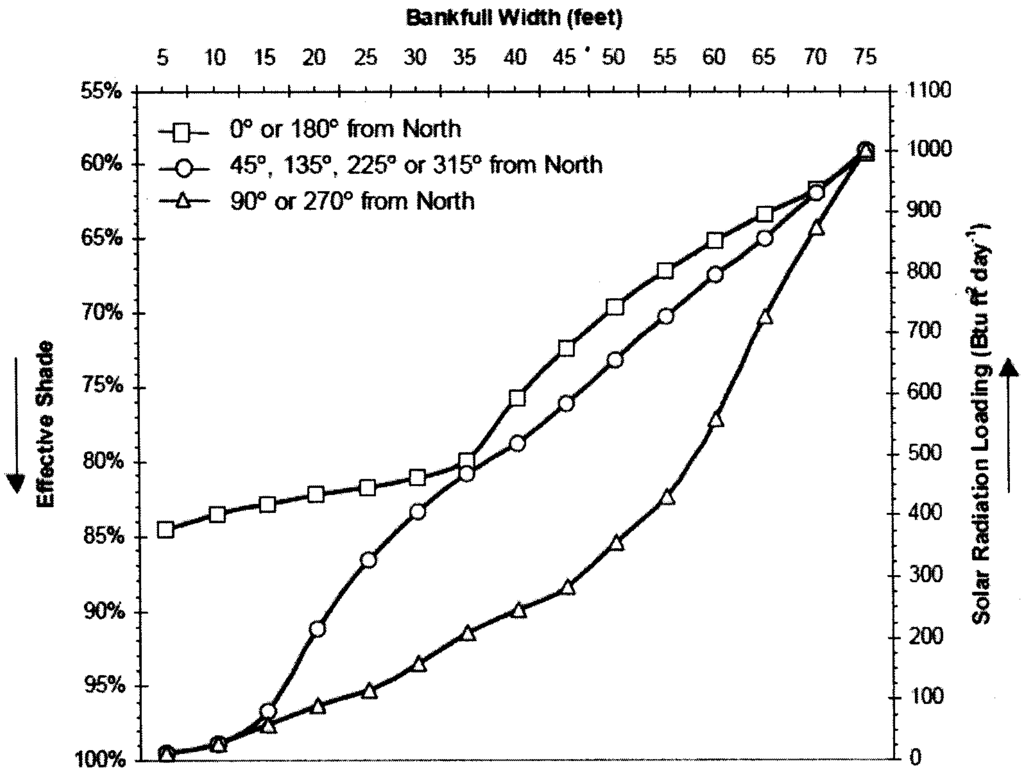
1989.8

Oregon DEQ.

1.

Figure 5. Site Potential Effective Shade and Solar Radiation Loading Based on Bankfull Channel Width and Stream Orientation (Aspect) for Late July and Early August

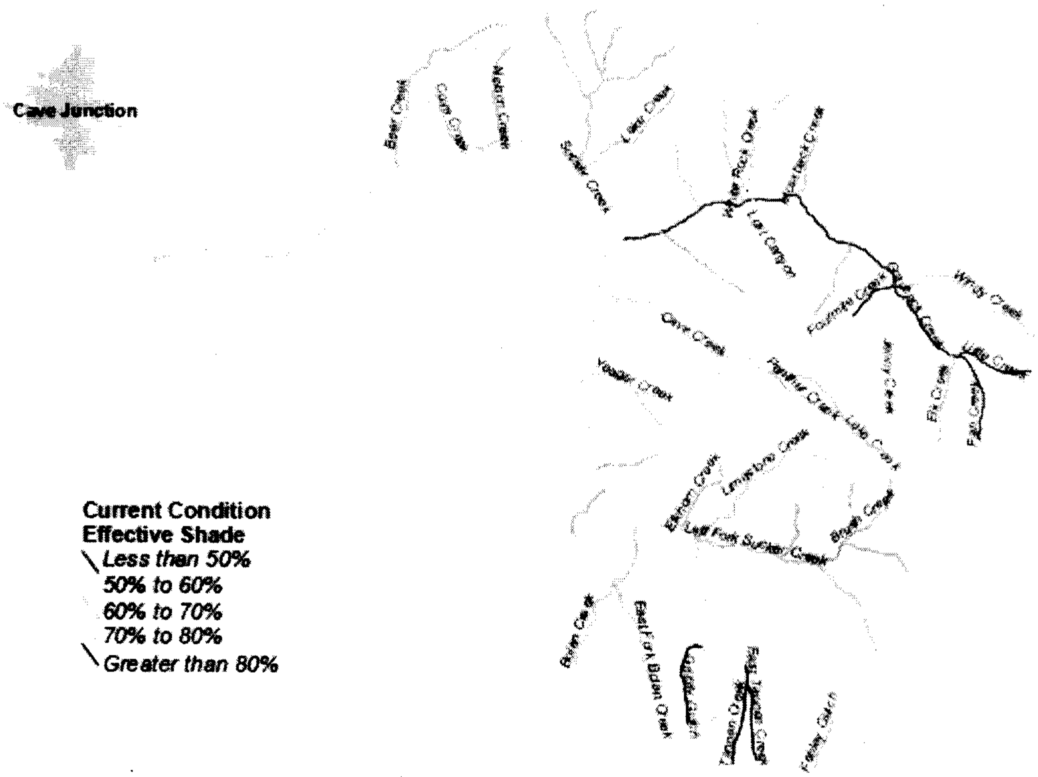
Site Potential Riparian Vegetation
Buffer Height: 120 feet
Buffer Width: 200 feet
Buffer Density: 65%



ODEQ. 1999. Sucker/Grayback Watershed TMDL. Supporting Documentation for Development of Temperature Load Allocation. Prepared by Siskiyou National Forest – Chris Park and Oregon Department of Environmental Quality - Matthew Boyd. Oregon Department of Environmental Quality, Portland, Oregon.

2.

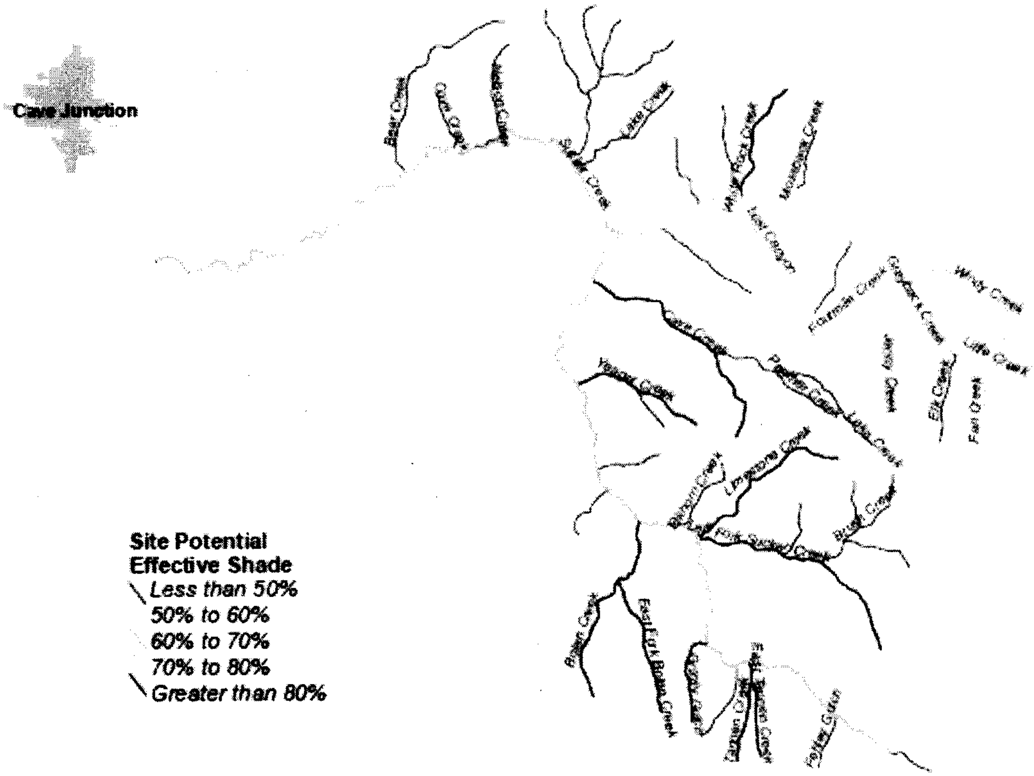
Image 4. Effective Shade - Current Conditions



ODEQ, 1999, Upper Sucker Creek TMDL
XXXXXXXXXXXXXXXXXXX

3.

