WRIA 9 Temperature TMDLs and Riparian Restoration "Rules of Thumb" For Temperature Management

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PHOTO: Green River near Flaming Geyser State Park looking towards Cascade crest - May 16, 2001

What is a TMDL?



- Total Maximum Daily Load

- Calculation - Max pollutant that a waterbody can receive and still meet water quality standards.



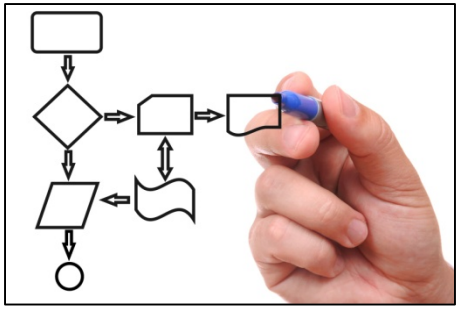
= Loading Capacity

What is a TMDL?



- Plan – to improve WQ.
  - Identify sources
  - Divide the Loading Capacity ‘Pie’
- Point sources (NPDES)
  - Wasteload allocations (WLAs)
- Non-point (BMPs)
  - Load Allocations (LAs)

TMDL Process



- WQ data collection
- Data assessment
- WQ Improvement Report and submit to EPA for approval
- Implement BMPs and adjust NPDES permits
- Effectiveness monitoring

Ecology Modeling Tools



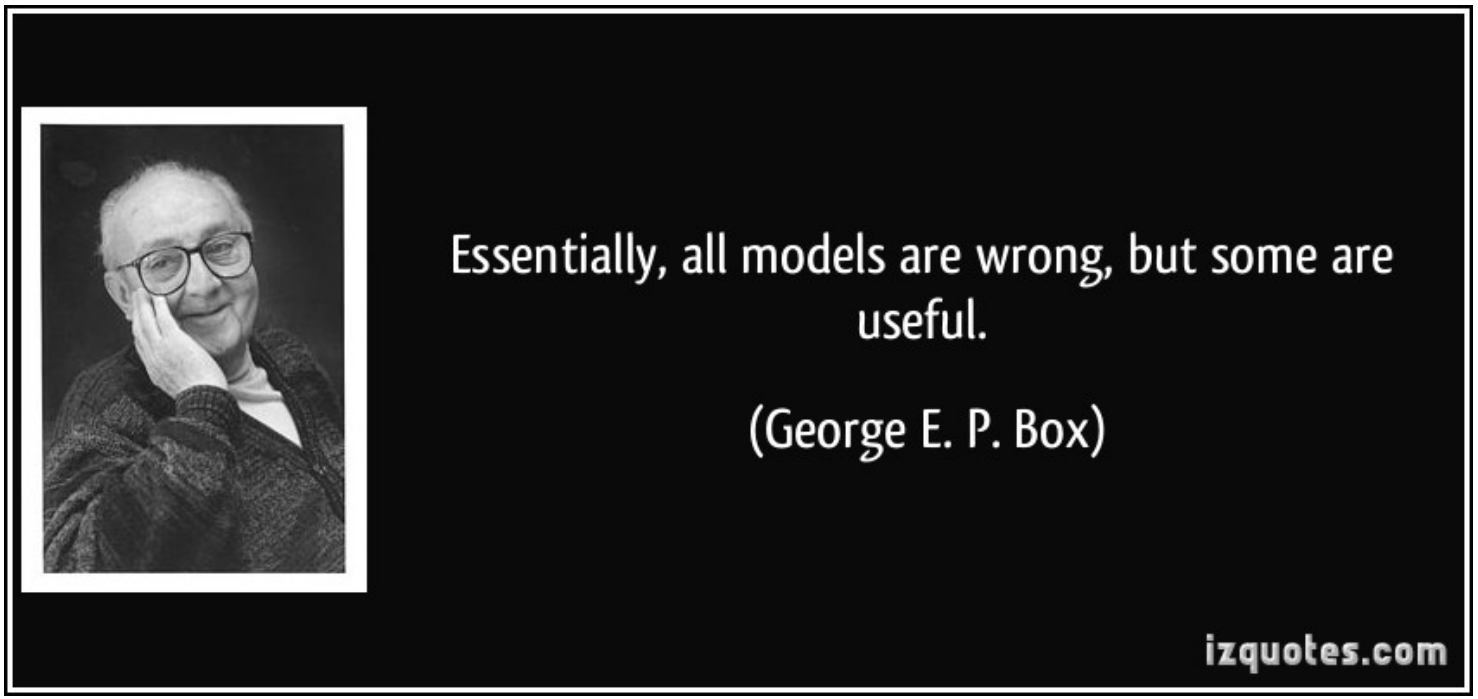


QUAL2Kw

- Shade
  - A tool for estimating shade from riparian vegetation.
- Ttools for ArcView
  - A tool to extract elevation, distance, and landcover data from computer based maps for input into the calculator for riparian shade and topography.
- QUAL2Kw
  - A modeling framework for simulating river and stream water quality (supported by EPA for temperature, DO, pH).

http://www.ecy.wa.gov/programs/eap/models.html

About Models



WRIA 9 Temperature TMDLs

- Green River below Howard Hanson Dam
  - Completed 2011
- Newaukum Creek
  - Completed 2011
- Soos Creek (Big/Little Soos, Covington, Jenkins)
  - Ongoing

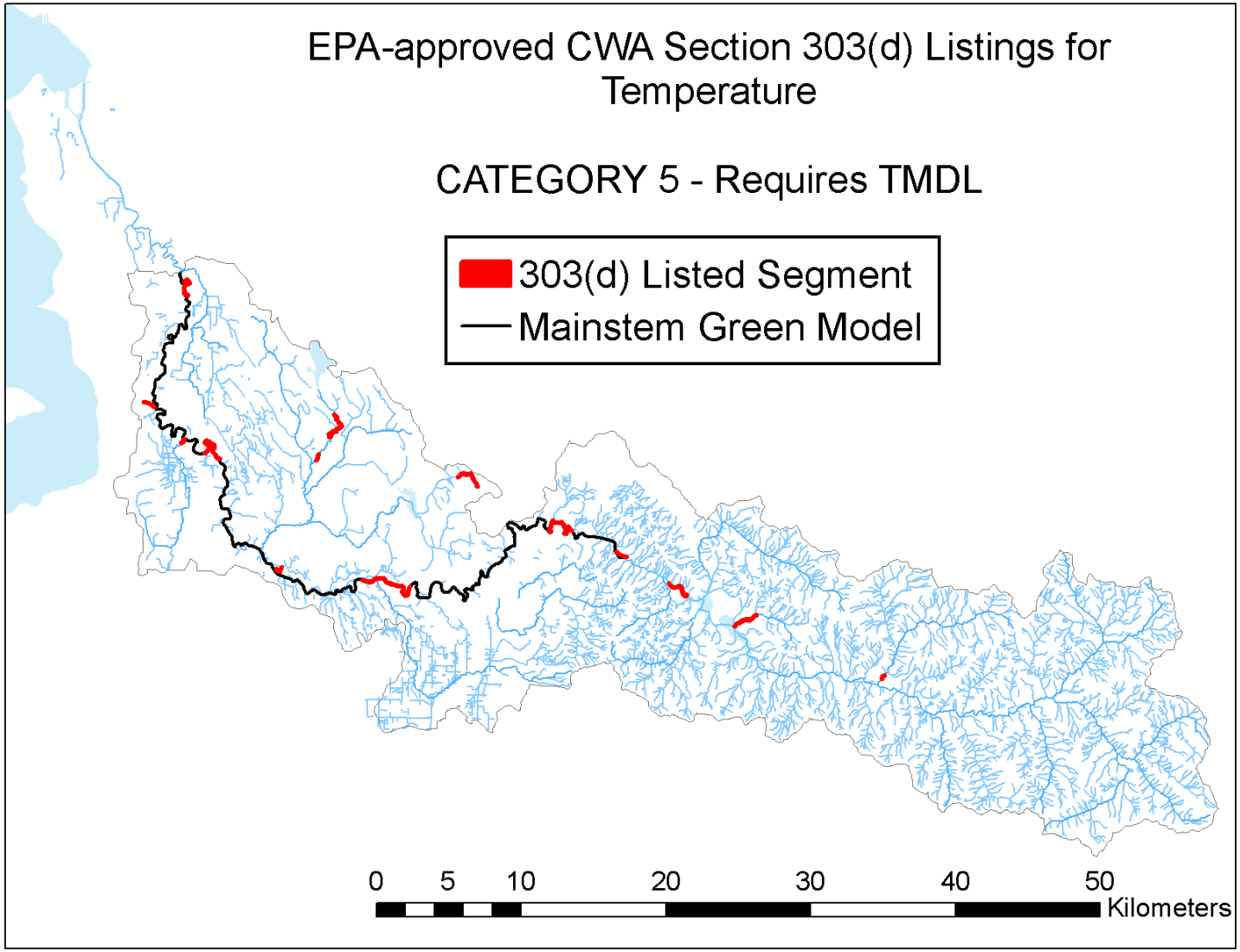
See Ecology web sites for more information

Potential Causes of Stream Temperature Alteration

- Loss of riparian habitat: solar radiation + heat
- Channel modification (widening, narrowing, deepening, shallowing)
- Loss of lateral connectivity or hyporheic exchange
- Flow changes due to surface and ground water withdrawals and flow management activities

Temperature

Temperature WQ Std = 16°C



303(d) listings

↓

TMDL Study

↓

Field Monitoring

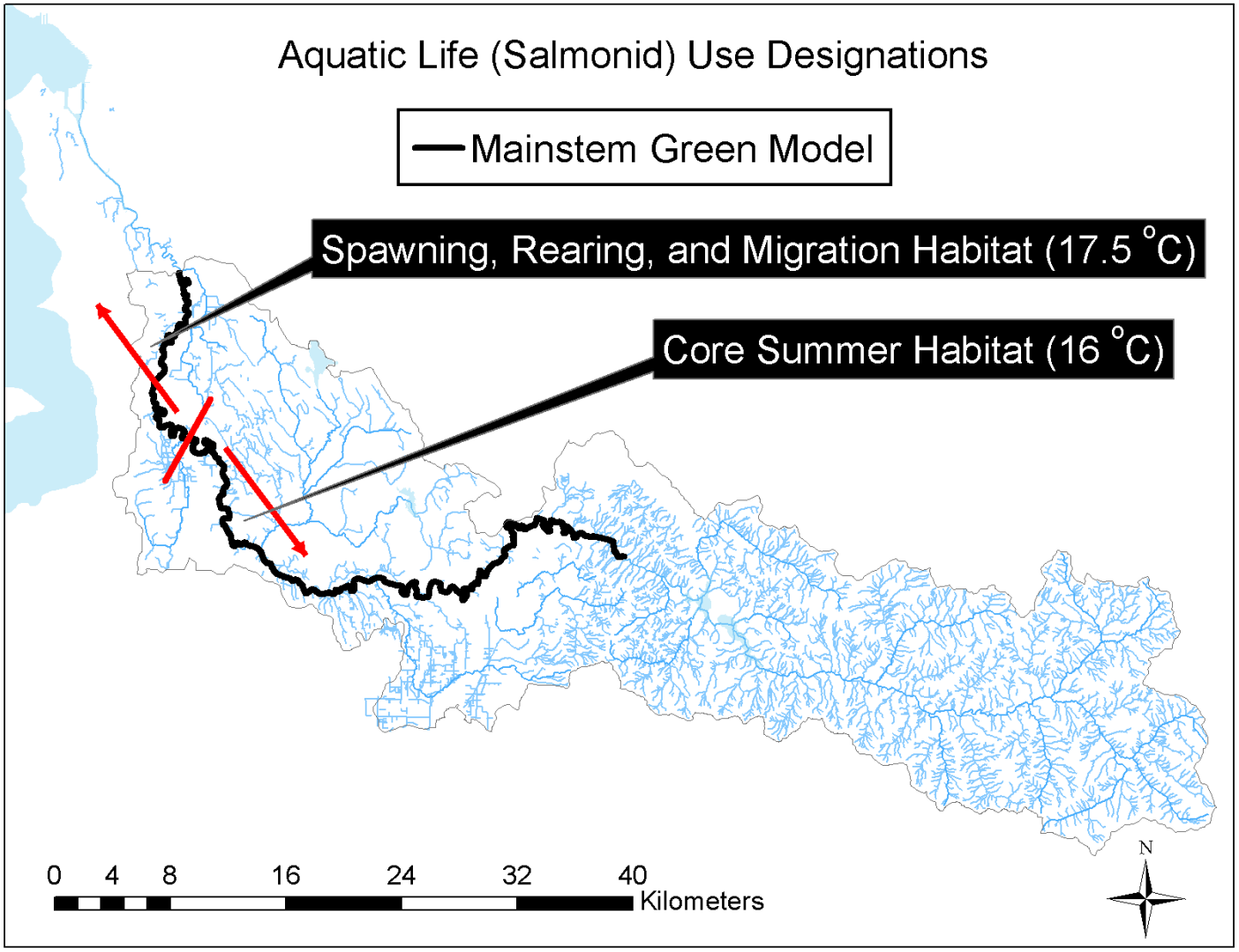
↓

Use Data to Develop Model

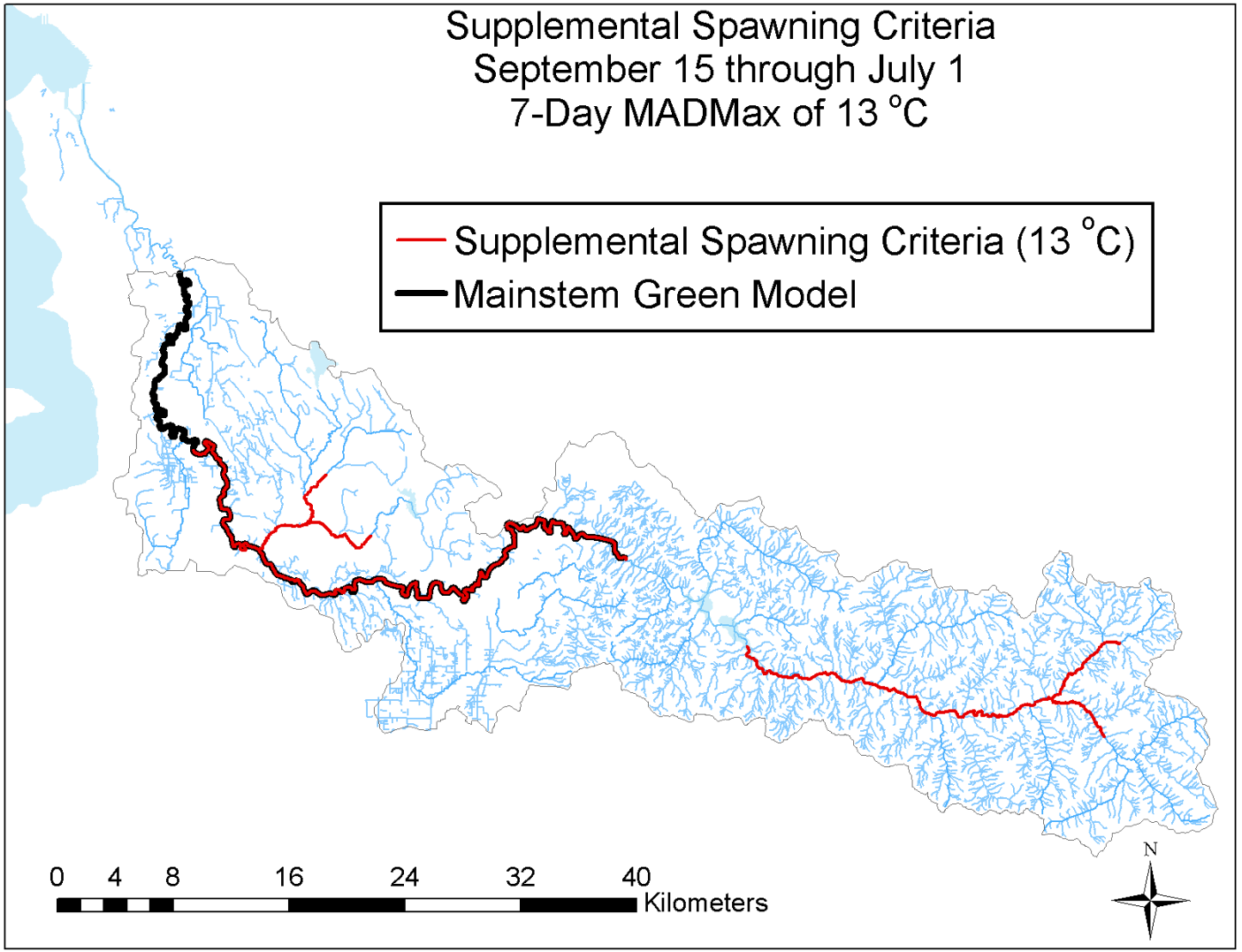
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Use Model Predictions to Guide Actions

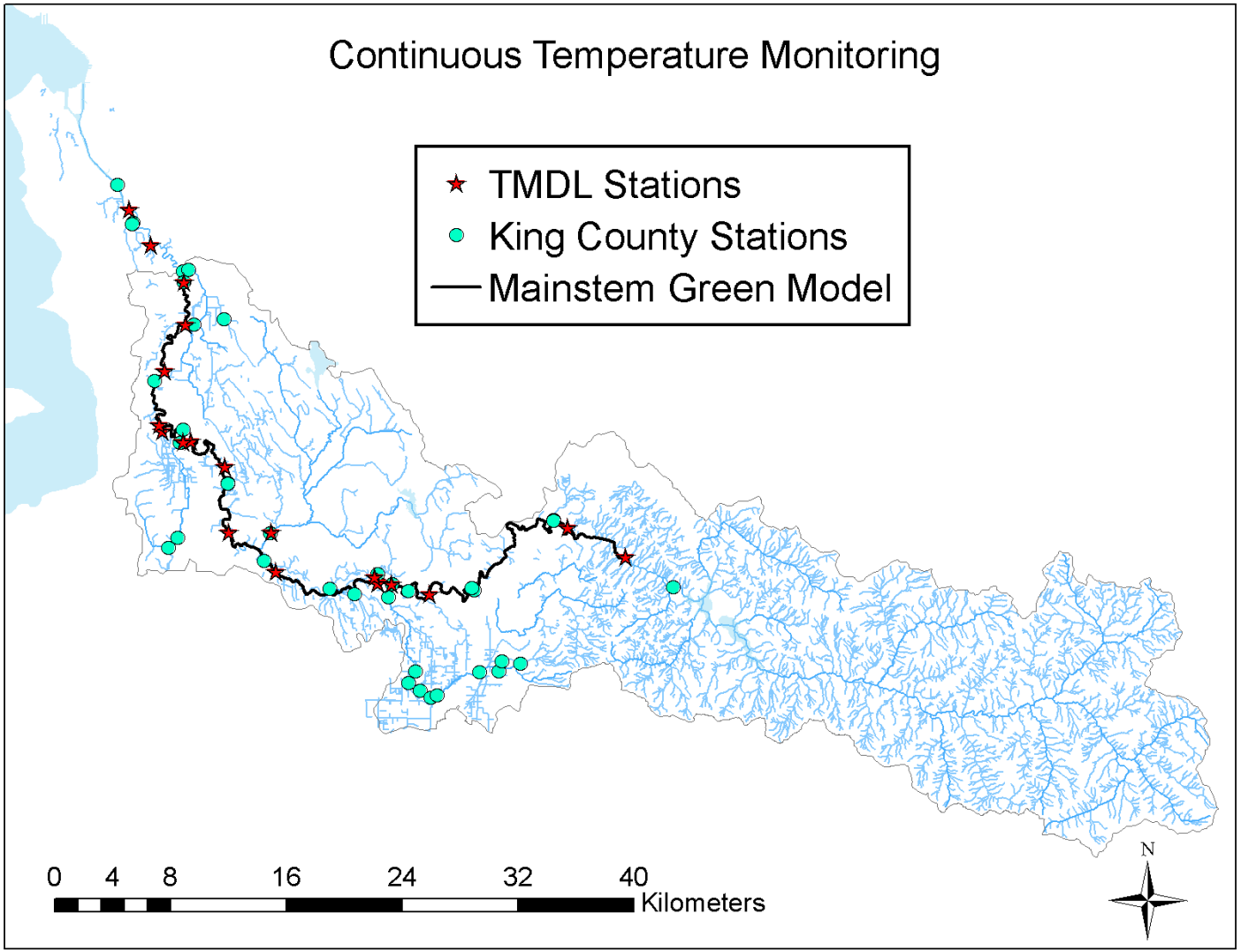
Temperature Criteria



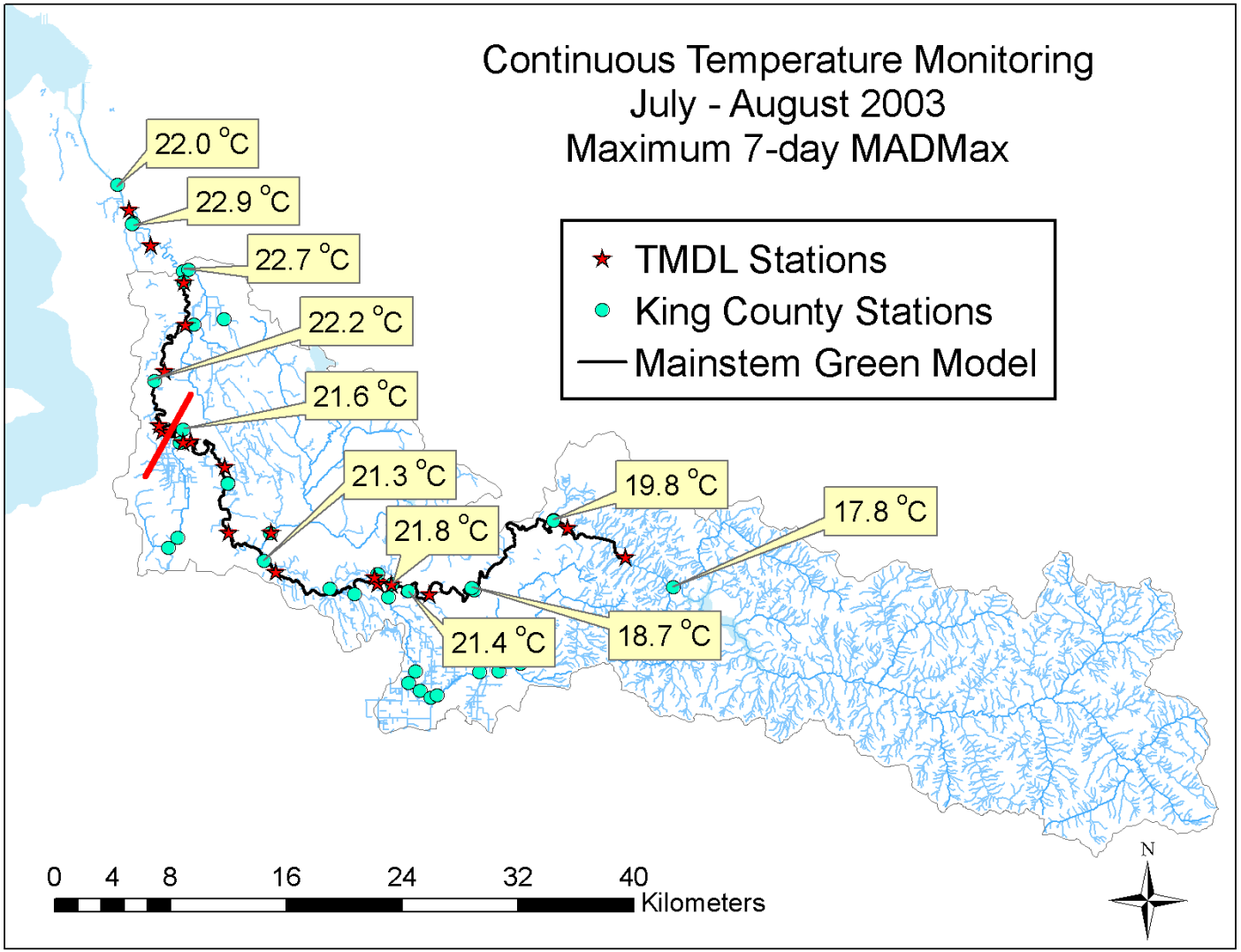
Supplemental Spawning and Incubation Criteria



