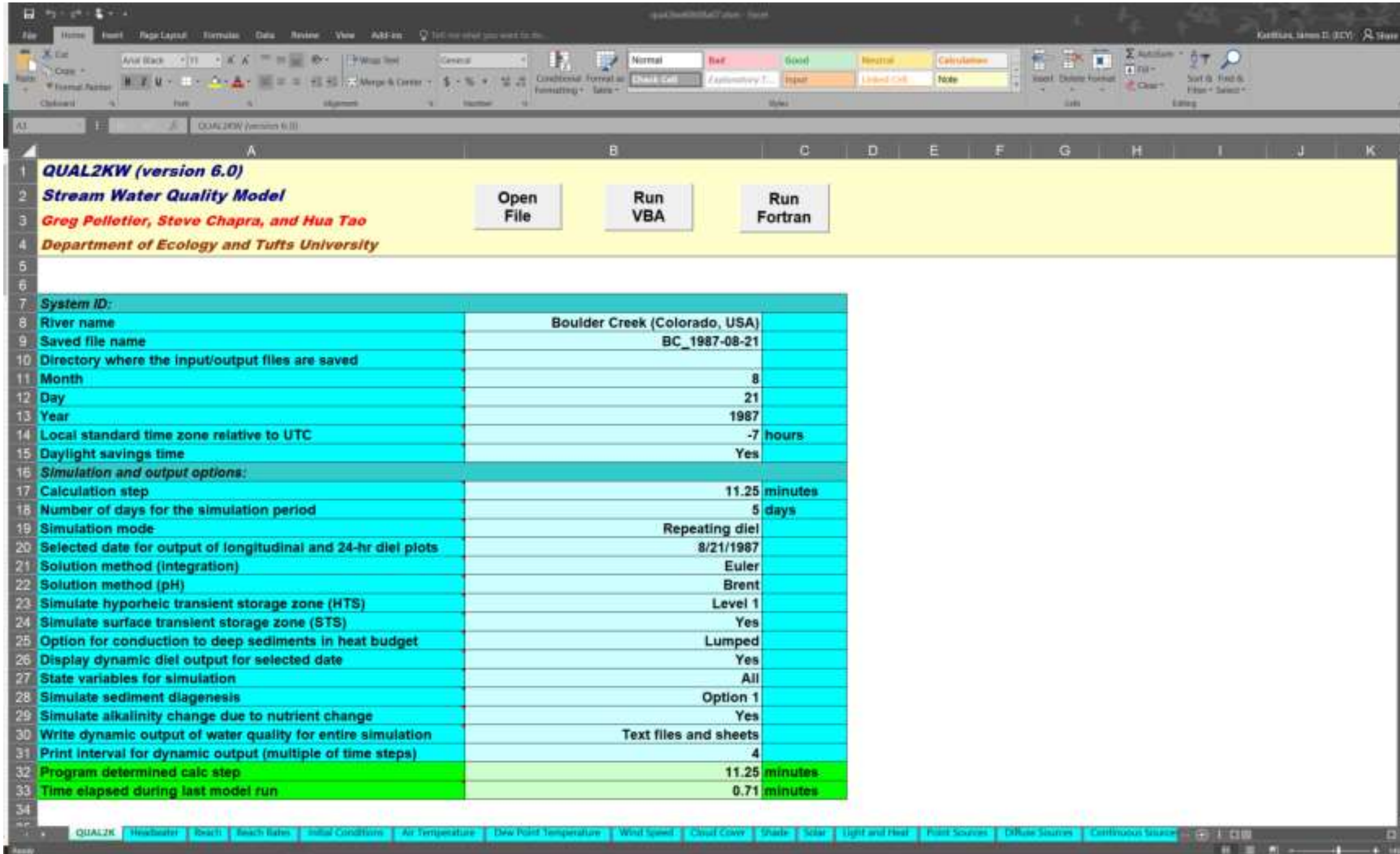
NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet
Map produced 04-10-2013 - H. Nicholas

N
0 1.25 2.5 5 Kilometers
0 1.25 2.5 5 Miles

TETRA TECH

Models for Water Quality

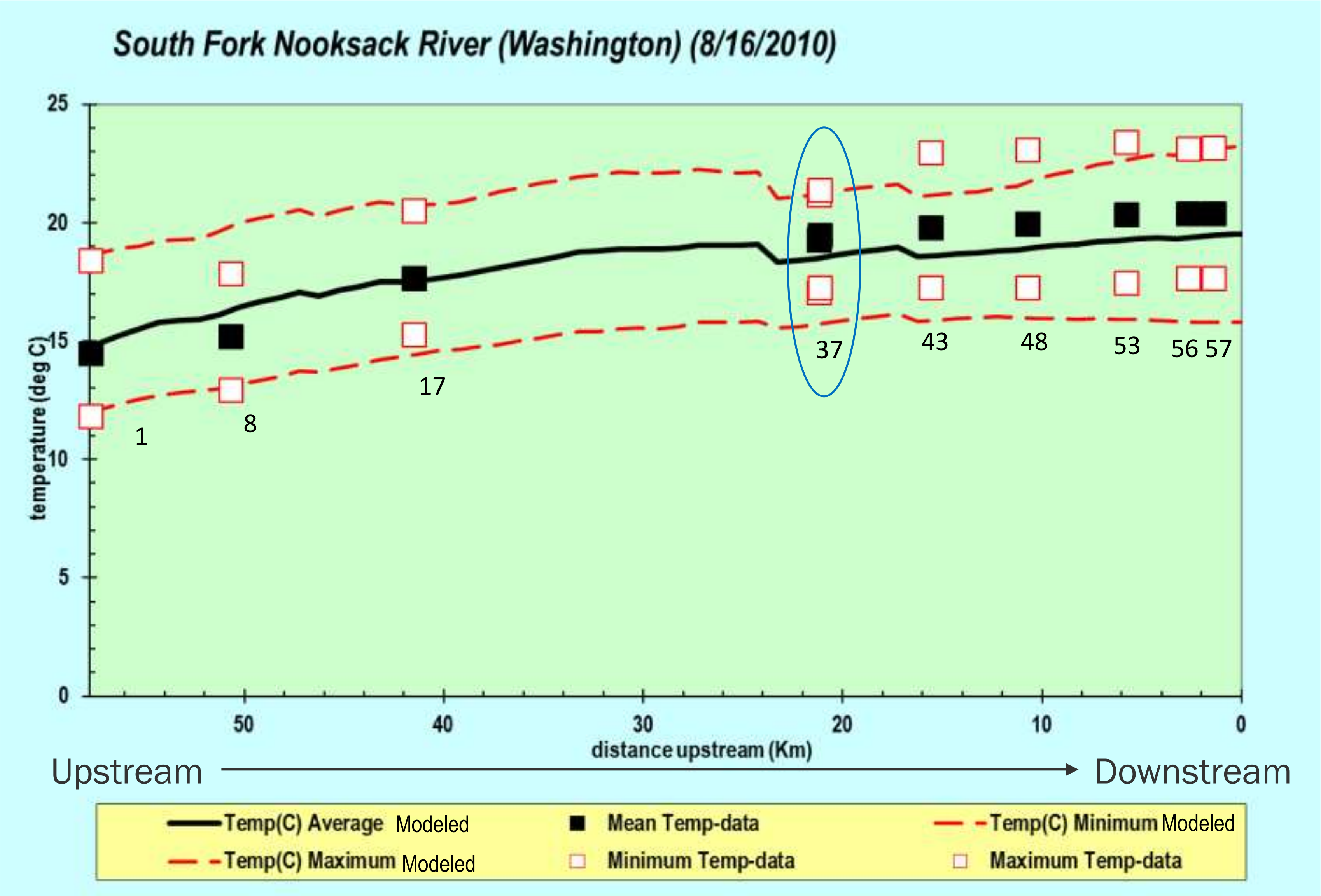
QUAL2Kw GUI (Pelletier et al. 2005)