Image 5. Effective Shade - Site Potential



ODEQ, 1999, Sucker/Grayback TMDL
xxxxxxxxxxxxxxxx

4.

Perennial Stream Reach	Contributing Flow (%)	Current Condition Solar Load ($Btu ft^{-2} day^{-1}$)	Loading Capacity Site Potential Solar Load ($Btu ft^{-2} day^{-1}$)	Required Solar Load Decrease (%)	Nonpoint Source of Pollutant	Time for Load Capacity Attainment (years)
Sucker Creek	N/A	1171	**1147**	2%	Harvest	60
Sucker Creek (Grayback to Yeager)	N/A	1171	**854**	34%	Mining	100
Tannen Creek	30	342	**268**	27%	Harvest	10
Deadhorse Creek	15	561	**342**	64%	Harvest	45
Grizzly Creek	17	439	**268**	64%	Harvest	35
LF Sucker Creek	30	756	**366**	107%	Harvest	50
Limestone Creek	6	781	**268**	191%	Harvest	50
Bolan Creek	20	586	**464**	26%	Harvest	35
Four Mile Creek	27	1781	**1025**	74%	Harvest	45
White Rock Creek	15	903	**342**	164%	Harvest	50
Lost Canyon Cr.	5	1122	**756**	48%	Harvest	50
All other tributaries*	N/A	N/A	**488**	N/A	N/A	N/A

Table 5. Loading Capacity - Summertime Solar Radiation Loading

* Streams without site potential analysis.

ODEQ, 1999, Sucker/Grayback TMDL
XXXXXXXXXXXXXXXXXXX

5.

Perennial Stream Reach	*Contributing Flow (%)*	*Current Condition Effective Shade (%)*	**Allocated**** *Site Potential Effective Shade (%)*	*Required Increased Effective Shade (%)*	*Nonpoint Source of Pollutant*	*Time for Surrogate Measure Attainment (years)*
Sucker Creek	N/A	52	53	1	Harvest	60
Sucker Creek (Grayback to Yeager)		52	65	13	Mining	100
Tannen Creek	30	86	89	3	Harvest	10
Deadhorse Creek	15	77	86	9	Harvest	45
Grizzly Creek	17	82	89	7	Harvest	35
LF Sucker Creek	30	69	85	16	Harvest	50
Limestone Creek	6	68	89	21	Harvest	50
Bolan Creek	20	76	81	5	Harvest	35
Four Mile Creek	27	27	58	31	Harvest	45
White Rock Creek	15	63	86	23	Harvest	50
Lost Canyon Cr.	5	54	69	15	Harvest	50
All other tributaries*	N/A	N/A	80%	N/A	N/A	N/A

ODEQ, 1999, Sucker/Grayback TMDL

ODF. (Oregon Department of Forestry)

1.

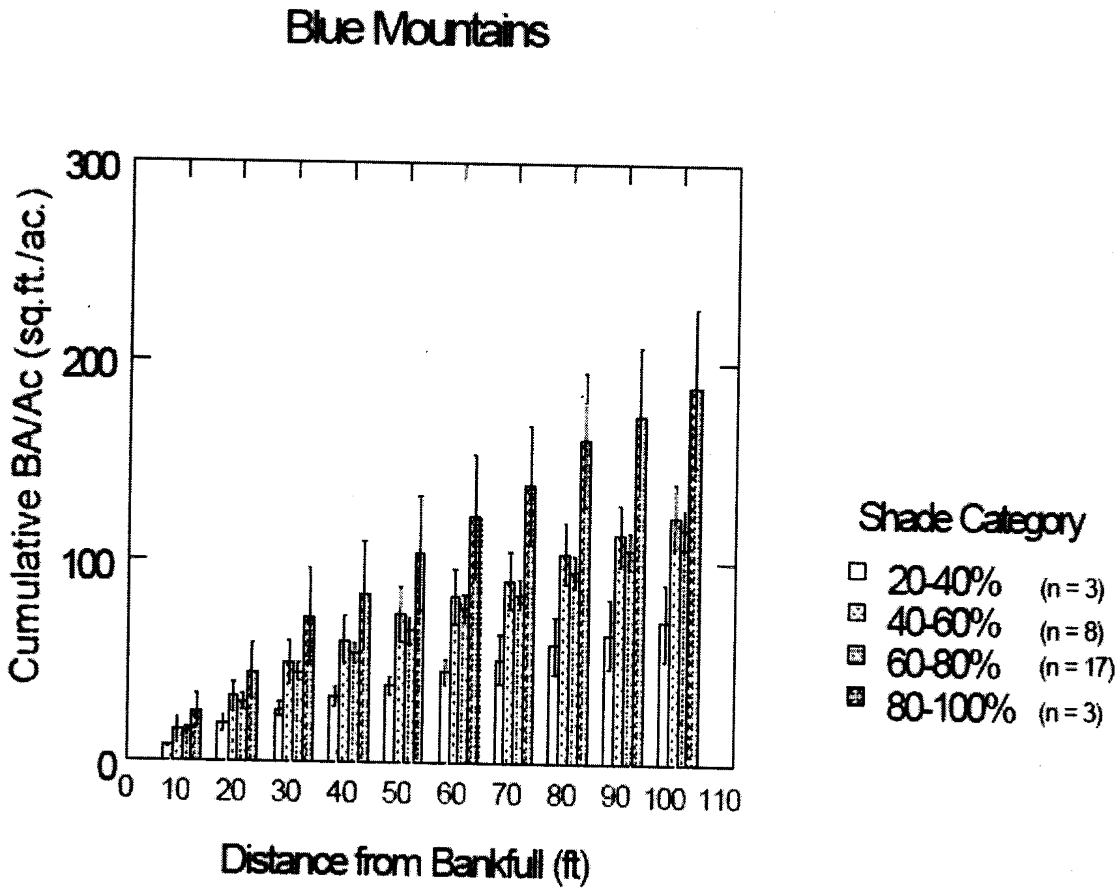


Figure 24. Mean cumulative basal area per acre by distance from bankfull and shade category in the Blue Mountains. Error bars show one standard error of the mean.
Allen, M. and L. Dent. 2001.