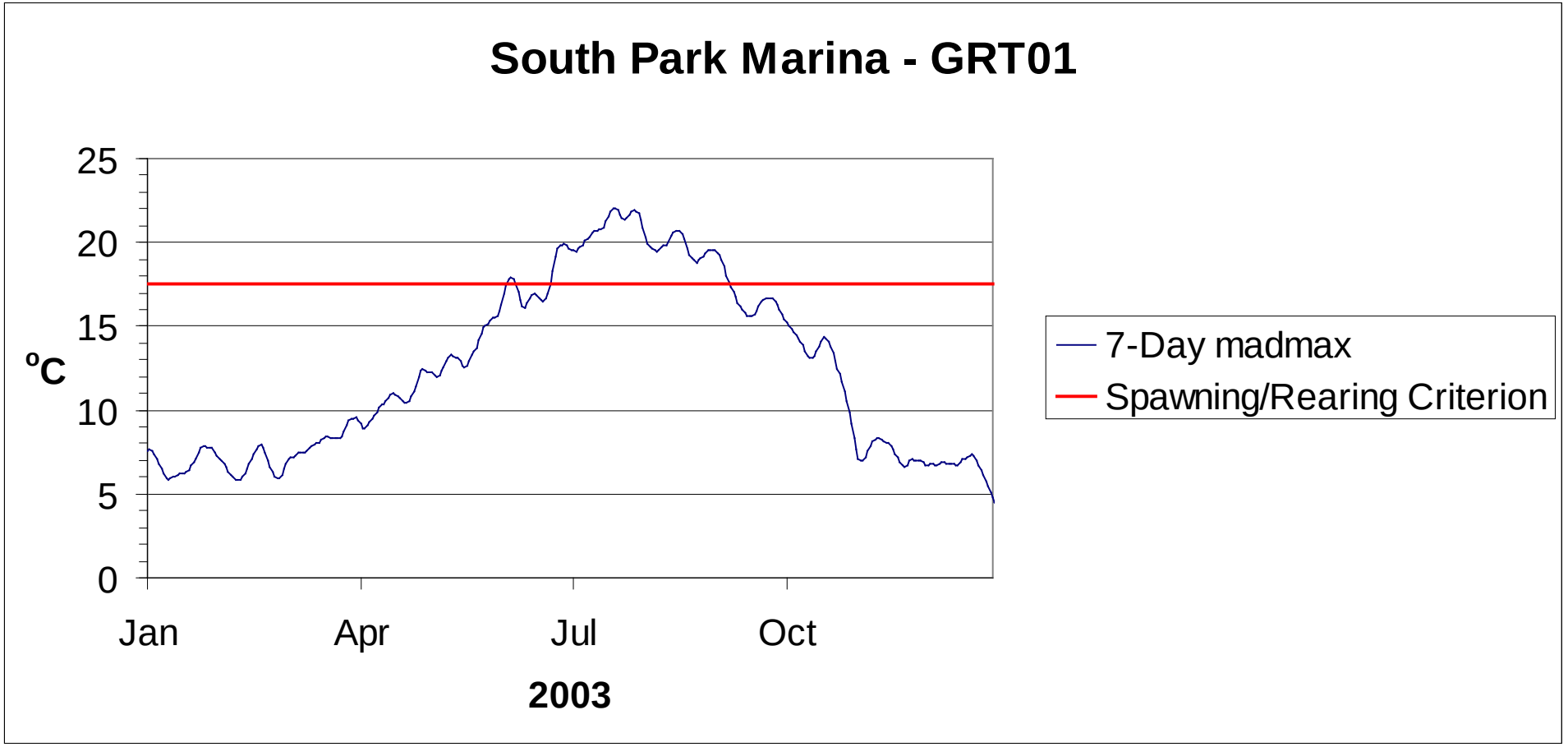
Continuous Temperature Data



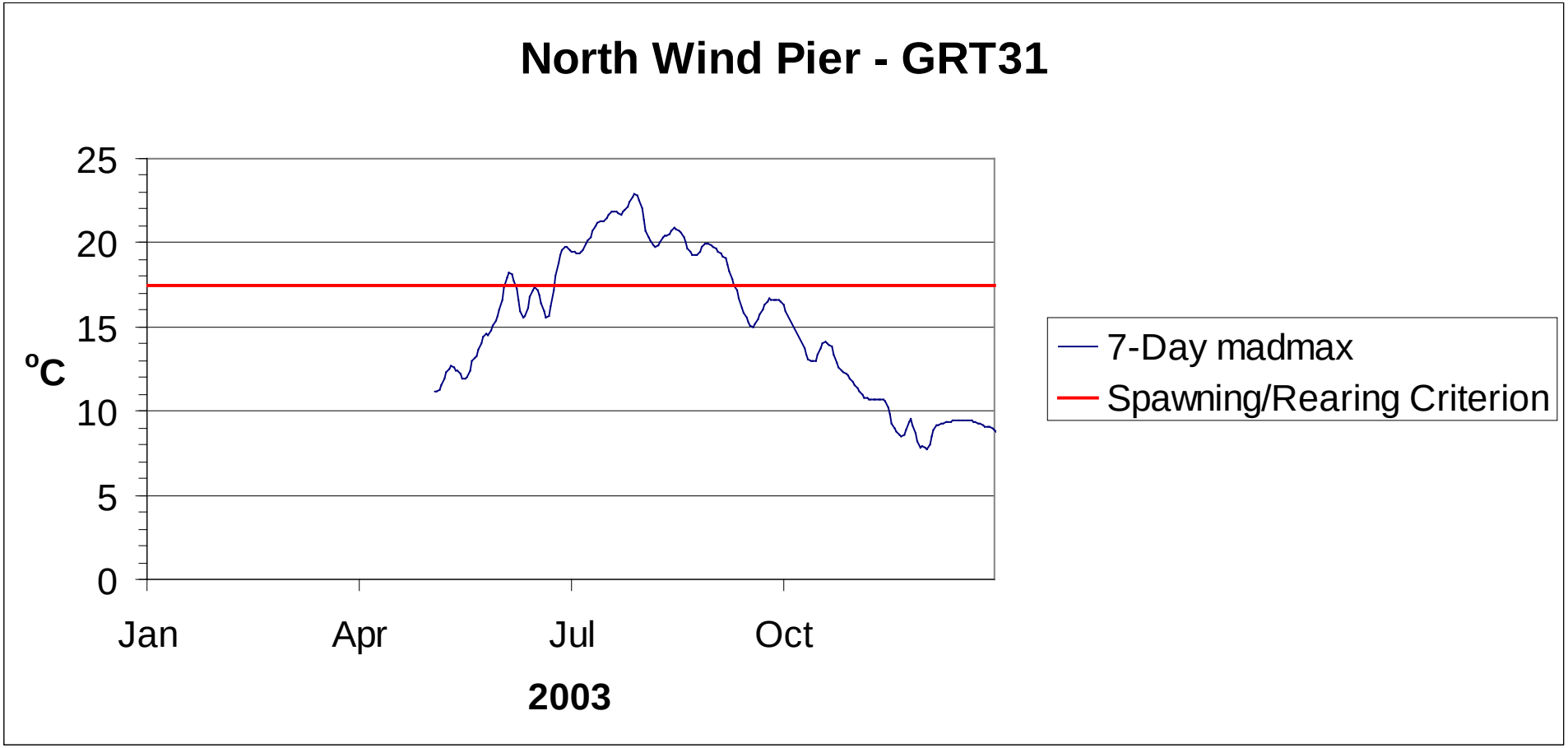
Continuous Temperature Data



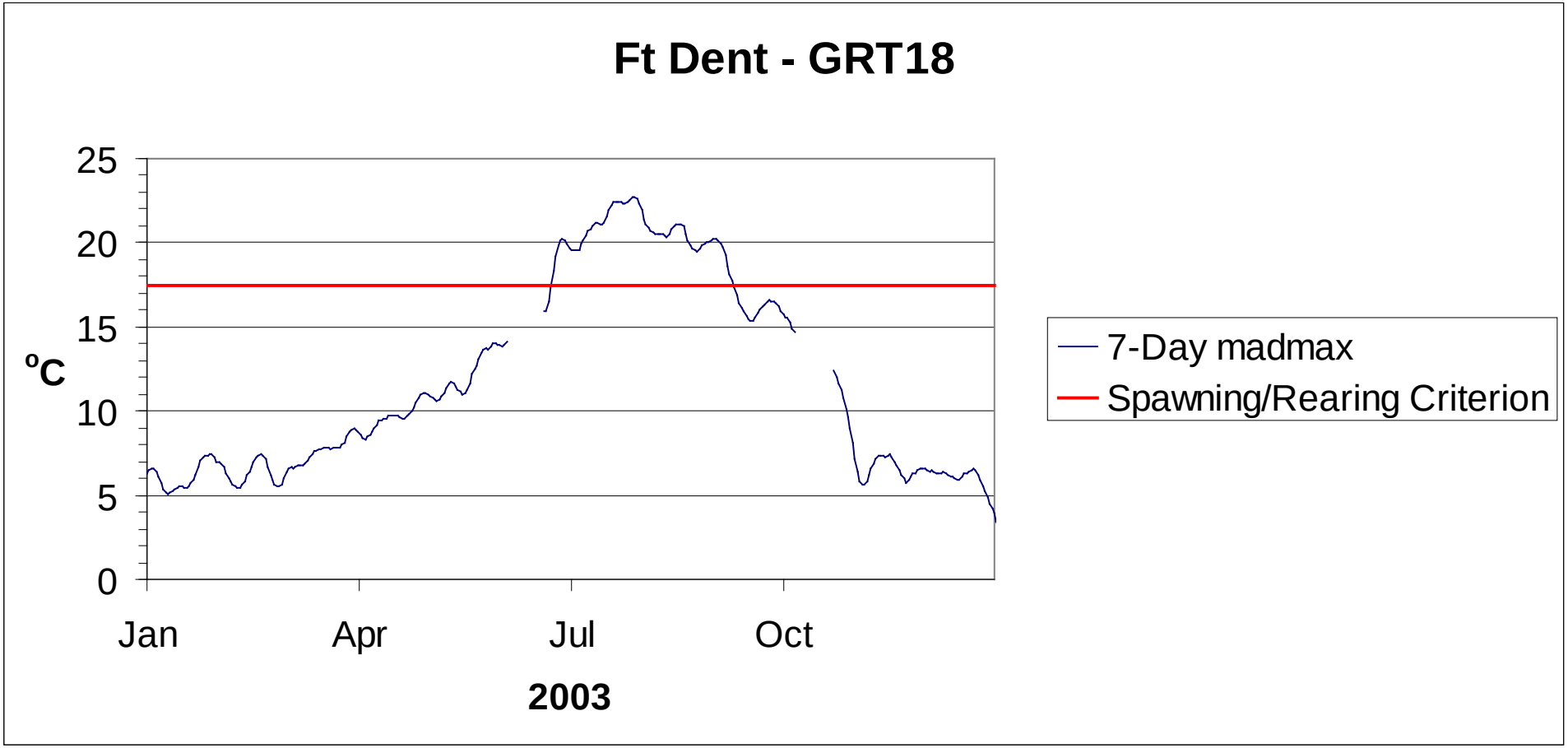
King County 2003
Continuous Temperature Data



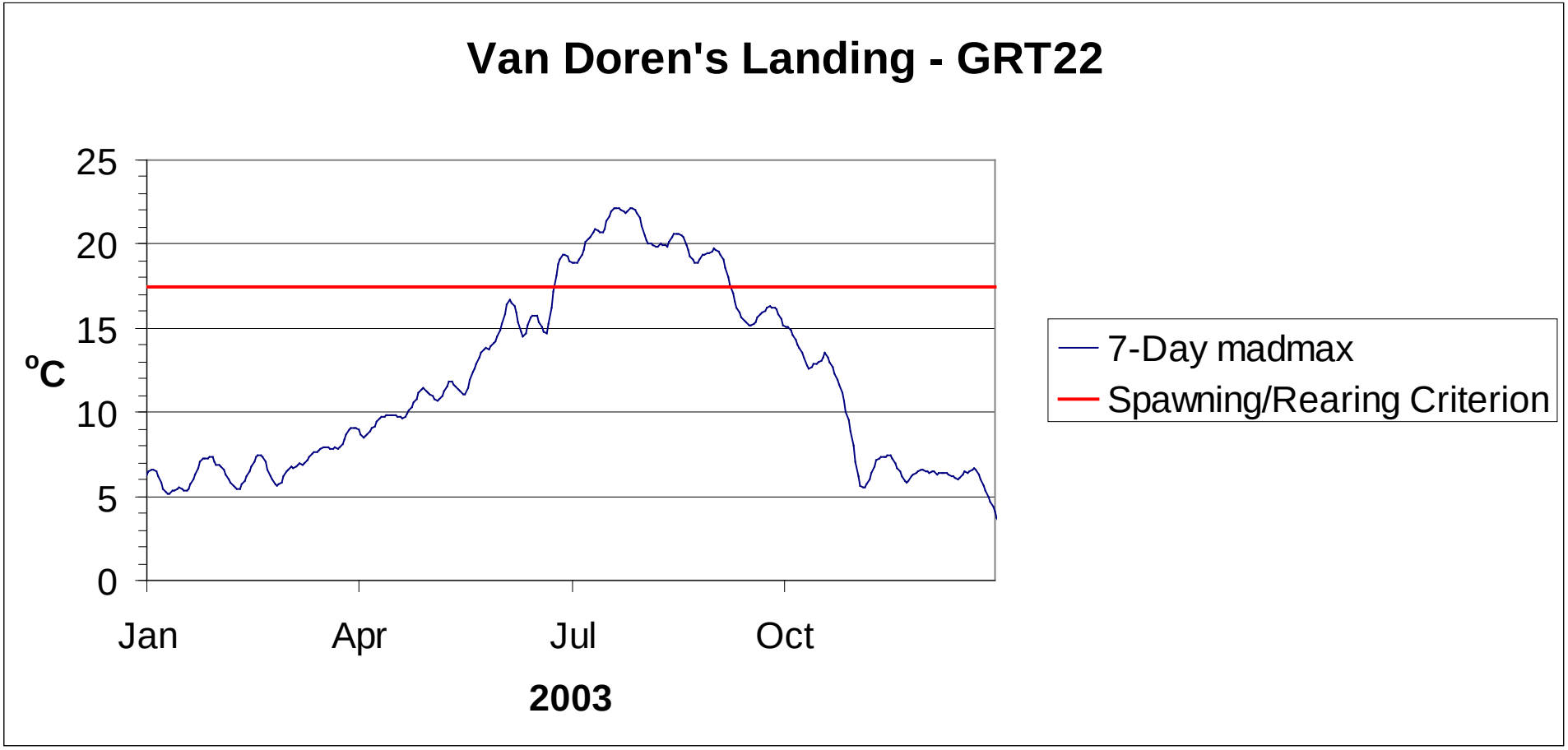
King County 2003
Continuous Temperature Data



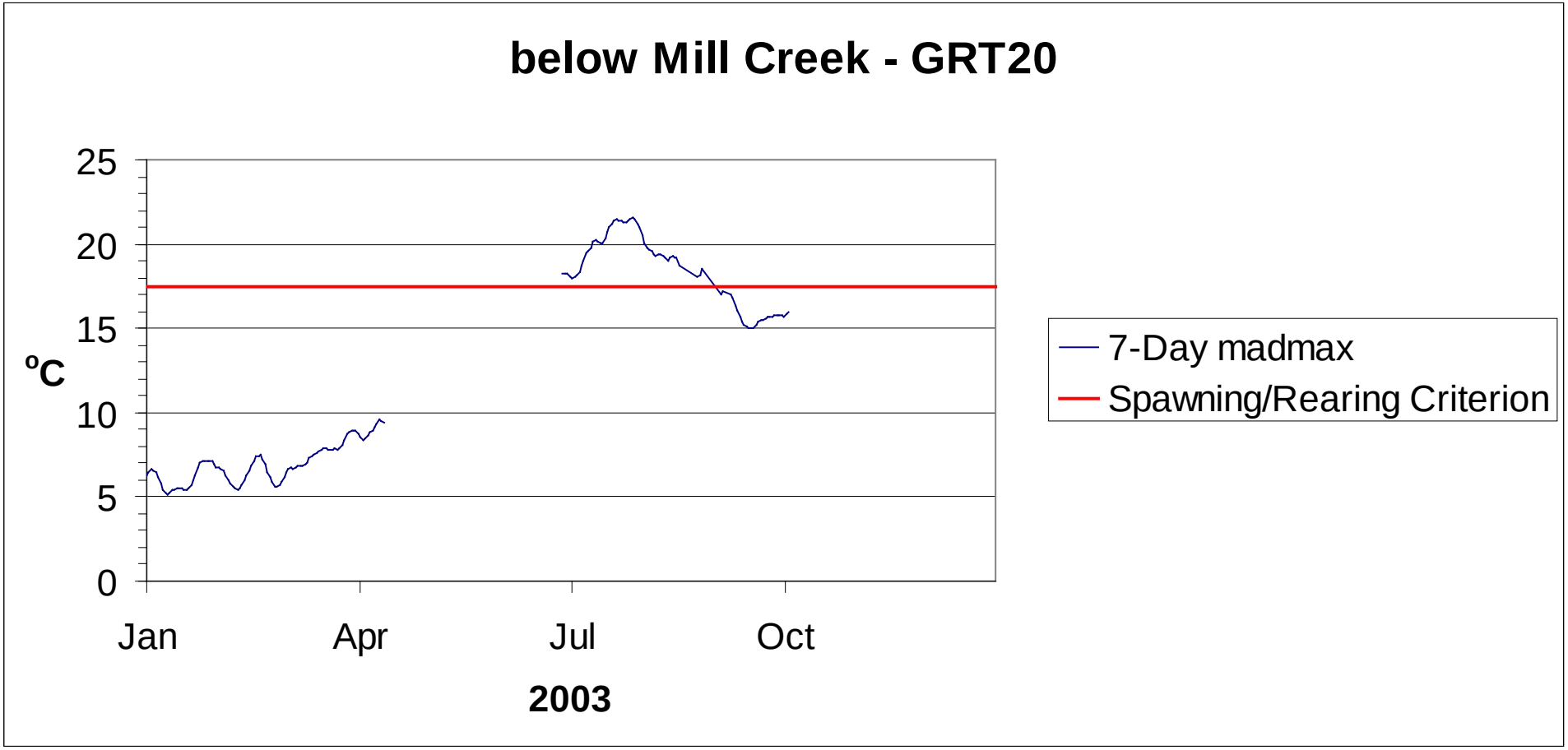
King County 2003
Continuous Temperature Data



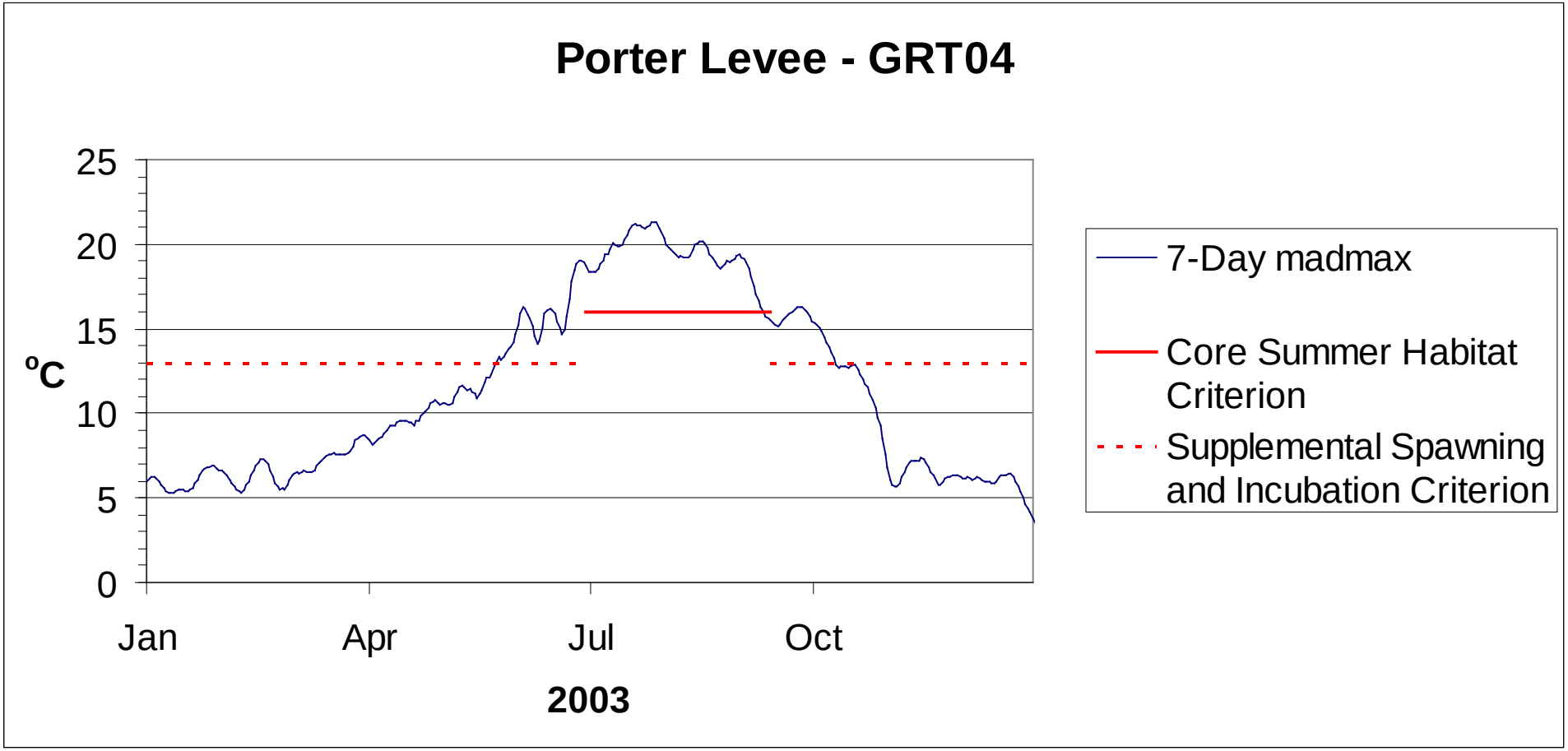
King County 2003
Continuous Temperature Data