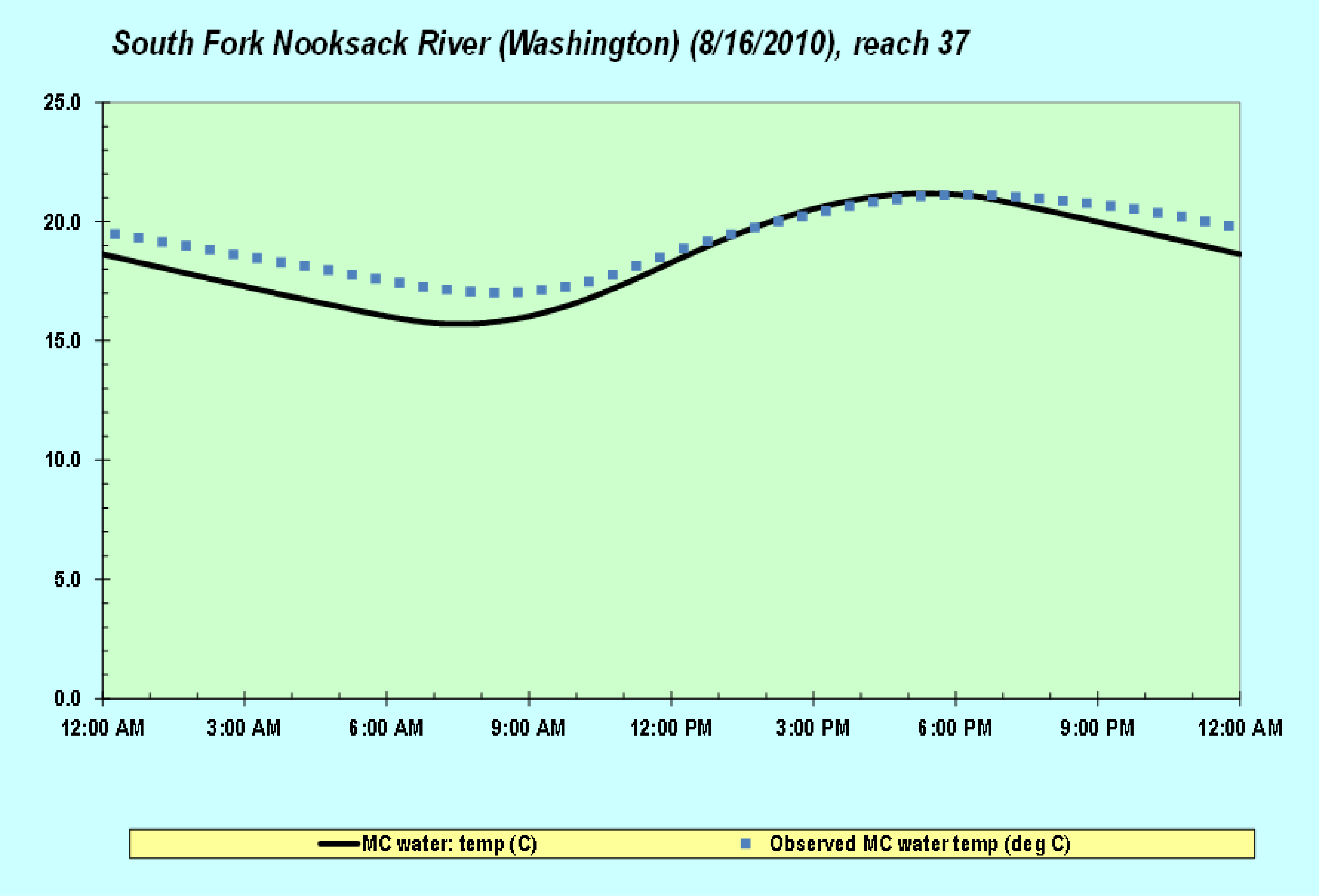
Ecology's modeling tools for TMDLs webpage hyperlink

QUAL2Kw example graphics

DEPARTMENT OF ECOLOGY
State of Washington



QUAL2Kw example graphics

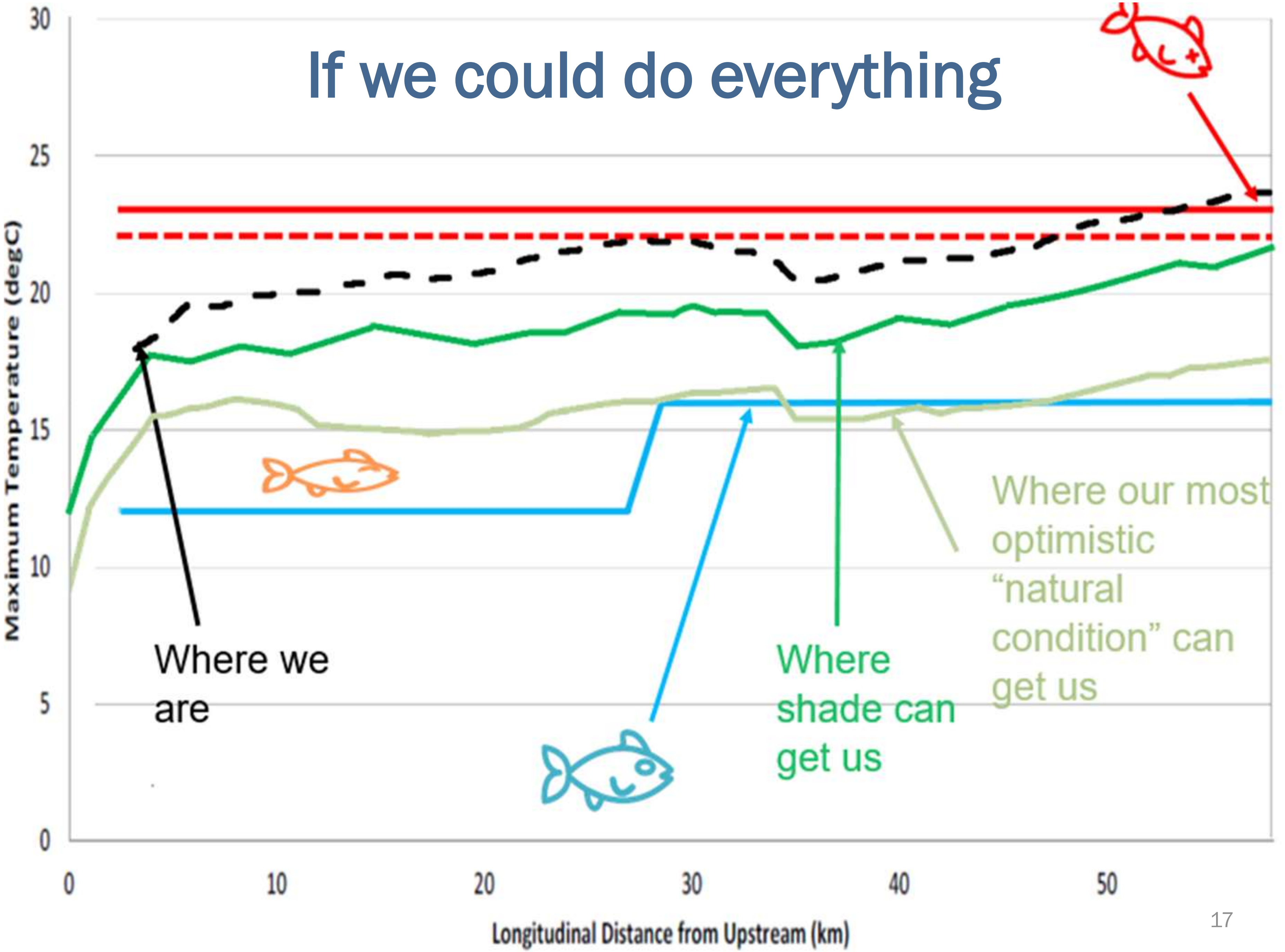


TMDL modeling scenario results

Scenario	Condition	Maximum Stream Temperature (°C) (averaged across select reaches)		
		All Reaches	Headwaters to Reach 28[a]	Reach 28[a] to Outlet
Typical Low Flow Conditions (7Q2 flows; 50th percentile air temperature)				
1	Current Conditions: 7Q2	19.00	18.44	19.66
2	100-year System Potential except where developed: 7Q2	16.99	16.22	17.55
Critical Low Flow Conditions (7Q10 flows; 90th percentile air temperature)				
3	Current Conditions: 7Q10	21.00	20.11	21.88
4	Current Conditions with cooler tributaries: 7Q10	20.77	19.66	21.66
5	100-year System Potential except where developed: 7Q10	18.77	17.88	19.66
6	100-year System Potential everywhere: 7Q10	18.77	17.88	19.66

