Upper Klamath and Lost River Subbasins Temperature TMDL Development

Model Setup, Calibration, and TMDL Scenarios Stage 1 Waterbodies

TMDL Advisory Meeting

Sept. 12, 2018

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DEQ
State of Oregon
Department of
Environmental
Quality

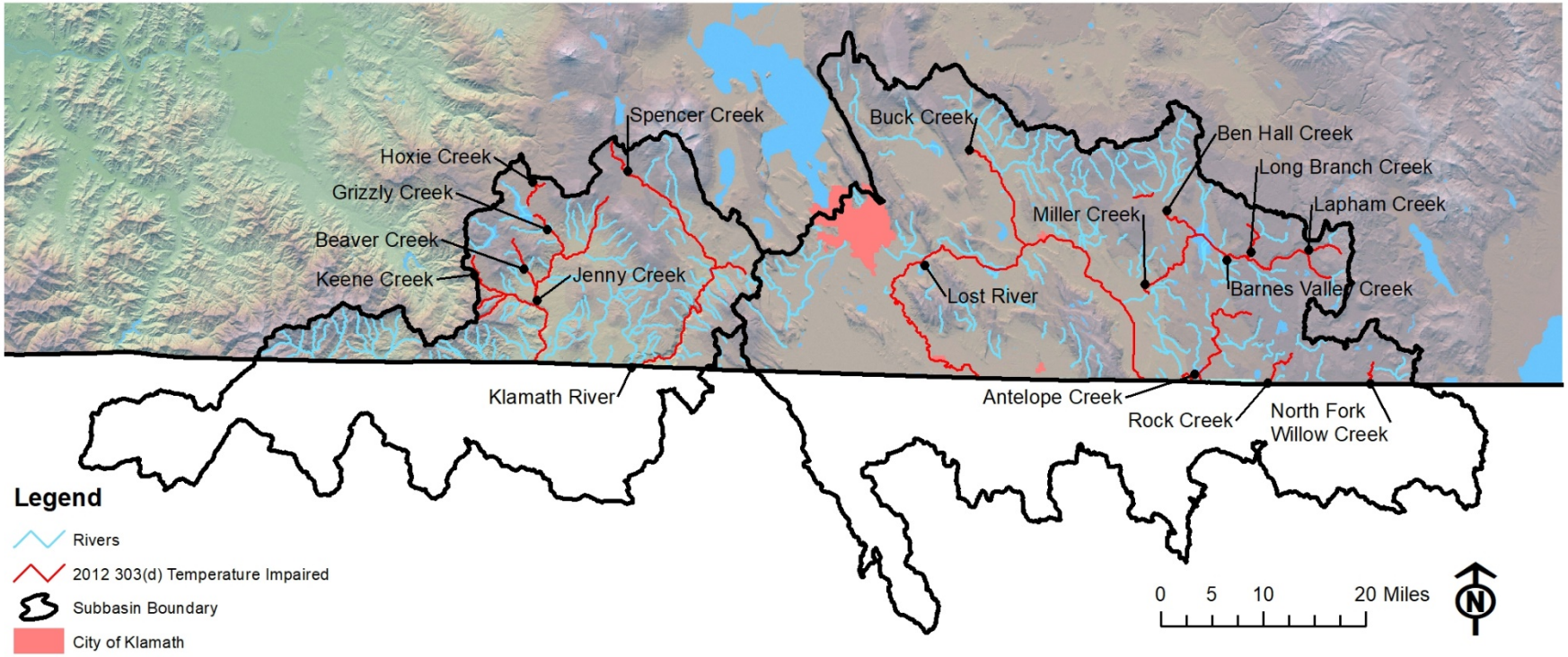
Presentation Overview

Model Setup and Inputs

Calibration

Scenarios

303(d) Temperature Impaired Waters



24 impaired segments - 2012 303(d) list

Technical Approach Overview

Technical Approach / Implementation Support	TMDL Development Stage
No modeling (Basic TMDL calculation)	Stage 1
Vegetation Assessment Solar radiation and effective shade modeling	Stage 1
Stream Temperature Modeling Various implementation and TMDL attainment scenarios	Stage1 and Stage 2
Range of conditions analysis/sensitivity analysis (TBA pending resources)	Stage 2

Modeling Process

Model Development

Data gathering (historic data, field monitoring)

Model input preparation and configuration

Model Evaluation

Calibration / Corroboration (predicted vs. measured conditions)

Peer review

Model Scenarios

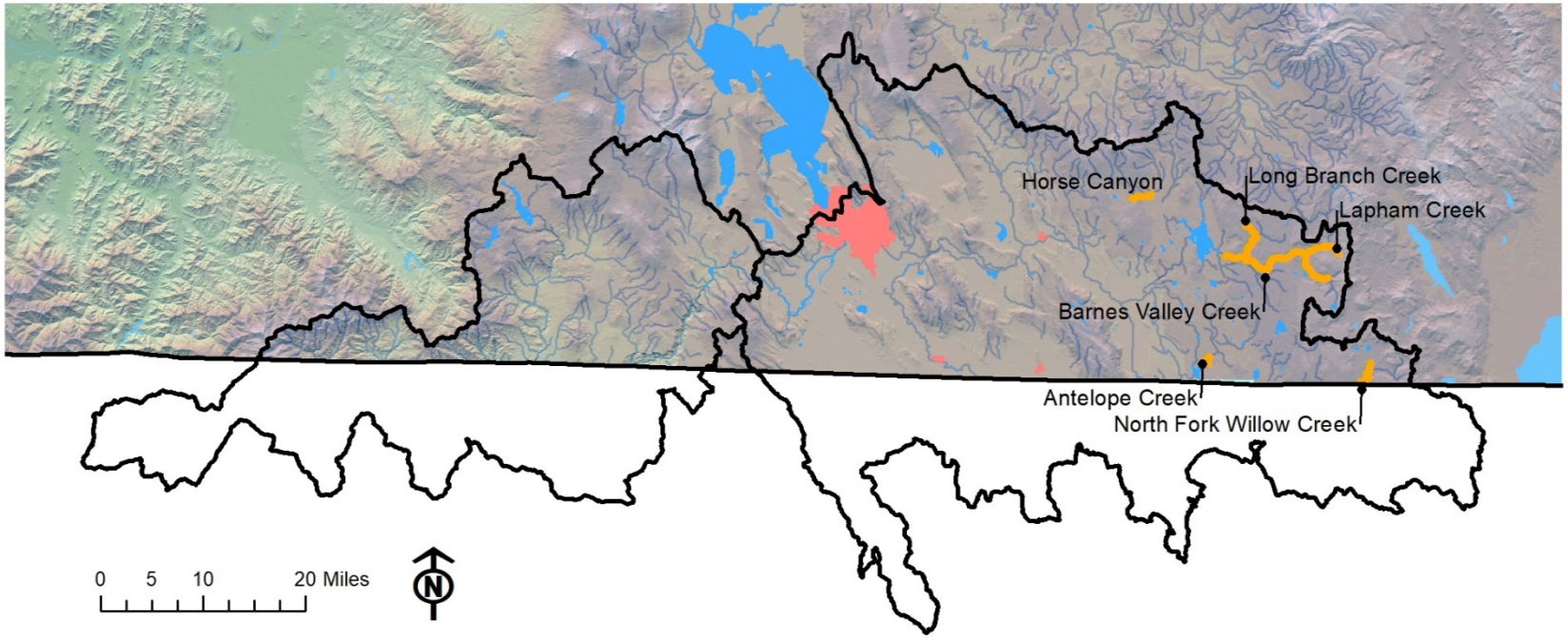
Analysis of TMDL Alternatives – Compliance Scenarios

Model Overview

River	Klamath River	Lost River	Tributaries
Model Extent	Upper Klamath Lake to Pacific Ocean	Malone Dam to Klamath Straits Drain	See Next
Model	CE-QUAL-W2, RMA, EFDC	CE-QUAL-W2	Heat Source
Model Period	2000 and 2002	1999 and 2004	July 2001, July 2005
Model Developer	Tetra Tech	Tetra Tech	ODEQ

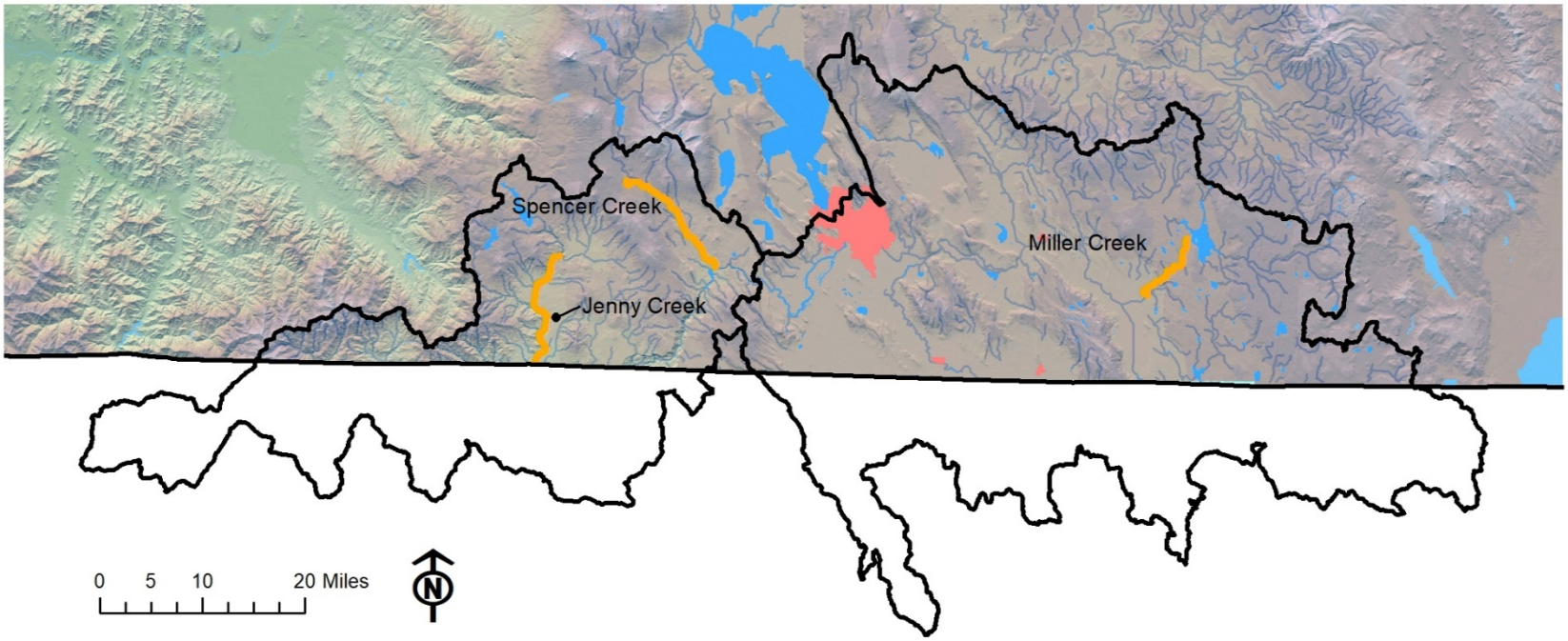
Tributary Solar Only Models

Model Output	Stream	Simulation Period	Simulation Extent
Solar Radiation and Effective Shade	Antelope Creek	July 15, 2005	1.77
	Barnes Valley Creek		23.9
	Horse Canyon		3.81
	Lapham Creek		7.44
	Long Branch		8.11
	North Fork Willow Creek		5.43



Tributary Temperature Models

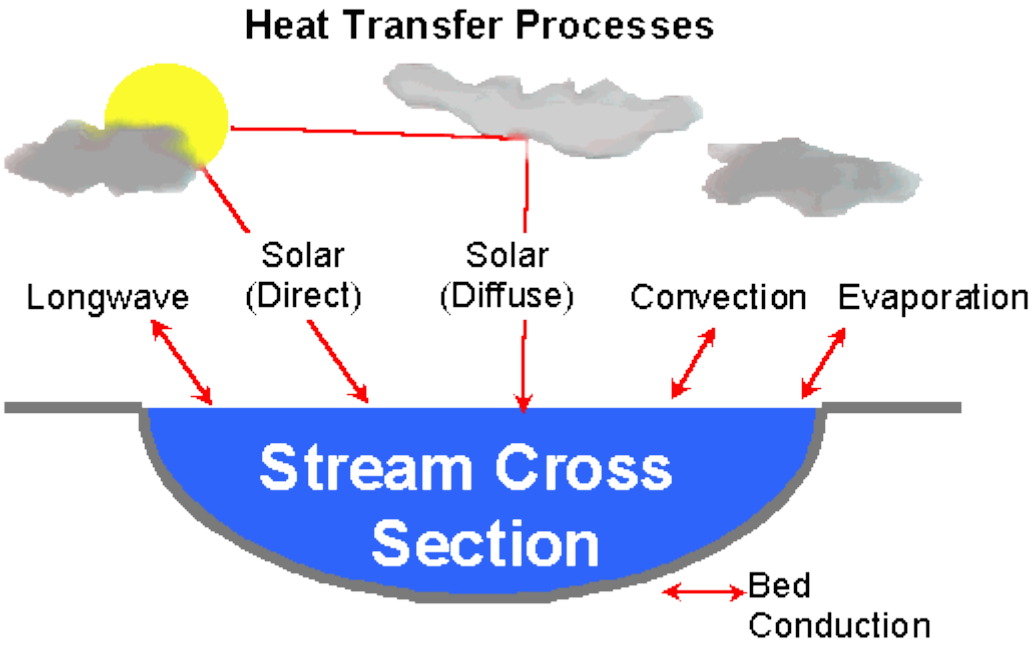
Model Output	Stream	Simulation Period	Simulation Extent
Temperature	Jenny Creek	July 2001	Confluence with Johnson Creek to OR/CA border: 23.7 km
	Spencer Creek	July 2001	Headwaters to mouth: 25.2 km
	Miller Creek	July – Early August 2001	Gerber Reservoir to mouth: 14.57 km