2. Coast Range

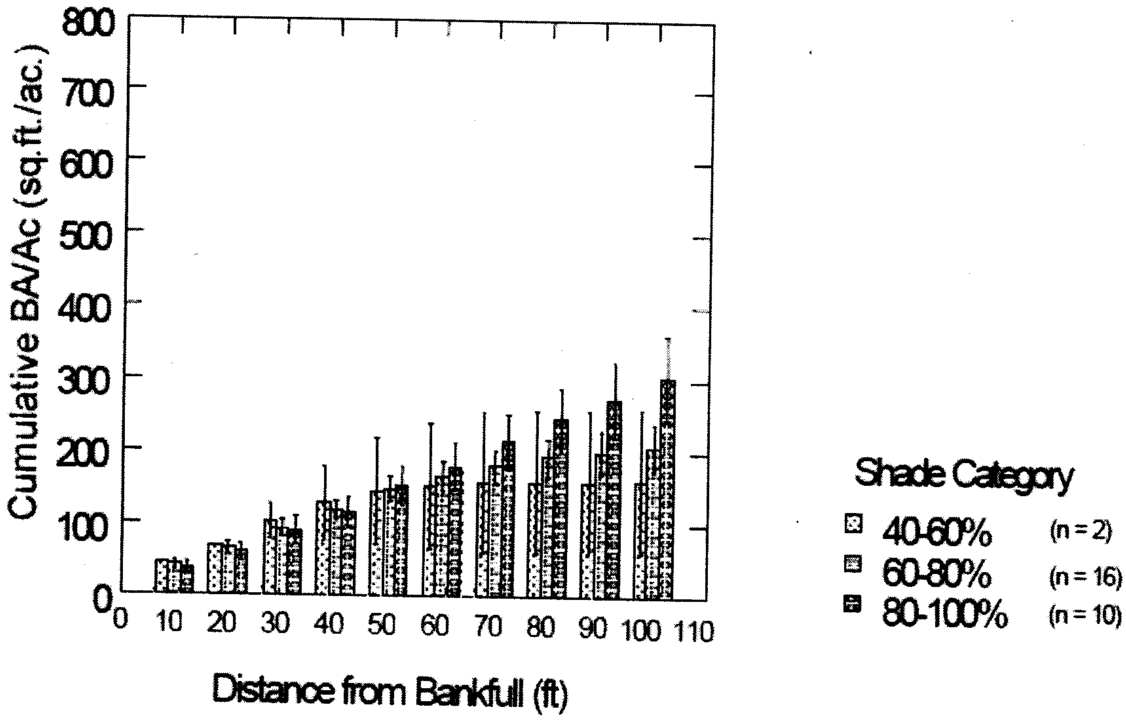


Figure 25. Mean cumulative basal area per acre by distance from bankfull and shade category in the Coast Range. Error bars show one standard error of the mean.
Allen, M. and L. Dent. 2001.

3.

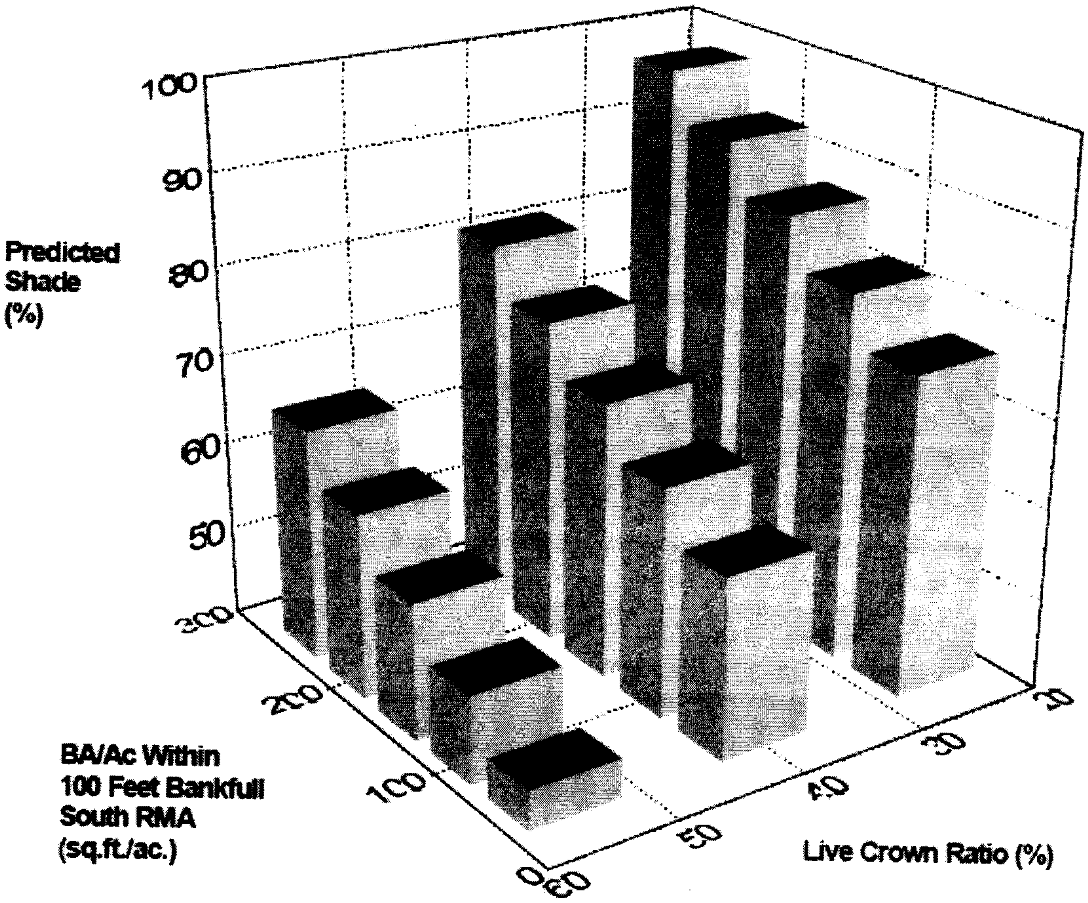


Figure 33. Predicted shade over east/west flowing Coast Range streams (Equation 2) across a range of live crown ratios (LCR) and basal areas within 100 feet of bankfull in the south RMA.
Allen, M. and L. Dent. 2001.

ODF and ODEQ. 2002.

Oregon Department of Forestry and Department of Environmental Quality Sufficiency Analysis: A Statewide Evaluation of FPA Effectiveness in Protecting Water Quality. Produced by: The Oregon Department of Forestry and Department of Environmental Quality. October 2002