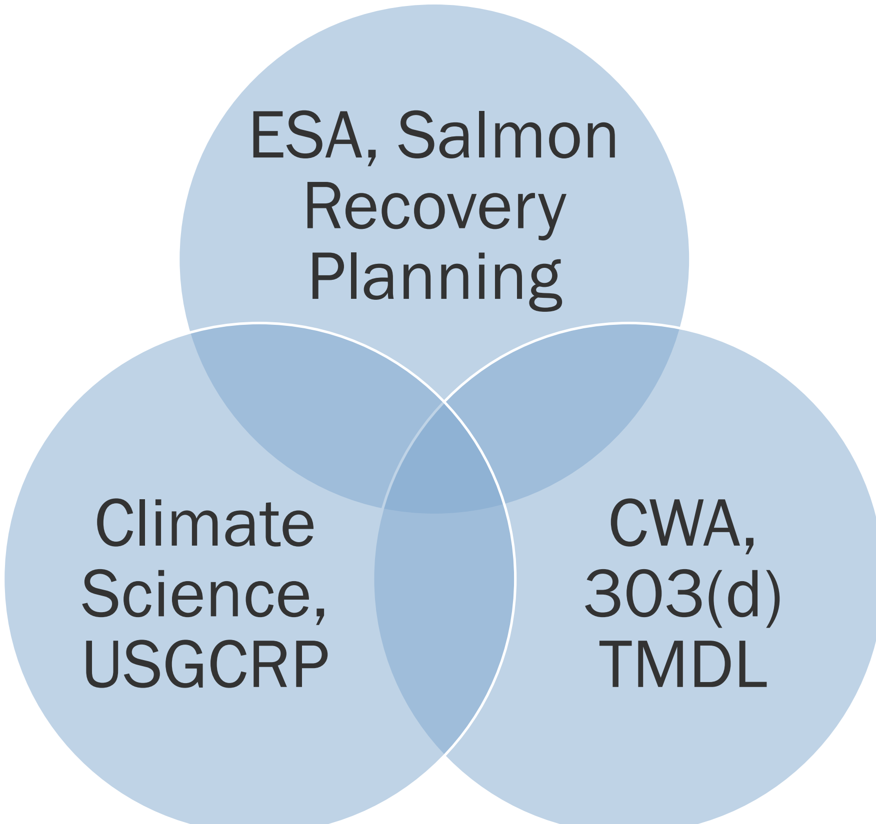
[a] From the headwaters to 27.5 km downstream, the water quality criteria during the modeling period is 12°C. Downstream of this section, the water quality criteria is 16°C during the modeling period.

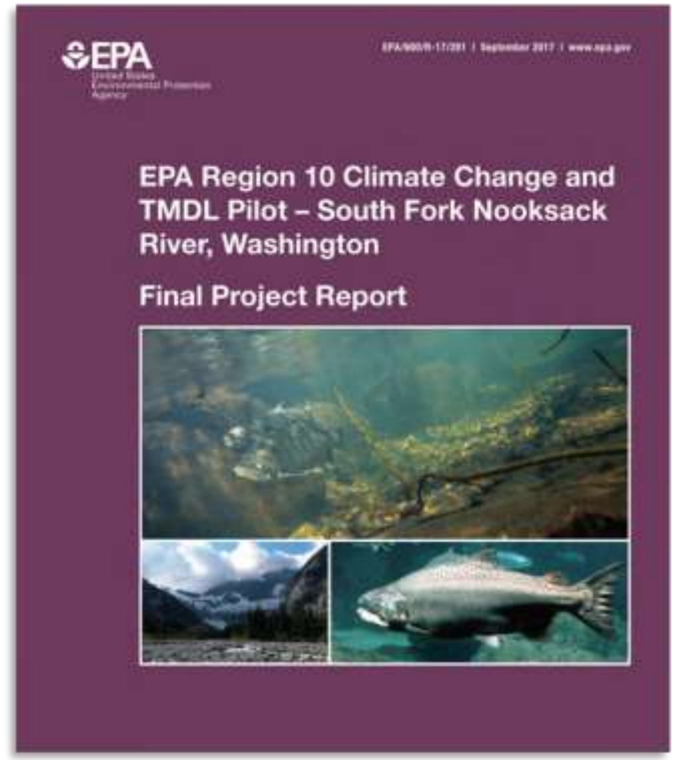
If we could do everything

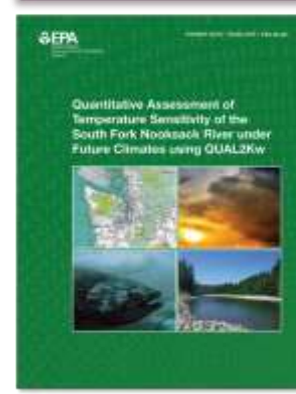


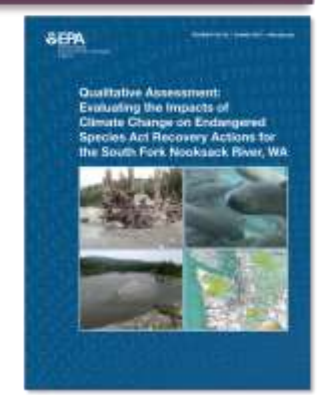
Climate Change Pilot Study

- Vulnerability analysis
- Qualitative and Quantitative
- Integrates 3 environmental management programs

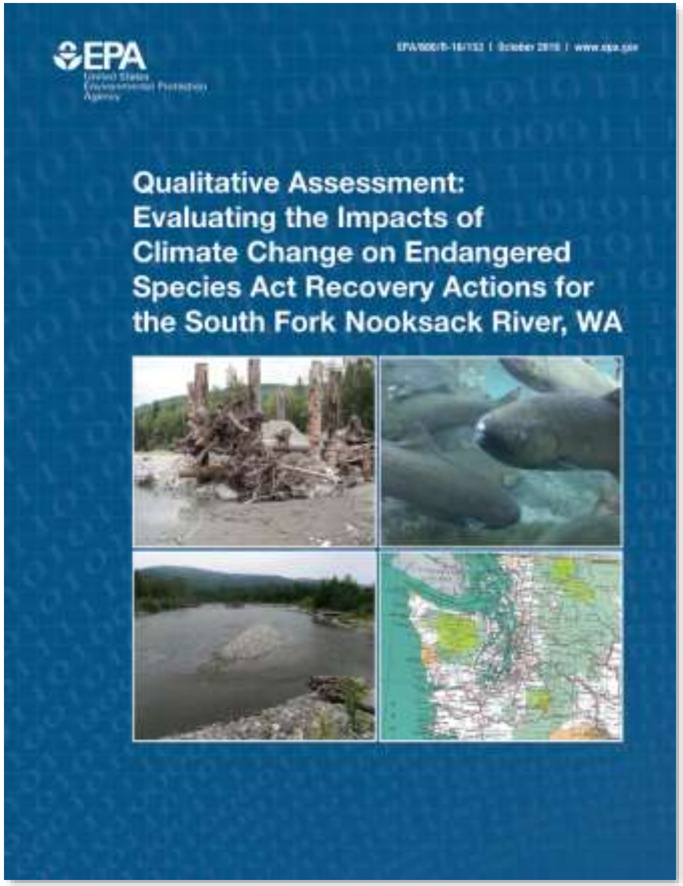








Climate and Species Recovery: Qualitative



- Salmon habitat restoration
- Updates Salmonid Recovery Plan
- Informs TMDL implementation
- Goes beyond SPV
- Assessed per:
  - Species
  - Restoration Action