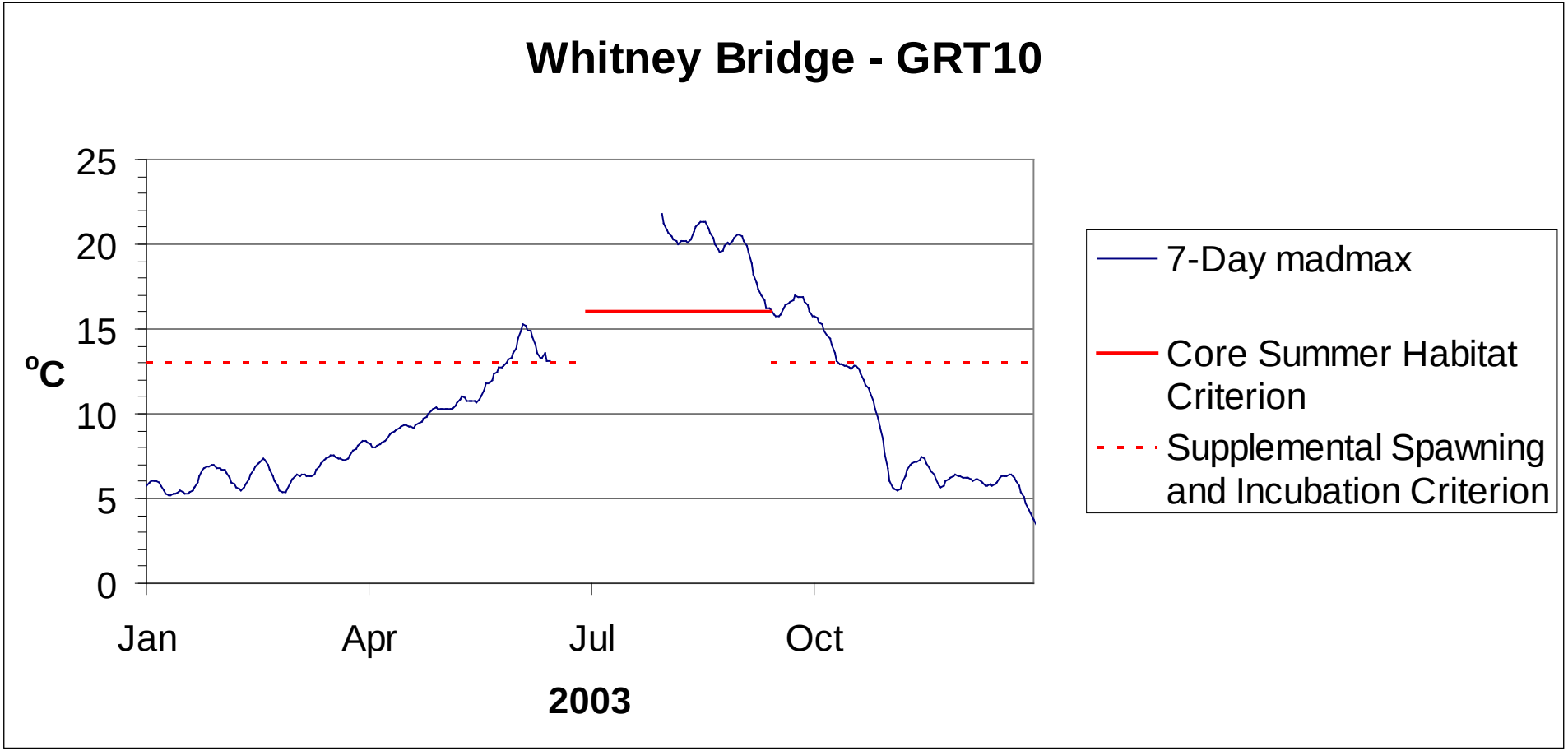
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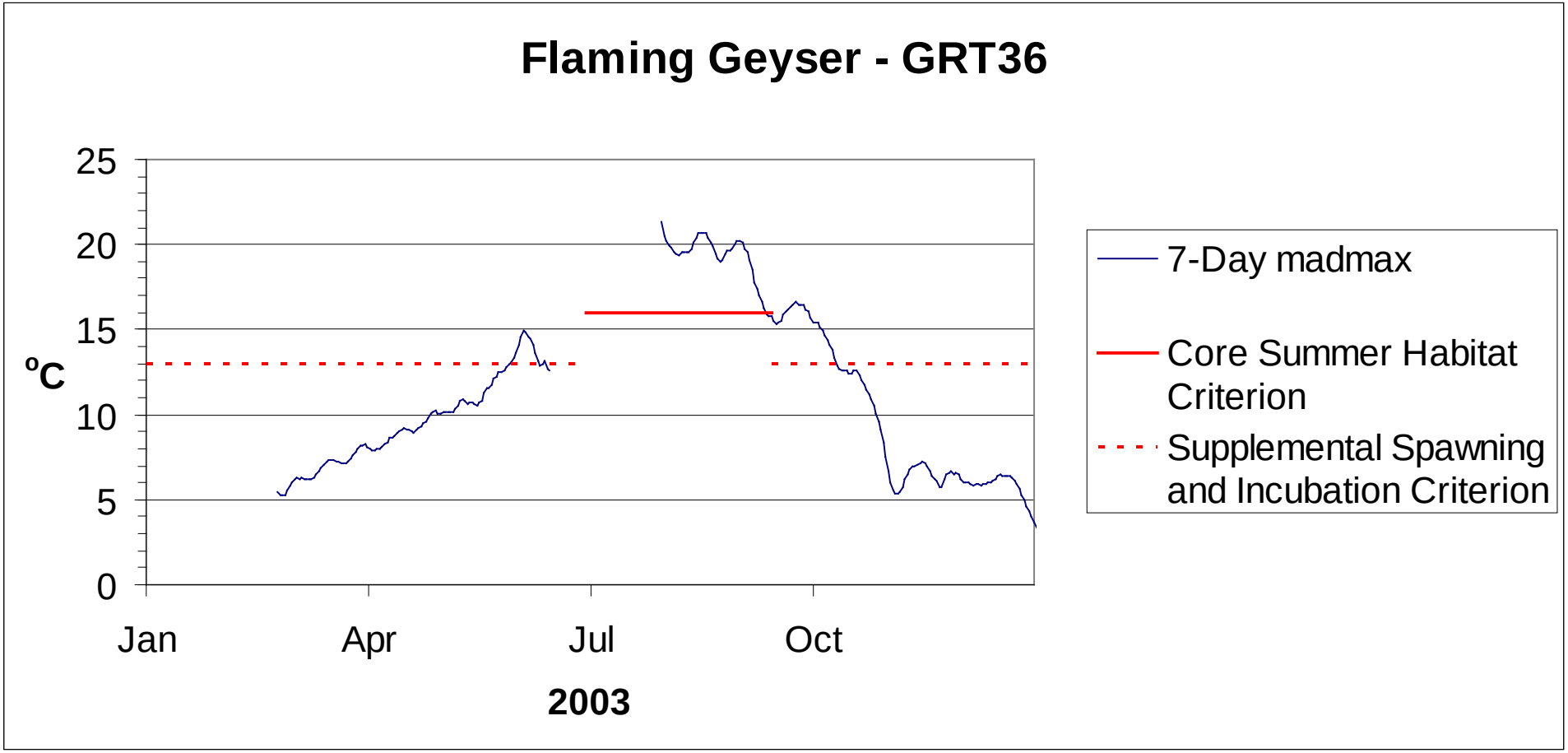
King County 2003
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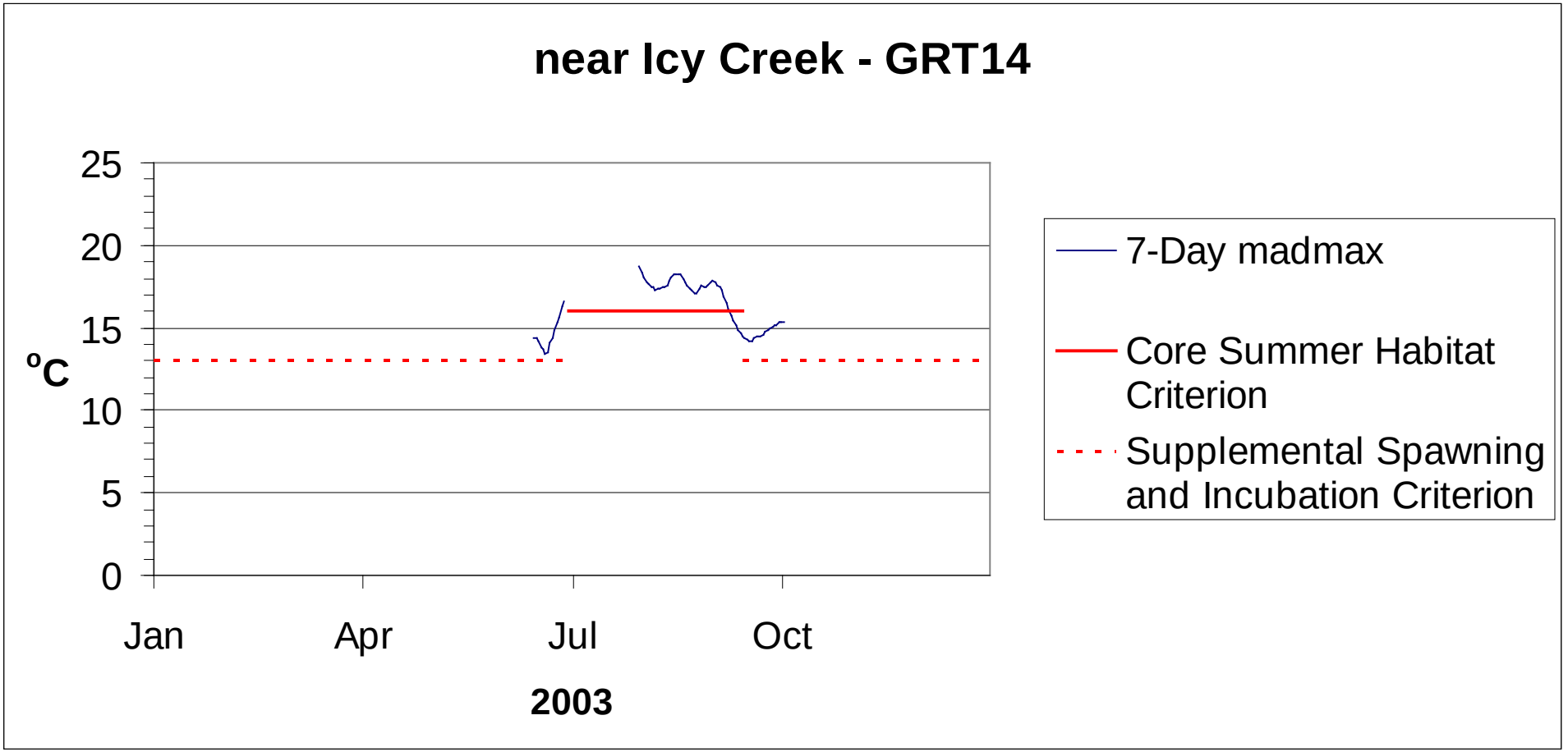
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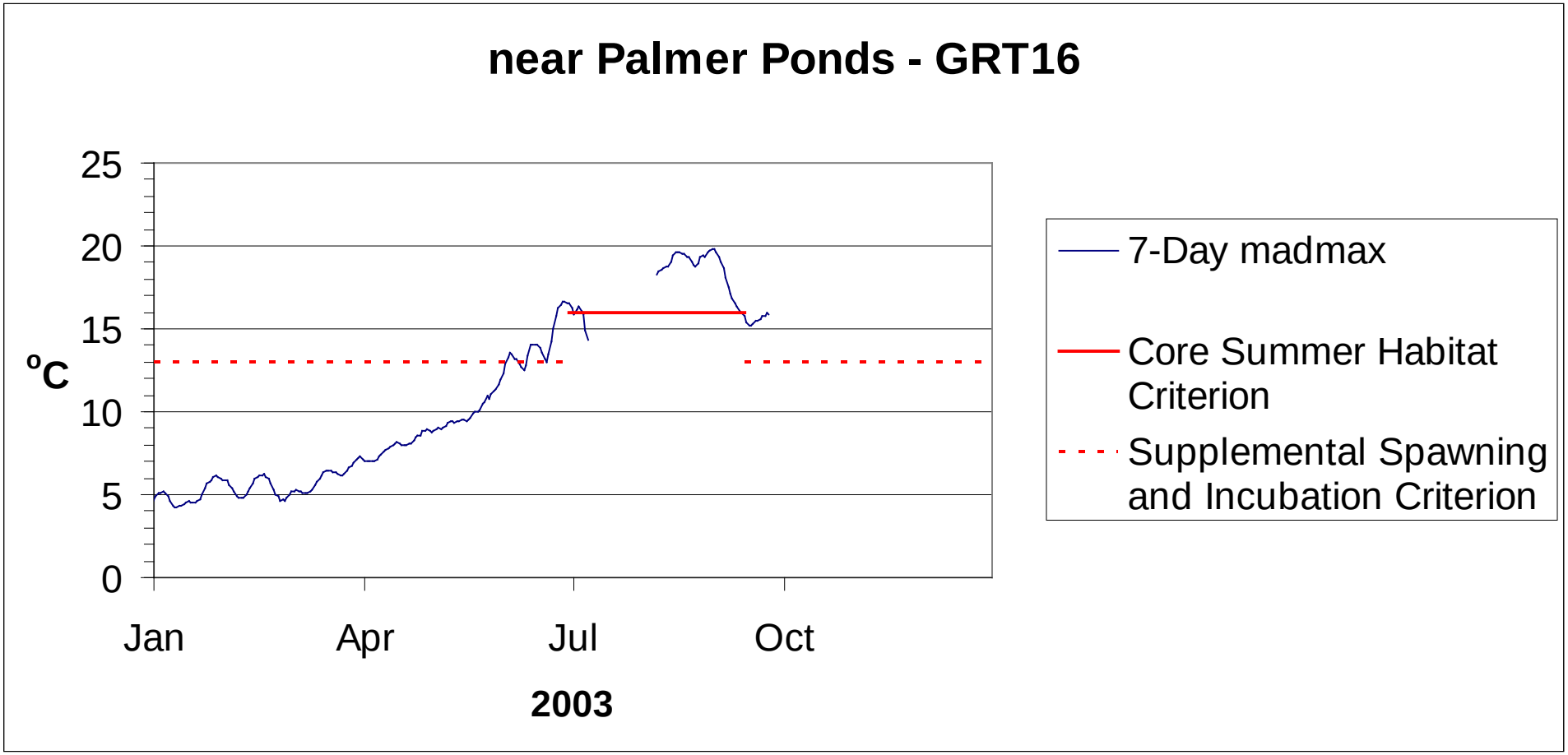
King County 2003
Continuous Temperature Data



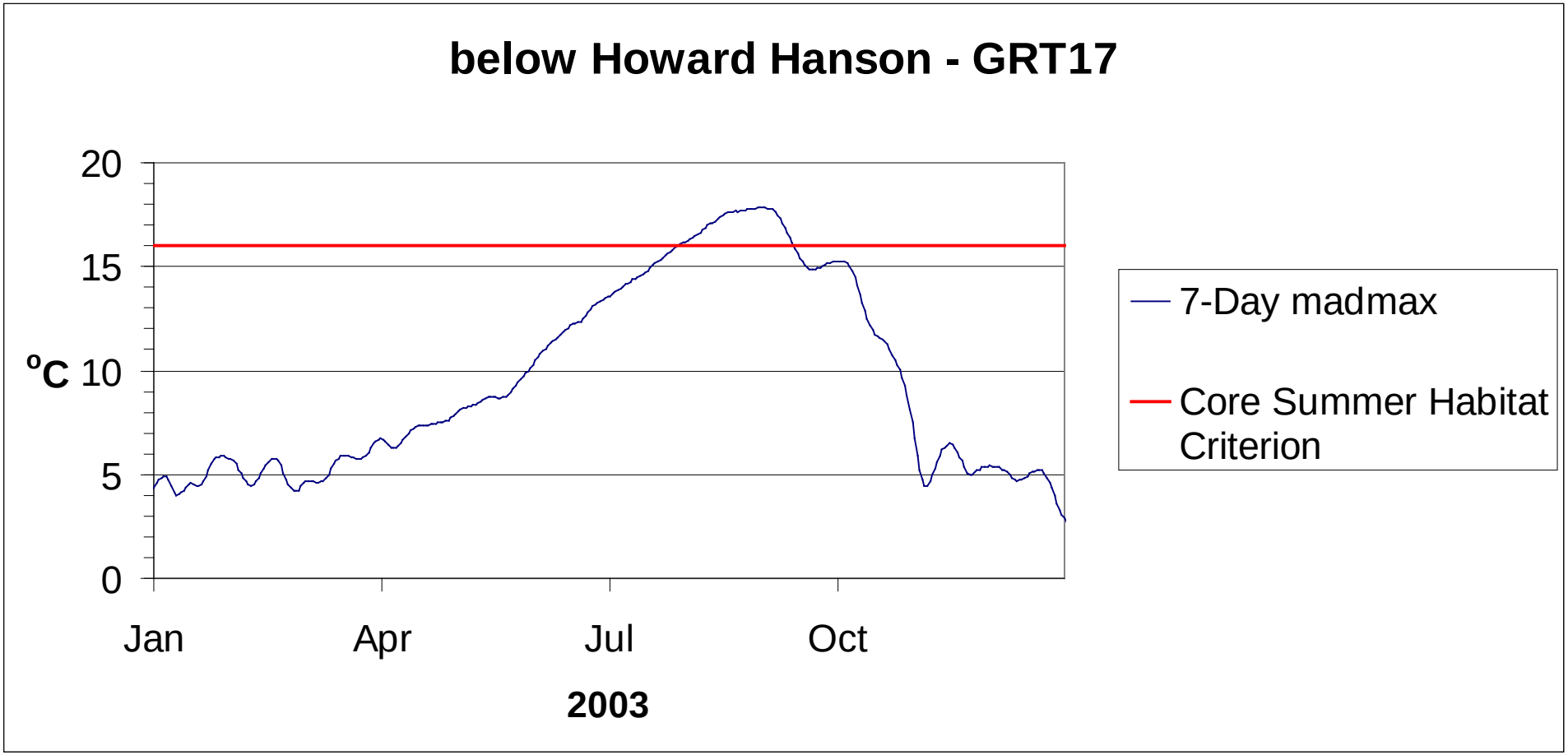
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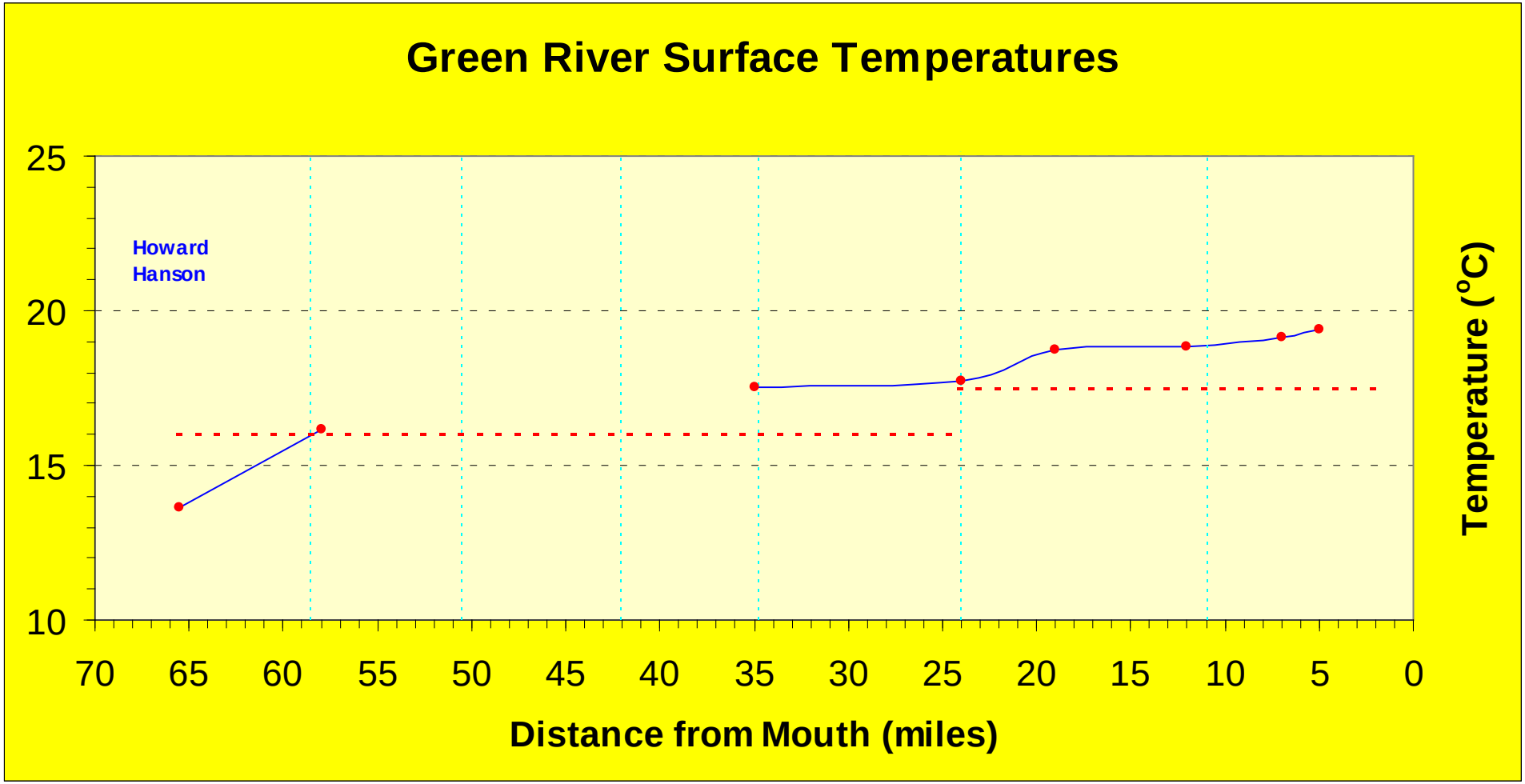
King County 2003
Continuous Temperature Data



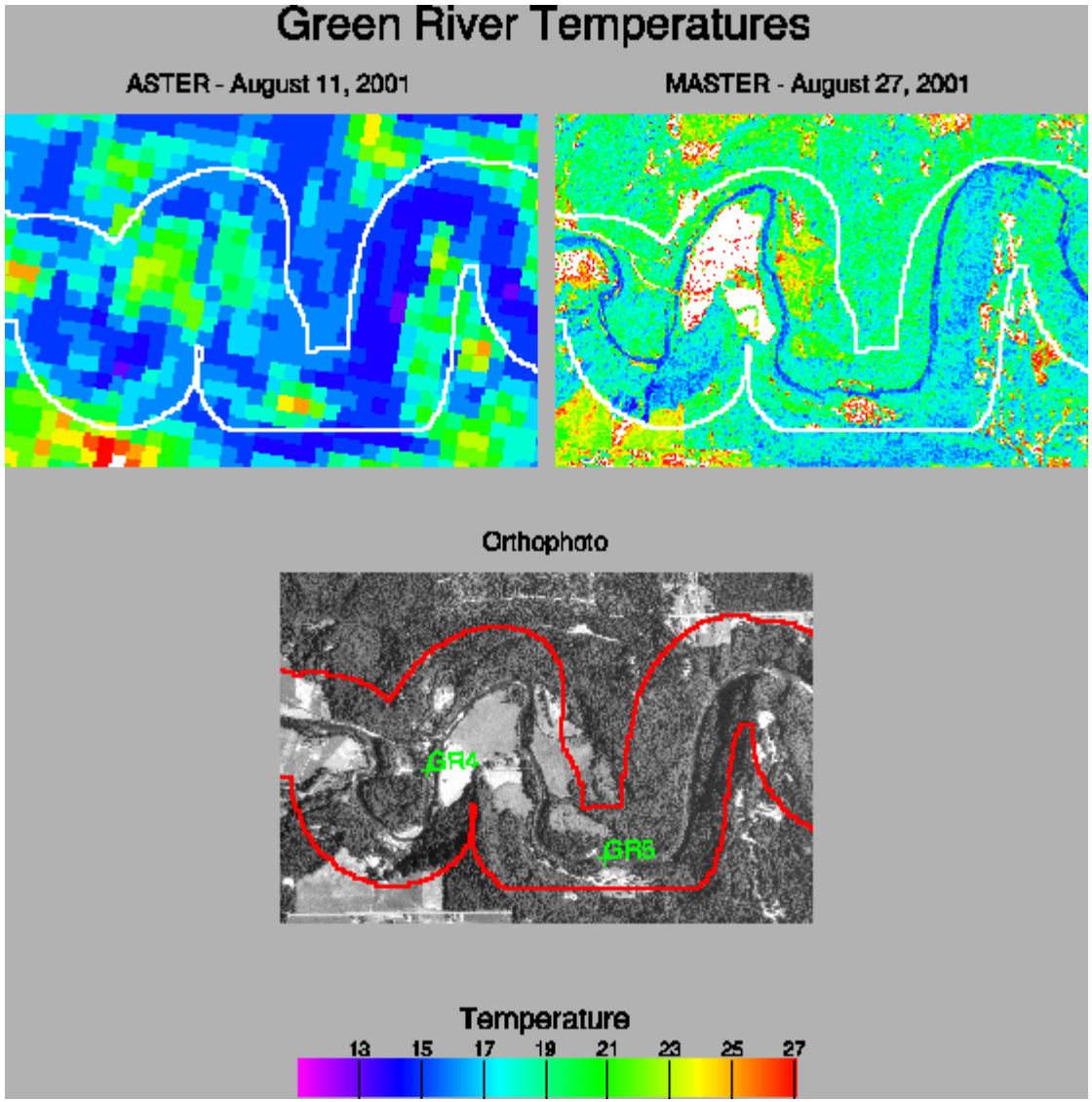
King County 2003
Continuous Temperature Data