1

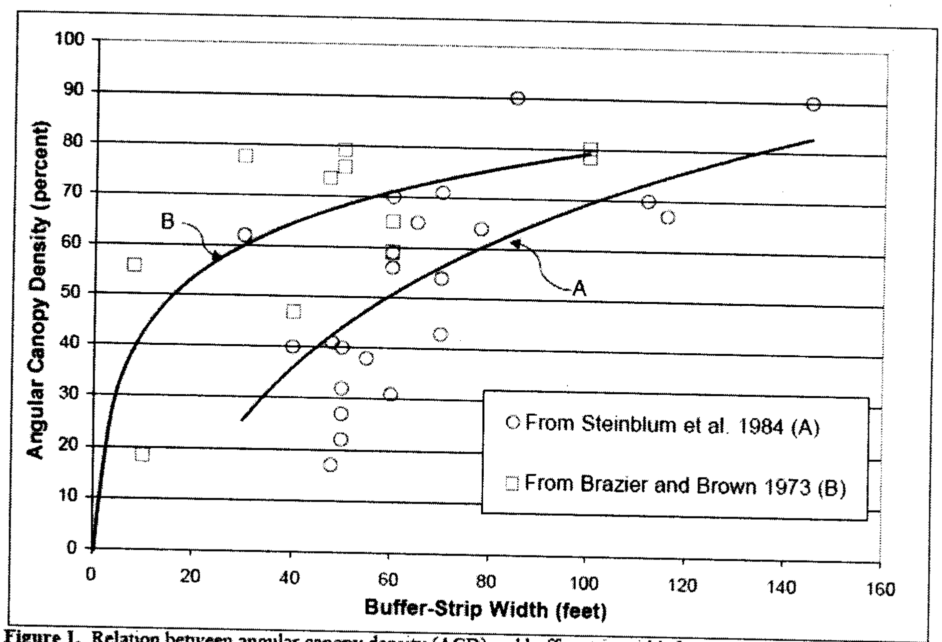


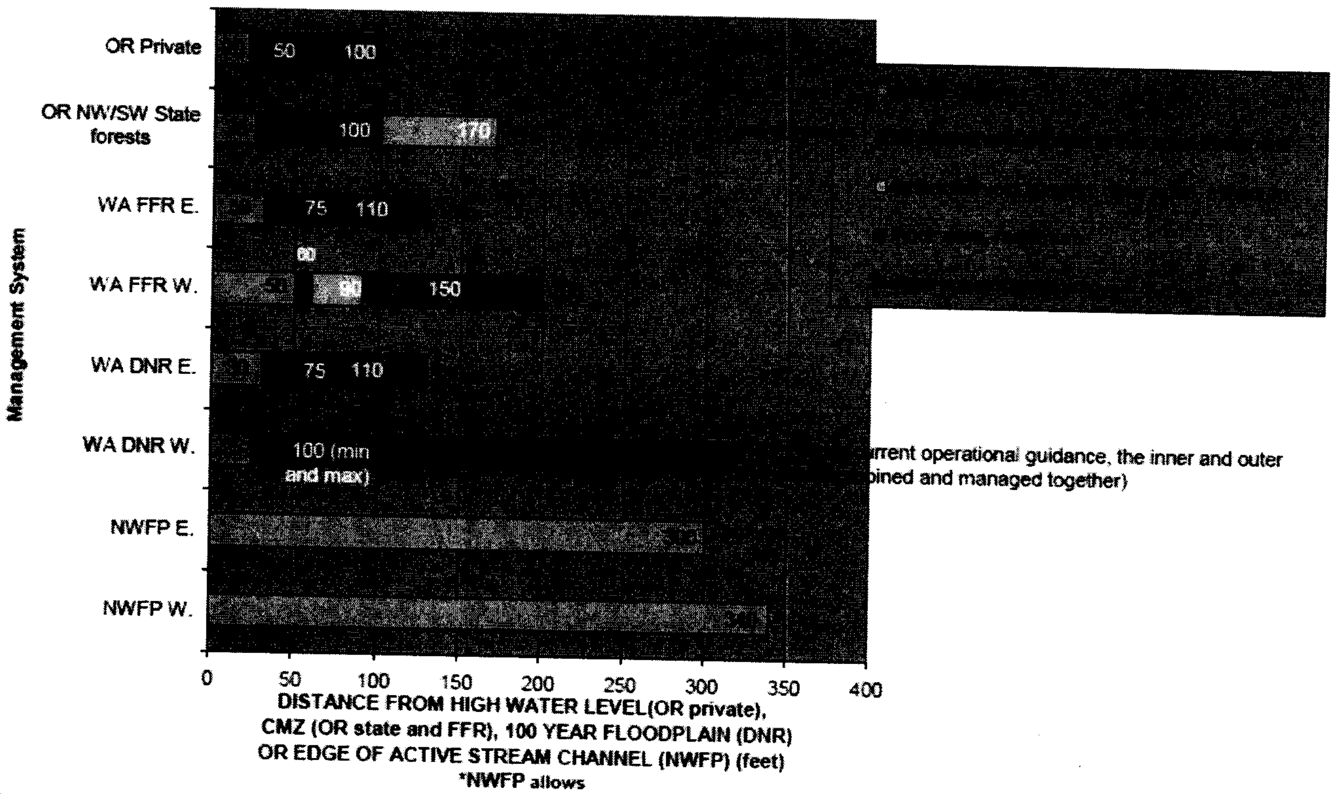
Figure 1. Relation between angular canopy density (ACD) and buffer-strip width for small streams in western Oregon (from Beschta et al., 1987).

ODF/ODEQ Sufficiency Analysis (2002)

PRC. 2005. (Pacific Rivers Council)

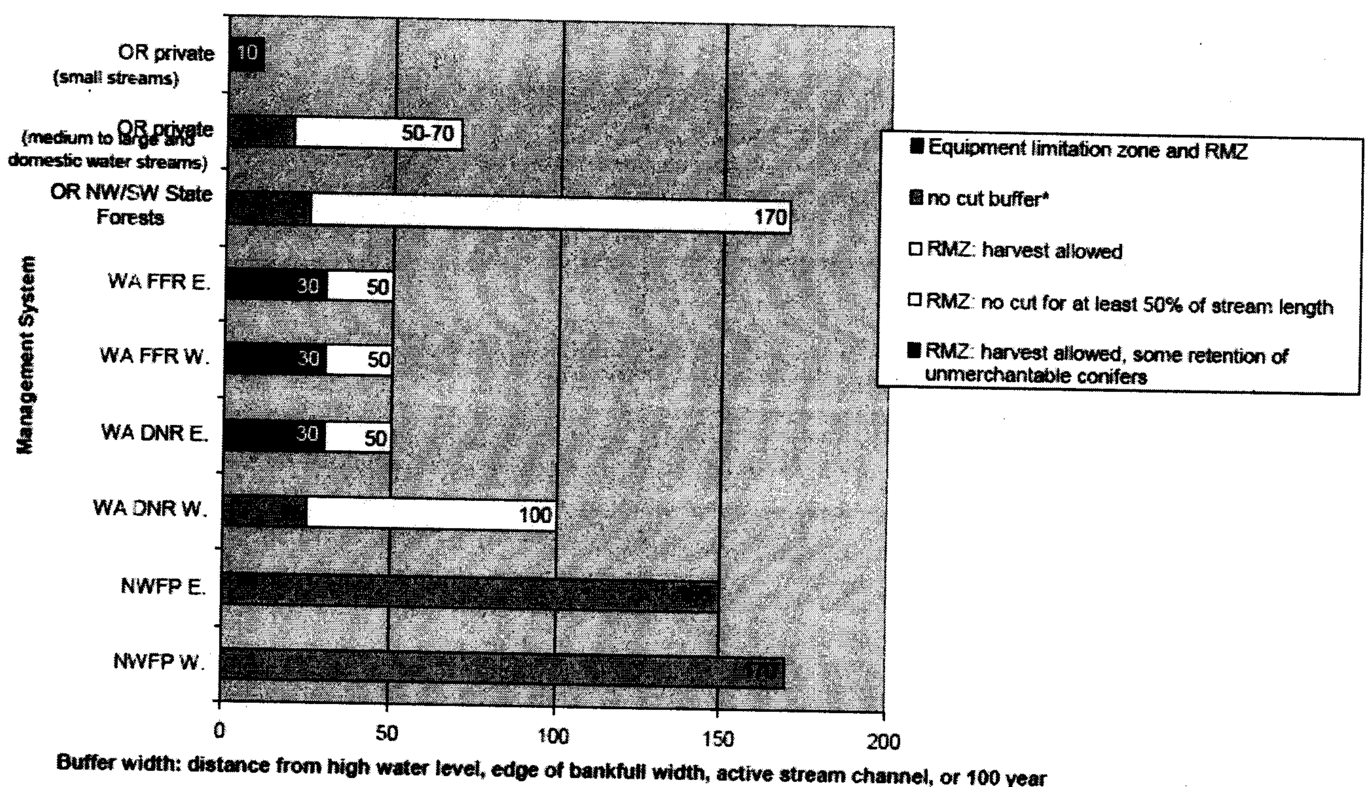
1. Riparian buffers-OR-WA-FEMAT-PRC.pdf

Riparian Buffers - Fishbearing Streams



2.