Photos: Roger Tabor/USFWS

Stream restoration effect and priority

Category	Analogous South Fork Technique	Ameliorates Climate Change Effects?					Priority of Action (by Reach)				
		Ameliorates Temperature Increase	Ameliorates Base Flow Decrease	Ameliorates Peak Flow Increase	Ameliorates Sediment Increase[1]	Increases Salmon Resilience	1	2	3	4	5
Longitudinal connectivity (barrier removal)	Improve passage at natural barriers	○	○	○	○	●	N/A	N/A	Mod	Mod	N/A
Floodplain reconnection	Hydromodification removal/setback	●	○	●	●	●	High	Low	Low	Low	Low
	Log jams to reconnect floodplains	●	●	●	●	○	High	Low	Mod	Low	Low
Stream flow regimes	Reduce water withdrawals	●	●	○	○	○	High	Low	N/A	N/A	N/A
	Restore floodplain wetlands	●	●			○	High	Low	Mod	Low	Low
Erosion and dediment delivery	Reduce stream-adjacent sediment inputs (wood placement to reduce toe erosion)	○	○	○	○	○	Low	Low	Low	Low	Low
Riparian functions	Planting (trees, other vegetation)	●	○	○	○	○	High	High	High	High	High
	Thinning or removal of understory	○	○	○	○	○	High	High	High	High	High
	Remove non-native plants	◓	◓	○	○	○	High	High	High	High	High
Instream rehabilitation	Placement of log jams, other wood	◓[2]	○	○	○	○	High	Low	High	Low	Low

[1] Beechie et al. (2013) did not evaluate potential for actions to ameliorate increases in sediment. Call is based on best professional judgment.

[2] Instream restoration can ameliorate temperature increase by creating temperature refuges, increasing hyporheic exchange by encouraging bedform diversity, and narrowing active channel and increasing effective shade.

Ability to Ameliorate Climate Change Effects		Action Priority	
●	Positive effect	(blue)	Low
○	No effect	(yellow)	Moderate (Mod)
◓	Context-dependent	(orange)	High

TMDL & Climate Change Marriage: Quantitative

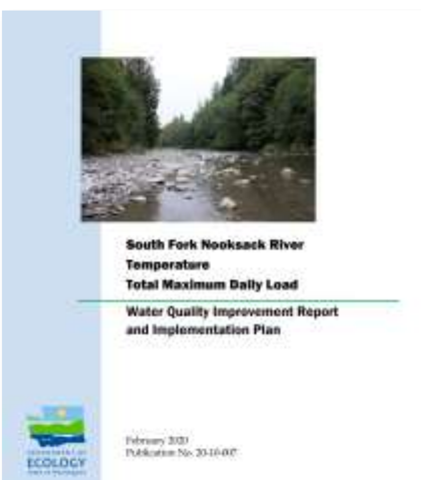
- Shade—QUAL2Kw models for TMDL

  Boundary condition adjustments from downscaled GCM — (1) SPV, (2) no veg

- Climate models:

  (1) Low, Medium, High (2) 2020s, 2040s, 2080s

Scenario	GCM	General Trends
Low Impact	CGCM3.1-t47 (Third Generation Coupled Global Climate Model)	Low warming, increased precipitation
Medium Impact	CCSM3 (Community Climate System Model)	Average warming, decreased summer precipitation
High Impact	HADGEM1 (Hadley Centre Global Environmental Model)	High warming, decreased precipitation