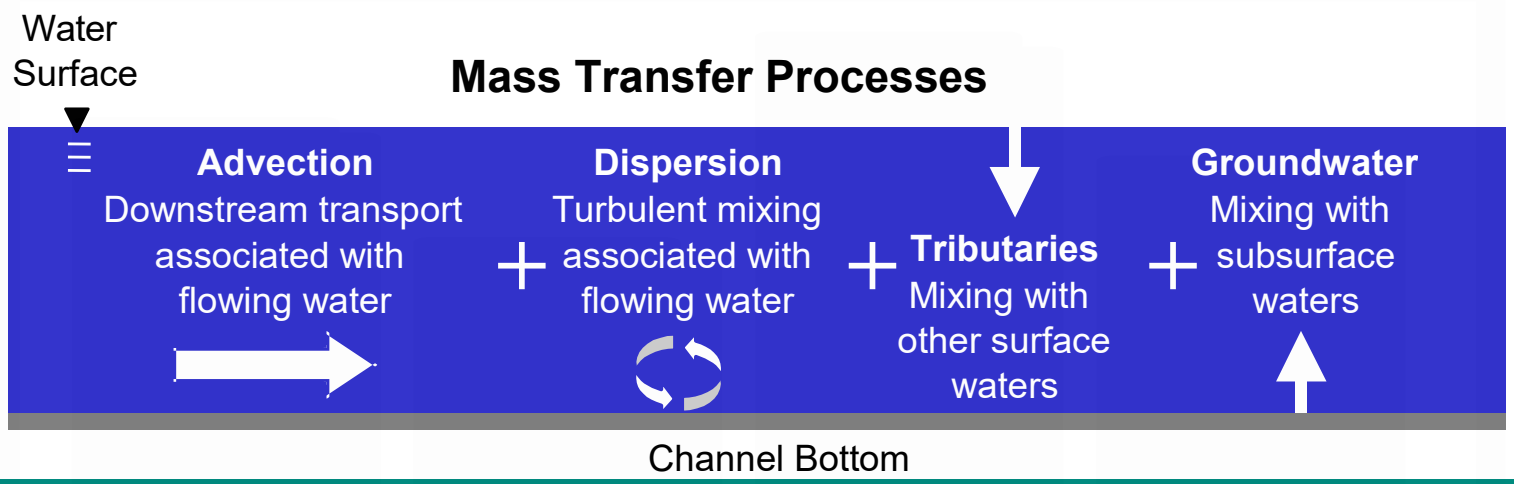


HEAT SOURCE

- Mechanistic model
- Simulates 1D open channel hydraulics, heat flux, mass transfer, and stream temperature
- Developed in 1996 at Oregon State University
- Independently peer reviewed
- Applied in multiple published studies
- Open source: https://github.com/rmichie/heatsource-9

http://www.deq.state.or.us/wq/TMDLs/tools.htm


Heat Transfer Processes
Longwave
Solar (Direct)
Solar (Diffuse)
Convection
Evaporation
Stream Cross Section
Bed Conduction


Water Surface
Mass Transfer Processes
Advection
Downstream transport associated with flowing water
Dispersion
Turbulent mixing associated with flowing water
Tributaries
Mixing with other surface waters
Groundwater
Mixing with subsurface waters
Channel Bottom

Model Inputs

Solar Modeling

Land Use/Land Cover

- Height / Elevation
- Canopy Closure / LAI
- Overhang
- Topographic Shade Angles

Stream Position

- Longitude
- Latitude

Channel Morphology

- Stream Elevation
- Gradient
- Bottom Width
- Channel Angle Z

Boundary Conditions and In/Out Flows

- Stream Temperature
- Stream Flow

Met Data

- Cloudiness
- Wind Speed
- Wind Coefficients “a” and “b”
- Relative Humidity
- Air Temperature

Substrate

- Deep Alluvium Temperature
- Sediment Thermal Conductivity
- Sediment Thermal Diffusivity
- Hyporheic zone thickness
- Percent Hyporheic exchange
- Porosity

Model Outputs

Temperature

- Stream Temperature
- Sediment Temperature

Flux

- Streambed Conduction
- Convection
- Evaporation
- Longwave
- Solar Radiation (Above Topography)
- Solar Radiation (Blocked by LULC)
- Solar Radiation (Above Stream Surface)
- Solar Radiation (Penetrating Stream)
- Effective Shade
- Thermal Radiation (Total)

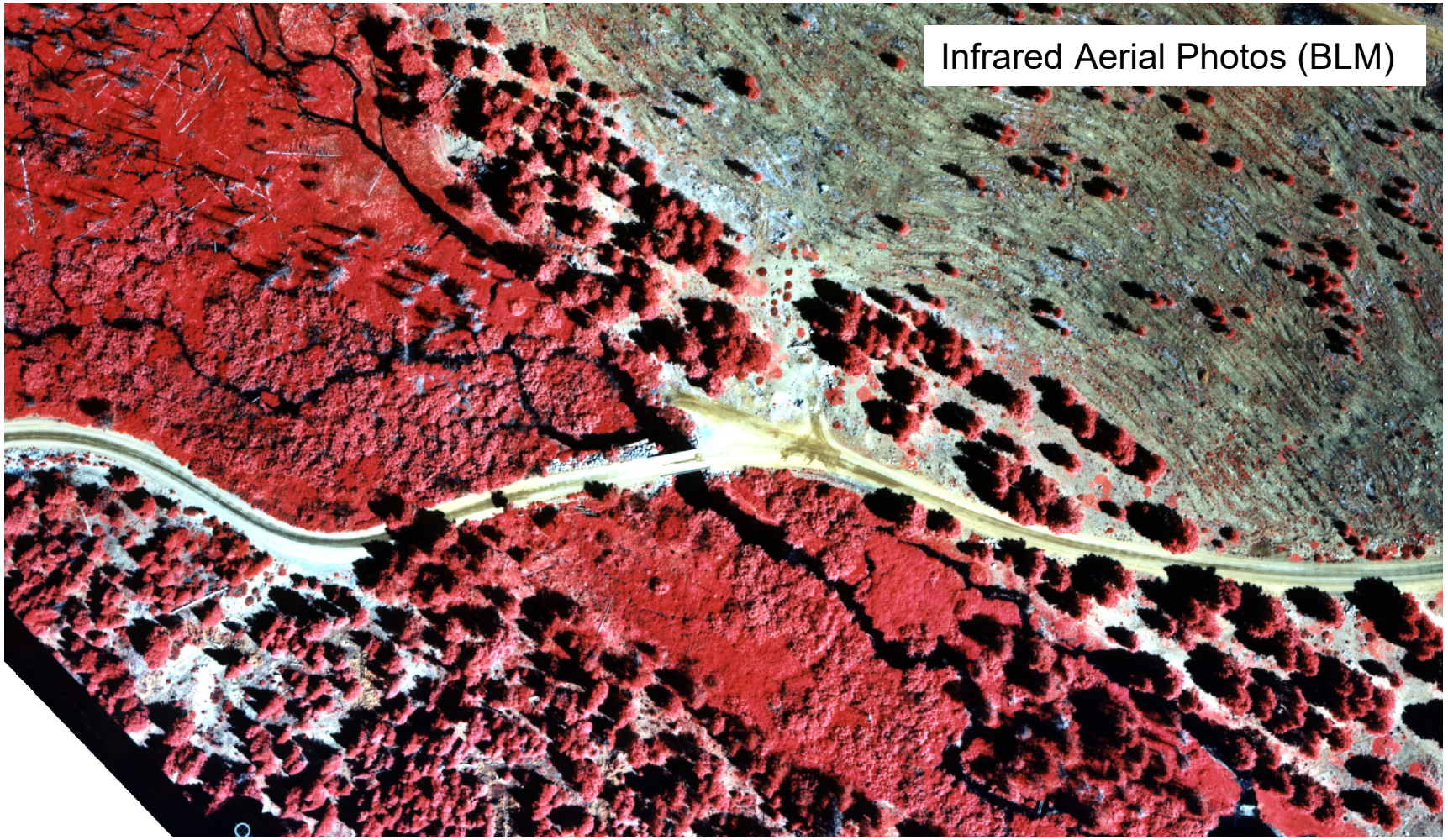
Hydraulics

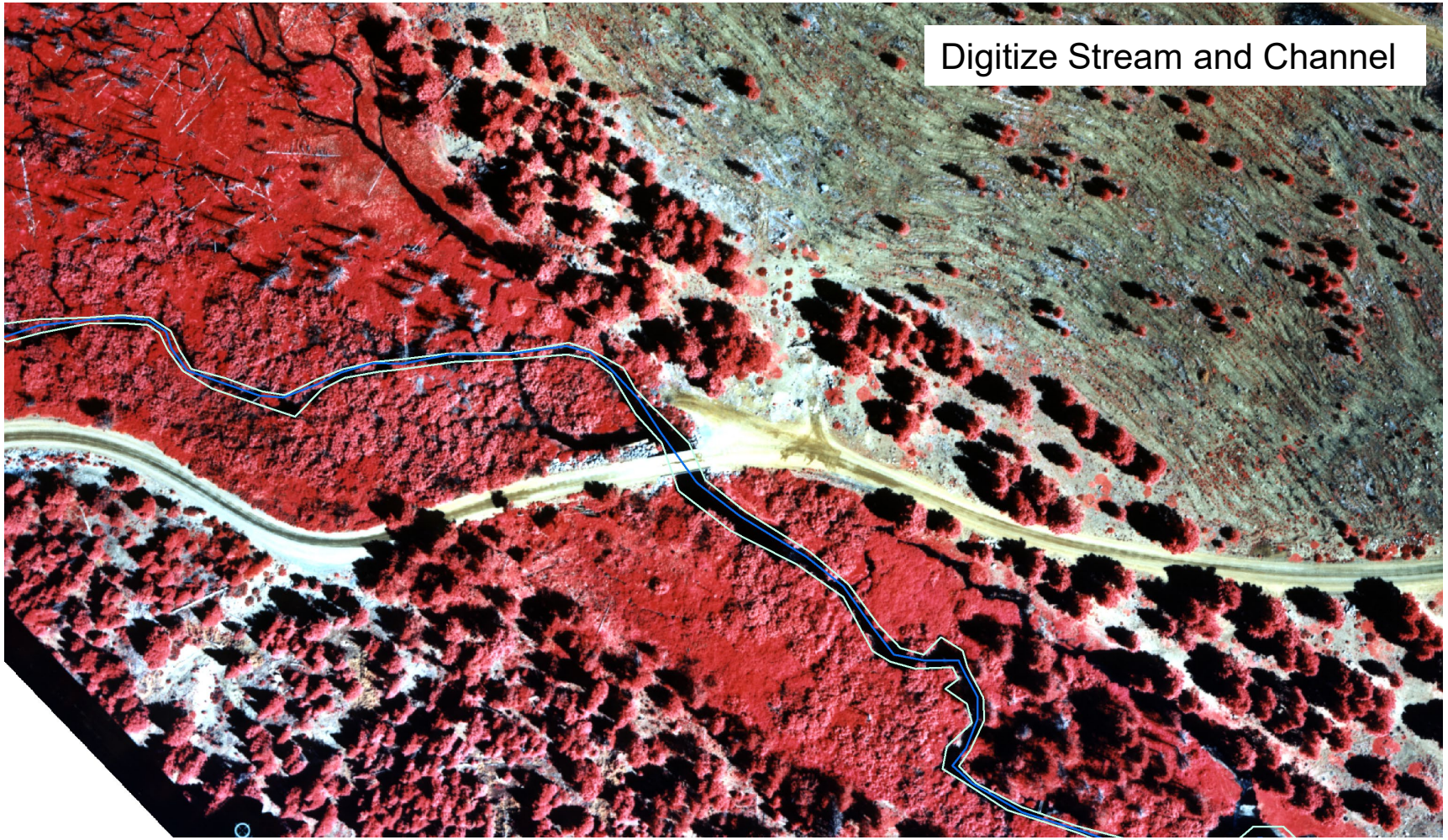
- Flow Rate
- Hyporheic Exchange (cms)
- Flow Velocity
- Top Wetted Width
- Average Wetted Depth
- Maximum Wetted Depth