Green River
Summer 2003



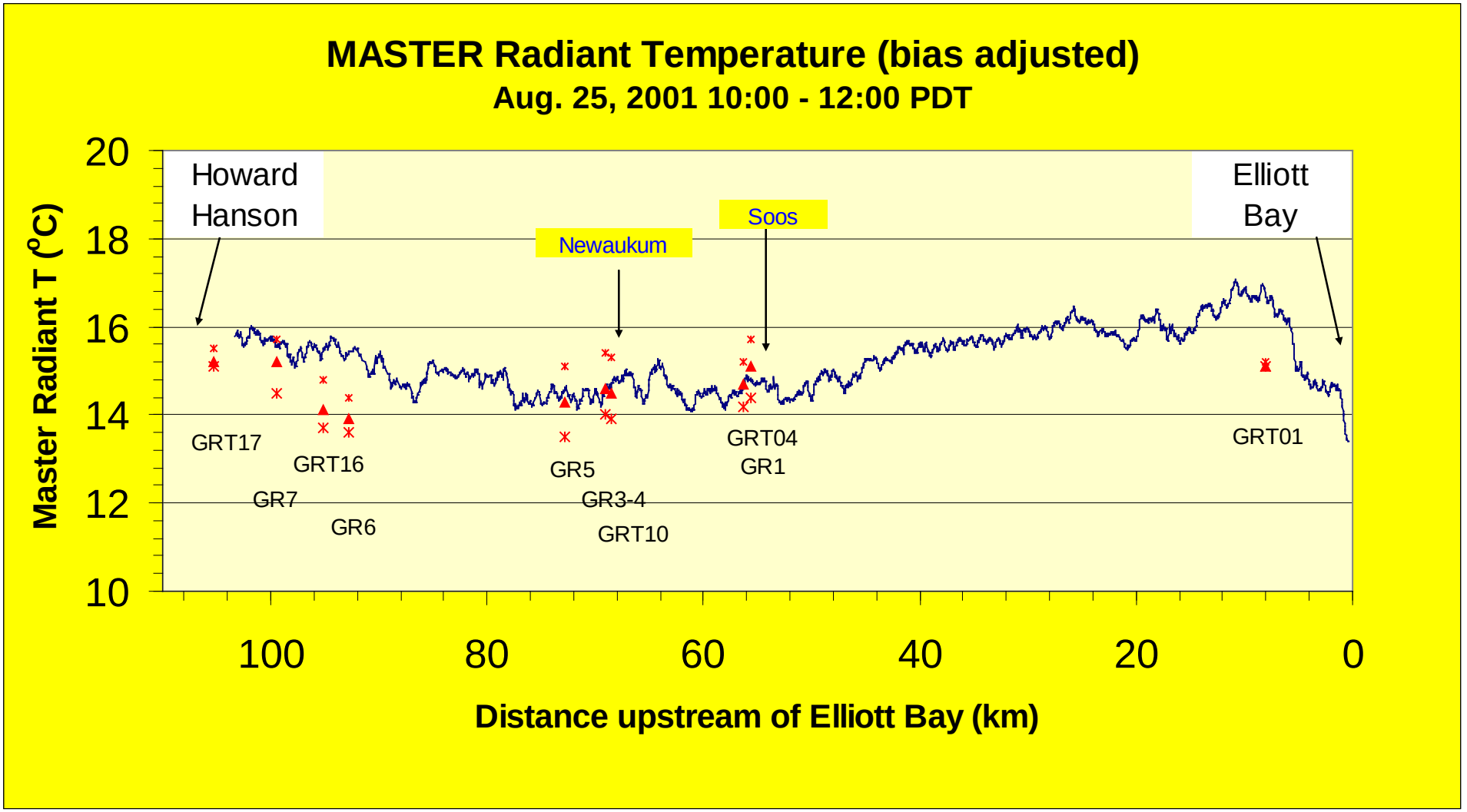
MASTER-ASTER TIR STUDY



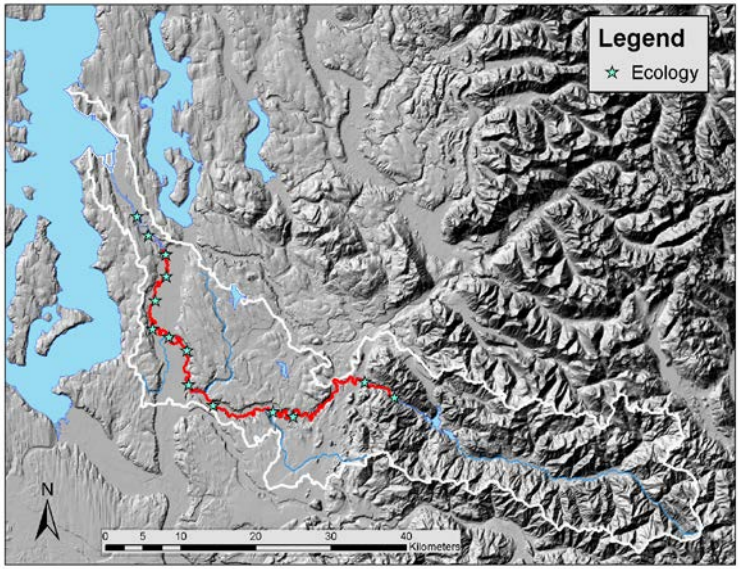
UW Civil Engineering

Principal Investigator:
Steve Burgess

MASTER-ASTER TIR STUDY

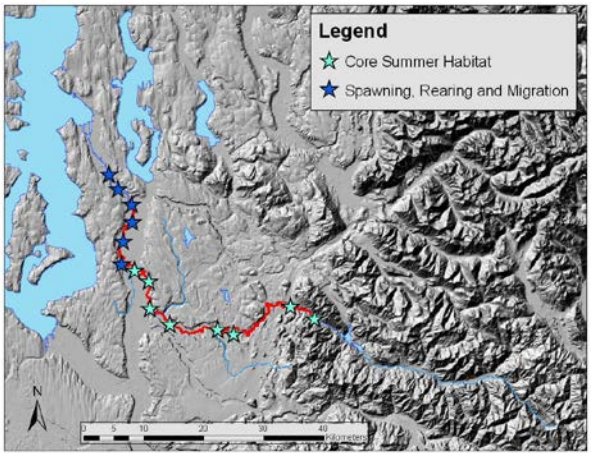


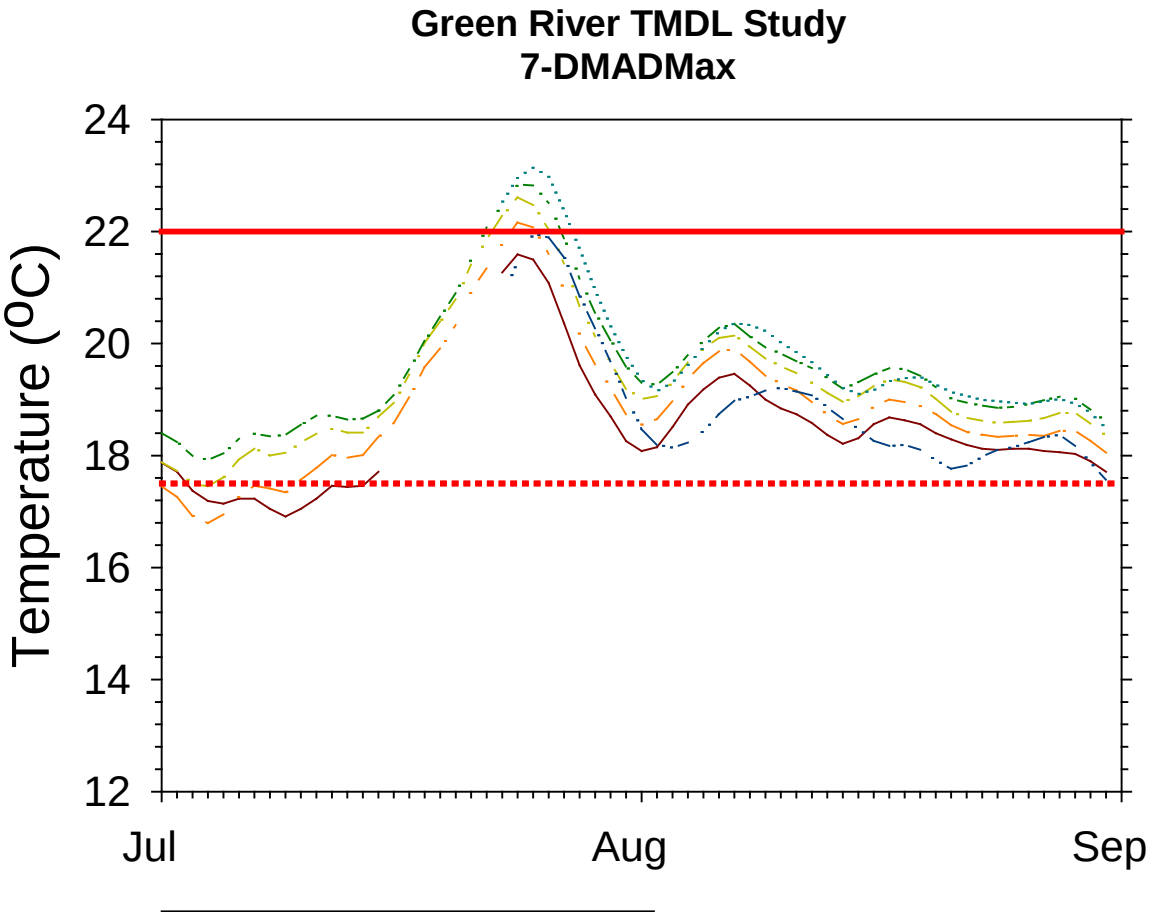
Summer 2006 Field Monitoring



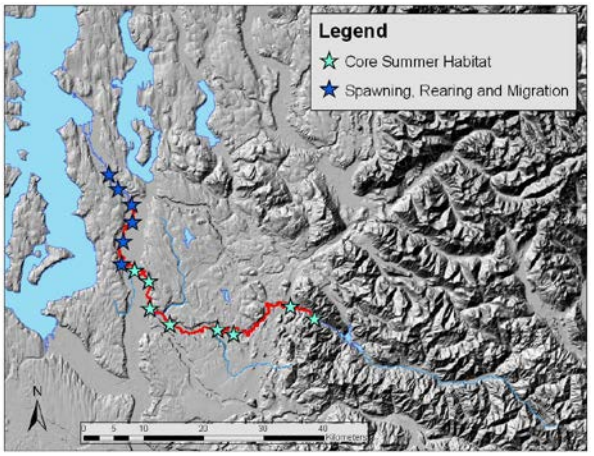
- Continuous temperature (air, water, relative humidity)
- Continuous dissolved oxygen, pH & conductivity
- Hemispherical photographs
- Synoptic productivity: nutrients, periphyton, & flows
- No travel time dye studies

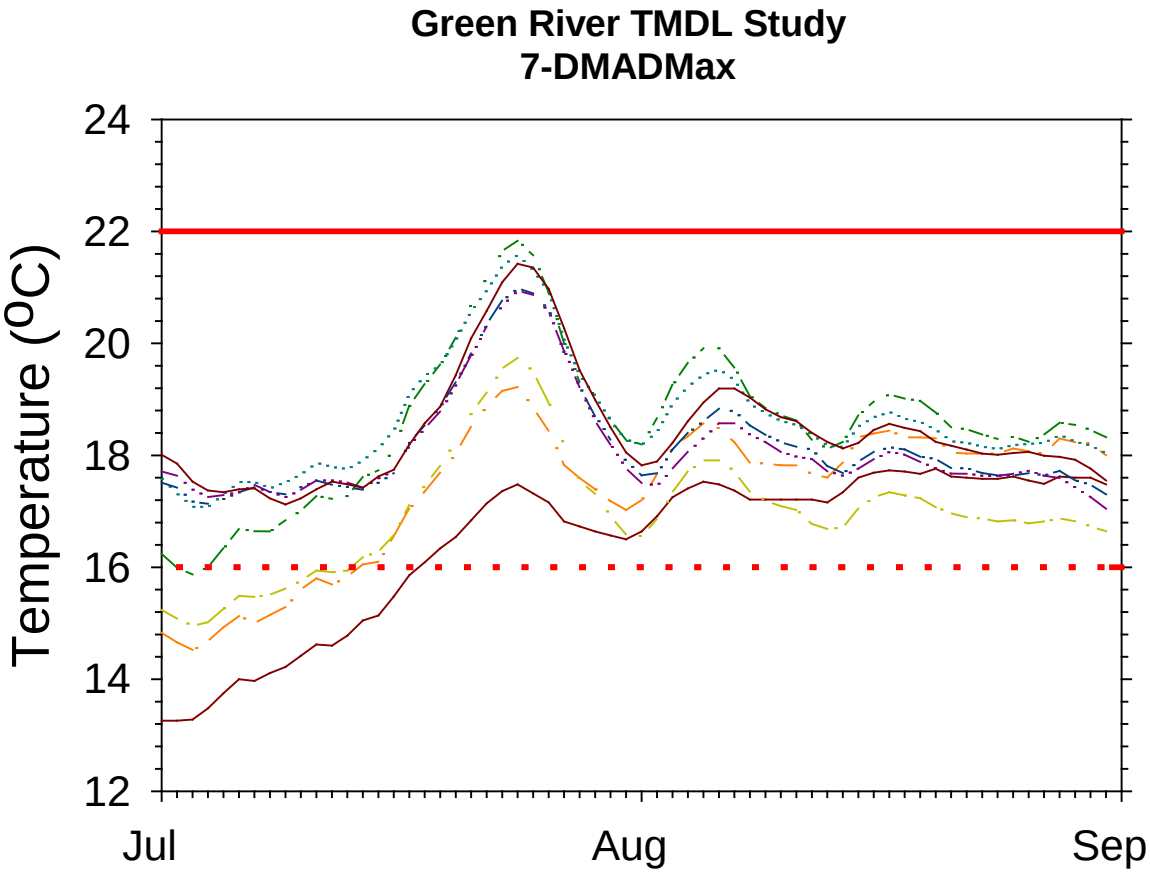
Green River Temperature Data

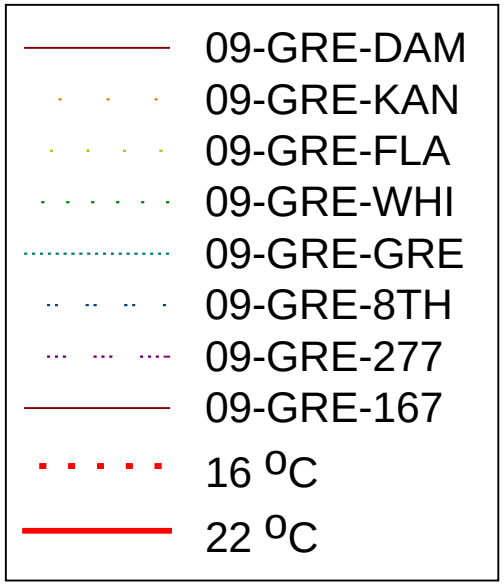




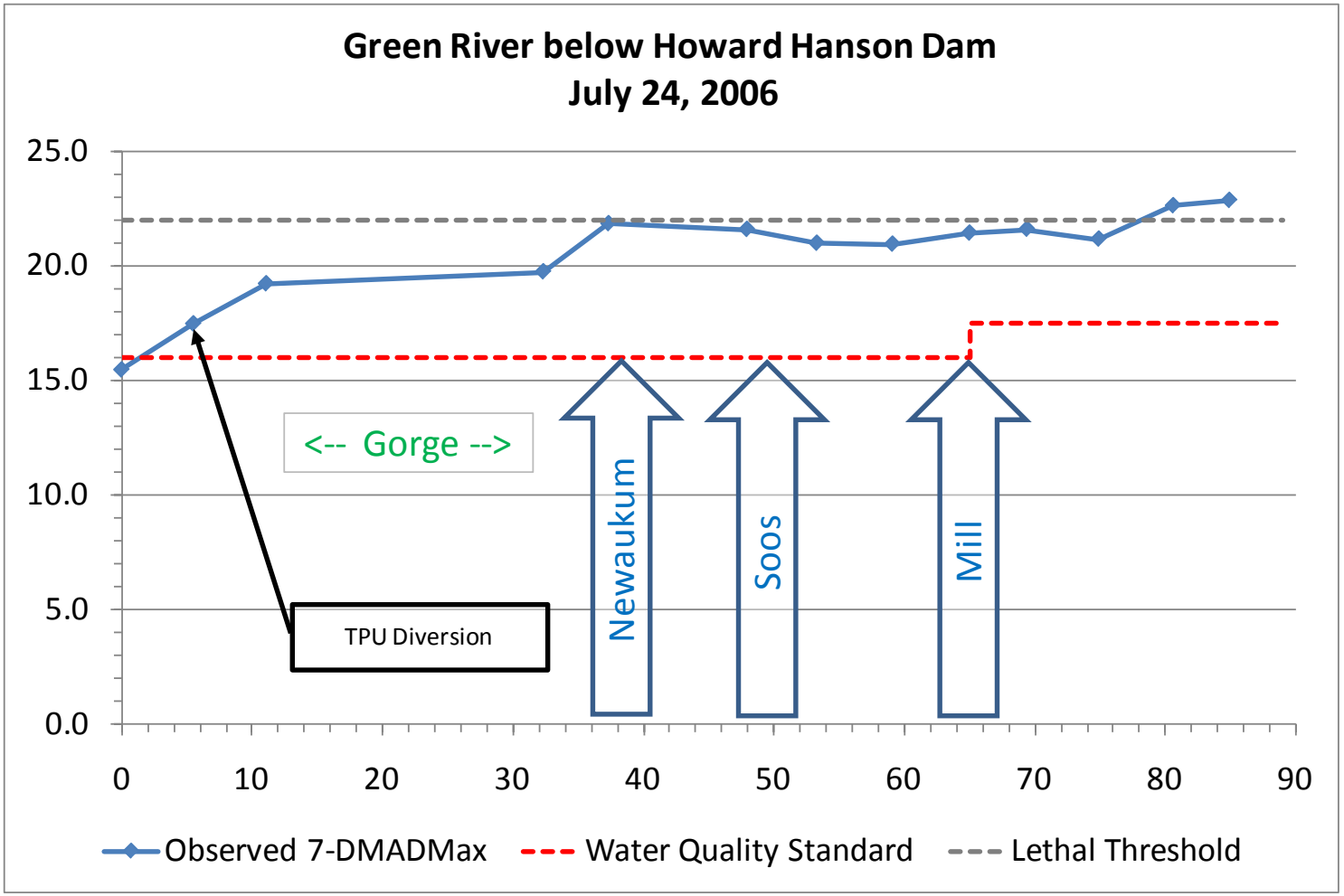
Green River Temperature Data







Green River Temperature Data



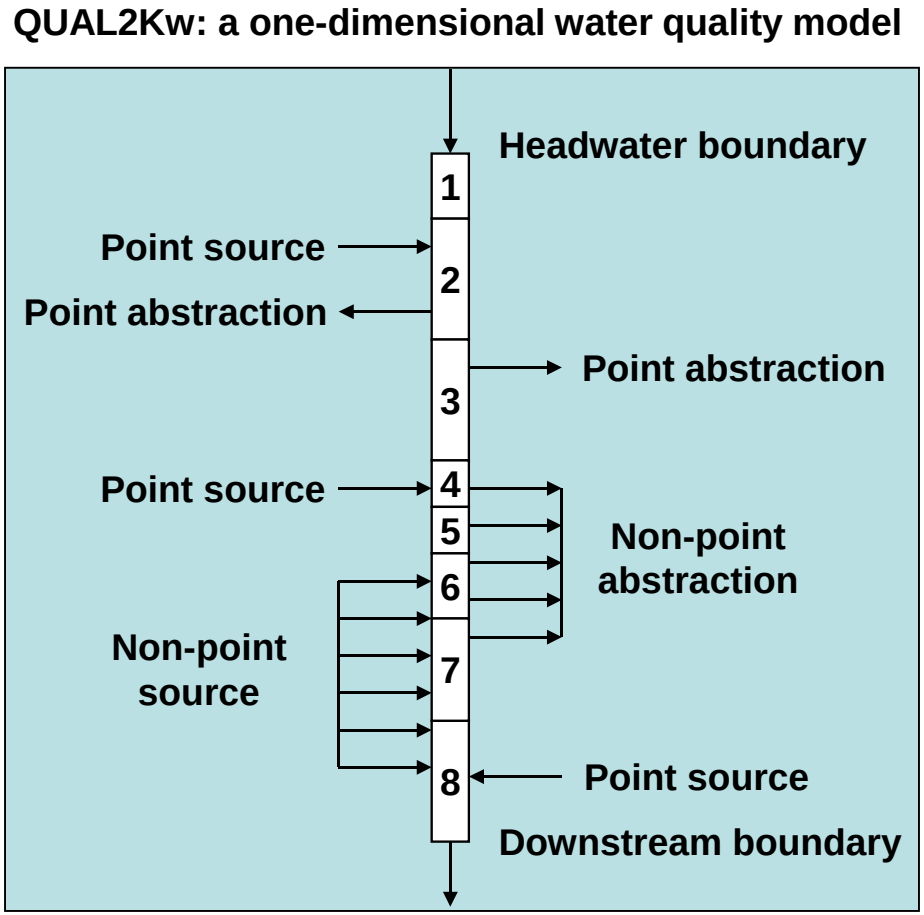


QUAL2K:

A Modeling Framework for Simulating River and Stream Water Quality
(Version 2.04)

- One-dimensional: vertically and laterally mixed
- Steady-state: non-uniform, steady flow
- Diel water-quality kinetics
- Point and non-point inputs/withdrawals simulated
- Effect of topographic and riparian shade included

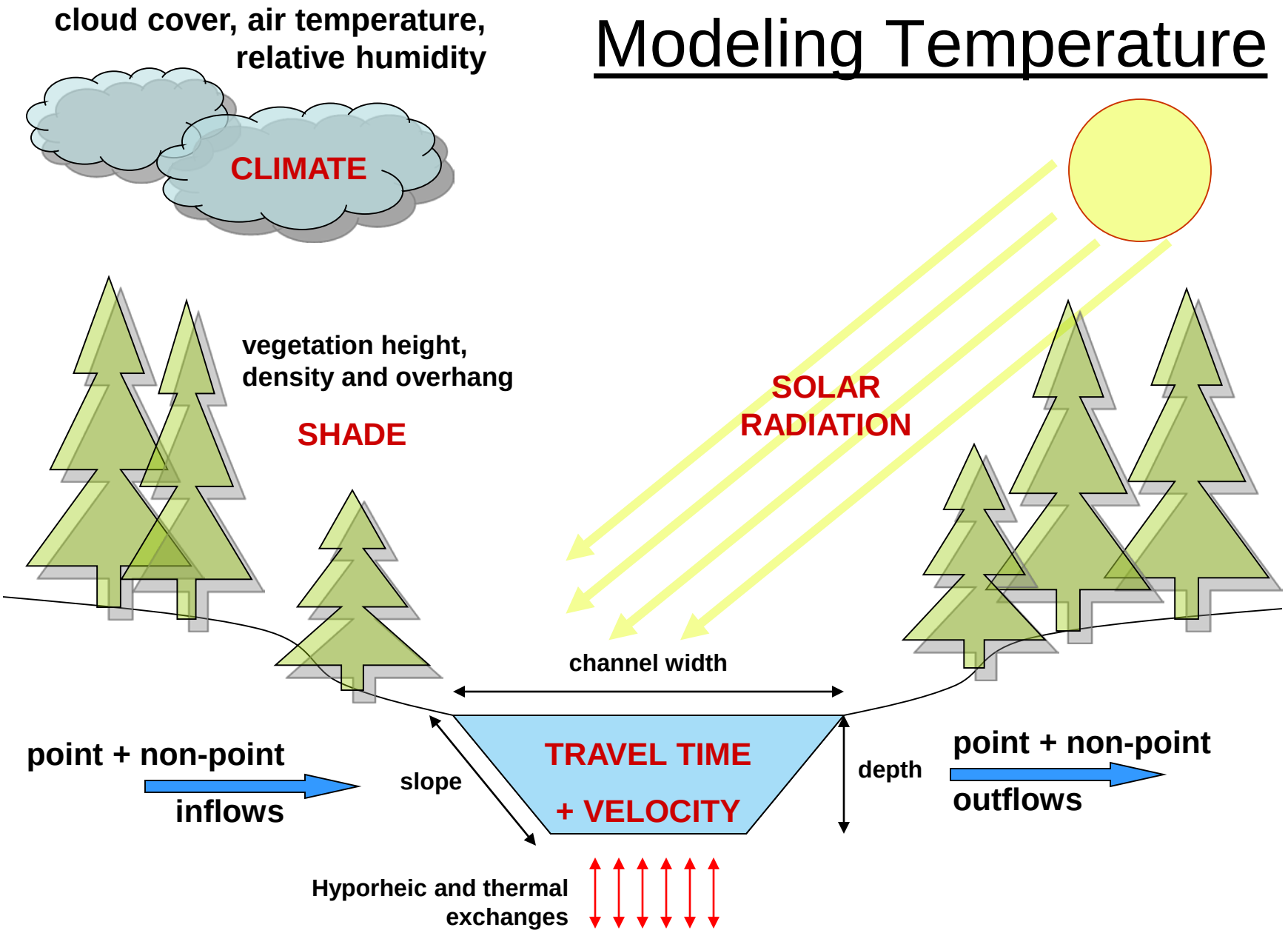
Modeling Temperature



Headwater/Boundary Conditions:

- Flow
- Temperature
- Channel geometry

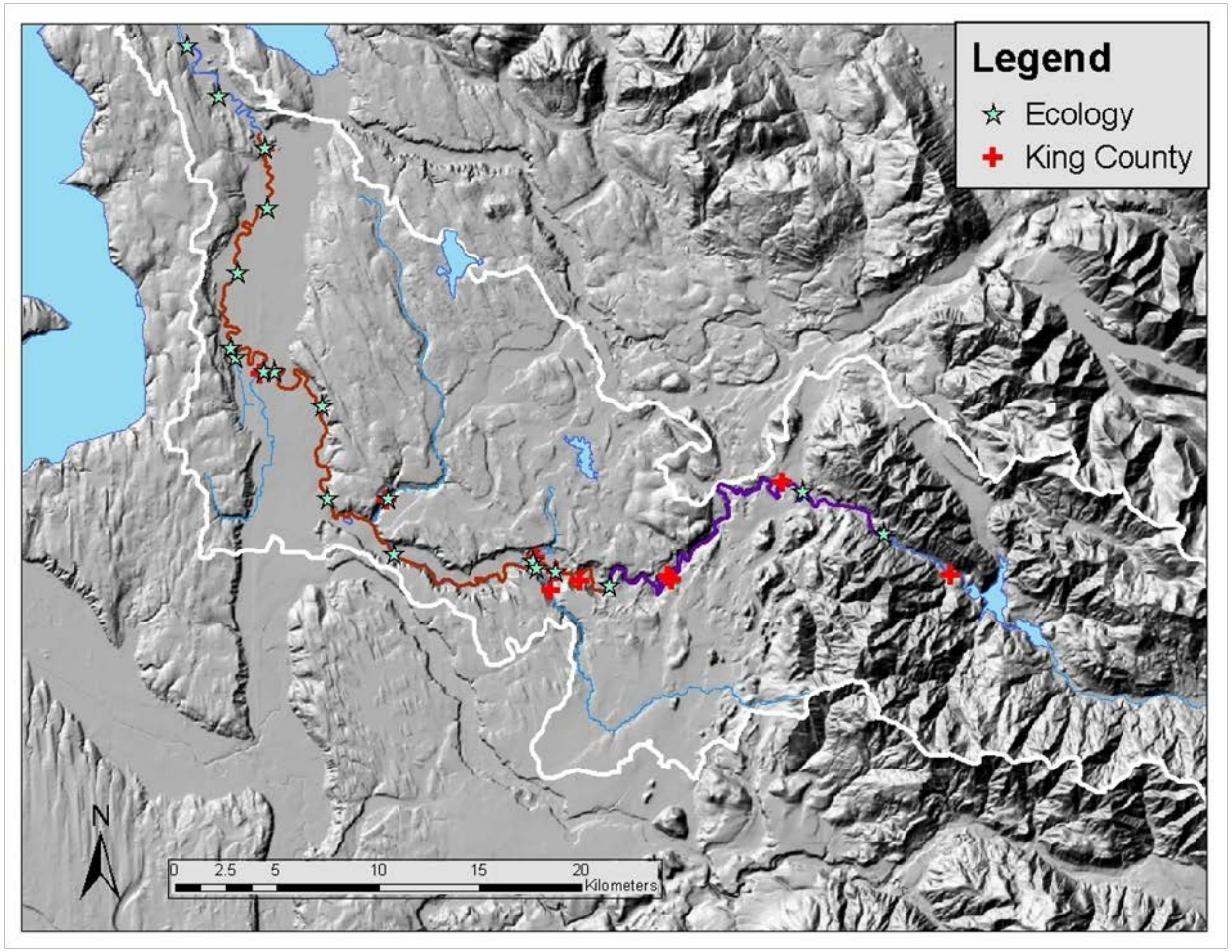
Modeling Temperature



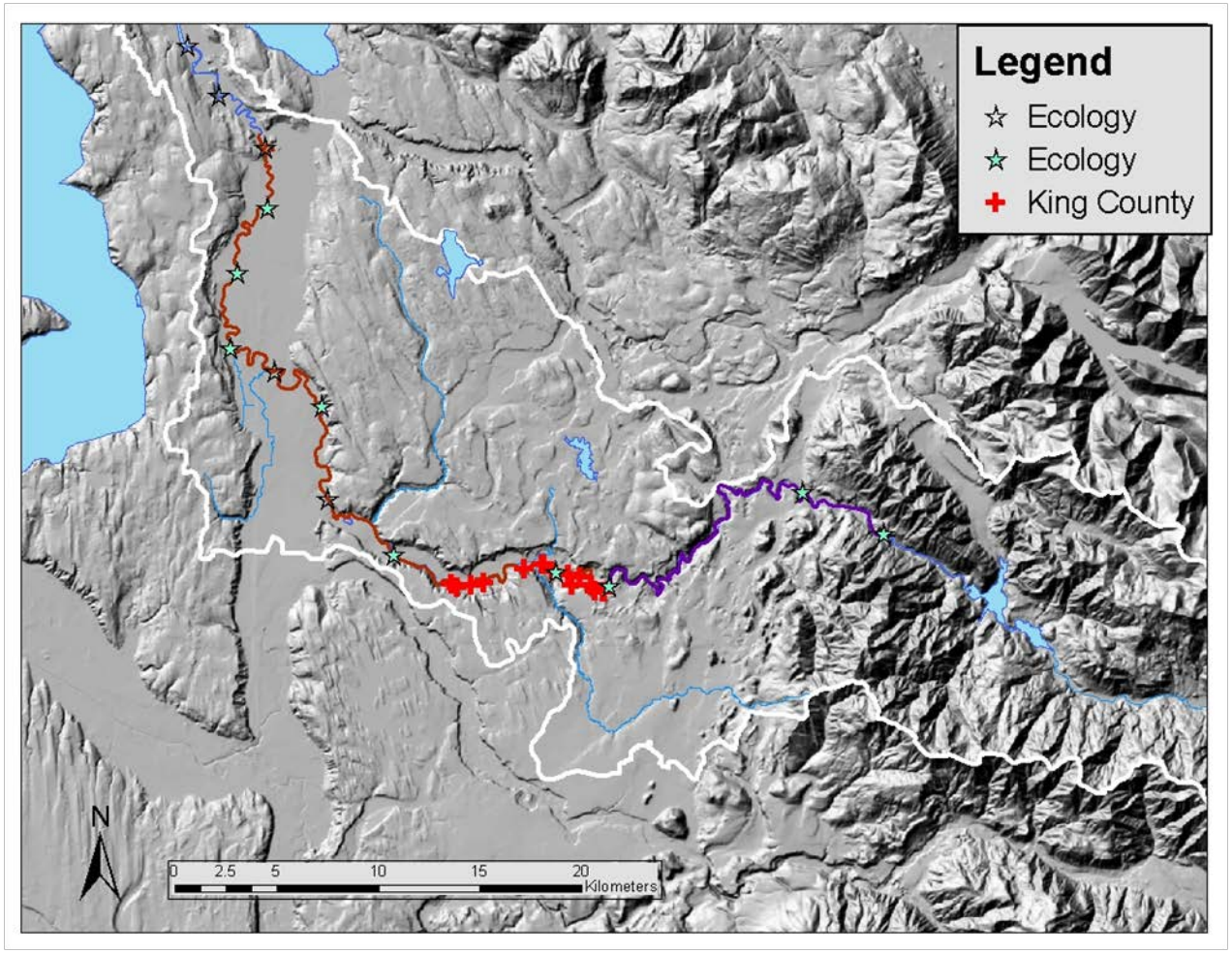
Model Development

- Model geometry (slope/width)
- Shade
- Hydraulics (flow/depth/velocity)
- Temperature

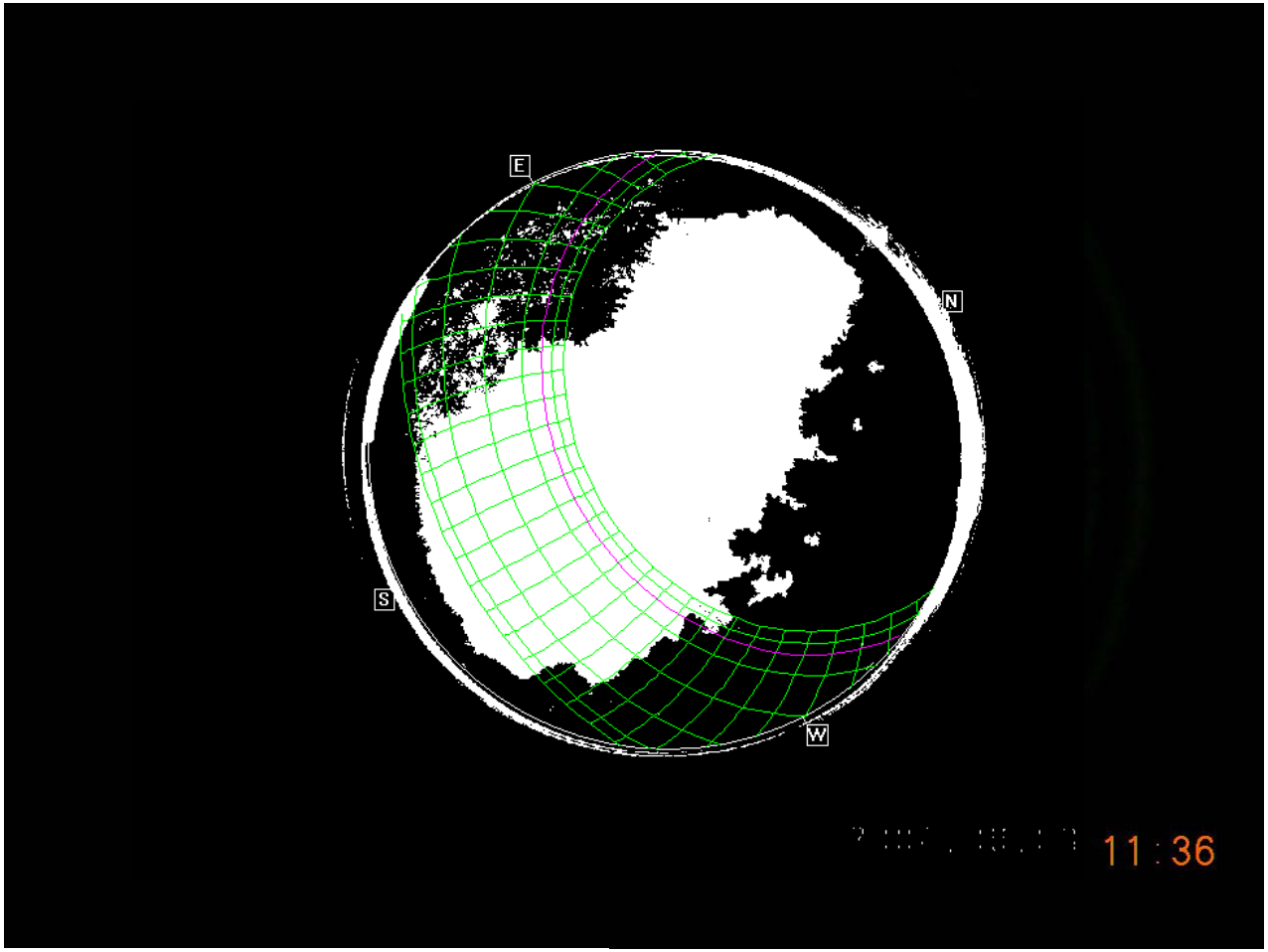
Data Collection
July-September 2006
Continuous Temperature Sensors



Data Collection
July-September 2006
Fisheye Photos

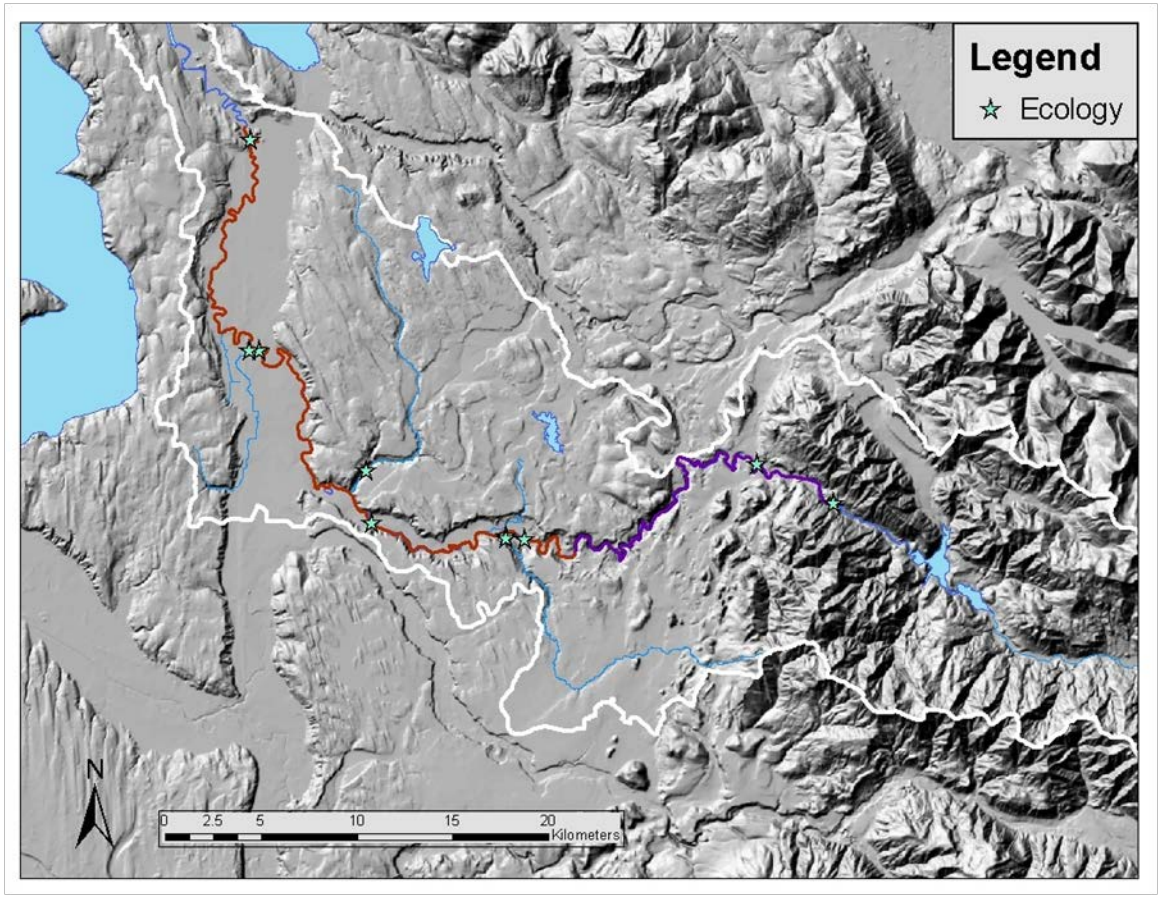


EFFECTIVE SHADE

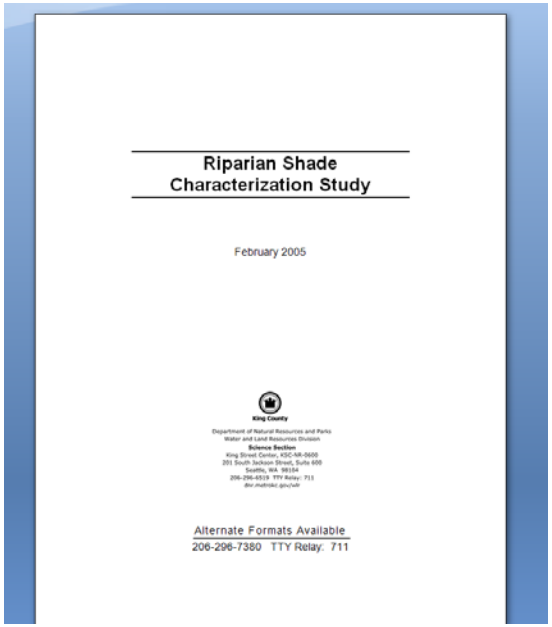


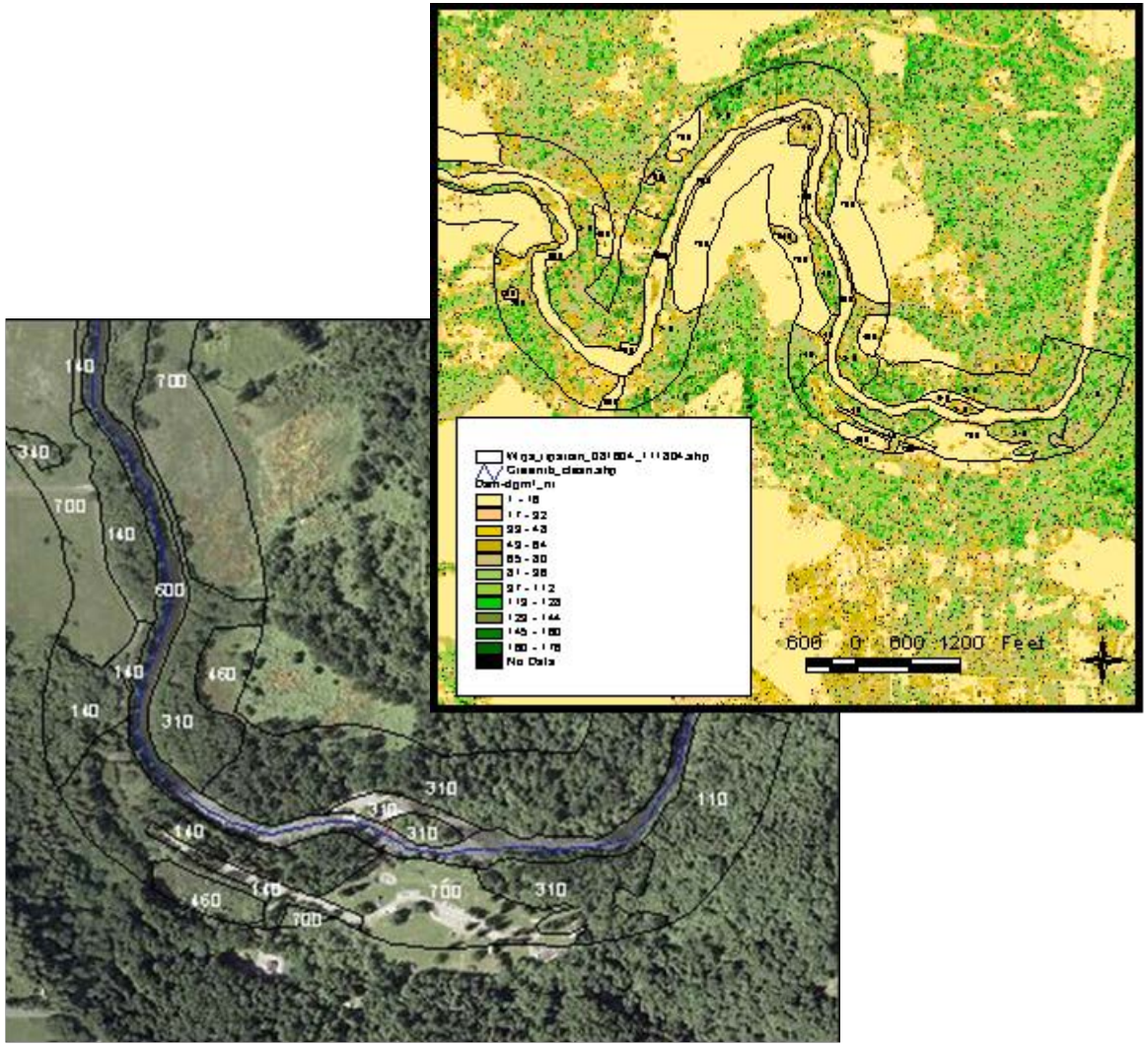
$$Effective\ Shade\ (\%) = \frac{I_o - I_i}{I_o}\ x\ 100$$

Data Collection
Synoptic Water Quality Study
August 1-2, 2006



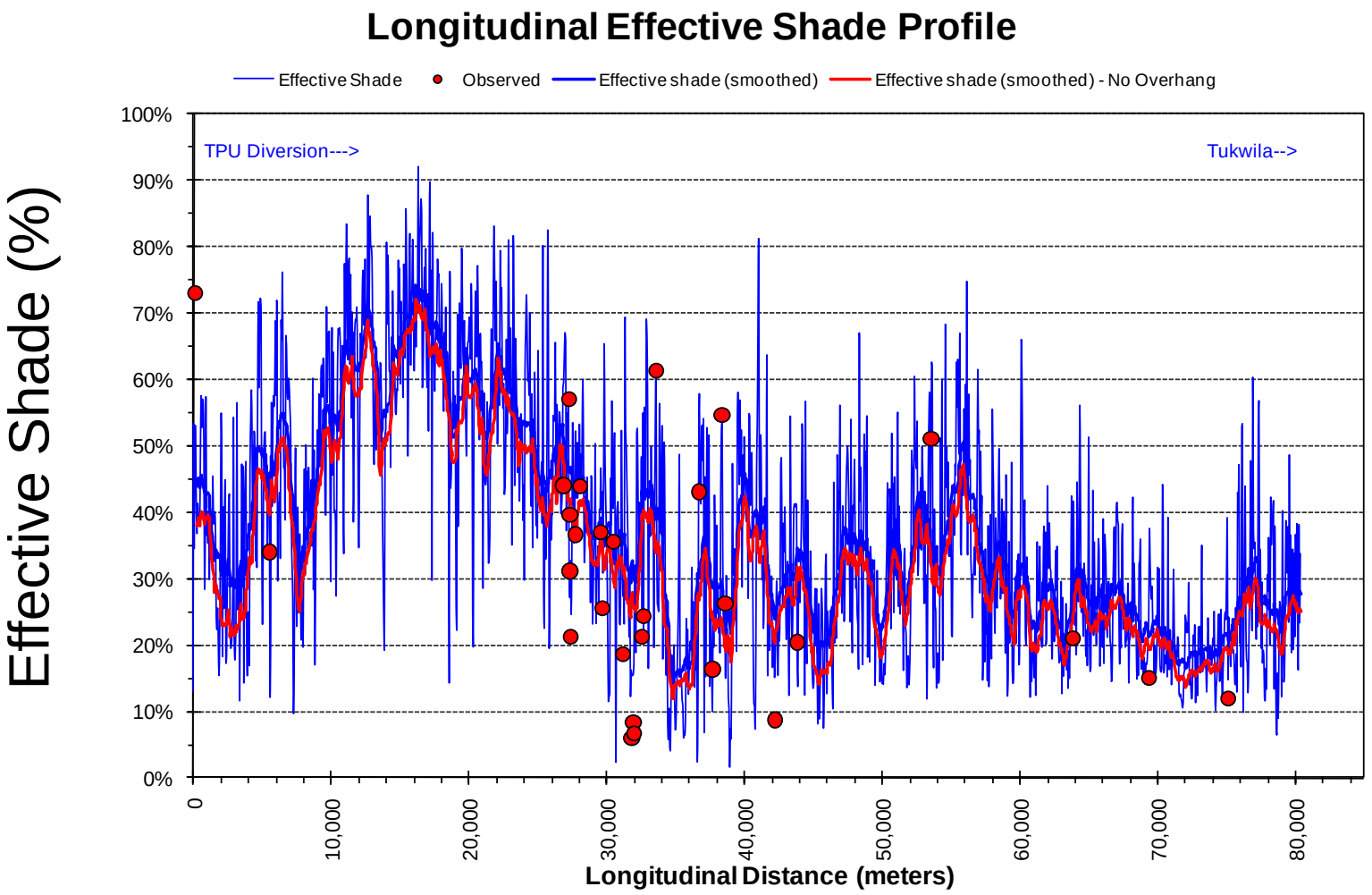
Riparian Shade Analysis





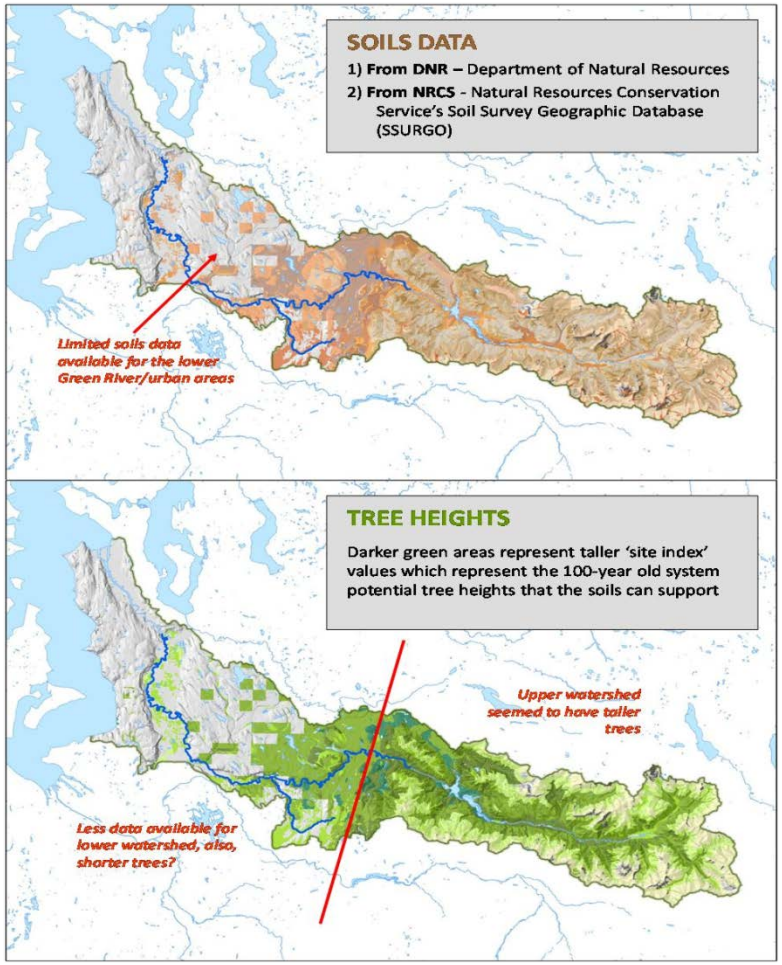
http://www.kingcounty.gov/environment/wlr/sections-programs/science-section/riparian-shade-characterization-study.aspx