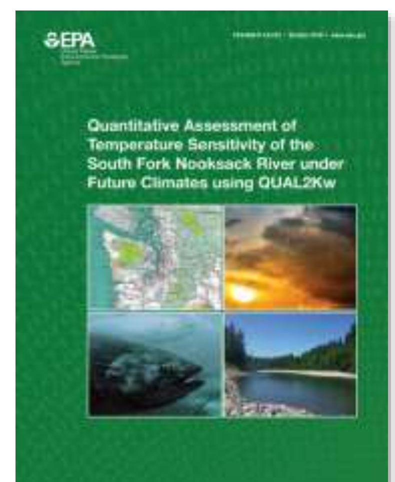


QUAL2Kw

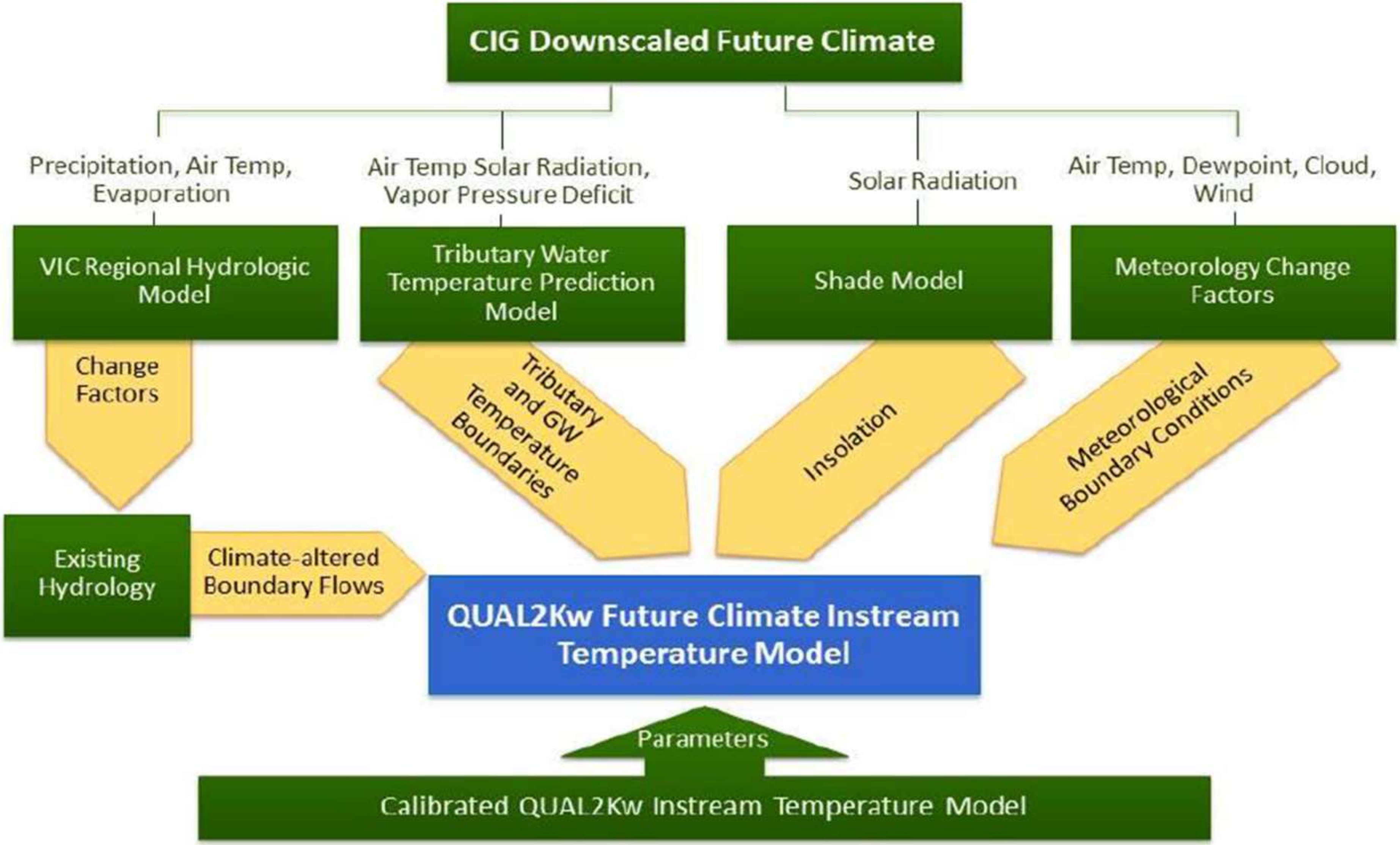
2 Scenarios

Climate Models

9 Scenarios



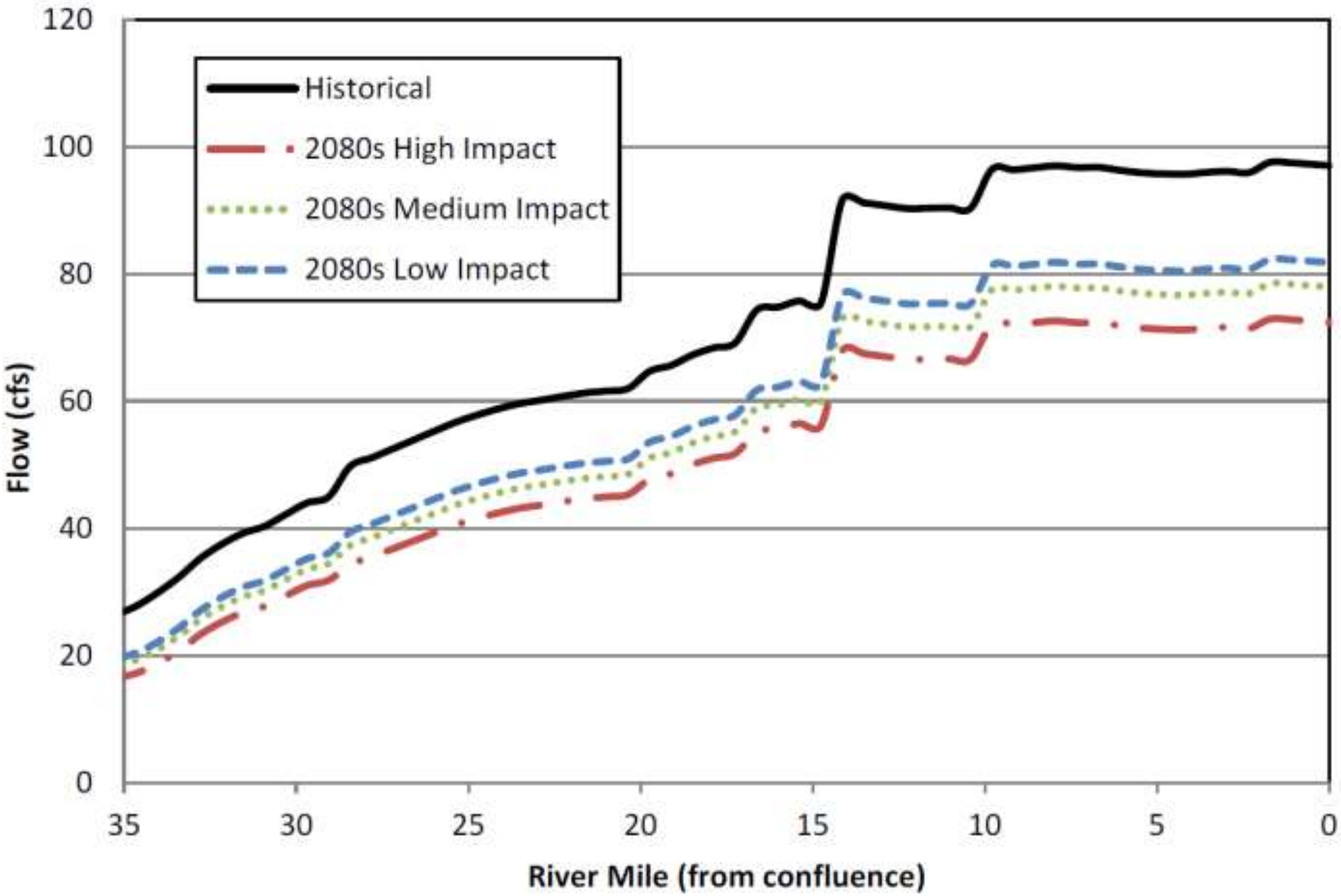
Schematic of model and climate data integration



Climate altered boundary conditions

Tributary, headwater, and groundwater flow

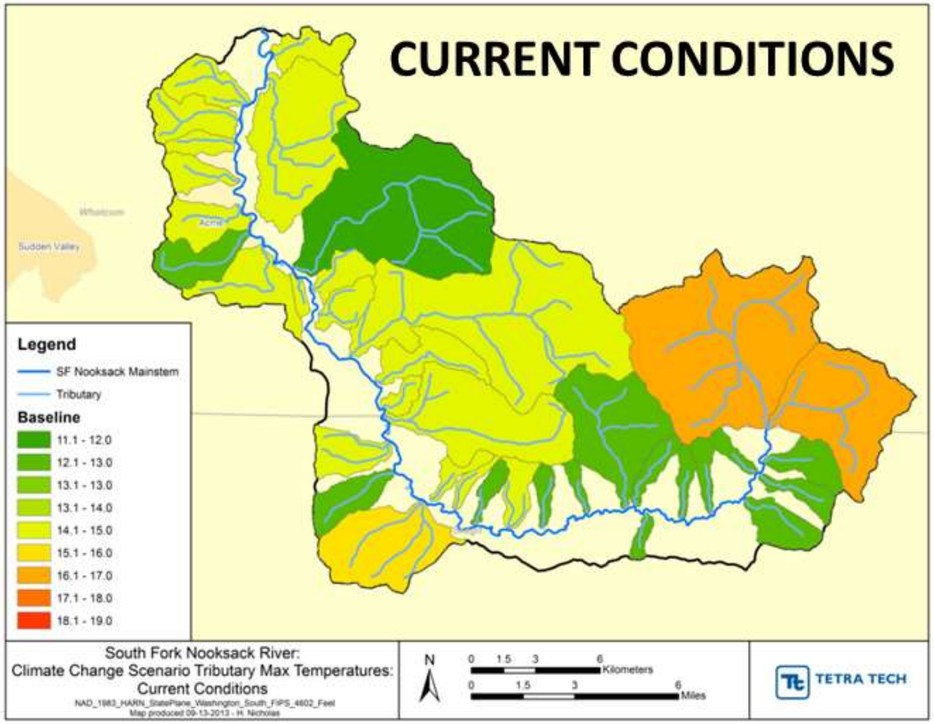
- VIC hydrology model — used to modify current 7Q10 flows
- Larger relative changes in flow are estimated at higher elevations