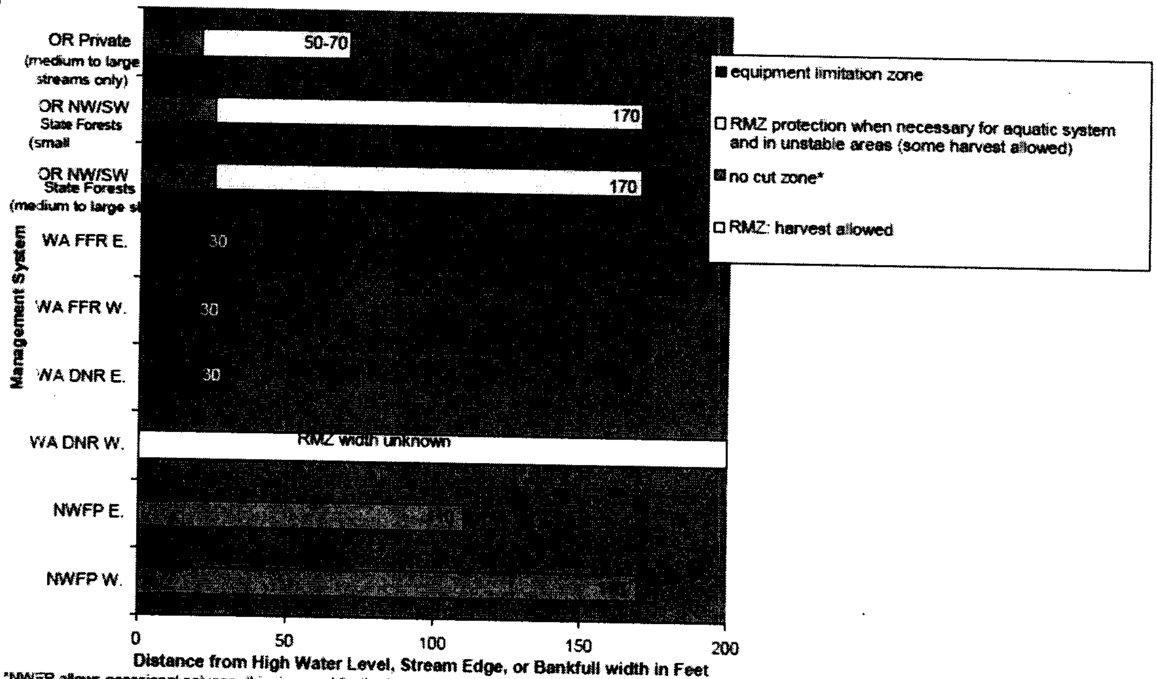
Riparian Buffers: Non-fishbearing, perennial



*NWFP allows occasional salvage, thinning, and feathering in riparian buffers; in OR NW/SW state forests, no cut buffer applies to at least 75 percent of reach for

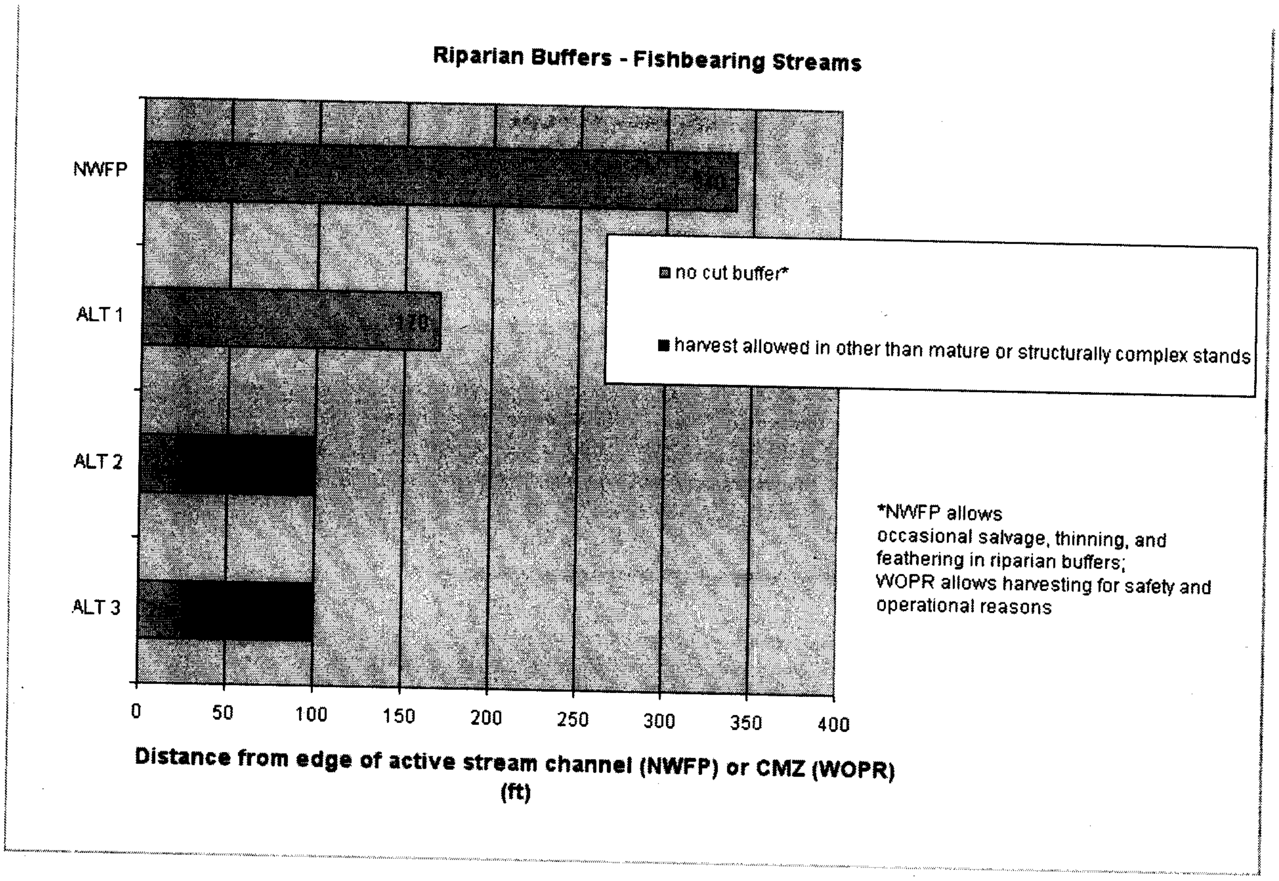
3.