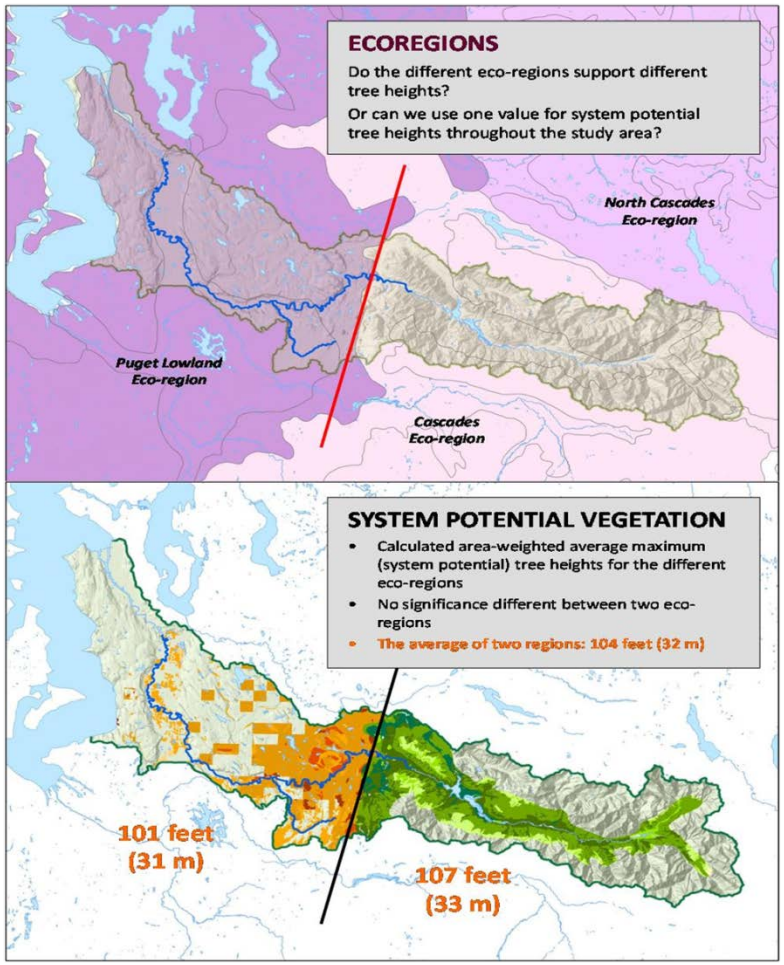
Current Shade Model Results



Shade modeled every 50 meters along the river for August 2, 200

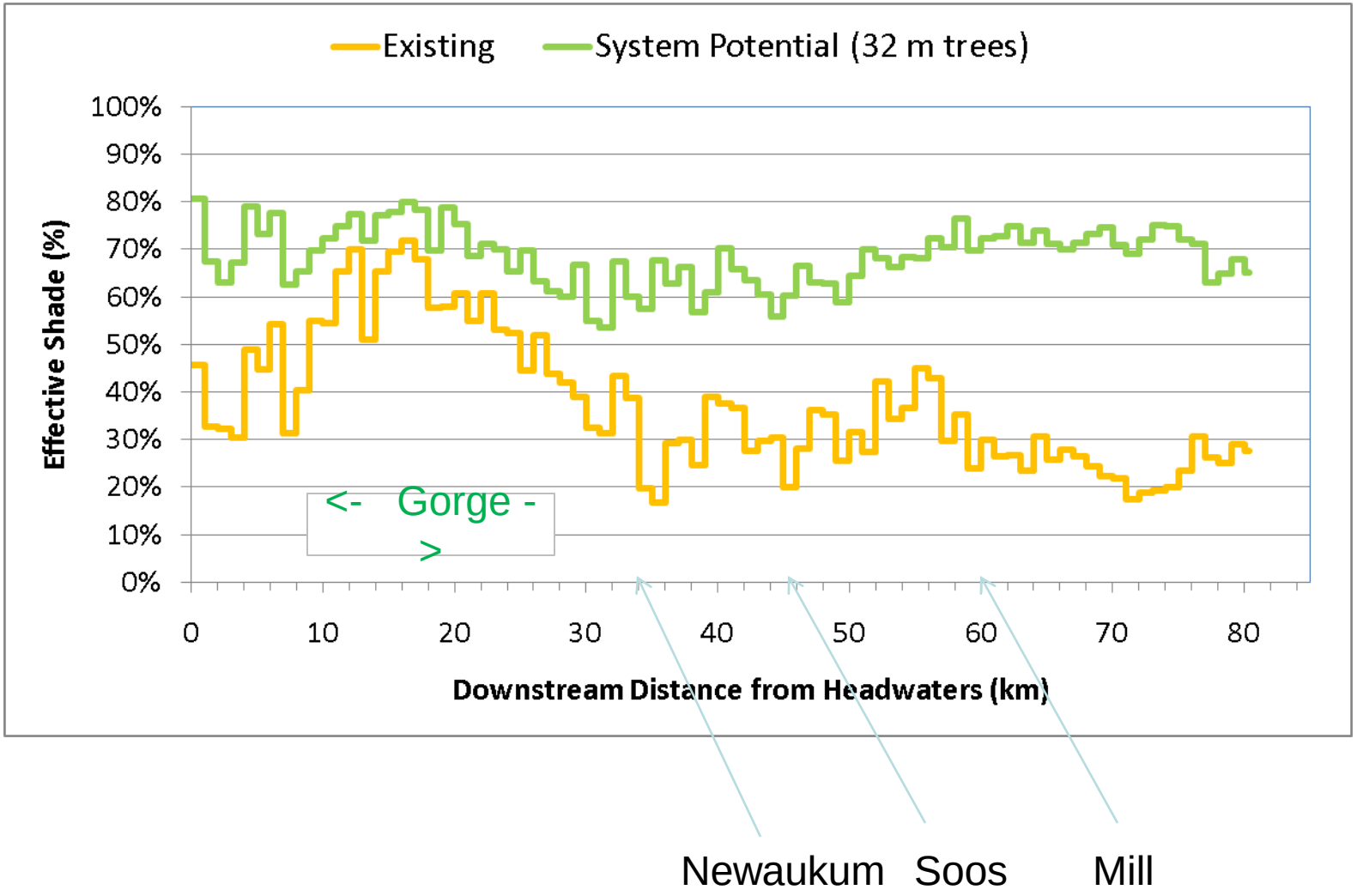
System Potential Shade



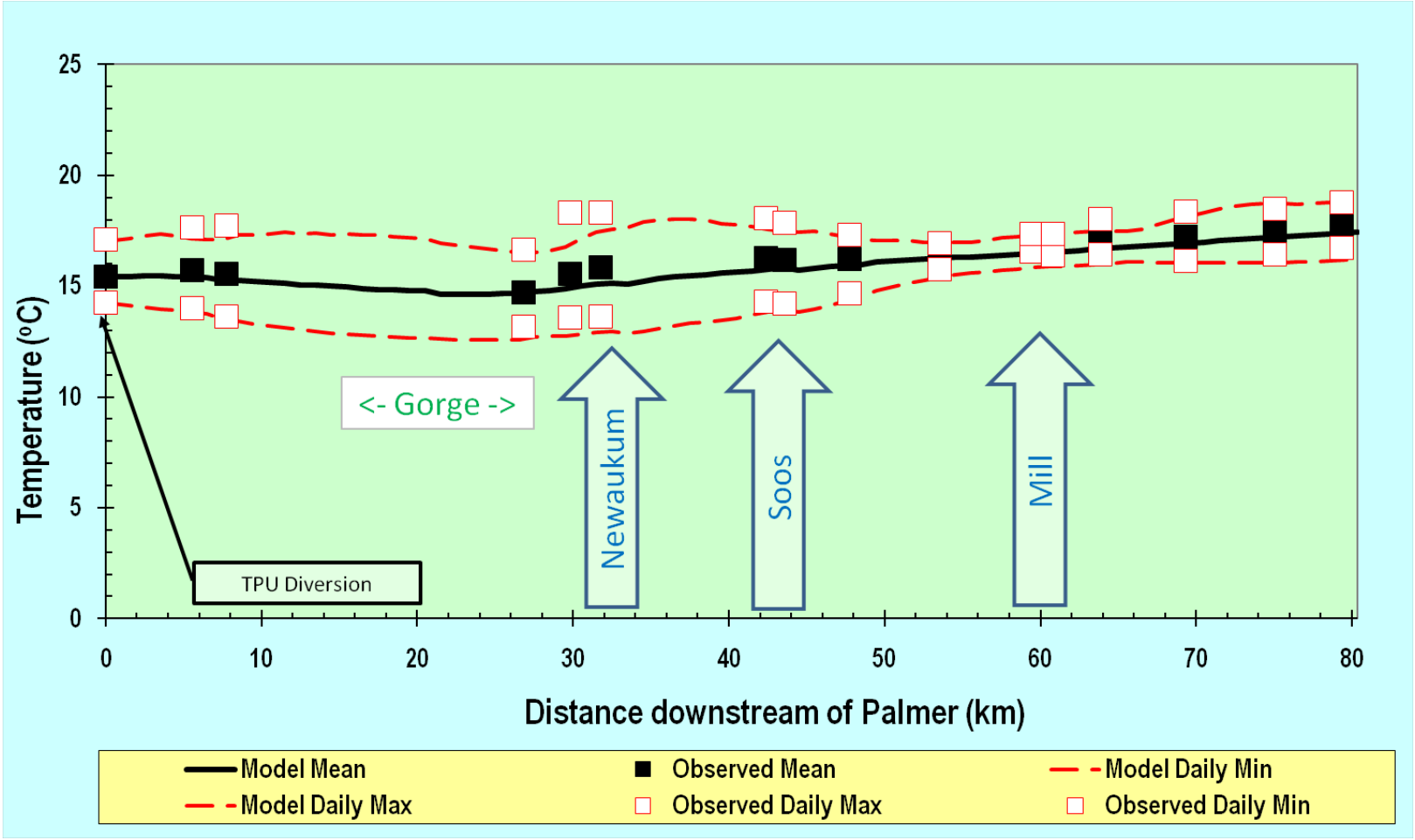


System Potential Tree Height Estimated to be 32 m

Current and System Potential Shade



Temperature Model Calibration

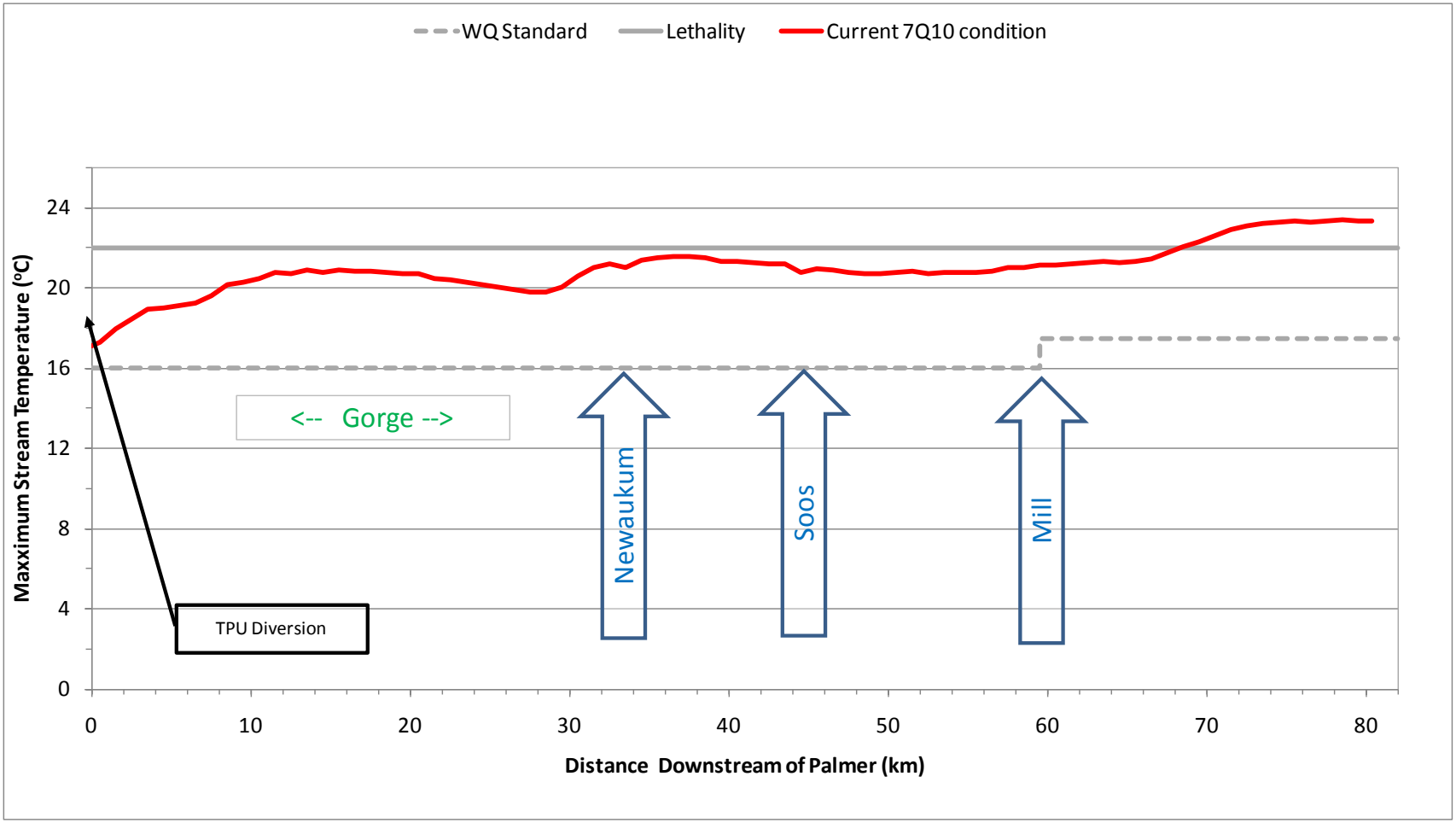


Critical Condition or 7Q10 Scenario



- 7Q10 Flow for Soos and Newaukum based on gauge data (21 and 12 cfs, respectively)
- Other tributary flows scaled from above
- 7Q10 weather based on long-term Sea-Tac data
- FDWR flow of 225 cfs at Auburn
- Head boundary (Palmer) flow 119 cfs

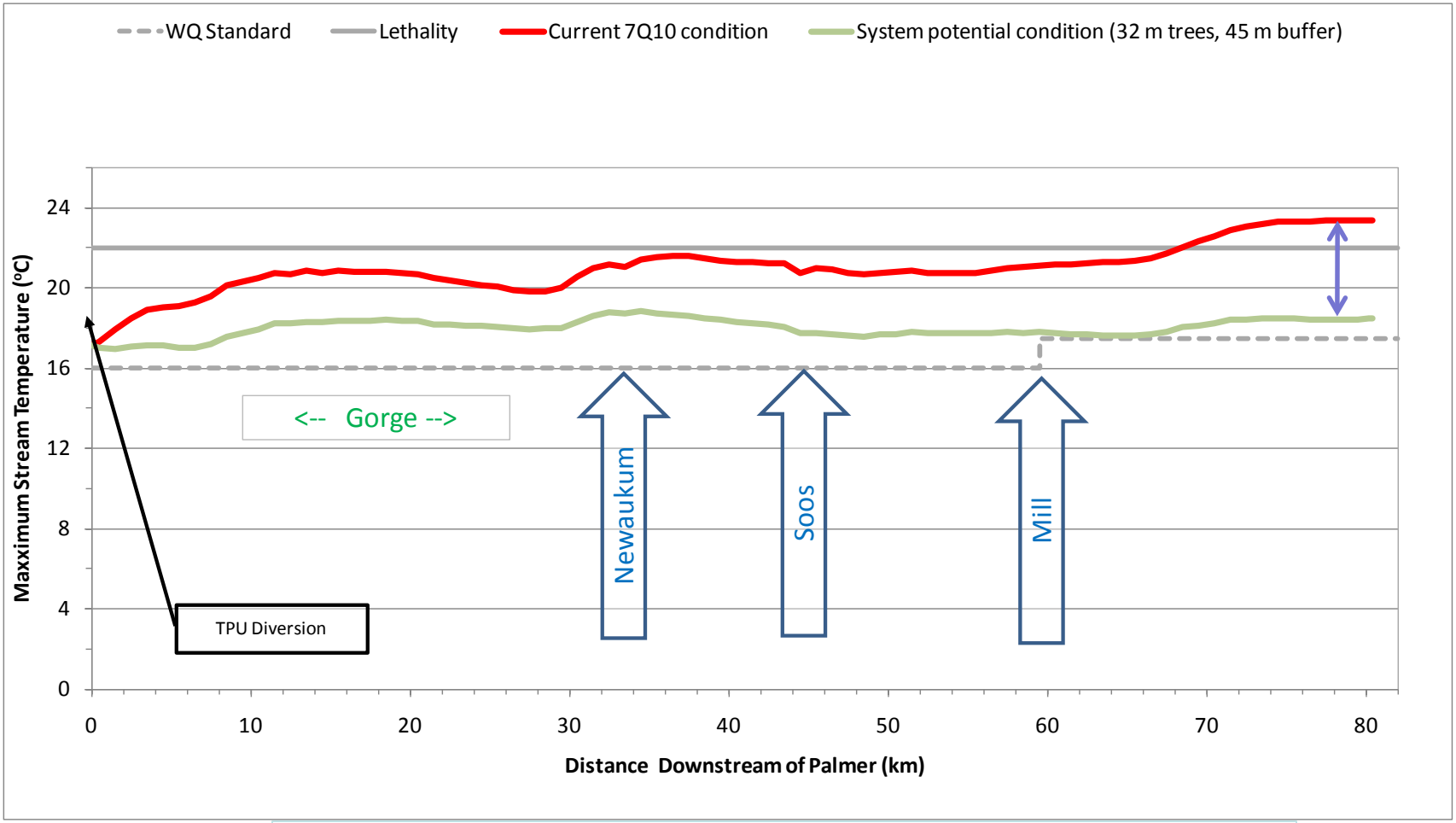
Results!



Current Riparian Condition

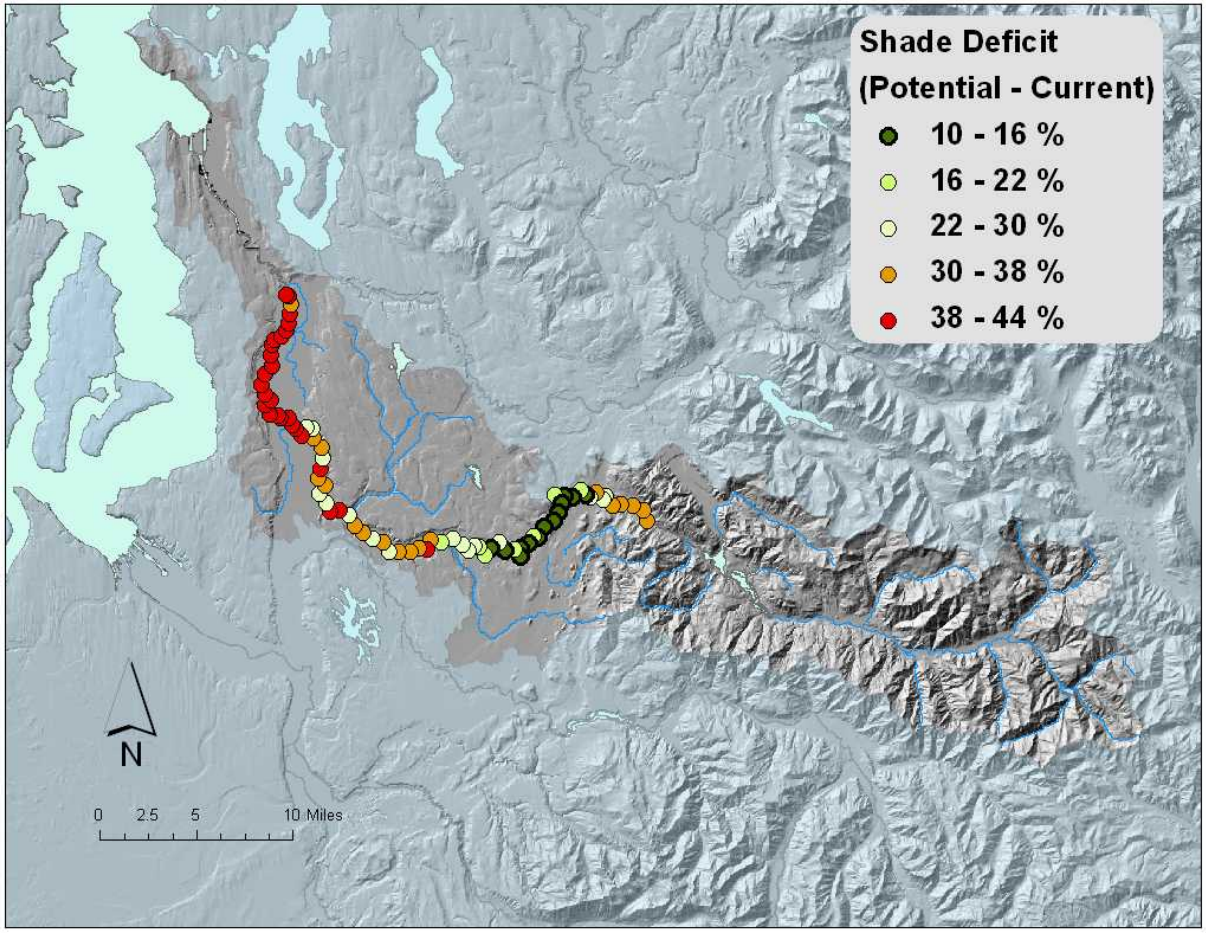
Results!