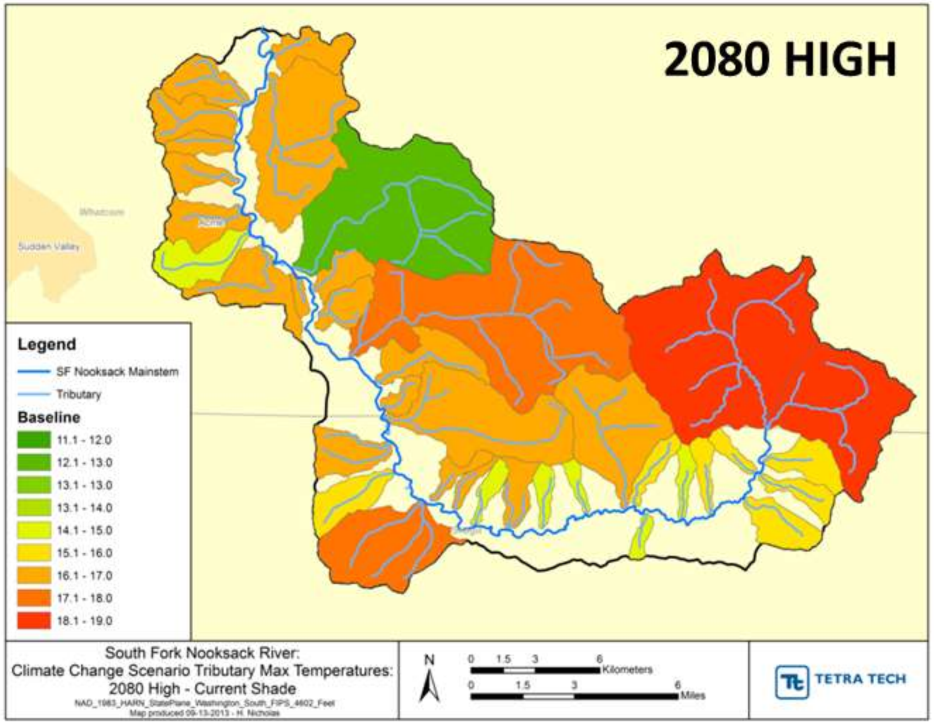


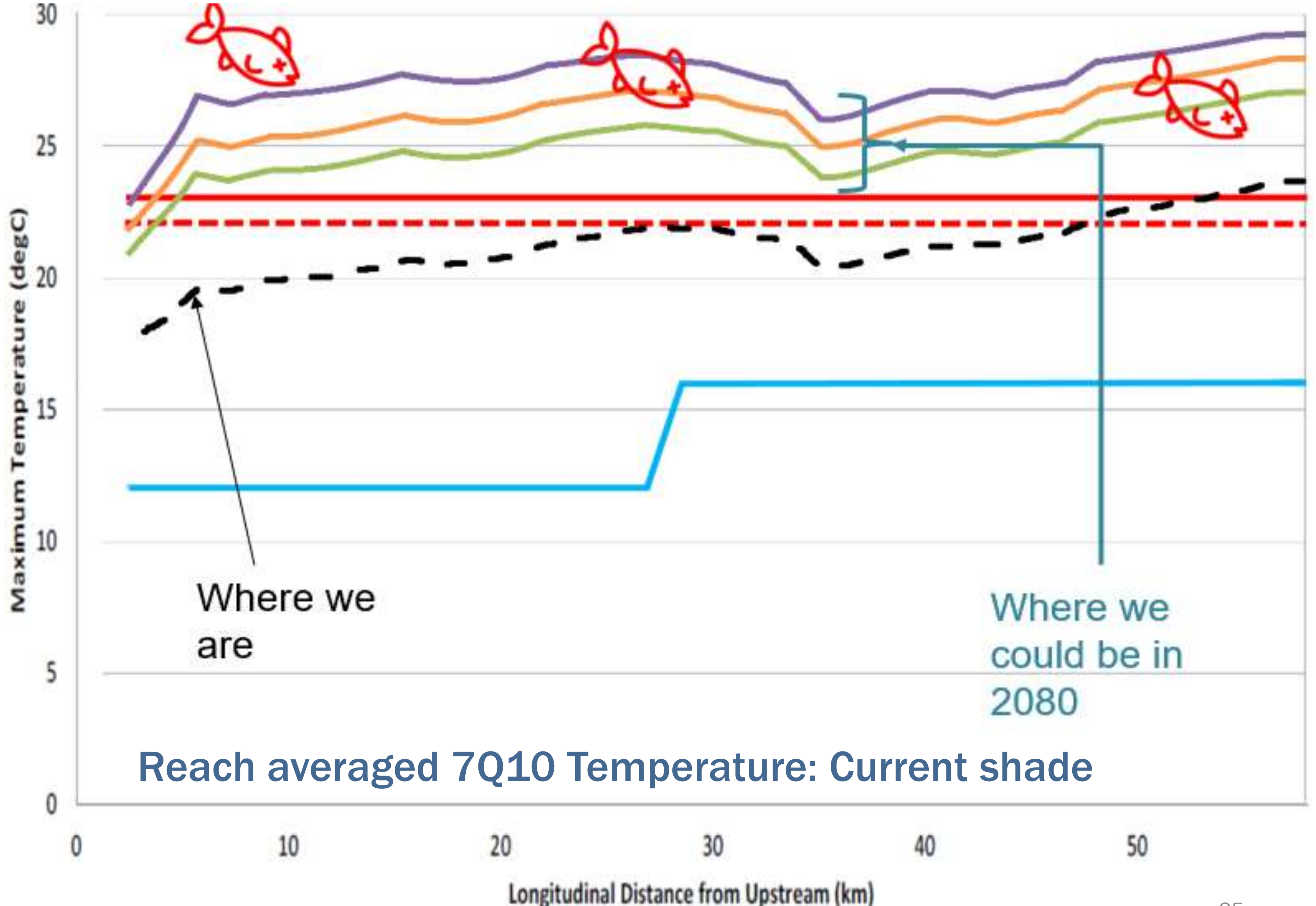
Climate altered boundary conditions

Tributary and headwater water temperature

- Estimated from landscape and climate variables using a non-linear combined regression method
- Variables: solar radiation, average air temperature, vapor density deficit, day of year, elevation, drainage area, and fraction forested