Riparian Buffers: Non-fishbearing, seasonal



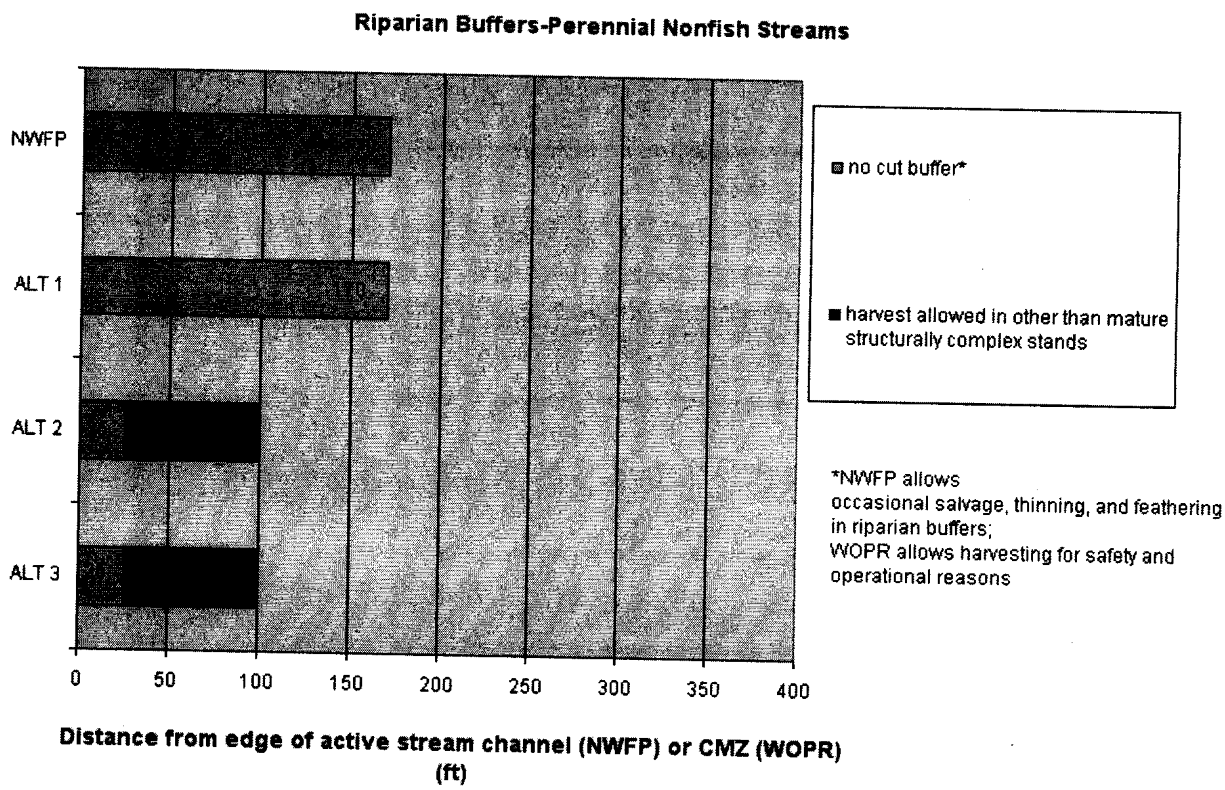
*NWFP allows occasional salvage, thinning, and feathering in riparian buffers; small streams on OR state forests without a no cut buffer do have an ELZ

4.



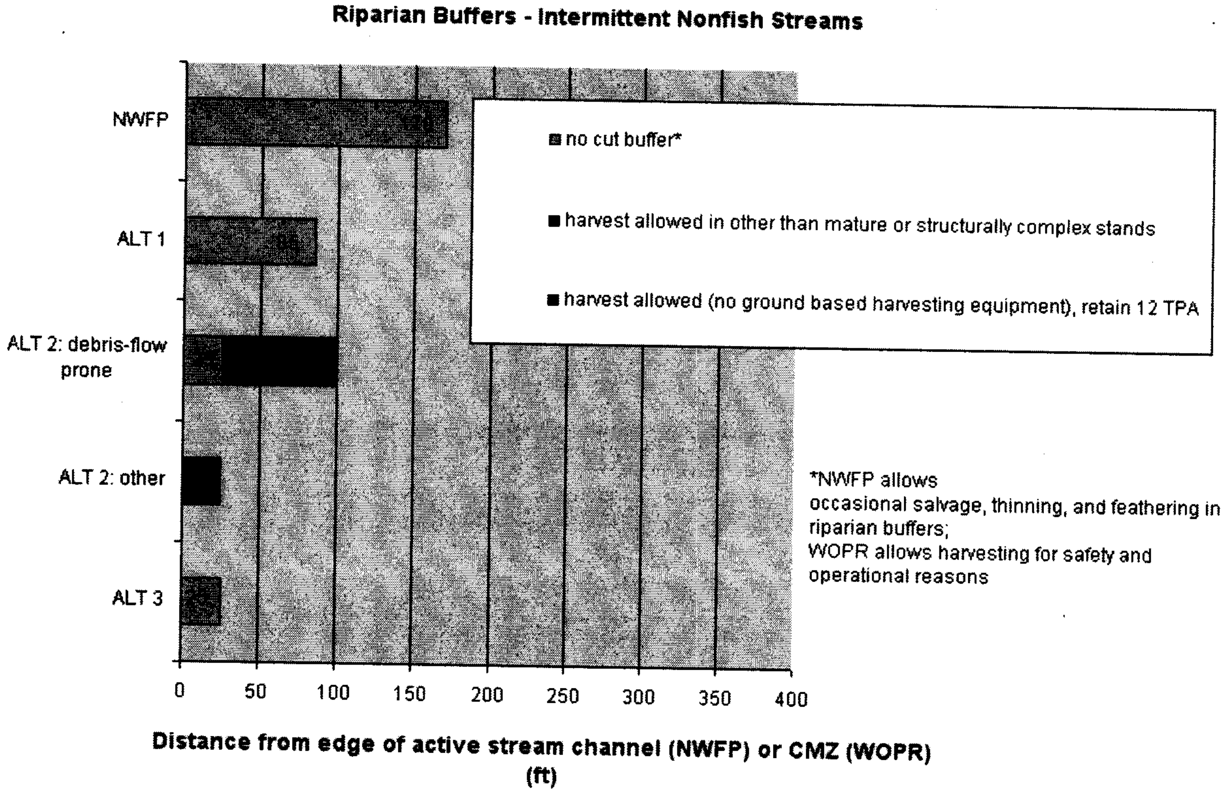
Riparian Buffers - Fishbearing Streams
NWFP
ALT 1
ALT 2
ALT 3
170
0
50
100
150
200
250
300
350
400
Distance from edge of active stream channel (NWFP) or CMZ (WOPR) (ft)
no cut buffer*
harvest allowed in other than mature or structurally complex stands
*NWFP allows occasional salvage, thinning, and feathering in riparian buffers; WOPR allows harvesting for safety and operational reasons

5.



Riparian Buffers-Perennial Nonfish Streams
NWFP
ALT 1
ALT 2
ALT 3
0
50
100
150
200
250
300
350
400
Distance from edge of active stream channel (NWFP) or CMZ (WOPR) (ft)
no cut buffer*
harvest allowed in other than mature structurally complex stands
*NWFP allows occasional salvage, thinning, and feathering in riparian buffers; WOPR allows harvesting for safety and operational reasons

6.



Riparian Buffers - Intermittent Nonfish Streams
NWFP
ALT 1
ALT 2: debris-flow prone
ALT 2: other
ALT 3
no cut buffer*
harvest allowed in other than mature or structurally complex stands
harvest allowed (no ground based harvesting equipment), retain 12 TPA
*NWFP allows occasional salvage, thinning, and feathering in riparian buffers;
WOPR allows harvesting for safety and operational reasons
0
50
100
150
200
250
300
350
400
Distance from edge of active stream channel (NWFP) or CMZ (WOPR) (ft)

Rhodes, J.J., D.A. McCullough, and F.A. Espinosa, Jr. 1994.

A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. Tech. Report 94-4. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 127 pp. + appendices.

1.