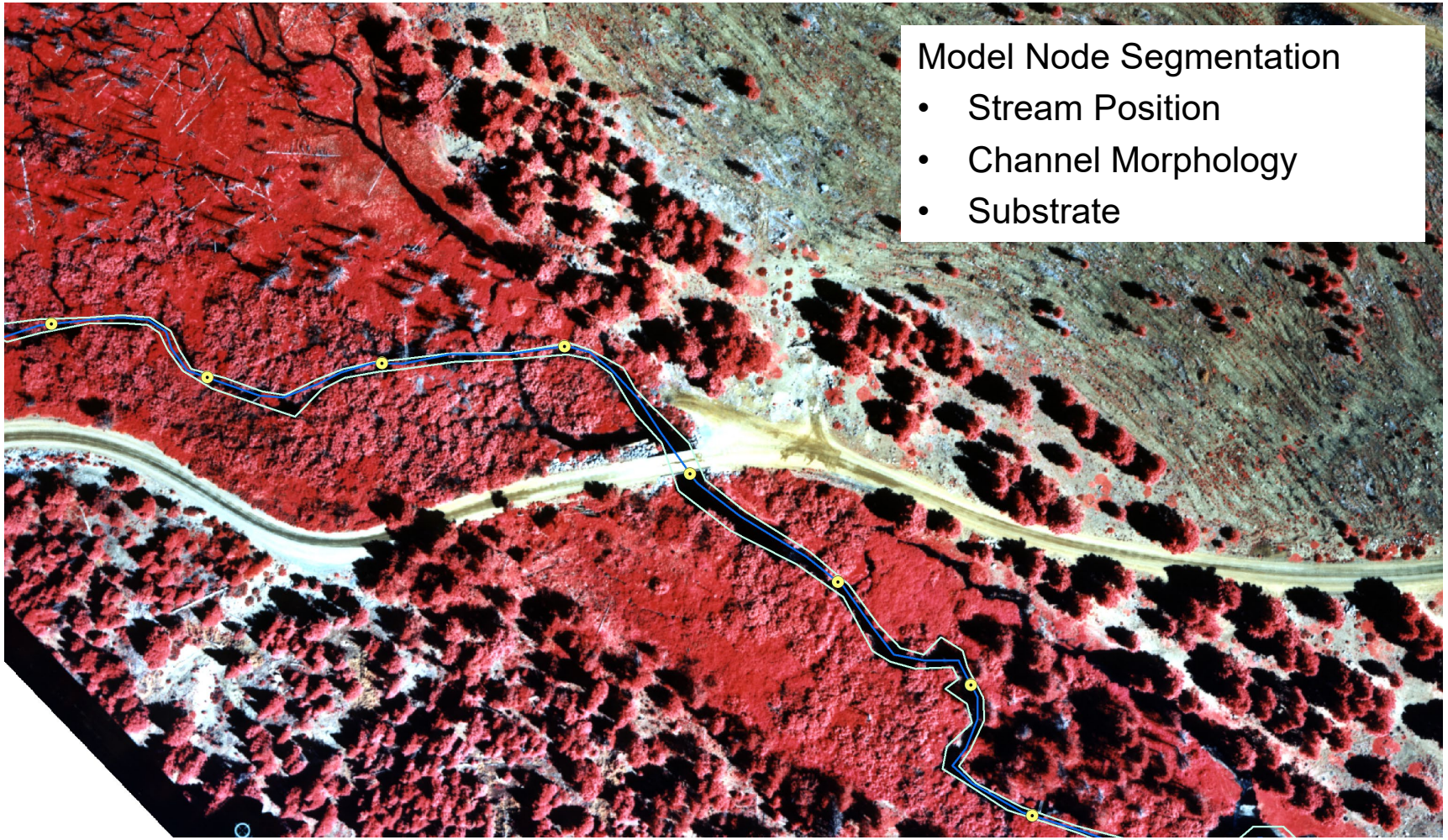
Others

- Hydraulic Dispersion (square meters/second)
- Evaporation Rate (mm/hour)
- View To Sky