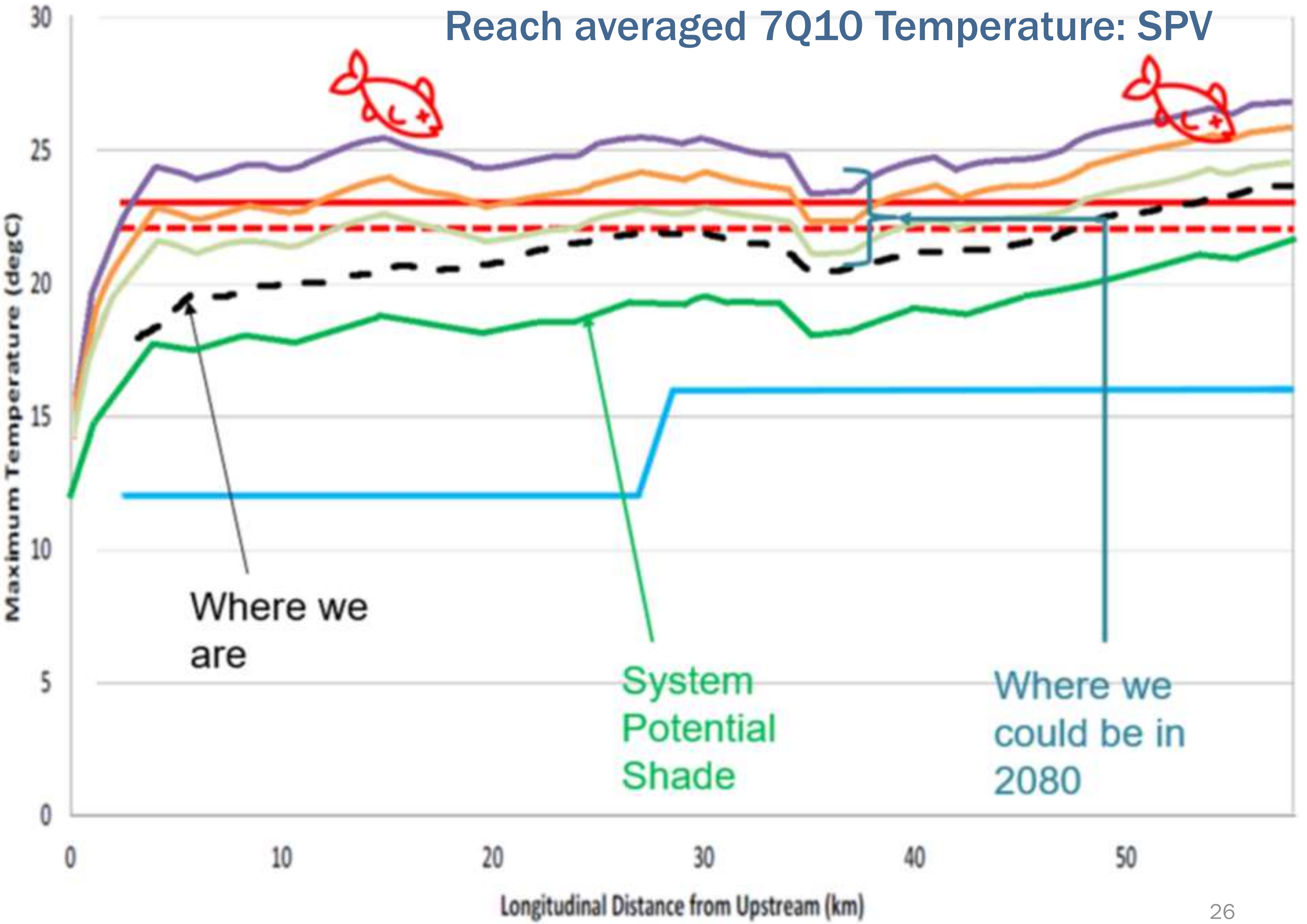




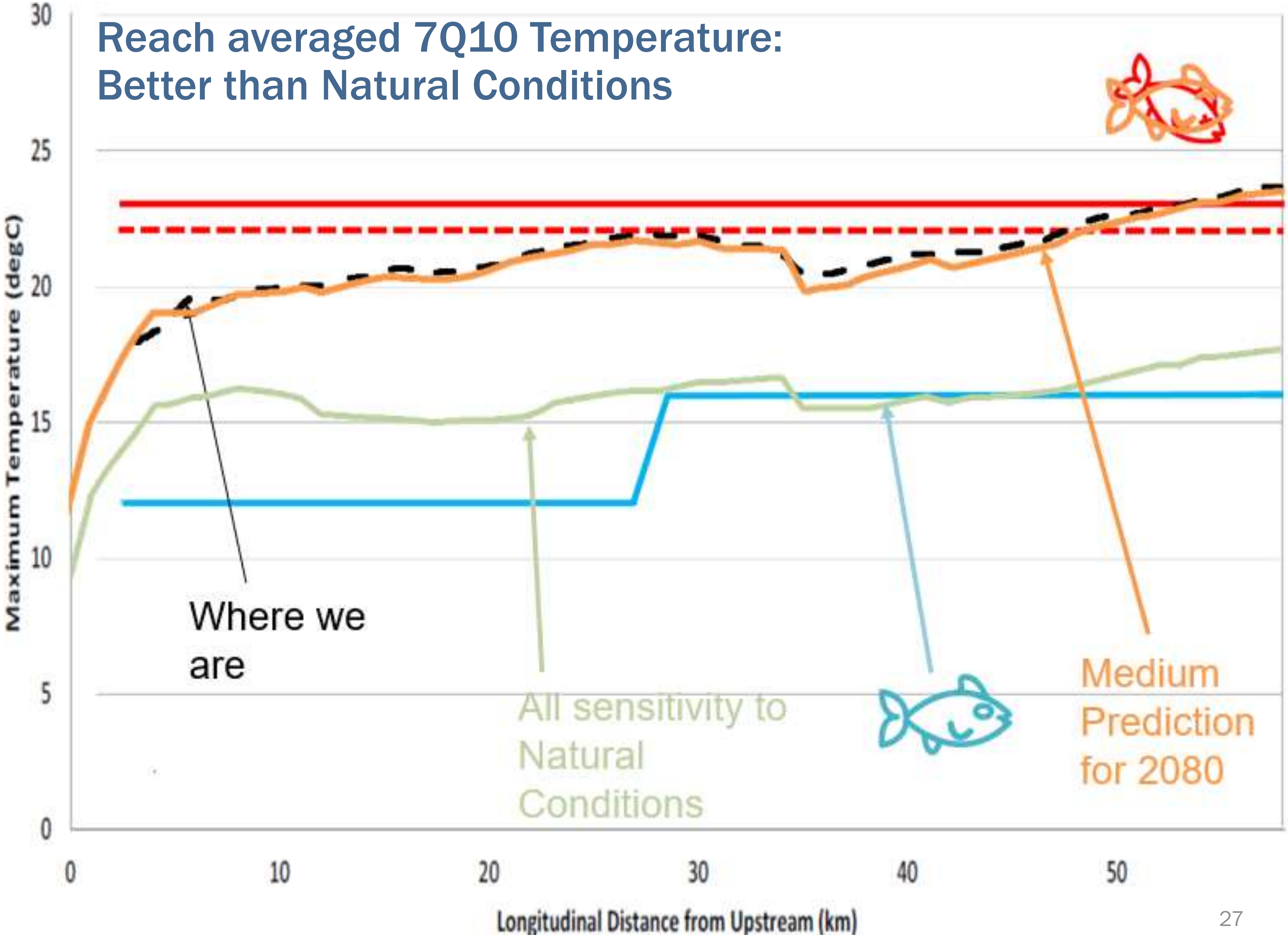


0
5
10
15
20
25
30
Maximum Temperature (degC)
Where we are
Where we could be in 2080
Reach averaged 7Q10 Temperature: Current shade
0
10
20
30
40
50
Longitudinal Distance from Upstream (km)