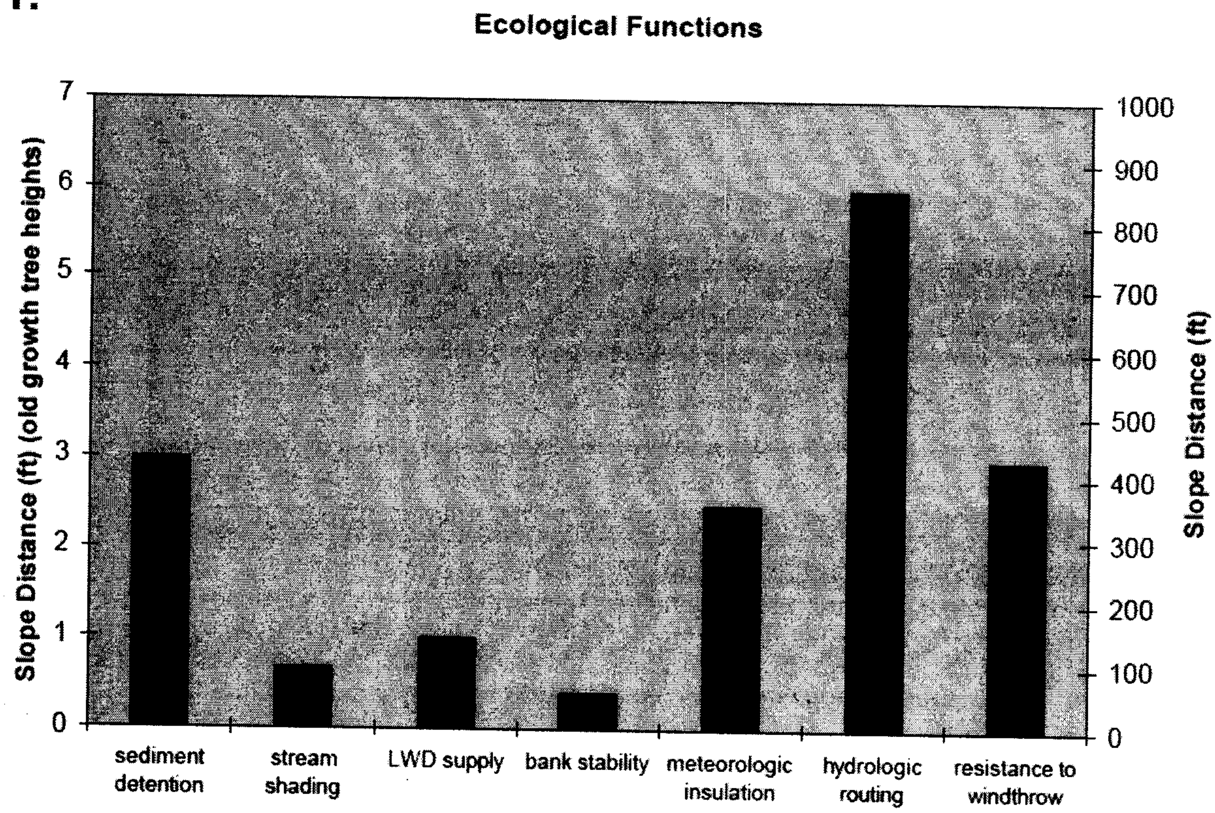


Figure 35. Estimated widths of protected areas, measured in slope distance from the edge of floodplain, needed to provide completely natural levels of ecological function over time with respect to some of the discrete ecological functions of riparian vegetation. Estimated slope distances in feet are based on the assumption that average old growth tree height is 150 feet. Widths of riparian reserves would have to extend to topographic divide to completely protect against increased sediment delivery during extreme events, alteration of hydrology, and increased susceptibility to windthrow.

Steinblums, I.J., Froehlich, H.A., and Lyons, J.K. 1984.

Designing stable buffer strips for stream protection. J. Foretry 82: 49–52.

1.

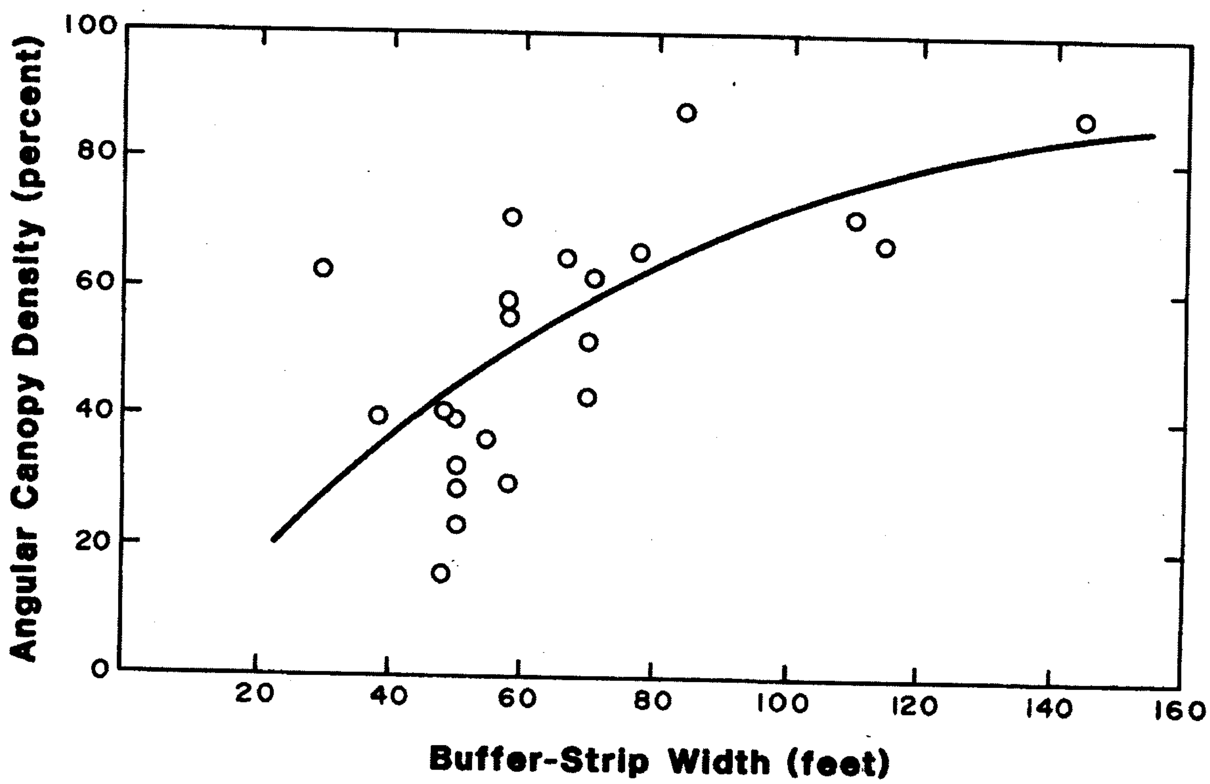


Figure 2. Regression functions relating angular canopy density (ACD) to buffer-strip width.

USBLM. 2007. WOPR (Western Oregon Plan Revisions)

Draft Environmental Impact Statement for the Revision of the Resource Management Plans of the Western Oregon Bureau of Land Management Districts

Prepared by
Oregon State Office
August 2007

1. DEIS Chap. 3a.

Figure 82. Number of road and stream crossings in the Evans Creek Watershed

USFS/BLM

Northwest Forest Plan Temperature TMDL Implementation Strategies

United States Forest Service and the Bureau of Land Management

July 9, 2002 (revised Dec. 6, 2002; January 2, 2003; January 7, 2003; January 29, 2003; January 31, 2003; February 5, 2003; February 26, 2003; March 3, 2003; April 2, 2003; April 16, 2003; May 19, 2003; Final Draft July 29, 2003; revised September 11, 2003; October 8, 2003; March 2, 2004; March 3, 2004; August13, 2004; October 21, 2004; December 30, 2004; February 9, 2005; April 15, 2005, September 9, 2005

1.

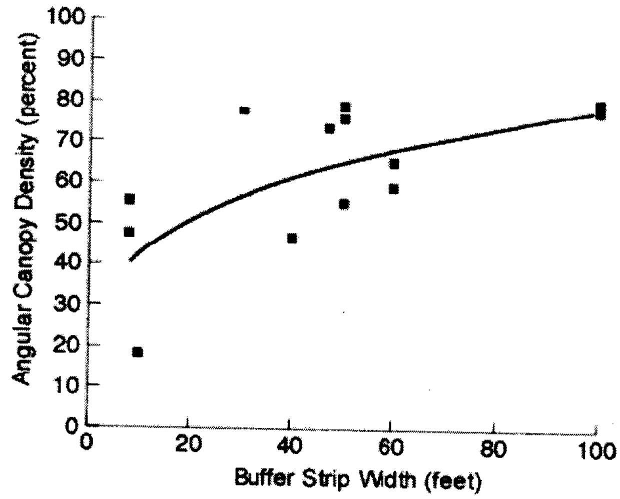


Figure 8. Angular canopy density (ACD) and buffer widths for small streams in western Oregon (Brazier and Brown, 1972)

USFS and BLM (2005)

2.