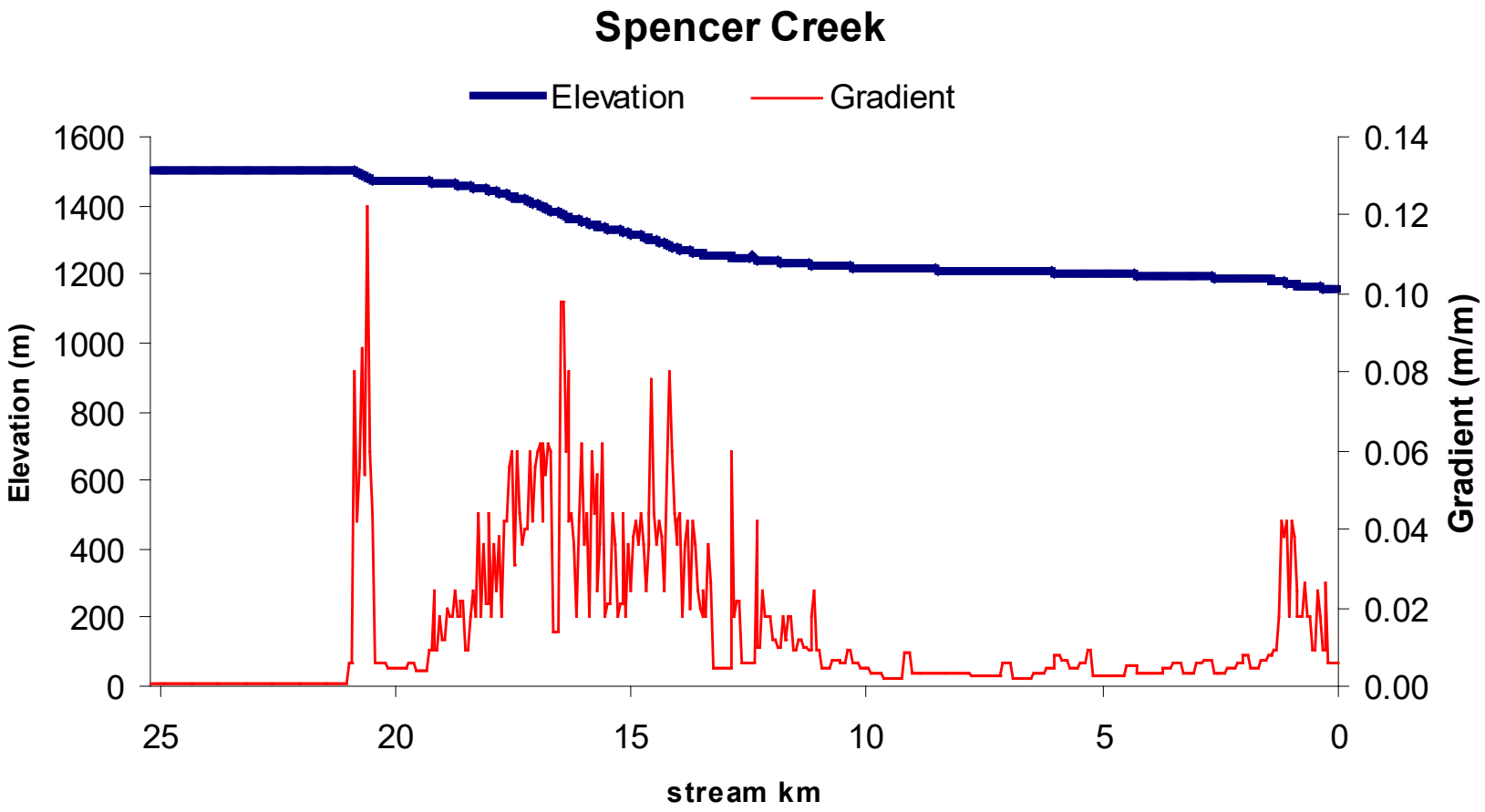
Spencer Creek at River Mile 7.75

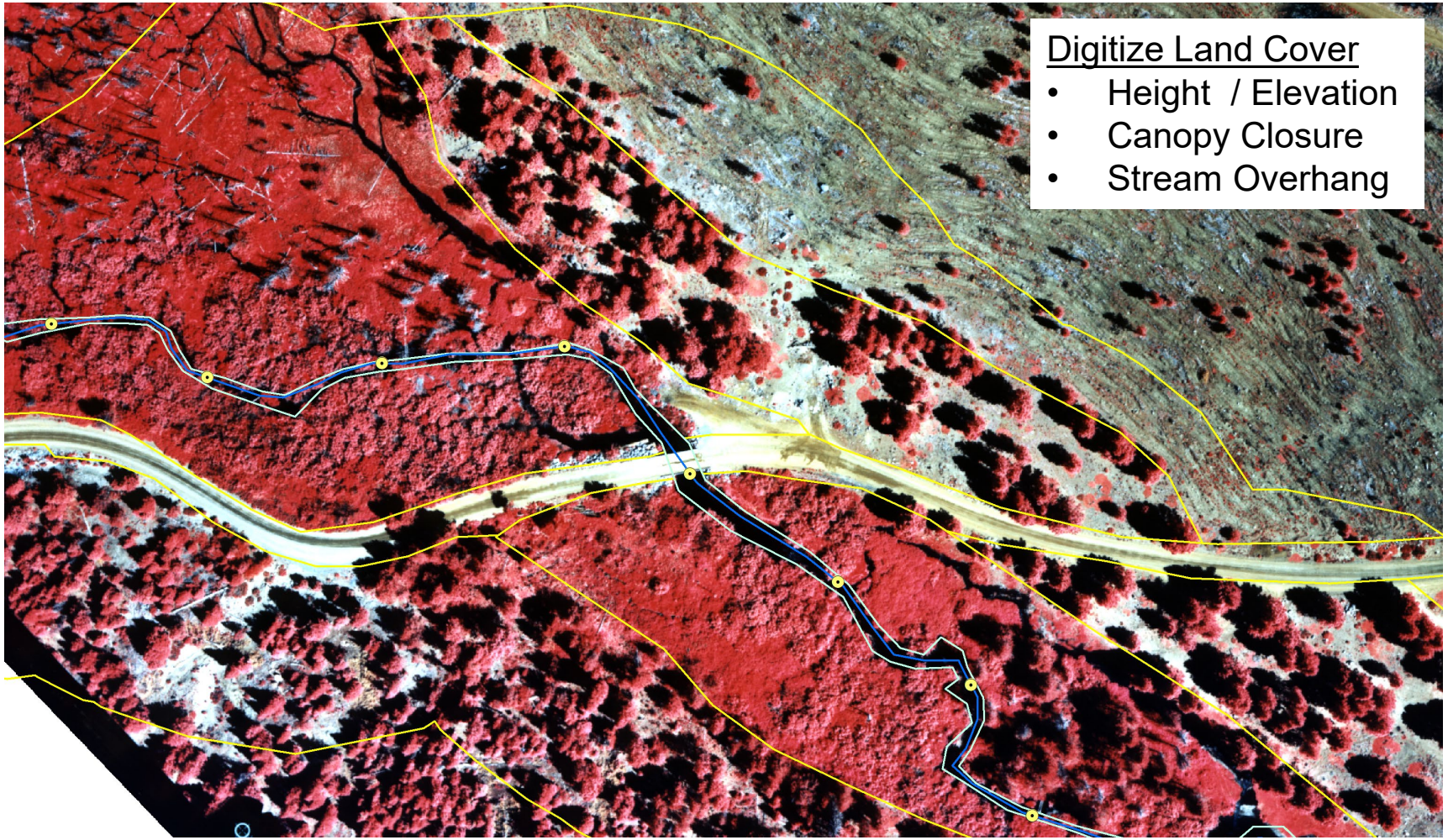




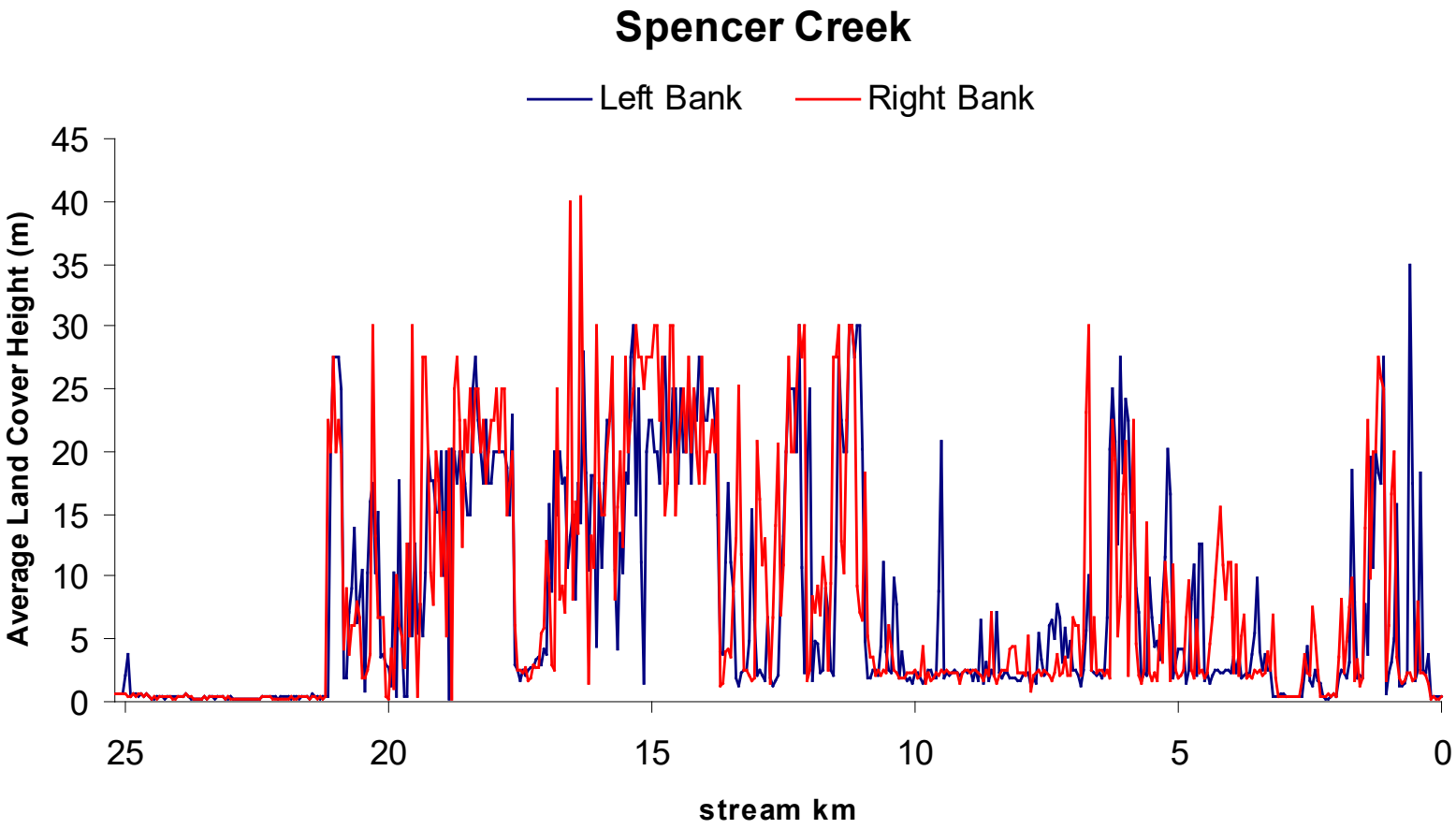


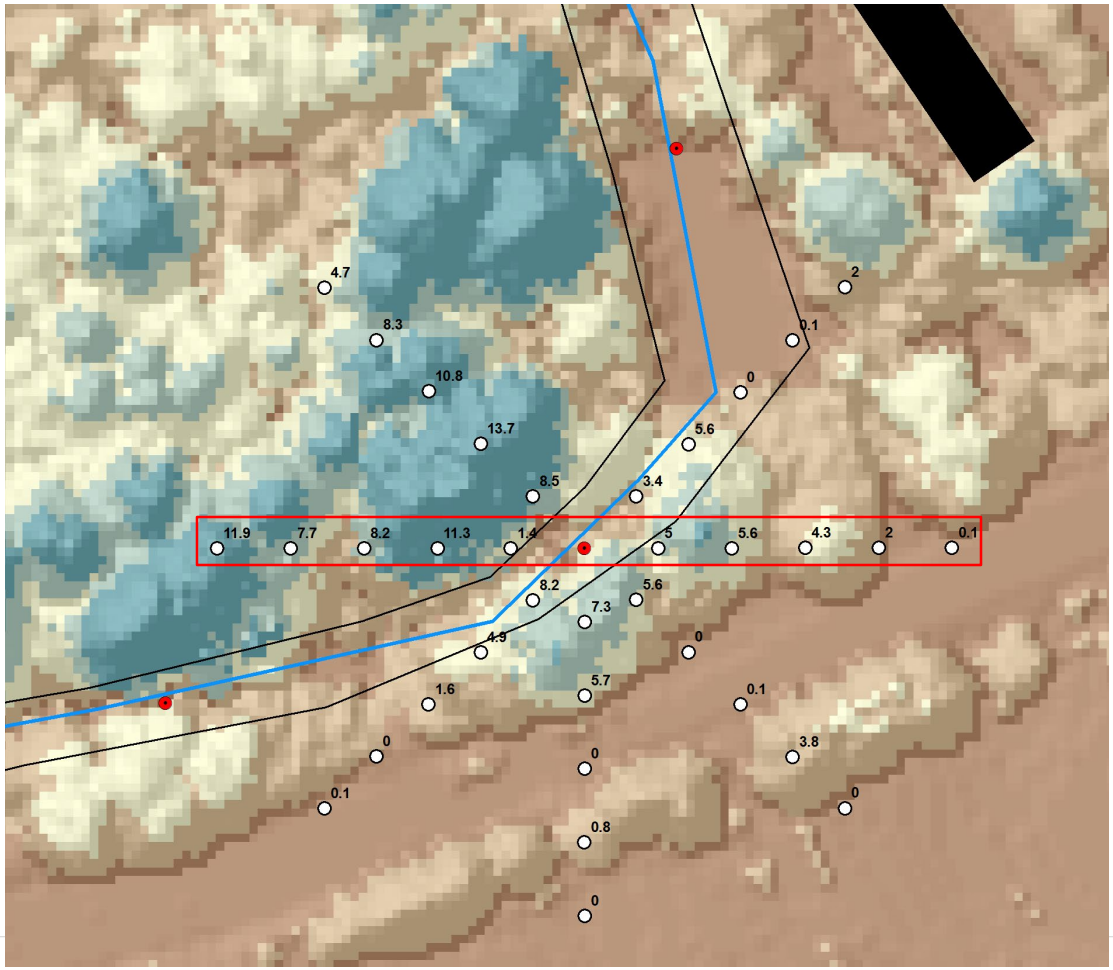
Spencer Creek Elevation and Gradient

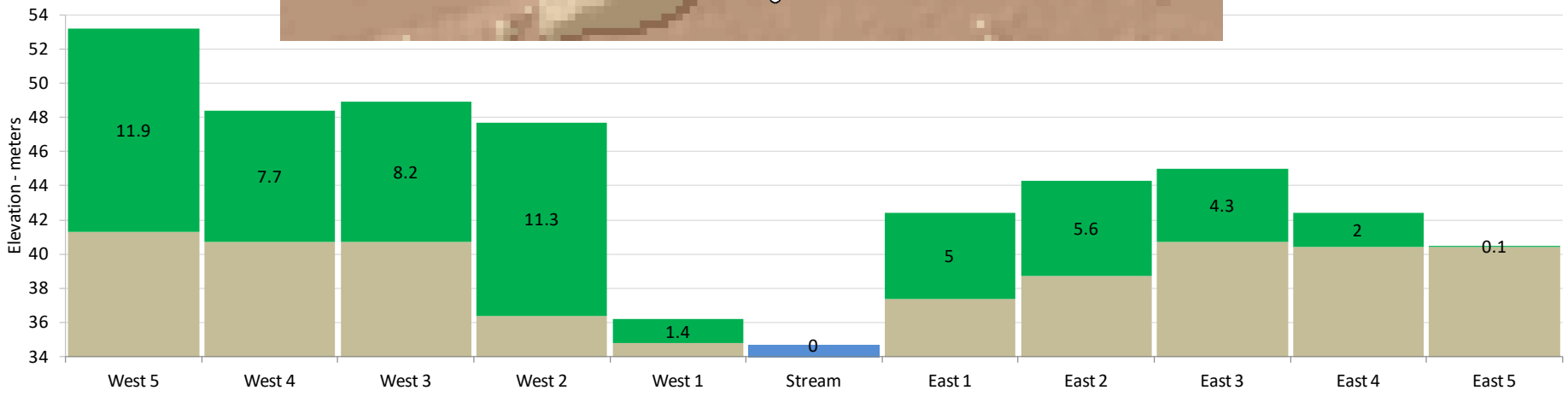




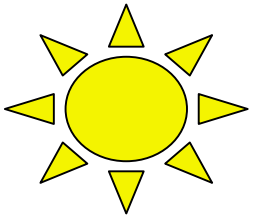
Spencer Creek Average Land Cover Height

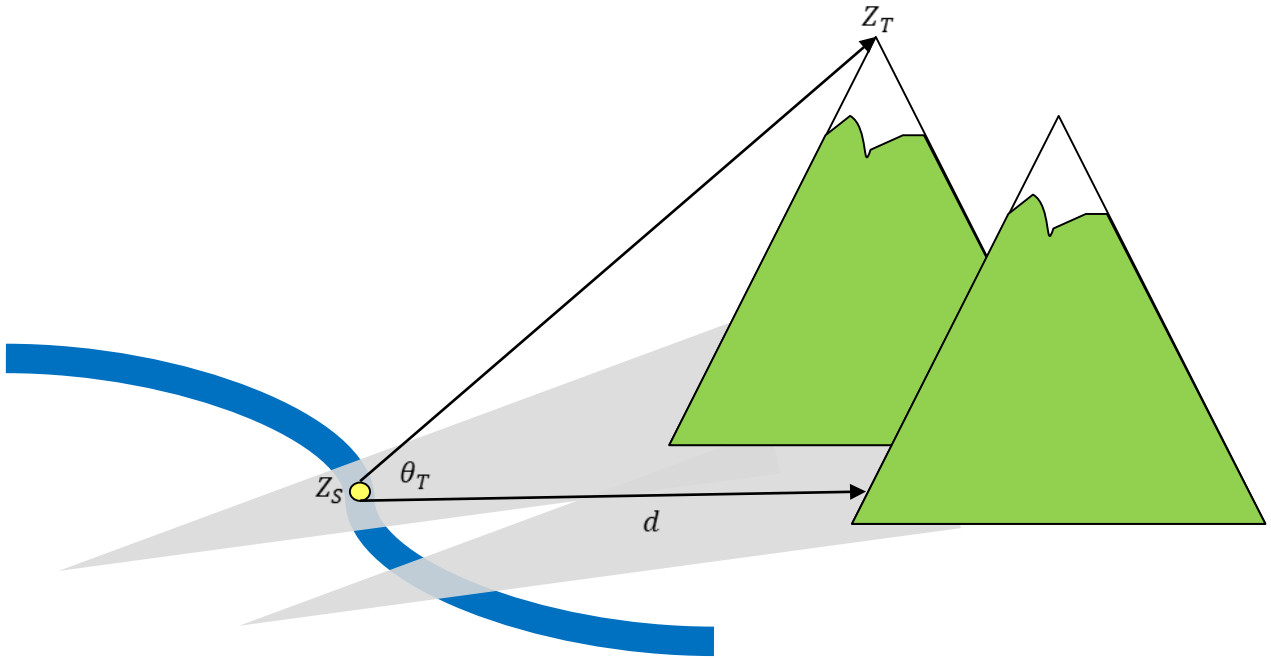



4.7
8.3
10.8
13.7
8.5
3.4
5.6
0
0.1
2
11.9
7.7
8.2
11.3
1.4
5
5.6
4.3
2
0.1
8.2
5.6
7.3
4.9
0
1.6
5.7
0.1
0
0
3.8
0.1
0
0.8
0


Elevation - meters
54
52
50
48
46
44
42
40
38
36
34
11.9
7.7
8.2
11.3
1.4
0
5
5.6
4.3
2
0.1
West 5
West 4
West 3
West 2
West 1
Stream
East 1
East 2
East 3
East 4
East 5

Calculate Topographic Shade Angles



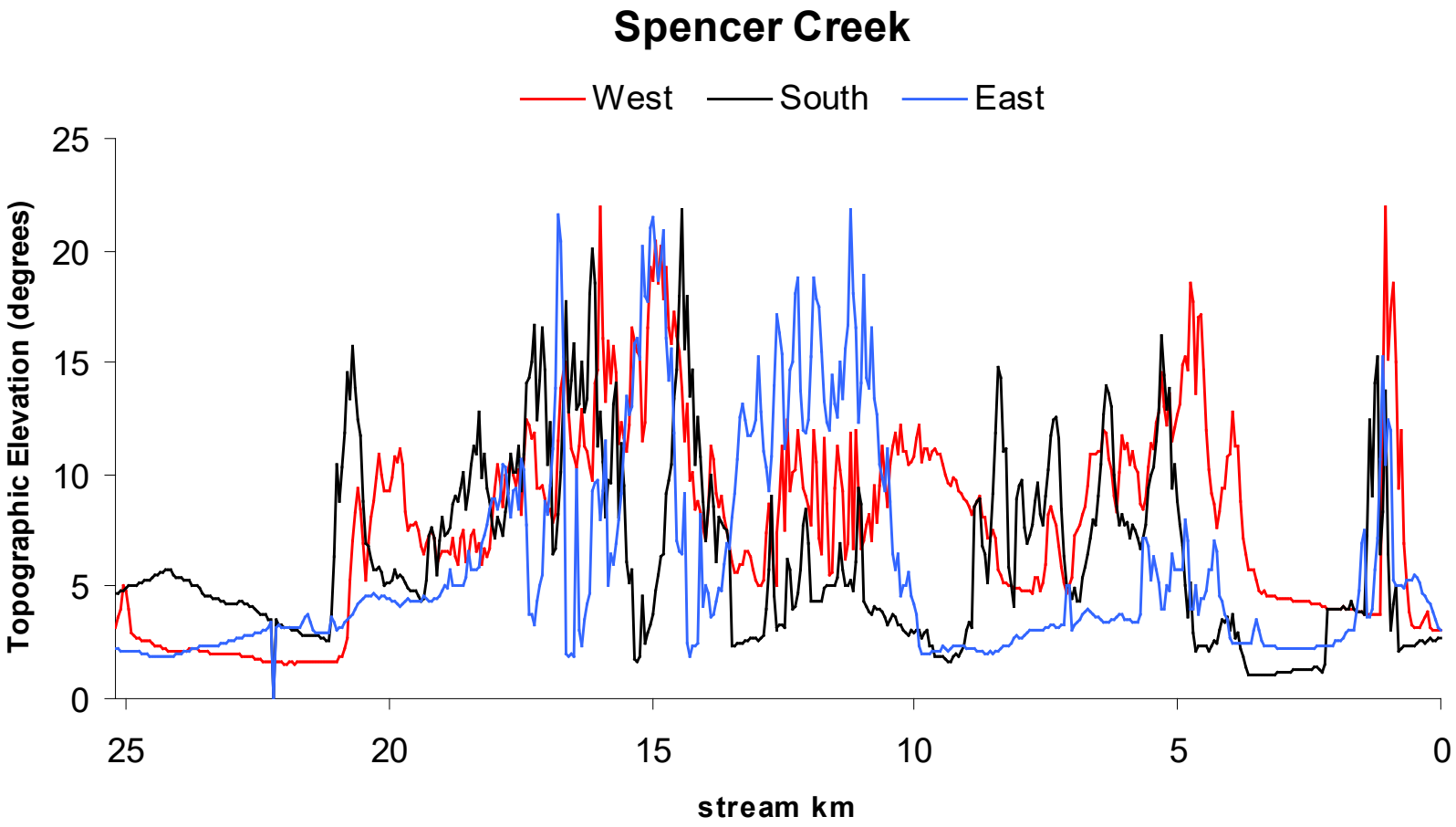


$$\theta_T = \tan^{-1}\left(\frac{Z_T - Z_S}{d}\right)$$ **Topographic Shade Angle**