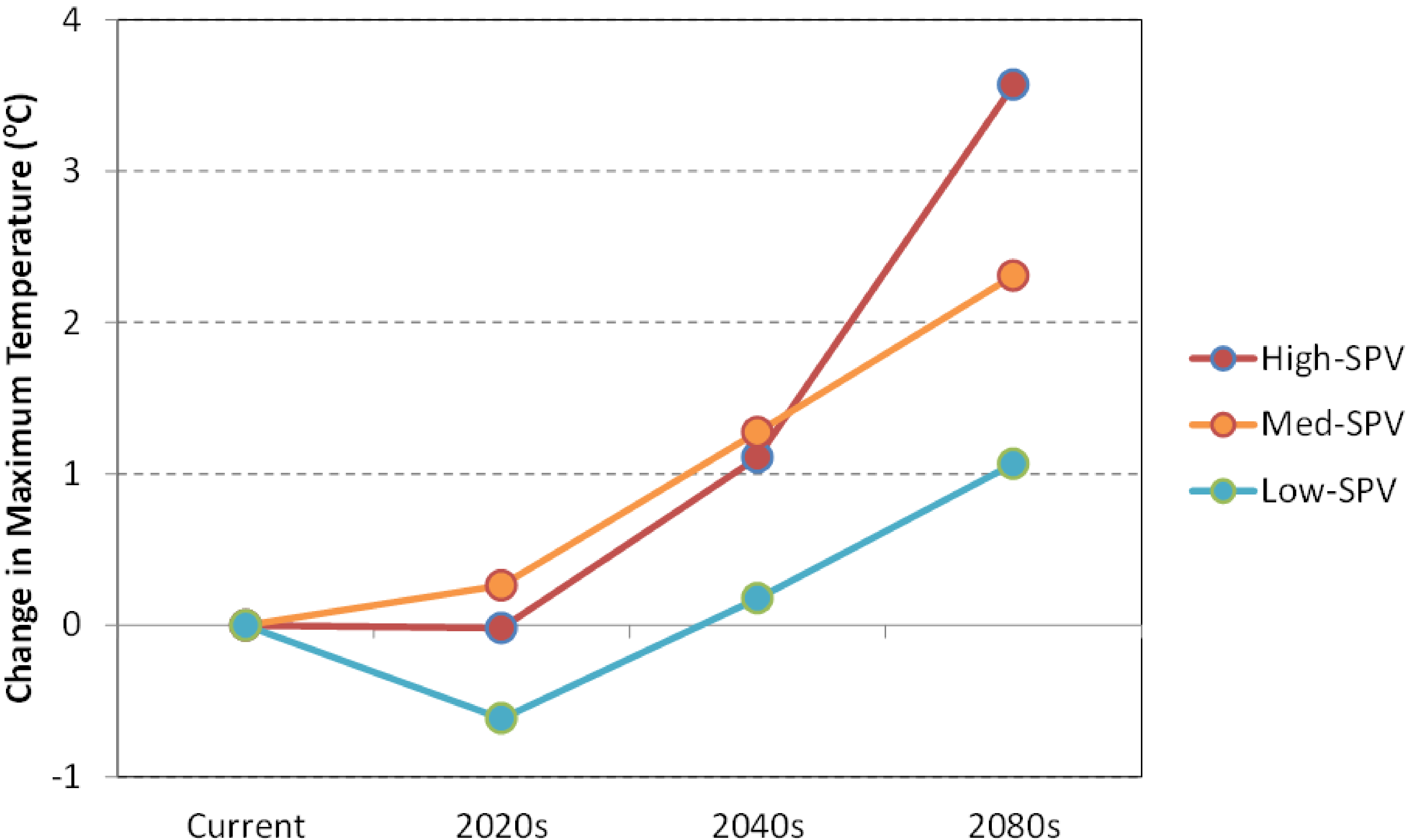
Reach averaged 7Q10 Temperature: SPV



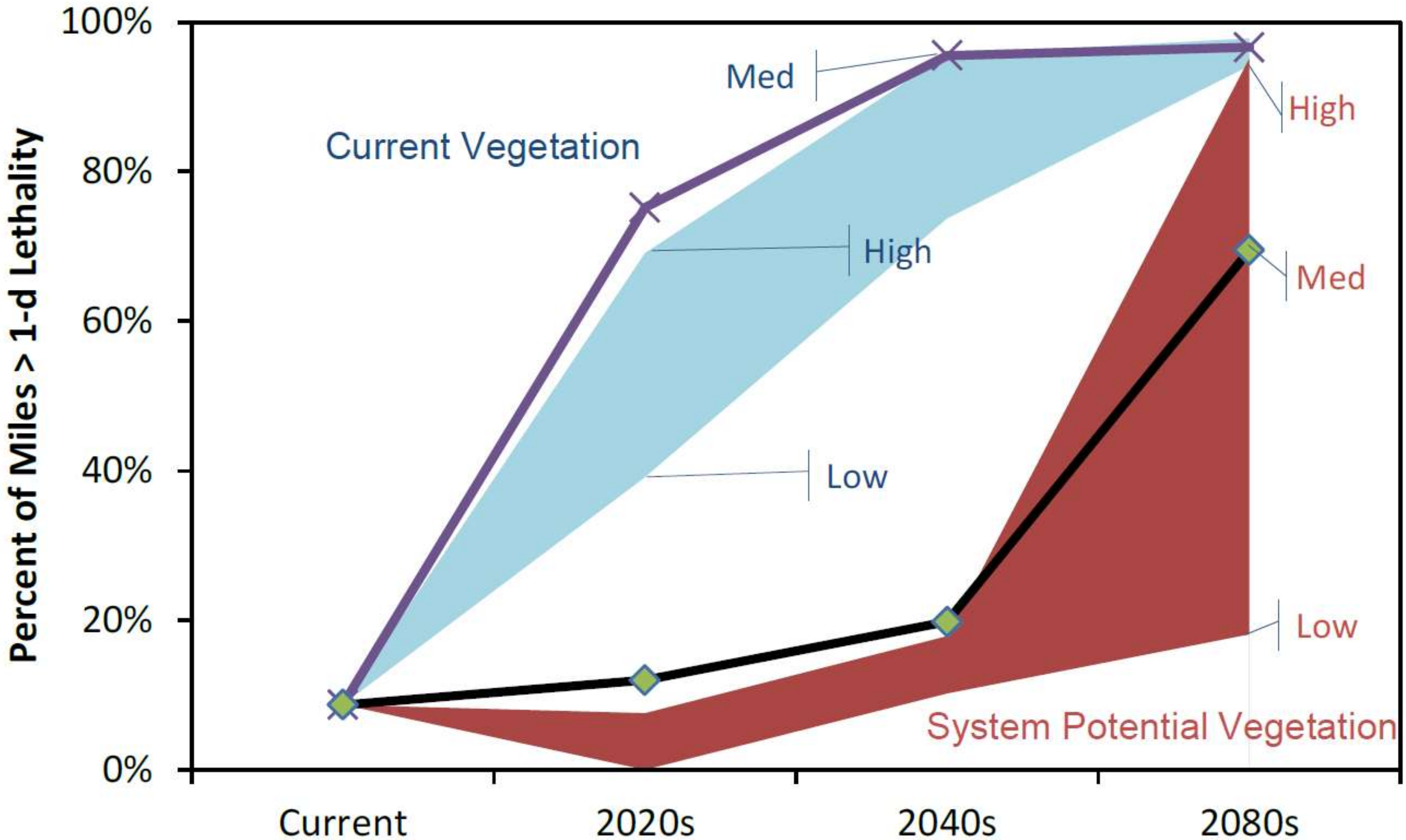
Reach averaged 7Q10 Temperature: Better than Natural Conditions



Reach averaged 7Q10 Temperature



Climate change impacts: % of RM > 23 °C



“Now, here, you see, it takes all the running you can do,
to keep in the same place. If you want to get somewhere else,
you must run at least twice as fast as that!”

— Red Queen *Through the Looking Glass by L. Carroll*

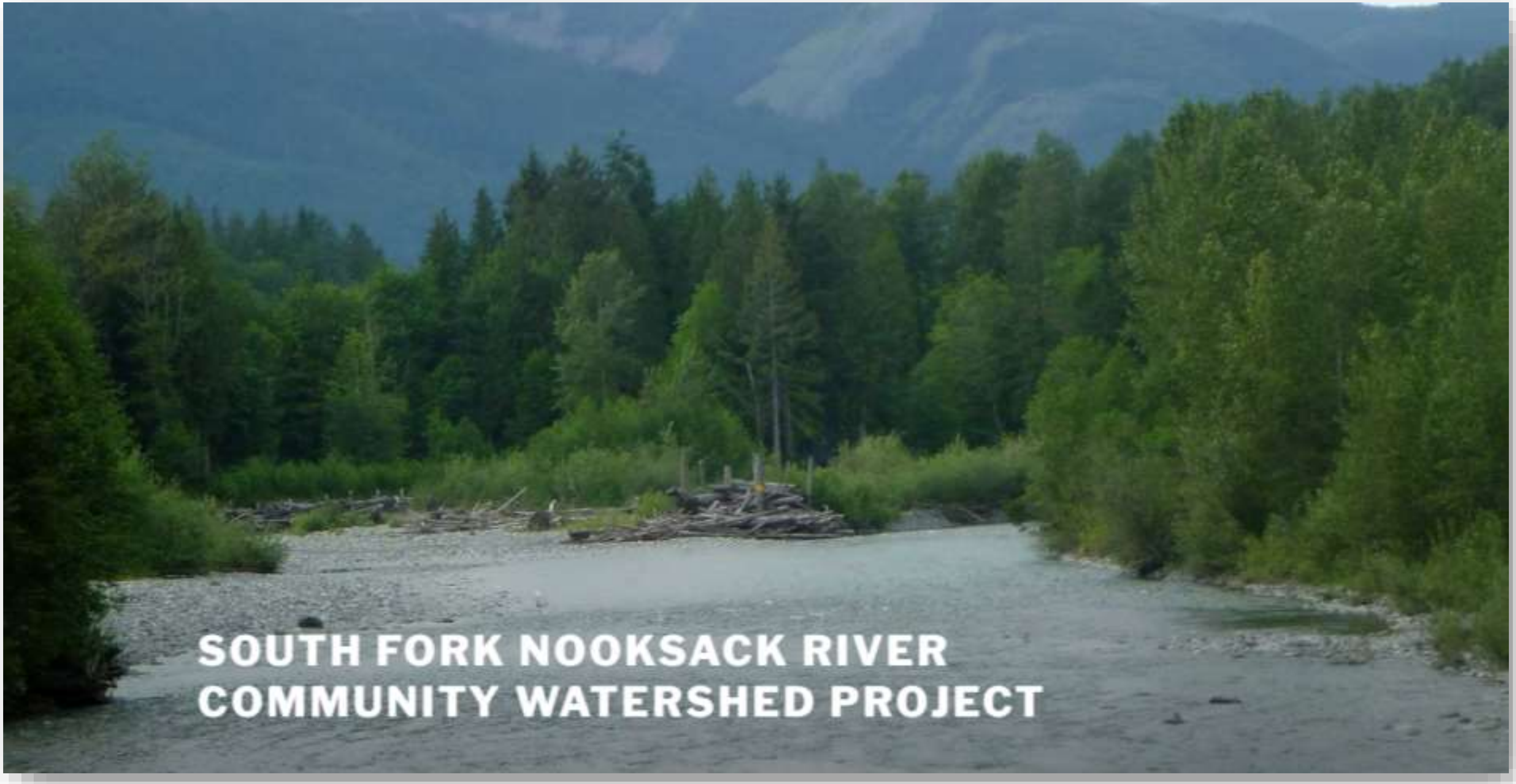
Restorative Implementation

- Incorporate the Climate Change Pilot study recommendations
- System potential shade will improve resiliency, but is insufficient to mitigate climate change effects after 2020
- Disconnect between modeled reach averaged conditions vs. where salmon hang out → need to protect retain/enhance thermal refugia
- Should we be thinking about time horizons for when TMDL allocations need to be achieved given the climate change effect?
- Importance of other non-shade restoration actions/adaptation strategies and need to prioritize timing of implementation actions to ameliorate climate change impacts
- TMDL implementation is only one part of a broader effort to attain clean water to support beneficial uses

Restoration:
Beyond Riparian Shading

- Promote river longitudinal connectivity
- Improve floodplain reconnection
- Restore streamflow regimes
- Reduce erosion and sediment delivery to the river
- Restore watershed function and process
- Continue to implement instream restoration and rehabilitation
- Develop and implement planning activities for the watershed
- Monitoring of restoration actions and adaptive management

Local Support and Engagement



Thank you

Photo: Nooksack Tribe

James Kardouni
james.kardouni@ecy.wa.gov