Max = 9 ºF (5 ºC)

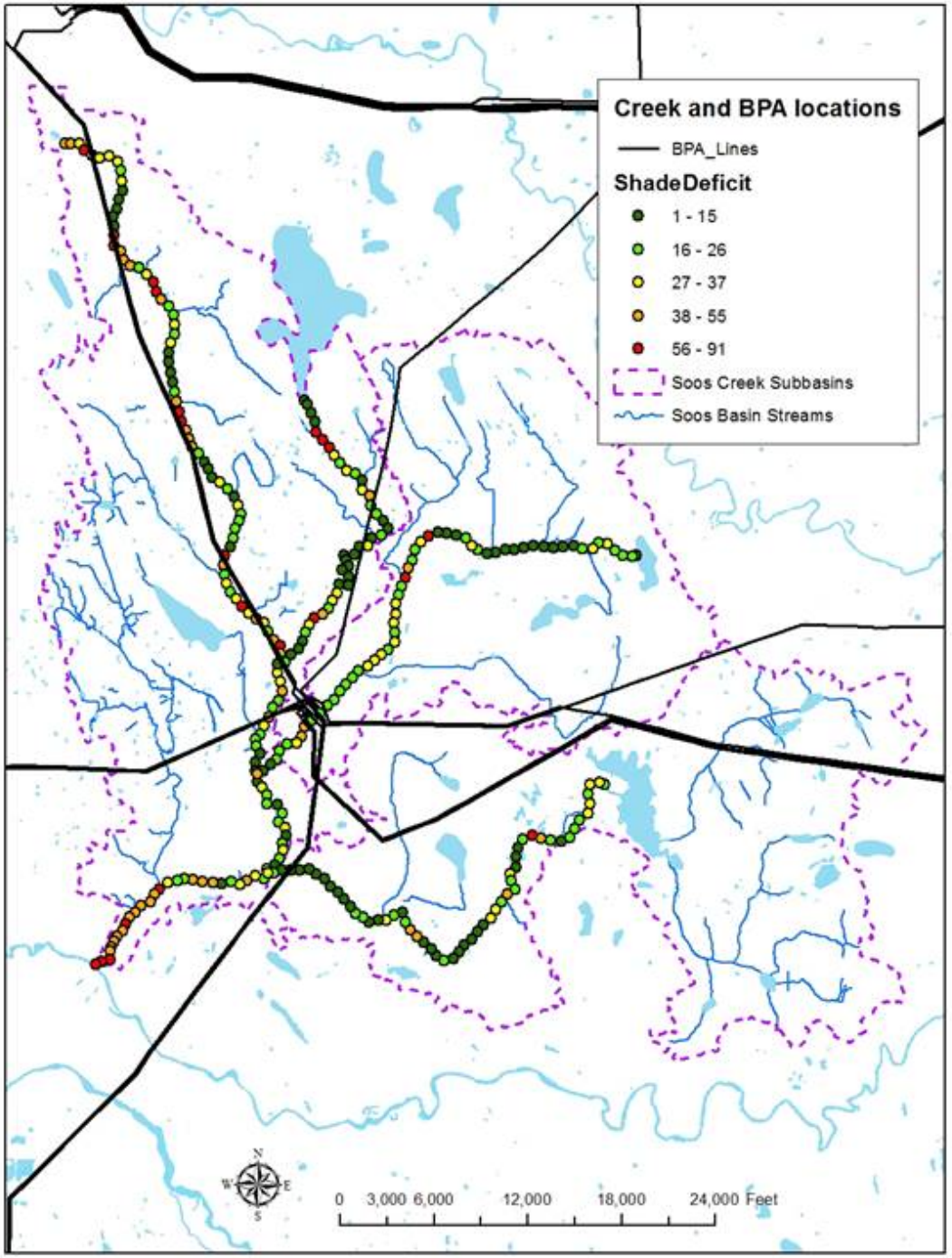


System Potential Riparian Condition

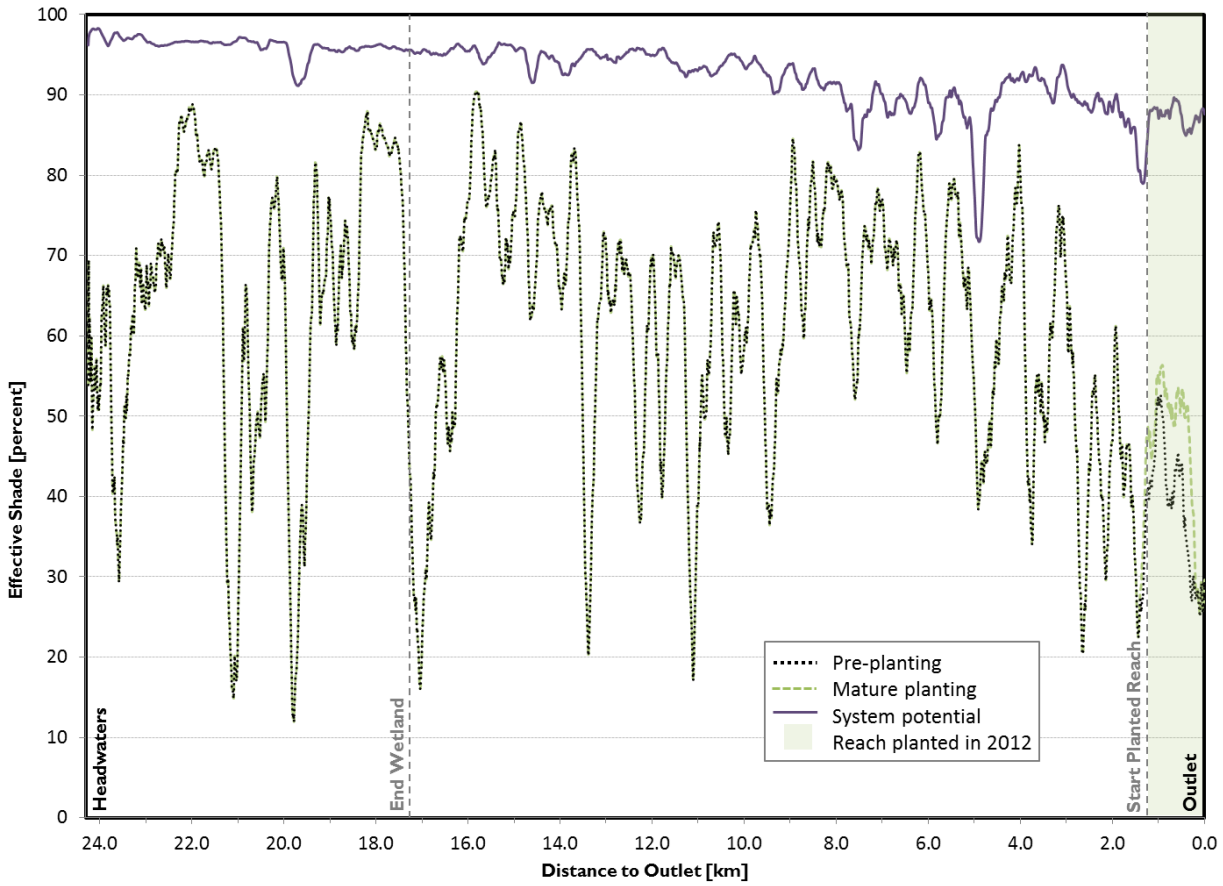
Shade Deficit



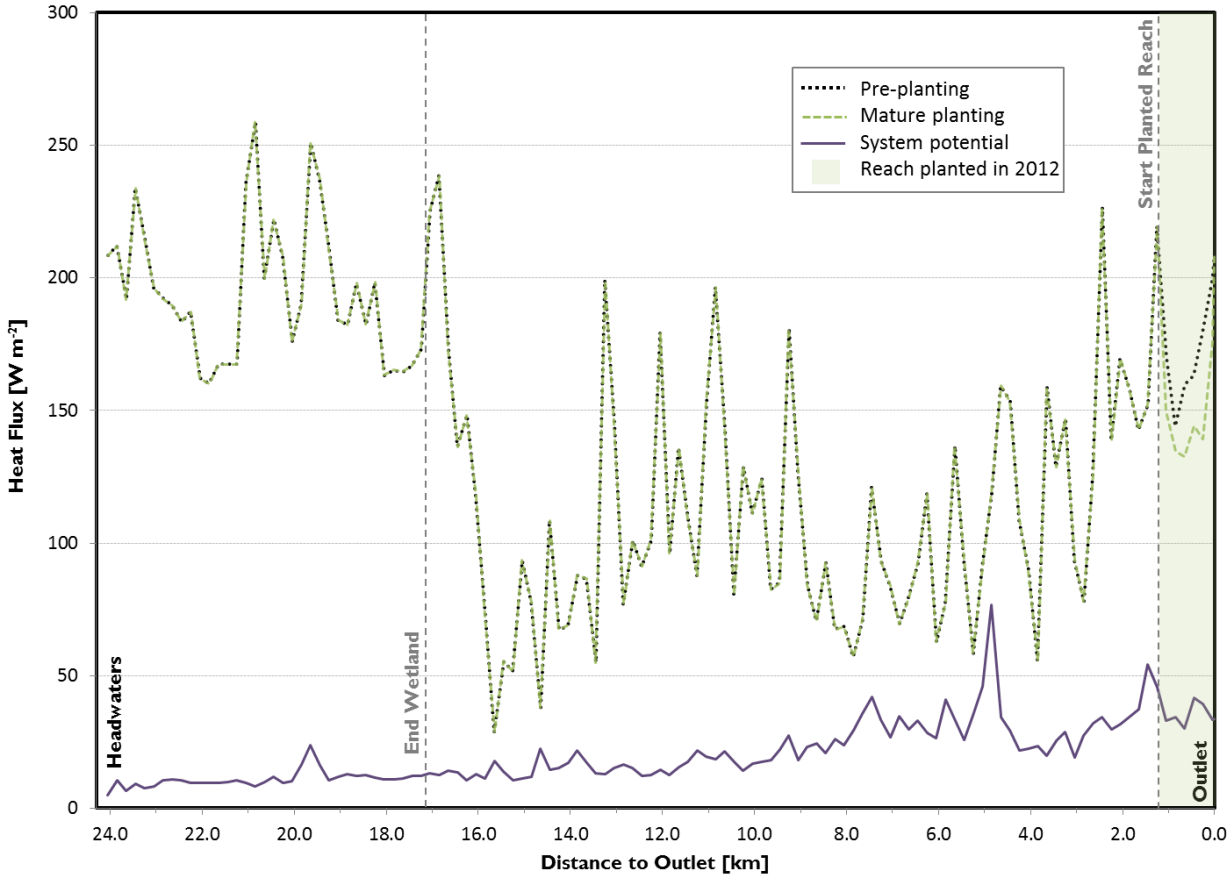
Soos Creek


Creek and BPA locations
BPA_Lines
ShadeDeficit
1 - 15
16 - 26
27 - 37
38 - 55
56 - 91
Soos Creek Subbasins
Soos Basin Streams
N
W
E
S
0 3,000 6,000 12,000 18,000 24,000 Feet

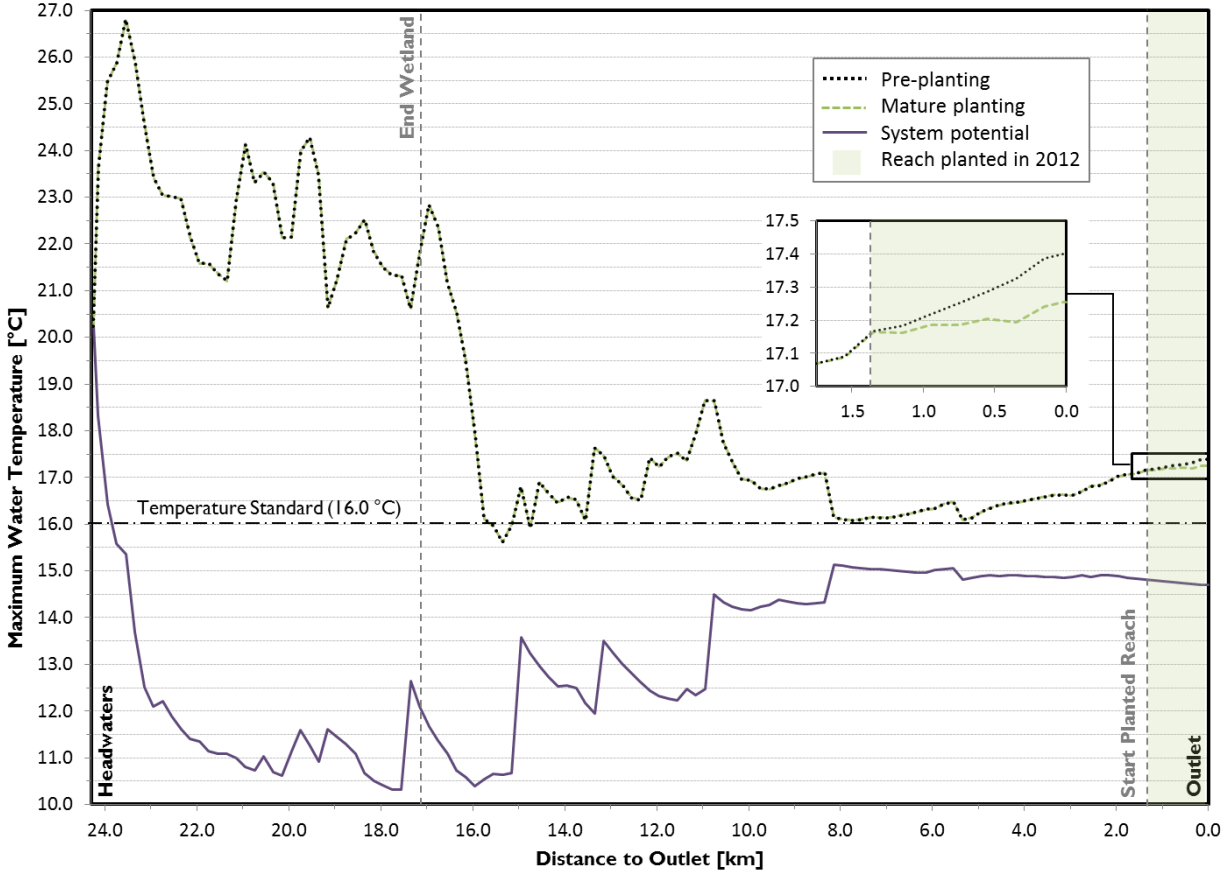
System Potential Shade



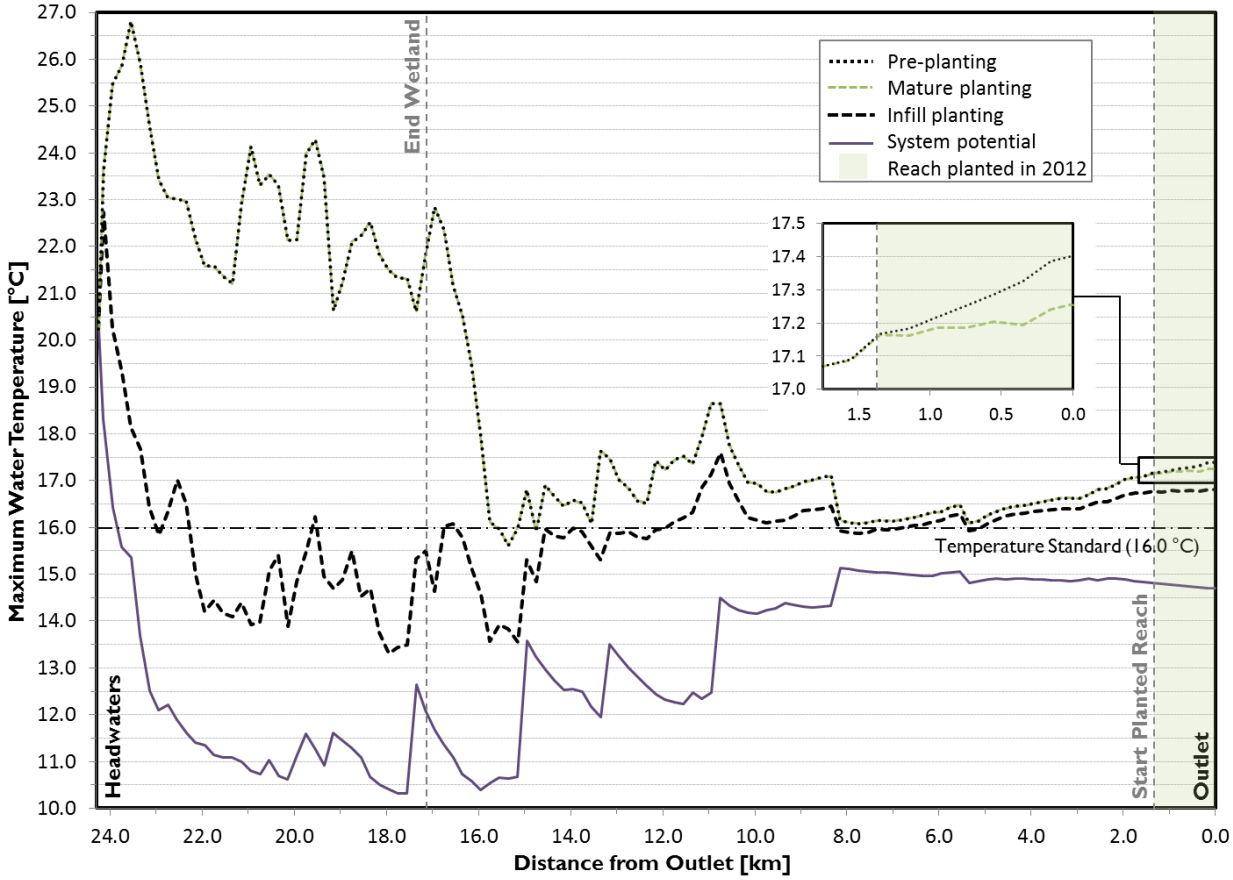
Heat Load


Heat Flux [W m-2]
300
250
200
150
100
50
0
24.0
22.0
20.0
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Distance to Outlet [km]
Pre-planting
Mature planting
System potential
Reach planted in 2012
Headwaters
End Wetland
Start Planted Reach
Outlet

Temperature Scenarios



Temperature Scenarios



Newaukum Creek

System Potential Shade

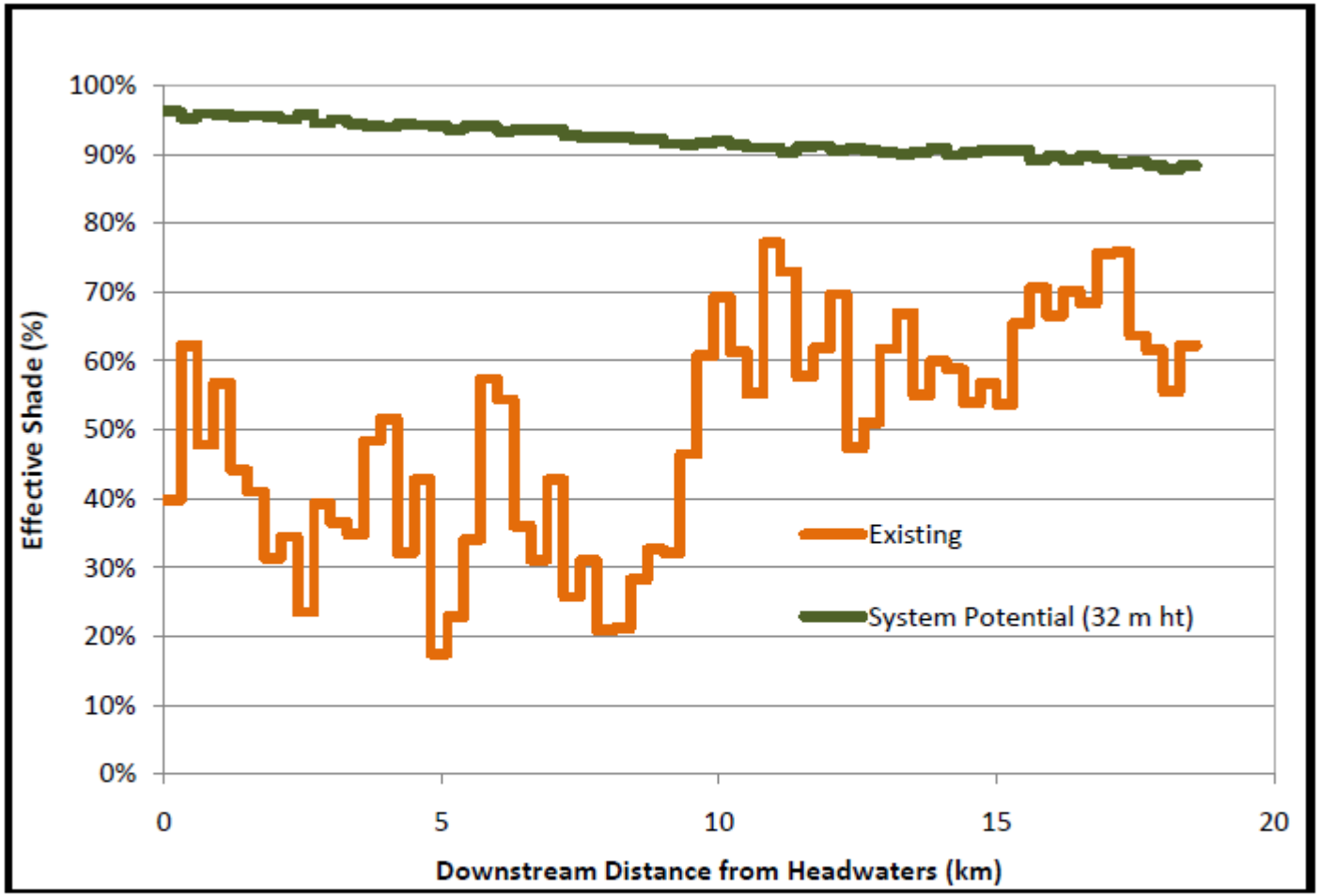
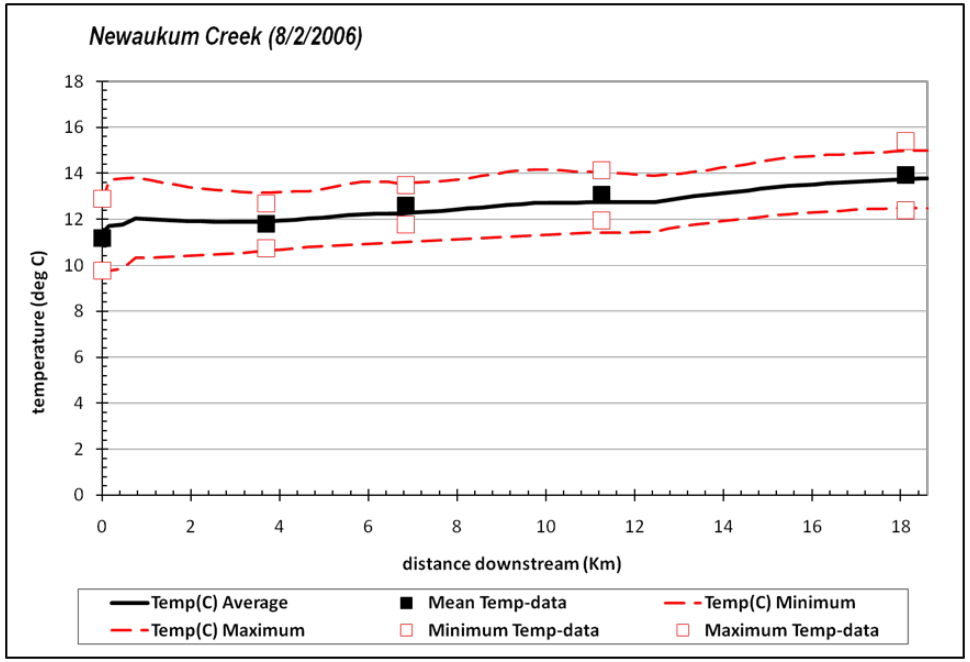