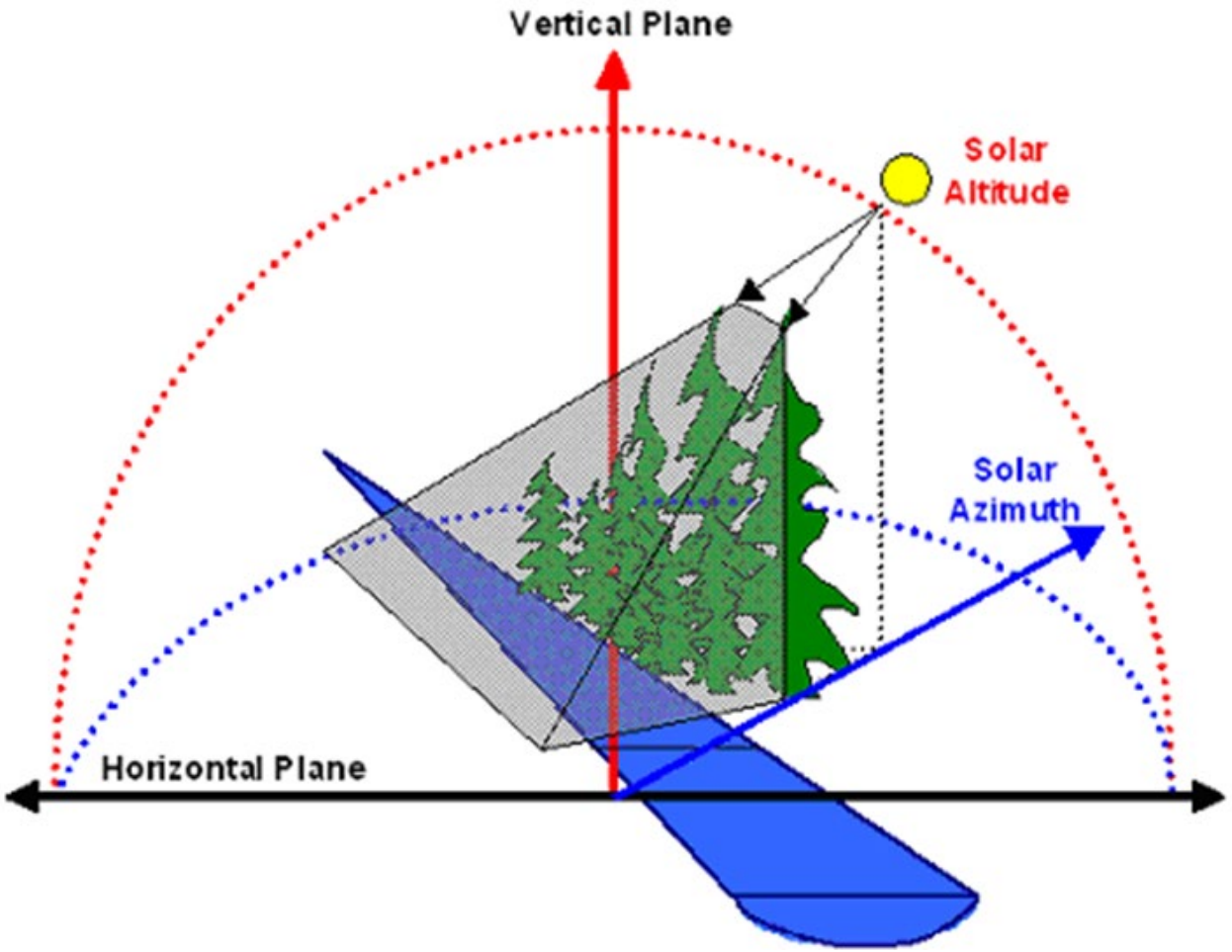
where,

$\theta_T =$	The topographic shade angle (degrees)
$Z_T =$	The elevation (meters) at the topographic feature.
$Z_S =$	The elevation (meters) at the stream node.
$d =$	Horizontal distance (meters) from the stream node to the topographic feature.

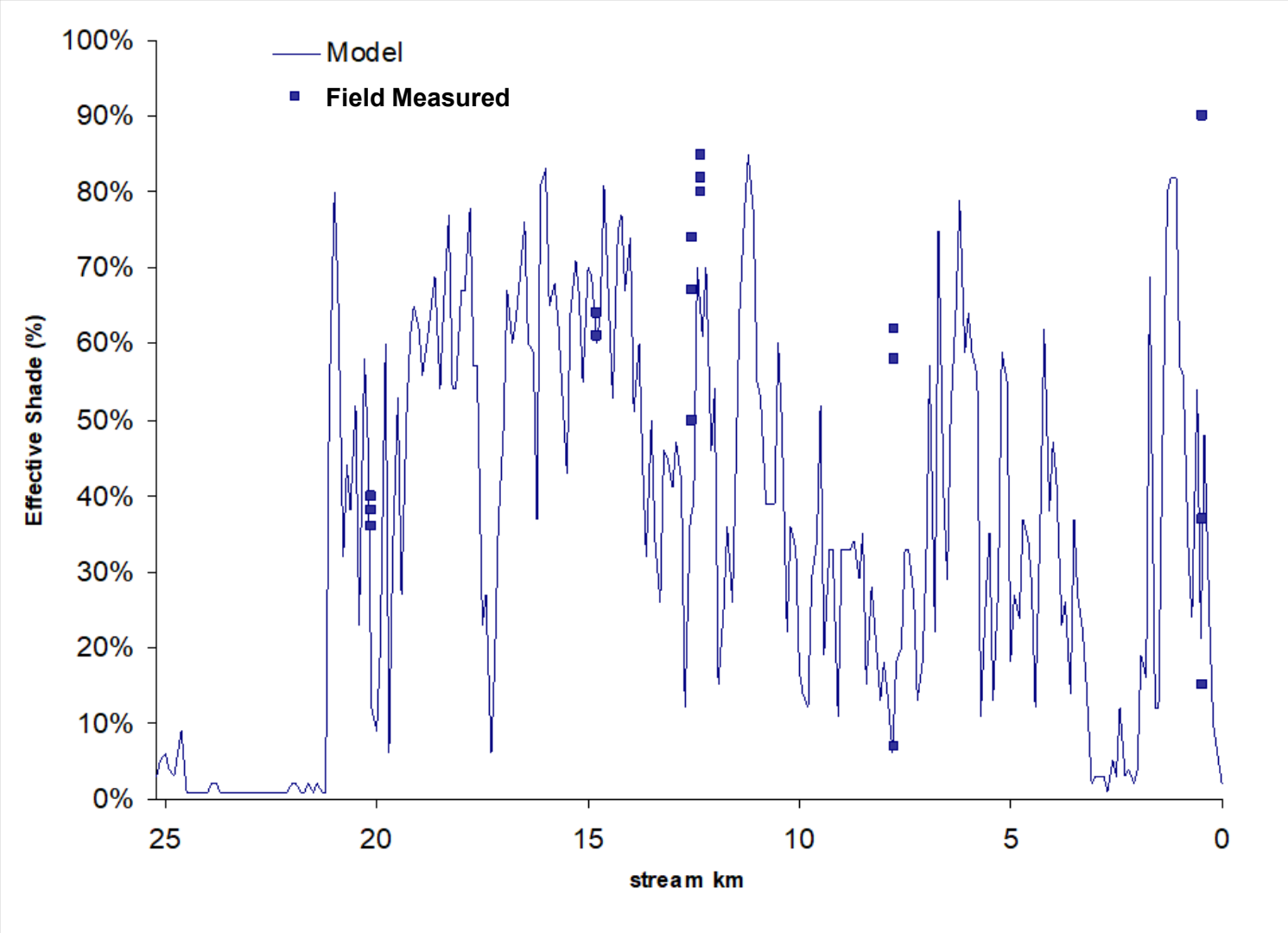
Spencer Creek Topographic Shade Angles



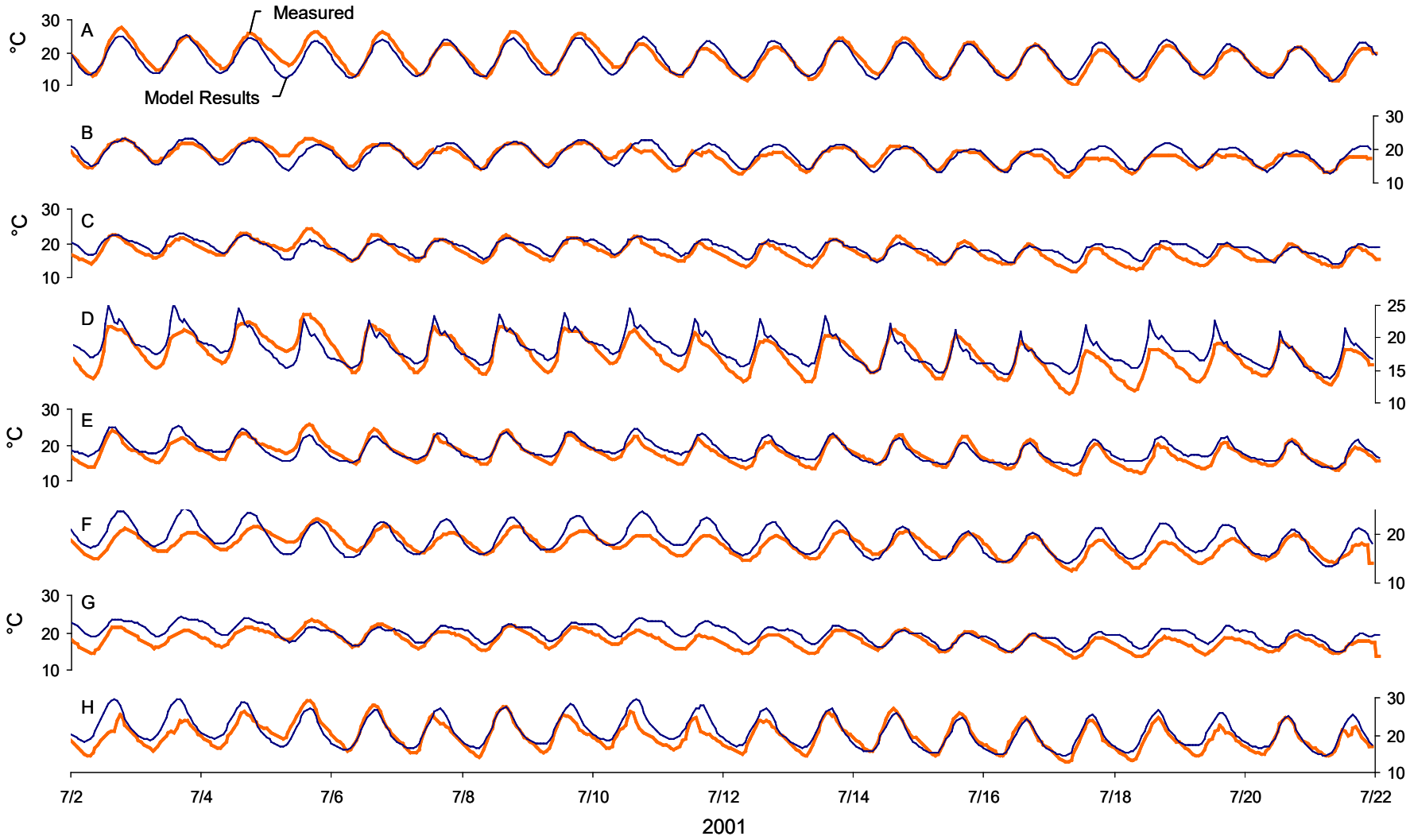
Solar Path and Flux Modeling



Spencer Creek Effective Shade



Spencer Creek Hourly Temperature



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Spencer Creek Model Error Statistics

				All data				
Ref	Site Name	Site #	KM	n	Mean Error	Abs Mean Error	RMSE	Nash-Sutcliffe
A	Spencer Cr. at outlet of Buck Lake	4920	21.1	480	-0.37	1.32	1.63	0.84
B	Spencer Cr. (section 17)	4800	18.8	480	0.38	1.26	1.62	0.60
C	Spencer Cr. (section 21)	4600	16.95	480	1.09	1.52	1.85	0.50
D	Spencer Cr. (section 28)	4300	14.7	480	0.89	1.41	1.71	0.57
E	Spencer Cr. upstream from Hook-Up Road (section 34)	4100	12.7	480	0.75	1.33	1.60	0.70
F	Spencer Cr. at upstream end of meadow (Broken Bridge)	4000	9.95	480	1.06	1.67	2.04	0.06
G	Spencer Cr. at downstream end of meadow	3985	7.4	480	1.78	1.95	2.32	-0.20
H	Spencer Cr. at mouth	3800	0.5	480	1.14	1.77	2.32	0.57
	Average				0.84	1.53	1.88	0.46

Source Assessment and Management Strategy Model Scenarios

1. Streamside vegetation restoration/protection (system potential vegetation)
2. Instream flow restoration
3. Dam removal (Klamath River)

Spencer Creek System Potential Vegetation Model Scenario

Model Scenario Elements

- Restoring streamside vegetation in areas to minimize anthropogenic loading of solar radiation.
- Protecting existing streamside vegetation and actively managing it to a mature stand in order limit new anthropogenic loading of solar radiation.
- Buck Lake is assumed to be returned to a more natural hydrological state of a wetland meadow with emergent vegetation.

Spencer Creek Site Potential Vegetation

Three habitat units were identified in Spencer Creek Watershed. Site potential vegetation types were characterized for each habitat unit.

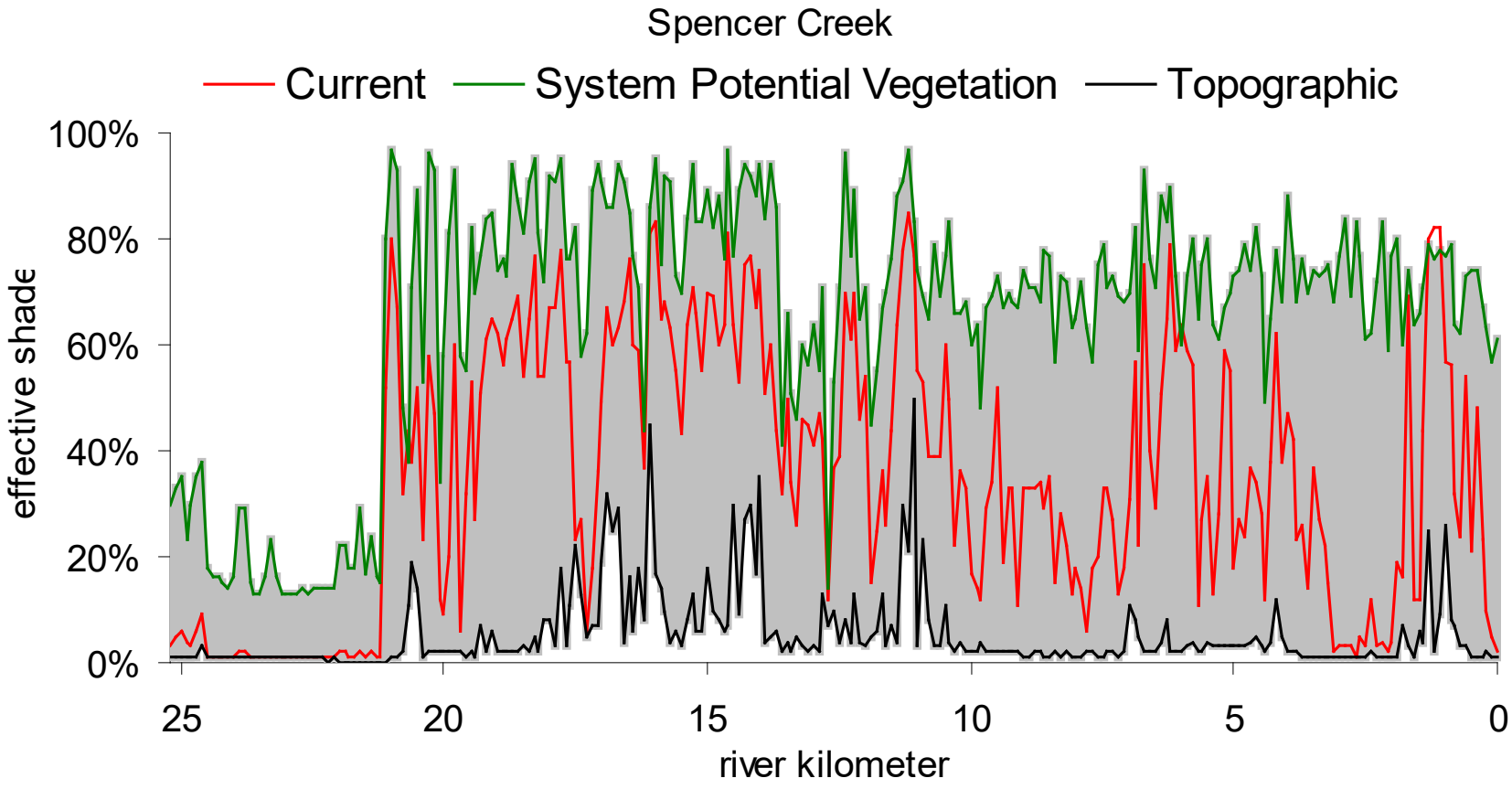
Buck Lake

Vegetation Type	Height (m)	Density (%)	Overhang (m)	Prevalence in model (%)	Potential Vegetation Type	Potential Height (m)	Potential Density (%)	Potential Overhang (m)
Shrubs and grasses floodplain / riparian (Upper watershed)	2.5	25	1.0	2	Riparian shrubs-Upper watershed	3.6	75	1.0
Shrubs and grasses floodplain / riparian (Lower watershed)	2.5	25	1.0	4	Riparian shrubs-Lower watershed	12.2	75	2.0
Grasses - upland	0.5	75	0.3	0	Ponderosa Pine - Large	30.0	60	2.0
Grasses - wetland (Buck Lake)	0.5	100	0.0	1	Wetland Complex - Buck Lake	2.3	75	0.3
Grasses - wetland (Upper watershed)	0.5	100	0.0	2	Riparian shrubs-Upper watershed	3.6	75	1.0
Grasses - wetland (Lower watershed)	0.5	100	0.0	1	Riparian shrubs-Lower watershed	12.2	75	2.0
Active Channel Bottom	0.0	0	0.0	0	Active Channel Bottom	0.0	0	0.0
Pine plantation	10.0	75	1.0	0	Ponderosa Pine - Large	30.0	60	2.0
Dense pine on floodplain	30.0	75	1.0	2	Ponderosa Pine - Large	30.0	60	2.0

Upper Watershed

Note: this table only presents a partial list of site potential vegetation types developed for the Spencer Creek Watershed.

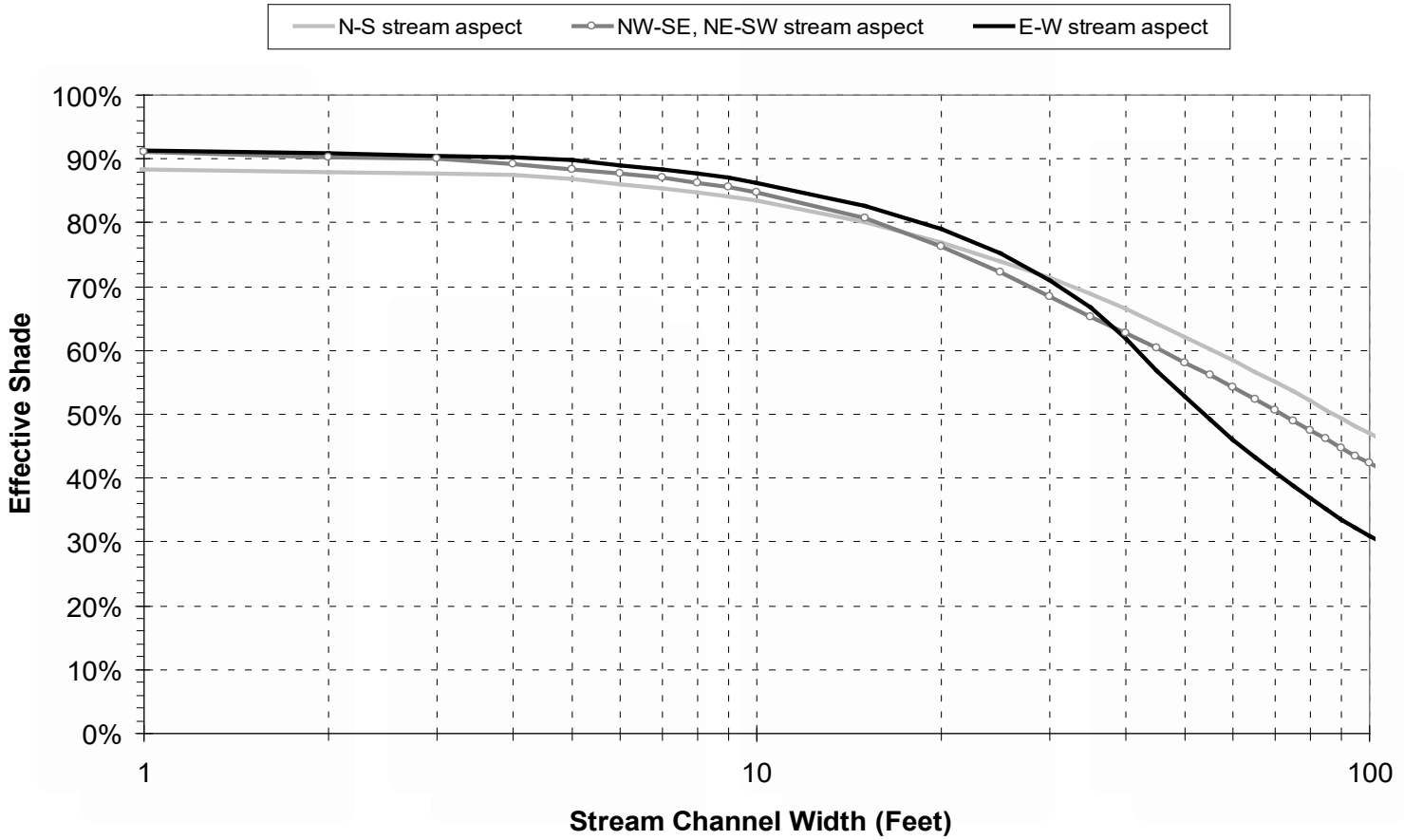
Lower Watershed



Spencer Creek Watershed

Ponderosa Pine

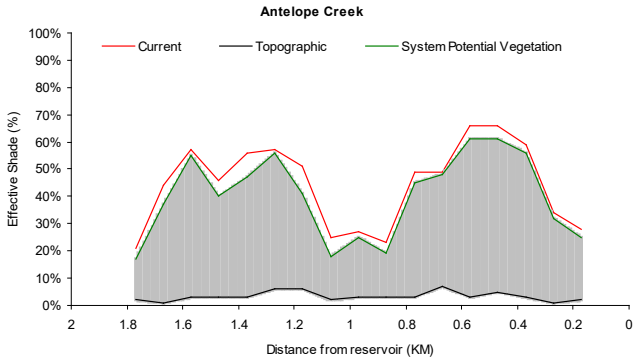
Height: 30.0m, Density: 60%, Overhang: 2.0m

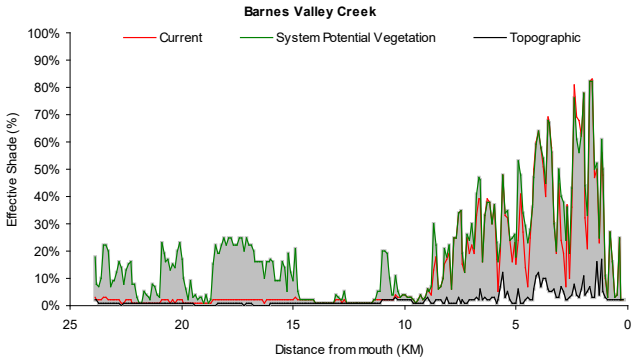


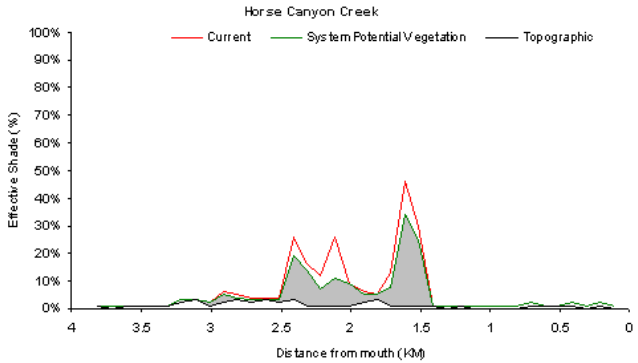
Lost River Subbasin Site Potential Vegetation

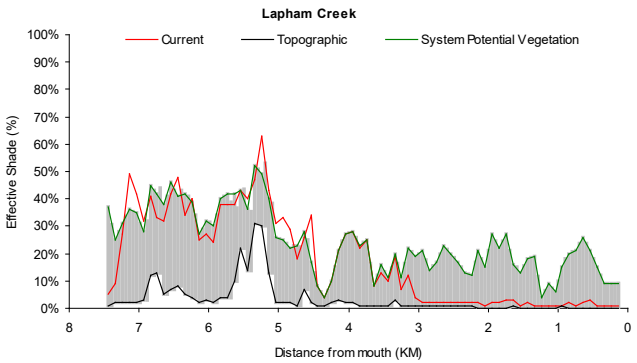
Vegetation Description	Height (m)	Canopy Closure (%)	Stream Overhang (m)
Large Conifer	30.5	60%	2.1
Large Conifer	30.5	30%	2.1
Western Juniper/Pine Mix	15.2	60%	0.9
Western Juniper/Pine Mix	15.2	30%	0.9
Shrubs with Ponderosa Pine mix	30.5	10%	0.9
Non-Riparian Juniper	9.1	60%	0.5
Non-Riparian Juniper	9.1	30%	0.5
Sagebrush / Grasses Mix	0.9	30%	0.3
Wetland Shrubs / Warm Willow	4.6	30%	0.9
Wetland Grasses	0.9	30%	0.3
Meadow	0.3	70%	0.3

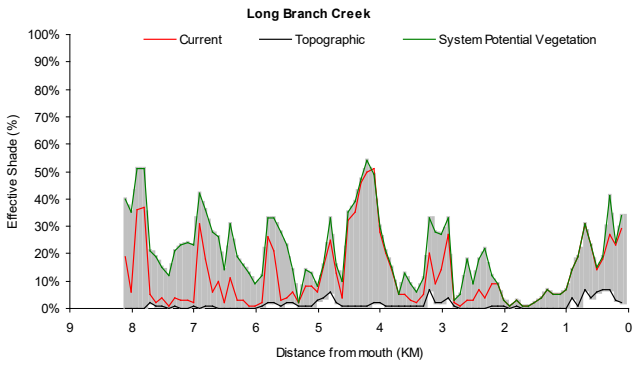
Lost River Subbasin Site Specific Effective Shade