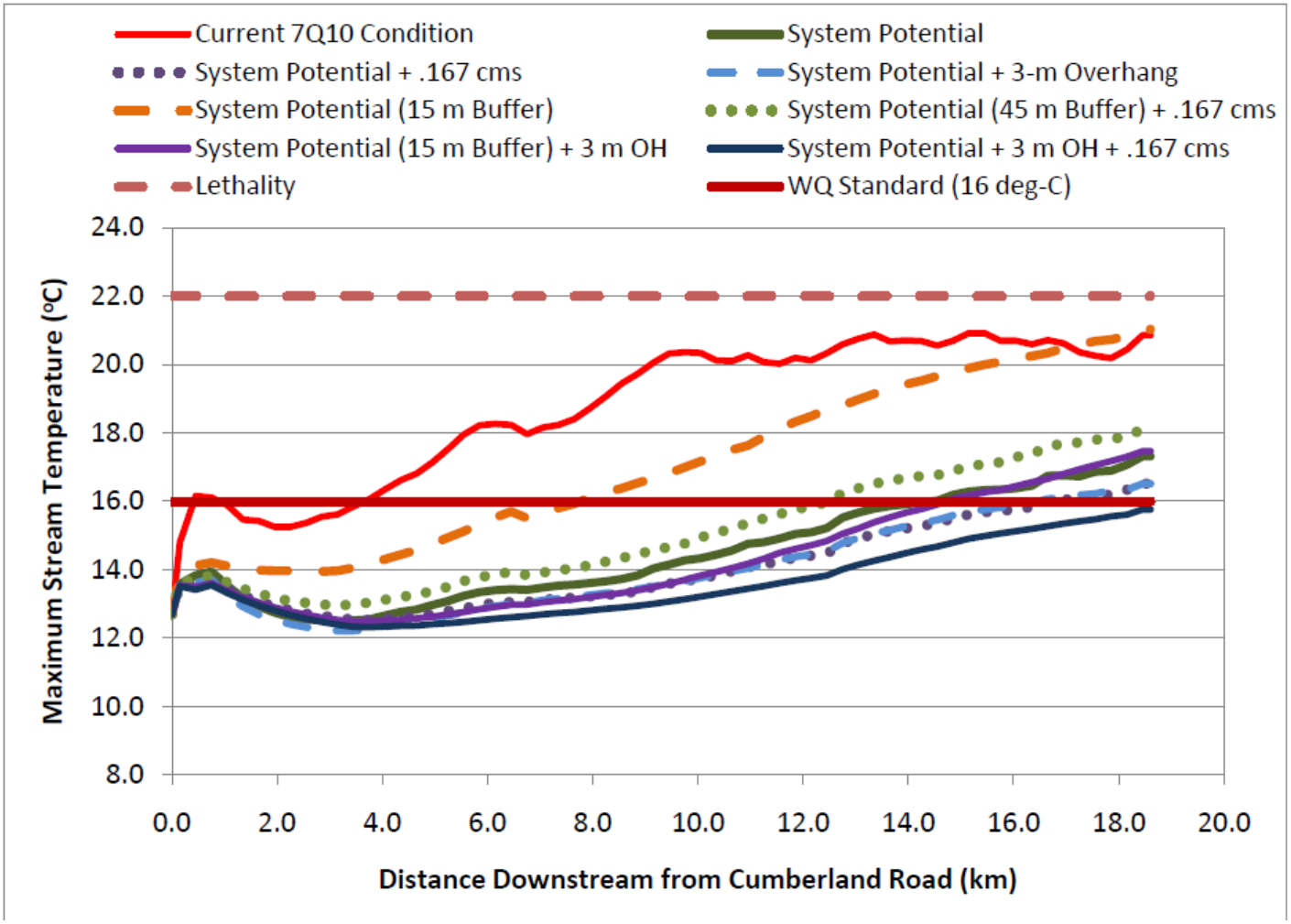
Figure 26. Current and system potential effective shade profiles for Newaukum Creek. *The greatest potential to improve effective shade is on the plateau reach within 10 stream kilometers of Cumberland Road.*

Water Temperature Cabliration

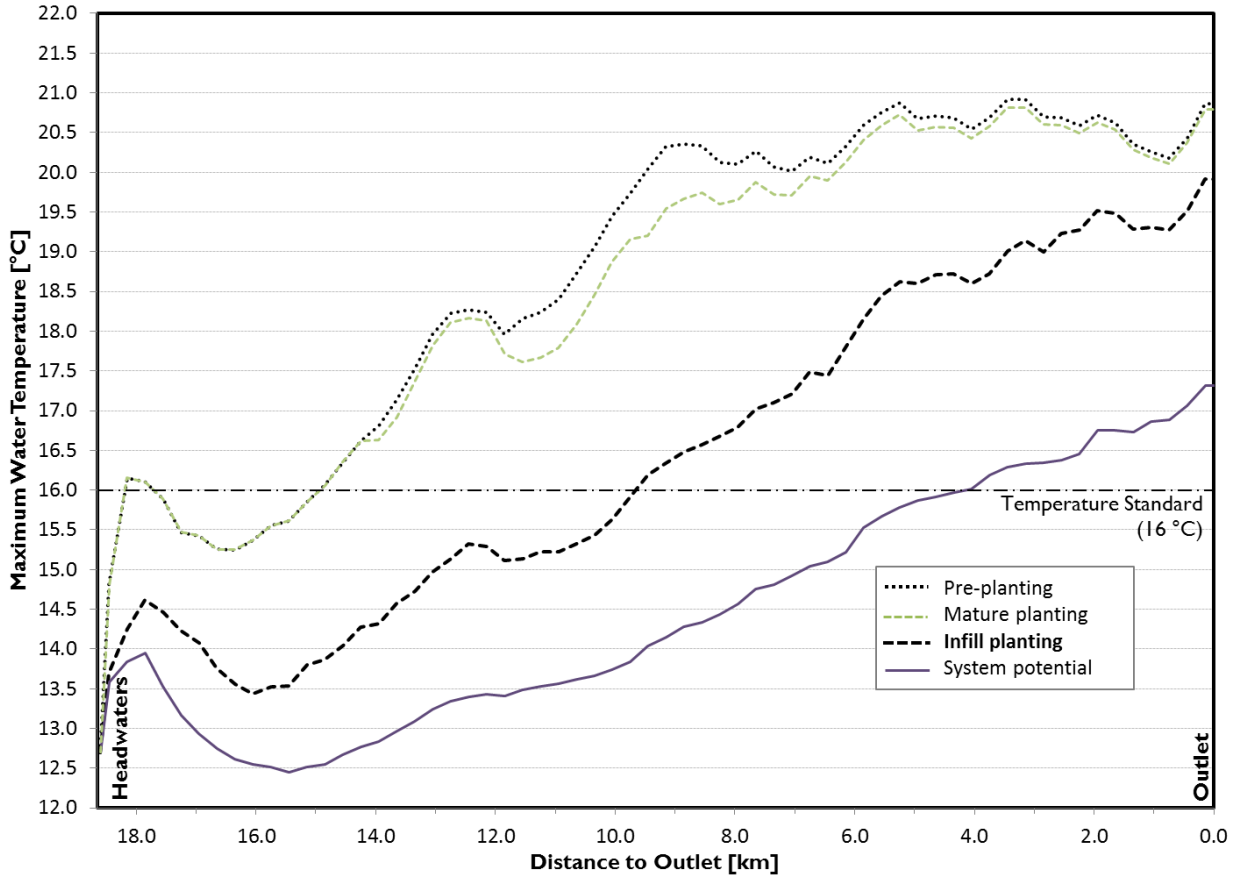


- Calibration for August 2, 2006
- RMSE = 0.42 ^{o}C

Temperature Scenarios

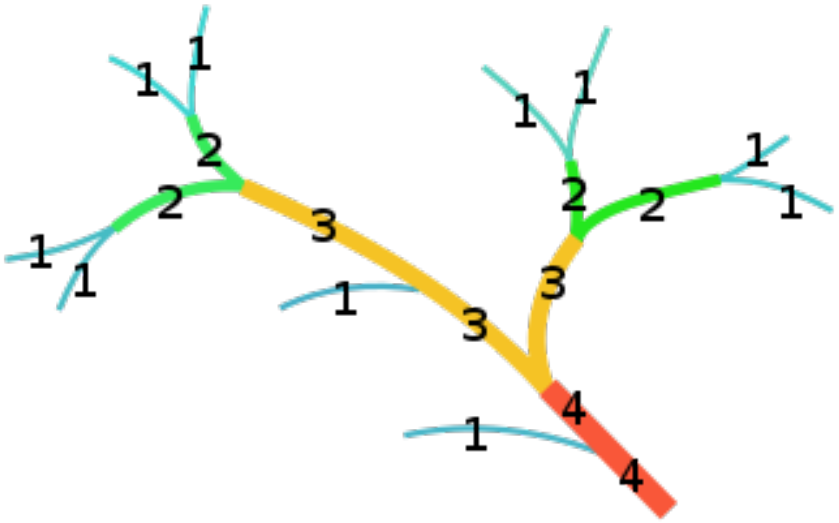


Temperature Scenarios



Rules of Thumb-from Riparian Restoration Research

- Restore lower order streams before higher order streams



Rules of Thumb from Riparian Restoration Research

- Work in areas with no vegetation before seeking to enhance areas with lower density of vegetation
- Preferentially revegetate sites that have the highest solar radiation aspects
- Restore reaches where soil properties are most favorable for successful establishment

Rules of Thumb-from Riparian Restoration Research

- Actively managing plantings may provide more benefit more quickly than passive approaches
- Restoration is most appropriately undertaken at the scale of entire subcatchments (~1000 m reach lengths)
- Vegetation density and height is as important as buffer width

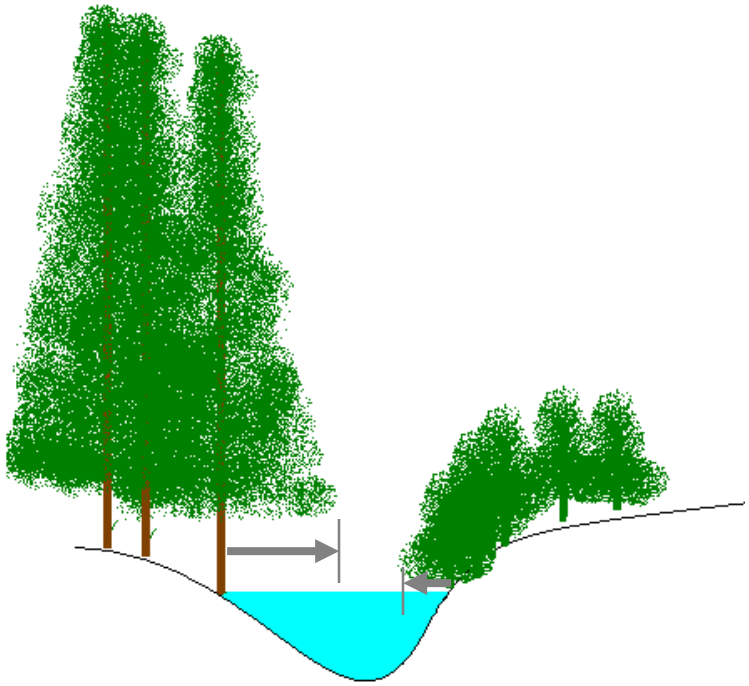
Rules of Thumb-from Riparian Restoration Research

- Preferentially restore southern aspects, but don't ignore east or west stream aspects

	33 m trees on:	**%Effective Shade**
North-South orientation	One bank only (left or right)	31.4
	Both banks	62.6
East to West flow (270^{o})	Left bank only	41.1
	Right bank only	5.7
	Both banks	46.6

Rules of Thumb-from Riparian Restoration Research

- Shade from stream overhang can be important in small streams







NorWeST Stream Temp



Regional Database and Modeled Stream Temperatures



The NorWeST webpage hosts stream temperature data and geospatial map outputs from a regional temperature model for the Northwest U.S. The temperature database was compiled from hundreds of biologists and hydrologists working for dozens of resource agencies and contains more than 50,000,000 hourly temperature recordings at more than 20,000 unique stream sites. These temperature data are being used with **spatial statistical stream network models** to develop an accurate and consistent set of climate scenarios for all streams.

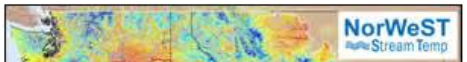
Temperature data and model outputs, registered to **NHDPlus** stream lines, are posted to the website after QA/QC procedures and development of the final temperature model within a river basin (example **interactive temperature map**). It is hoped that open access to the data and the availability of accurate stream temperature scenarios will foster new research and collaborative relationships that enhance management and conservation of aquatic resources.

Funding for the project was provided by the **GNLCC** and **NPLCC** with additional funds and in-kind support from the USFS, USGS, USFWS, California Fish Passage Forum, and NASA. **Original grant proposal**

Project Boundary

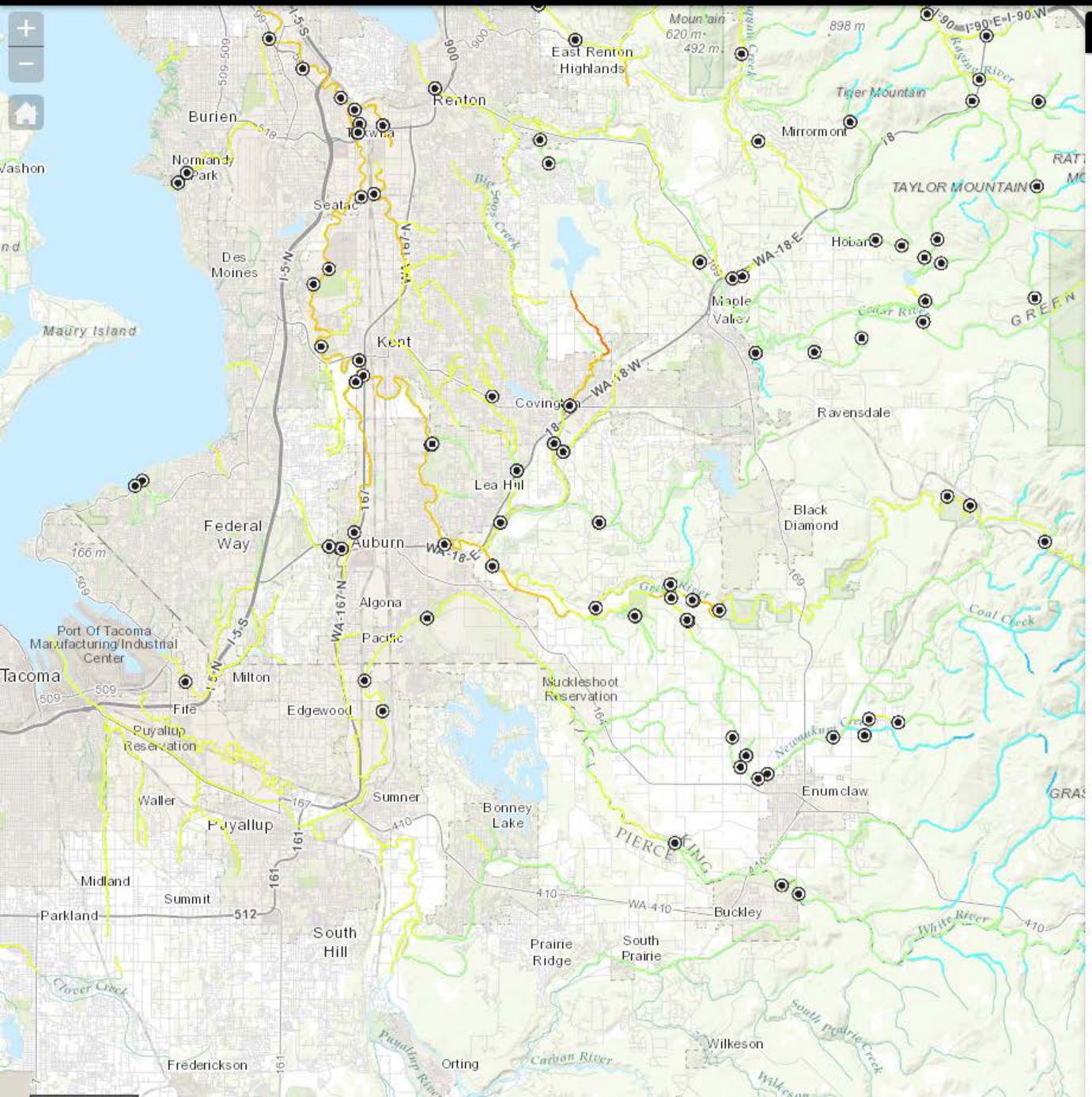


Thermalscape



Processing Status & Data Call





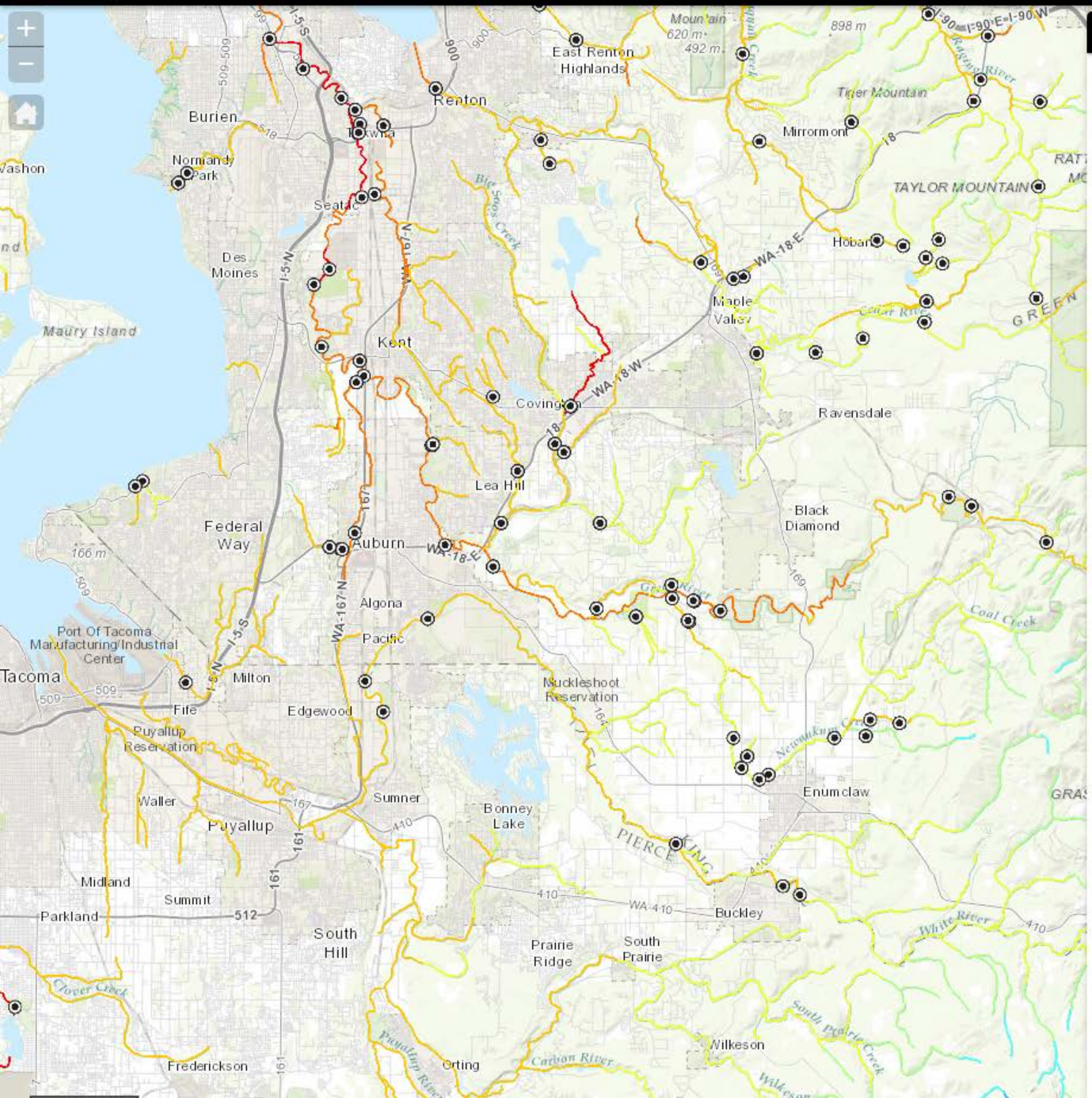
Legend

53616f96e4b082a3ecf53f7c

Observed Temperature Points

Mean August Stream Temperature

- 0-8
- 8-10
- 10-12
- 12-14
- 14-16
- 16-18
- 18-20
- 20-30



Legend

53616f96e4b082a3ecf53f7c

Observed Temperature Points

2080 A1B Future Scenario

- 0-8
- 8-10
- 10-12
- 12-14
- 14-16
- 16-18
- 18-20
- 20-30

Relevant Examples?

Clean Water Services

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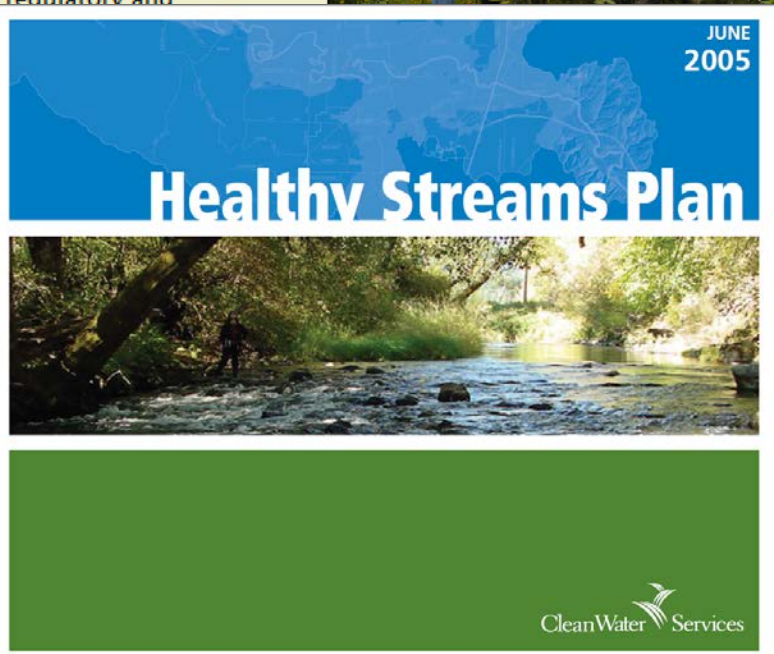
Watershed Management Department

The Watershed Management Department (WMD) at Clean Water Services plans, manages and provides leadership in Water Resources Infrastructure, Strategic Watershed Assessment and Planning, Stream System Stewardship and Community Watershed Action. The WMD supports and implements programs identified in the integrated watershed based permit. Department staff partner with local governments, natural resource agencies, businesses, nonprofits, local watershed groups and citizens to address the regulatory and ecological needs of the Tualatin River Basin.



Water Resources Infrastructure

Investing in natural capital infrastructure for



http://www.cleanwaterservices.org

RipStream Monitoring Questions

(Riparian Function and Stream Temperature)

1. Are riparian rules effective in meeting water quality standards?
2. Are riparian rules effective in maintaining large wood recruitment to streams, downed wood in riparian area, and shade?
3. What are the trends in riparian area regeneration?
4. What are the trends in overstory and understory riparian characteristics and how do they, along with channel and valley characteristics, relate to stream temperature and shade?

Oregon's RipStream

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Publication Information

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Title: Stream temperature responses to timber harvest and best management practices—findings from the ODF RipStream project

View PDF (75 KB)

Author: Groom, Jeremy D.;

Date: 2013

Source: In: Anderson, P.D.; Ronnenberg, K.L., eds. Density management in the 21st century: west side story. Gen. Tech. Rep. PNW-GTR-880. Portland, OR: US Department of Agriculture, Forest Service, Pacific Northwest Research Station: 207-207.

Publication Series: General Technical Report (GTR)

Note: This article is part of a larger document. View the larger document

Description: Studies over the past 40 years have established that riparian buff er retention along streams protects against stream temperature increase. Th is protection is neither universal nor complete; some buff ered streams still warm, while other streams' temperatures remain stable. Oregon Department of Forestry developed riparian rules in the Forest Practices Act (FPA) to protect fishbearing streams from temperature increases, but it did so with acknowledgement that its rules might be insuffi cient. It developed the Riparian and Stream Function project, otherwise known as RipStream, to validate the eff ectiveness of these rules. Th e FPA stipulates that for Small and Medium fi sh-bearing streams, no cutting is to occur within 6 m adjacent to the stream and limited entry may occur within 15 and 21 m, respectively. Th e Oregon State Forest Management Plan (FMP) builds upon the FPA but includes additional protections in order to meet multiple management objectives. State forest riparian protections include an 8-m no-cut zone, an 8- to 30-m zone to be managed for producing mature forest conditions, and limited harvest between 30 m and 52 m. Harvest on state forest can differ from private lands, as state forest stands may be subject to thinning instead of clearcutting. Th e RipStream project represents a joint effort between State and Private Forest divisions at Oregon Department of Forestry to quantify the effects of timber harvest on stream temperatures. Th e study includes 15 state forest and 18 private sites. Data on stream temperature, riparian vegetation, channel characteristics, and channel shading were collected at every site for two years pre-harvest and fi ve years post-harvest. Each site included an upstream unharvested control reach and a treatment reach that was harvested after year two. All private sites were clearcut; seven out of eight state sites were thinned. By the second year post-harvest we found no change in maximum temperatures for state forests while private sites increased pre-harvest to post-harvest on average by 0.7°C, with an observed range of response from -0.9 to 2.5°C. State sites additionally demonstrated no diff erence in temperatures between clearcut and thinned treatments. The observed changes in stream temperature were most strongly correlated with shade levels measured before and after harvest. Treatment reach length, stream gradient, and changes in the upstream reach stream temperature were additionally useful in explaining treatment reach temperature change. Shade was best predicted by riparian basal area and tree height. These findings suggest that riparian protection measures that maintain higher shade, such as those followed in state forests, were more likely to maintain stream temperatures similar to control conditions.

Keywords: riparian buffer, stream temperature, mixed-eff ects, shade, thinning.

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Key Information Sources

- Booth et al. (2013)
- DeWalle (2010)
- Davies-Colley et al. (2009)
- Moore et al. (2005)
- Davies et al. (2004)
- Rutherford et al. (2004)

QUESTIONS – COMMENTS?



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- *PHOTO: Green River Hemispherical Photo - 2006*