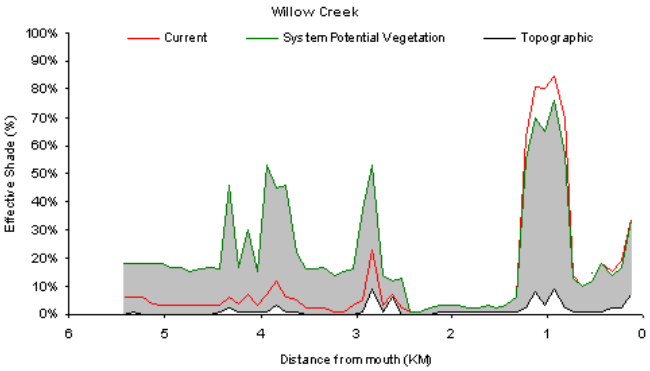












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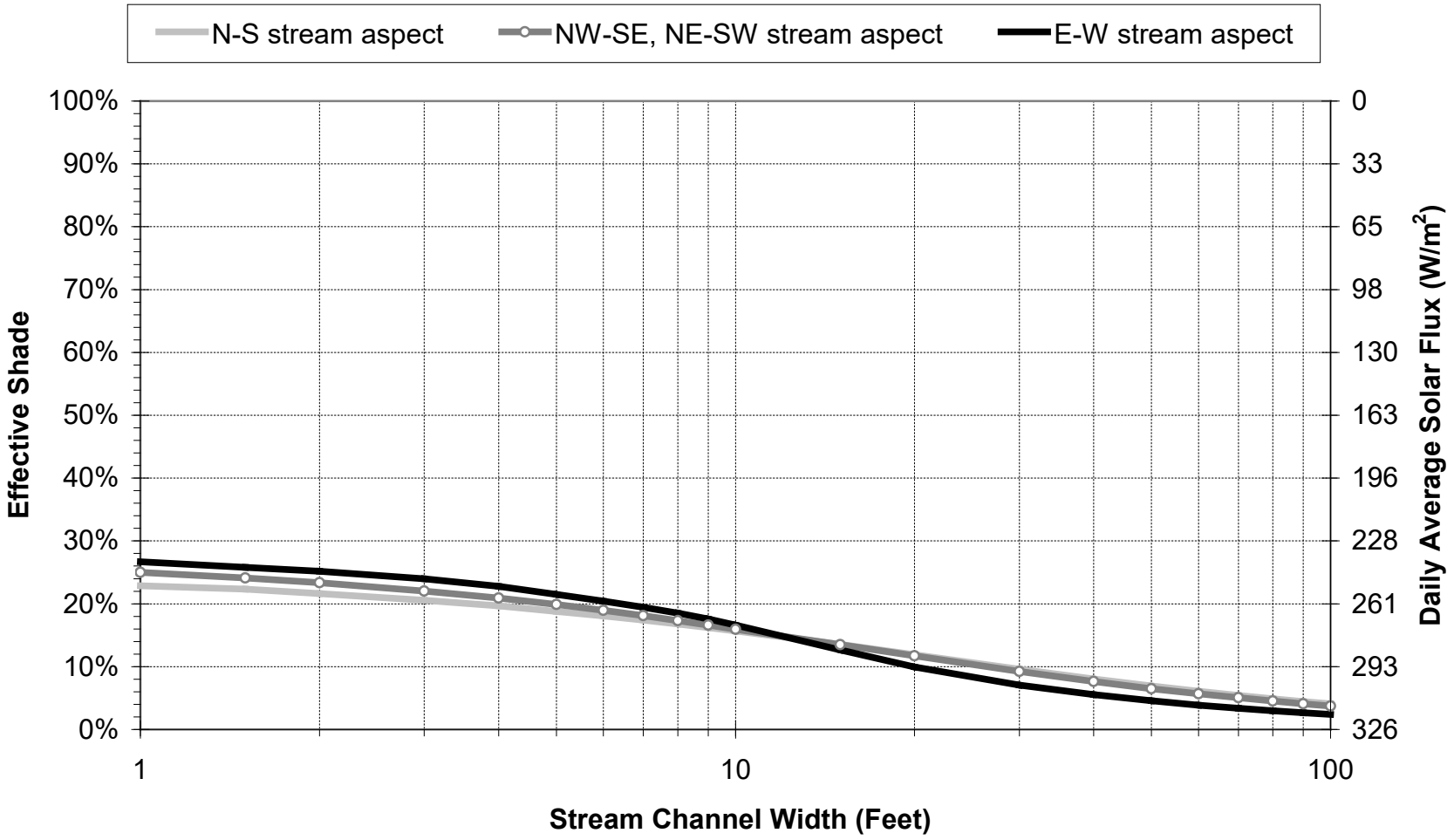
Lost River Subbasin

Shrubs with Ponderosa Pine Mix

Height: 31 m Density: 10% Overhang: 0.9 m



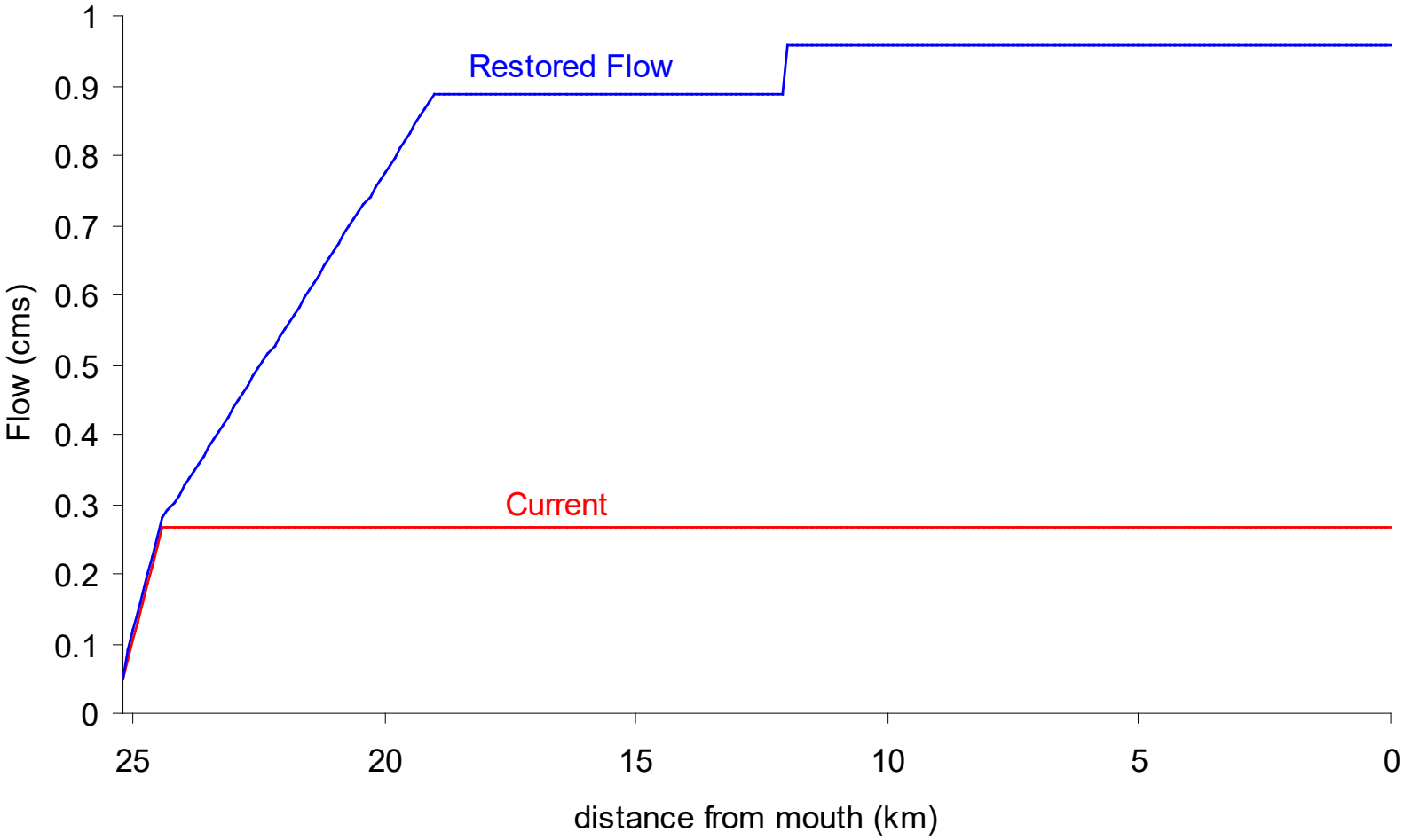
Spencer Creek Restored Stream Flow Model Scenario

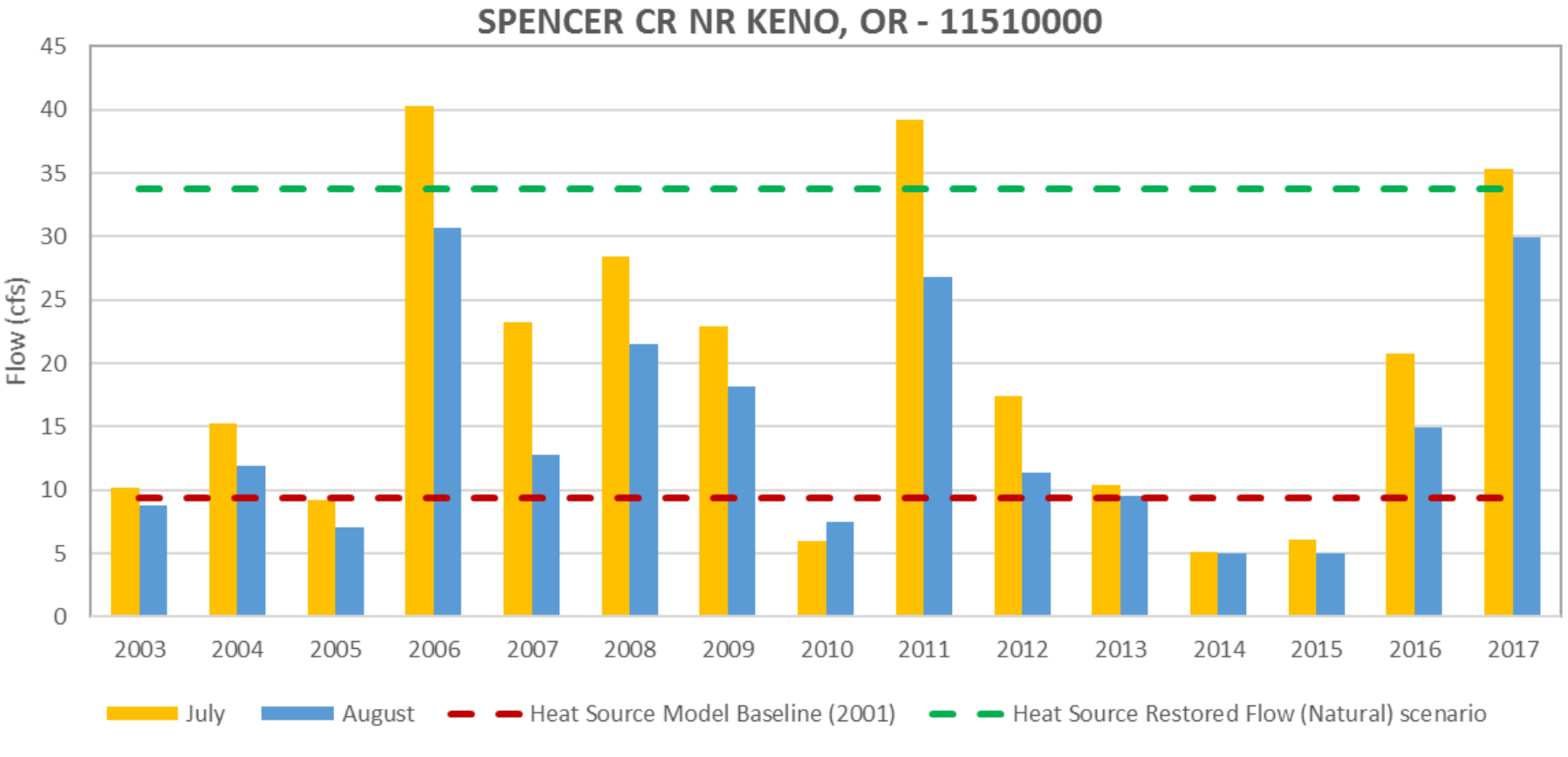
Model Scenario Elements

- Stream flows were set to the 50th percentile natural flow based on a study by OWRD (OWRD 2002)
- Accretion flow was added upstream of the USFS boundary to represent spring inflow around Buck Lake.

Oregon Water Resources Department. 2002. Determining Surface Water Availability in Oregon, Open File Report SW 02-002, by Richard M Cooper, Salem, Oregon.

Spencer Creek Restored Stream Flow Model Scenario





Spencer Creek Model Scenario Results

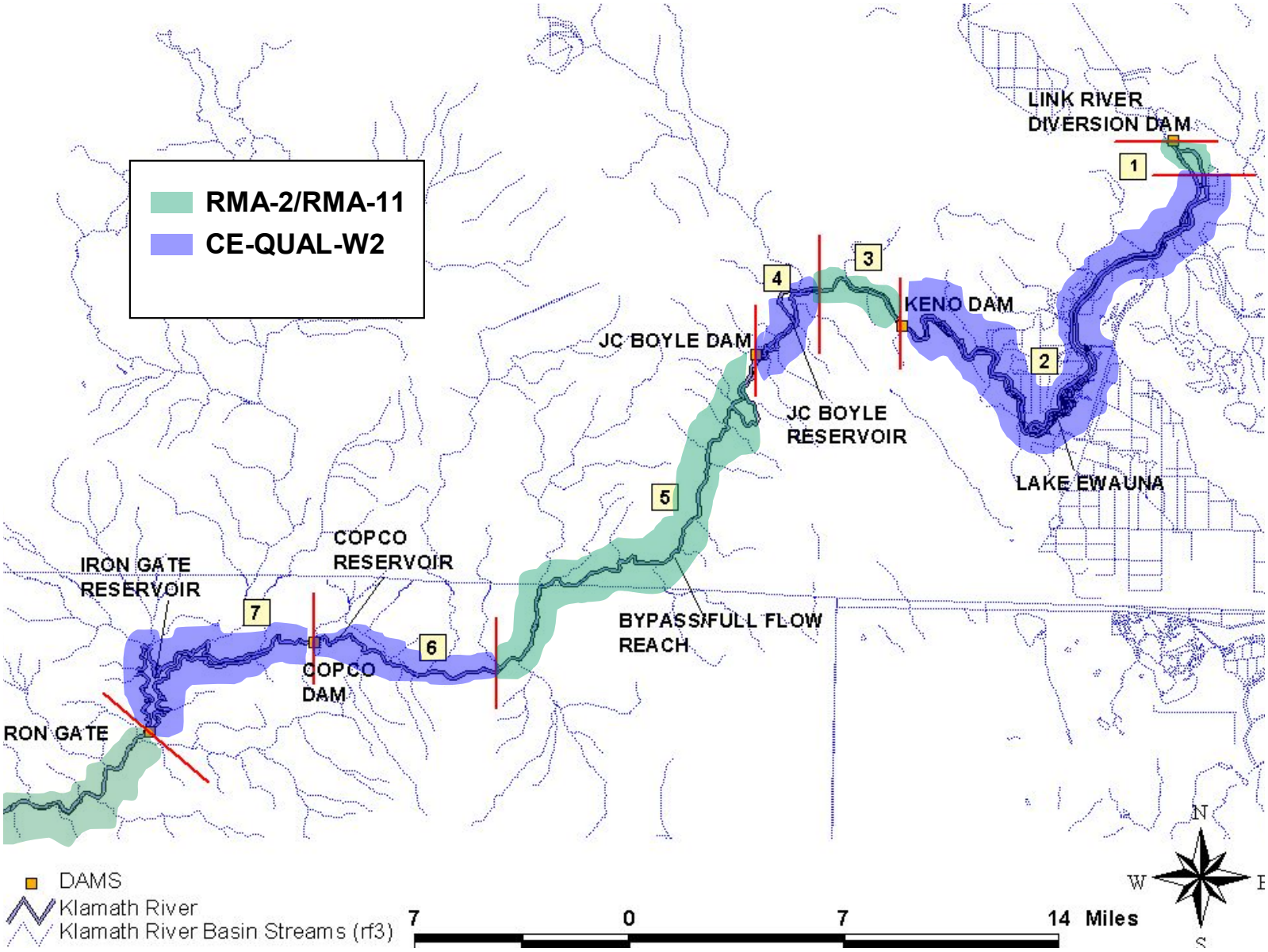
Spencer Creek Model Scenario Results

- Vegetation restoration and protection management strategies will increase effective shade above current conditions on average 30 percentage points and by as much as 82 percentage points in some locations. The mean 7DADM temperature reduction is 3.5 ^{o}C with a maximum 7DADM reduction of 7.9 ^{o}C at the point of maximum impact (stream kilometer 2.0, river mile 1.2).

- Restoring instream flow will reduce 7DADM temperatures by 5.5 ^{o}C on average and by as much as 9.0 ^{o}C at the point of maximum impact (stream kilometer 2.0)

- Restoring and protecting both streamside vegetation and instream flow will achieve the 20^{o}C applicable temperature standard in Spencer Creek. The mean 7DADM temperature reduction is 7.2 ^{o}C with a maximum 7DADM reduction of 11.8 ^{o}C at the point of maximum impact (stream kilometer 2.0).

Klamath River Model Overview



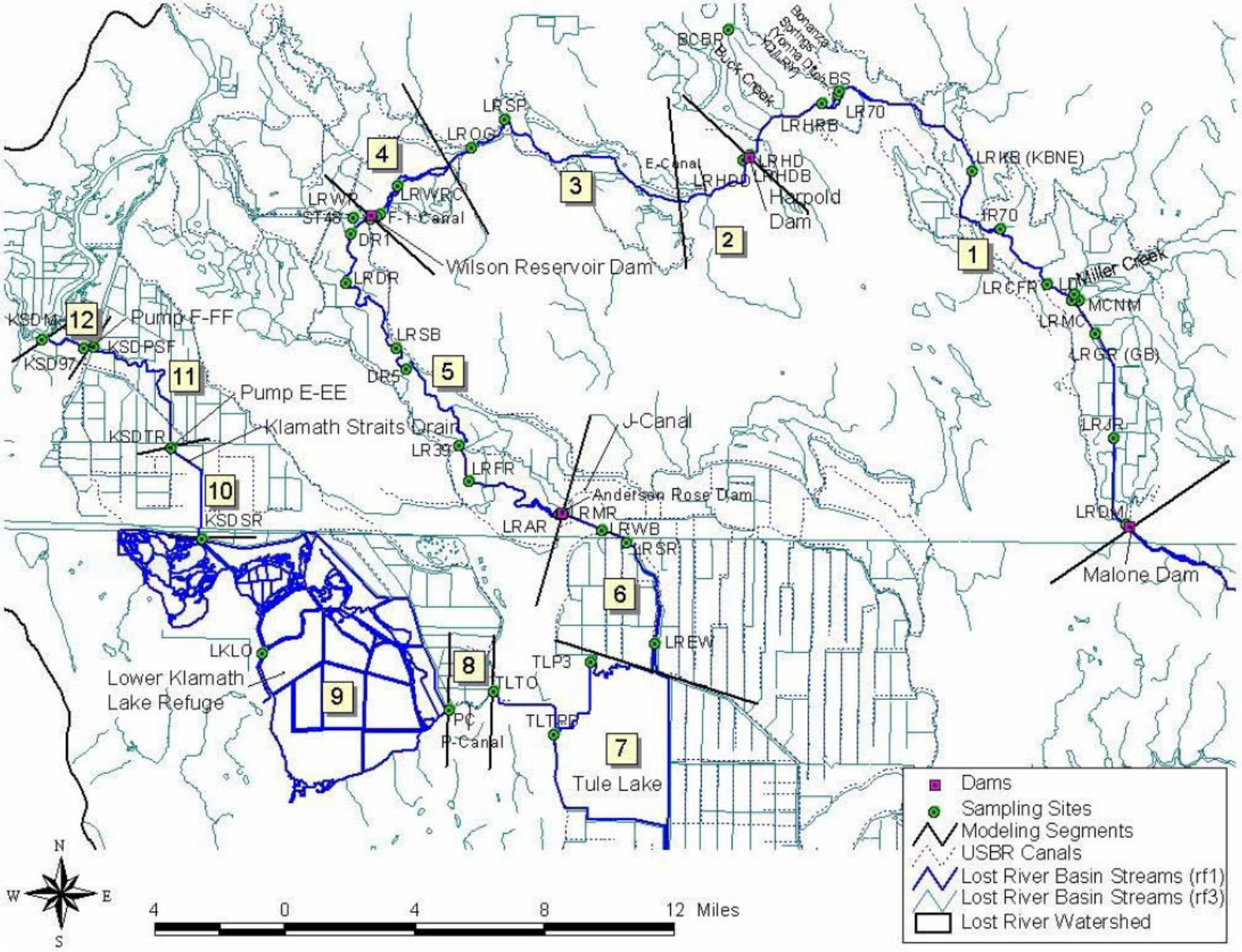
Klamath River Model Scenarios

Current Condition (2000, 2002)

Natural Condition Baseline (T1BSR)

- Dams and reservoirs removed
- Point sources removed
- Upstream boundary based on Upper Klamath Lake
- Everything else same as current

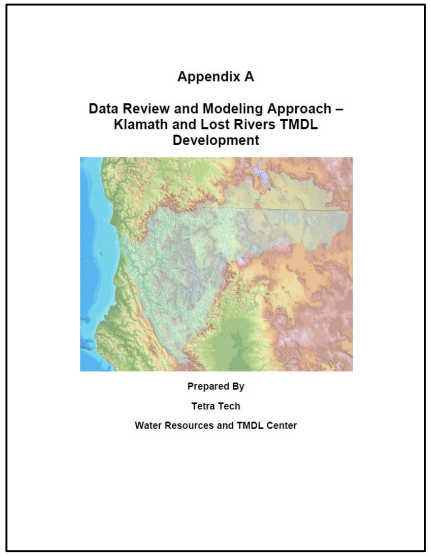
Lost River Model Overview

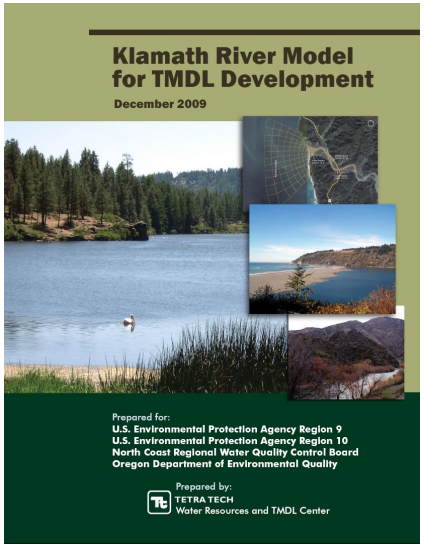


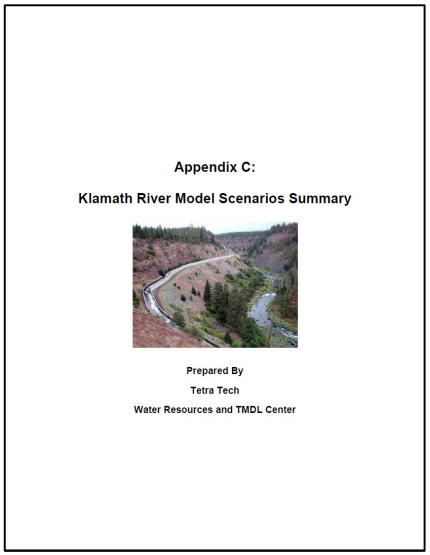
Additional Background Information

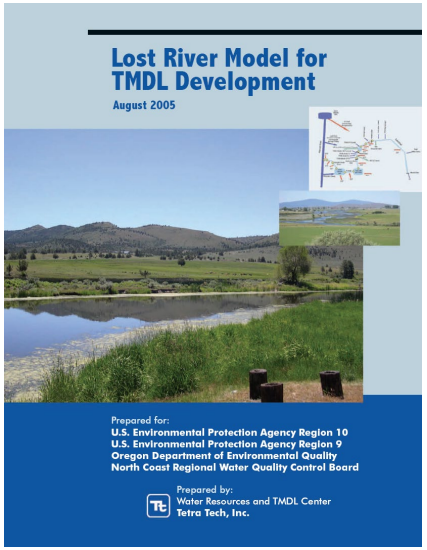
Upper Klamath and Lost River Subbasins
Nutrient TMDLs (2017)
Appendix A, B, C, F

https://www.oregon.gov/deq/wq/tmdls/Pages/TMDLs-Klamath-Basin.aspx#klamath2017









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Thank you!

Water Quality

Upper Klamath and Lost River TMDL Water Quality Management Plan

Sept. 12, 2018
Klamath Falls

Mike Hiatt | Oregon Department of Environmental Quality

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Documents can be provided upon request in an alternate format for individuals with disabilities or in a language other than English for people with limited English skills. To request a document in another format or language, call DEQ in Portland at 503-229-5696, or toll-free in Oregon at 1-800-452-4011, ext. 5696; or email deqinfo@deq.state.or.us.

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Overview

- What is a Water Quality Management Plan (WQMP) or TMDL Implementation Plan
- Who is required to submit plans to DEQ
- What are the basic elements for an implementation plan
- What is the timeline for completing the plan

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WQMP / TMDL Implementation Plan

Water Quality Management Plan (WQMP)

- Part of the TMDL but a separate order
- Outlines those responsible for planning
- Provides information on the Adaptive Management Approach
- Provides guidance on the TMDL Implementation Plans

TMDL Implementation Plan

- Source specific plans developed by Designated Management Agencies (DMA's) and Responsible Persons
- Based on Adaptive Management and a best management practices (BMP) approach
- Developed by DMA or Responsible Person

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Who is required to submit plans to DEQ

DMA's or Responsible Persons

- Oregon Department of Agriculture
- Bureau of Land Management
- US Forest Service
- US Fish and Wildlife
- US Bureau of Reclamation
- Oregon Department of Forestry
- Water Management Districts
- PacifiCorp
- Point Source Permit Holders
- Oregon Department of Transportation
- Department of State Lands
- Oregon Parks and Recreation
- Oregon Department of Geology and Mineral Industries

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Basic Elements of an Implementation Plan

- Condition Assessment and Problem Description
- Goals and Objectives
- Proposed Management Strategies
- Timeline for Implementing Management Strategies
- Relationship of Management Strategies to Attainment of Water Quality Standards
- Monitoring and Evaluation
- Maintaining Management Strategies Over Time

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Timeline for Plan Submittal

DMA's and Responsible Persons identified in the TMDL have 18-months from the date of issuance to have a completed plan in place.

- Drafts of the plan can be submitted to DEQ for review and technical assistance.
- DMA's and Responsible Persons will design a plan that can be implemented for their specific situation.
- Plan must include a mechanism for review.
- Plans shall obtain effectiveness monitoring;
  - Data collection through WQ sample analysis; or
  - BMP evaluation check sheet with observation completed on a periodic basis (i.e. monthly, weekly, daily).
- Annual reports of monitoring progress will be submitted to DEQ

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