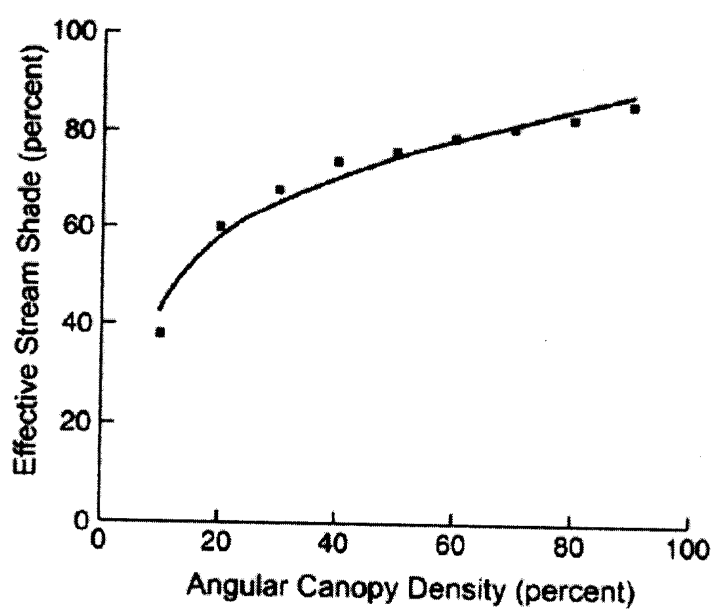


Figure 10. Angular canopy density (ACD) and stream shade (Park, 1991).

USFS and BLM (2005)

3.

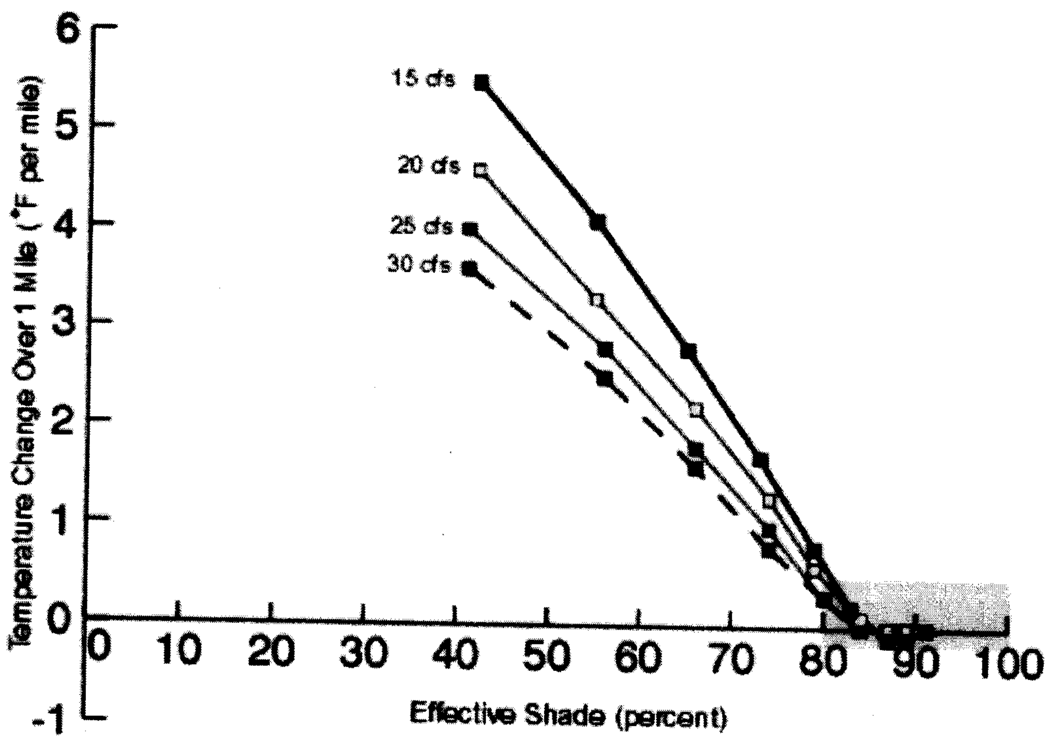


Figure 2. Stream shade and change in water temperature

4.

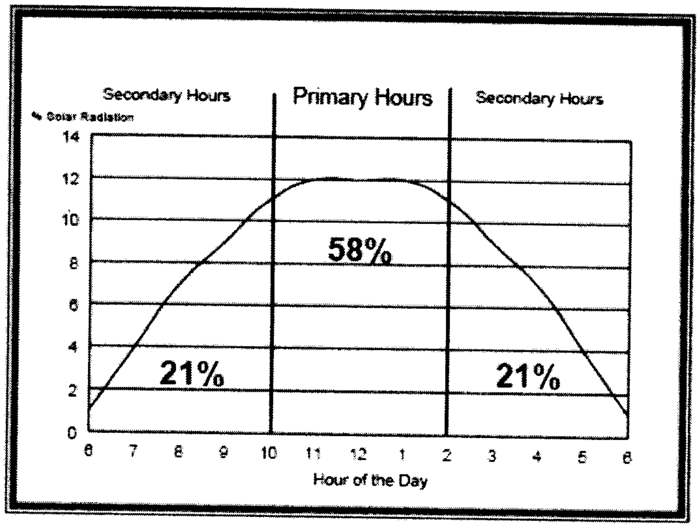


Figure 11. Percent total solar radiation available for each hour of the day, August 1 (source: Solar Pathfinder (43° to 49° N Lat.)

USFS and BLM (2005)

5.

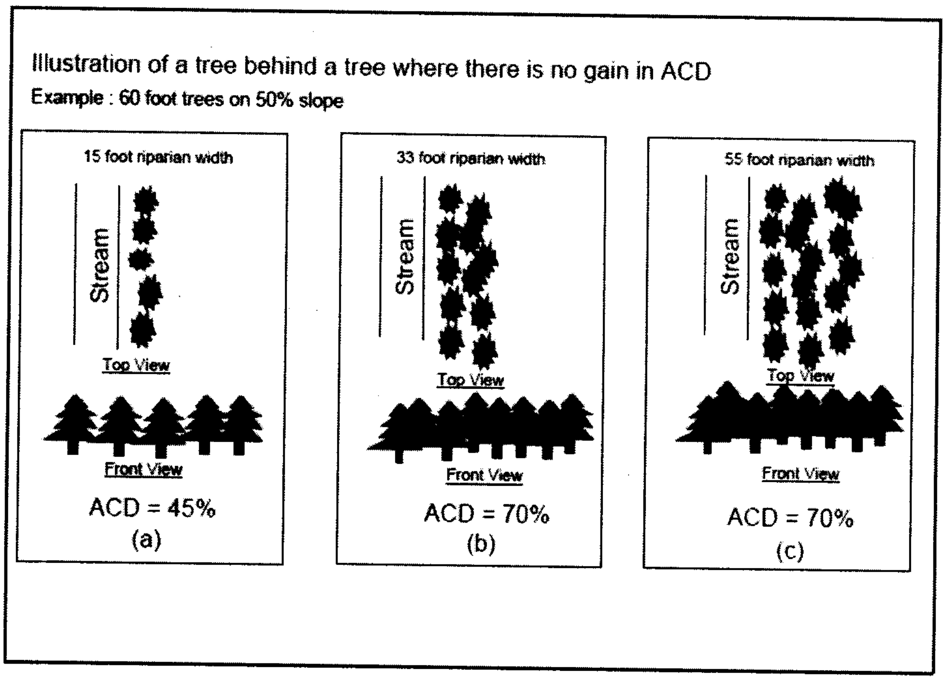
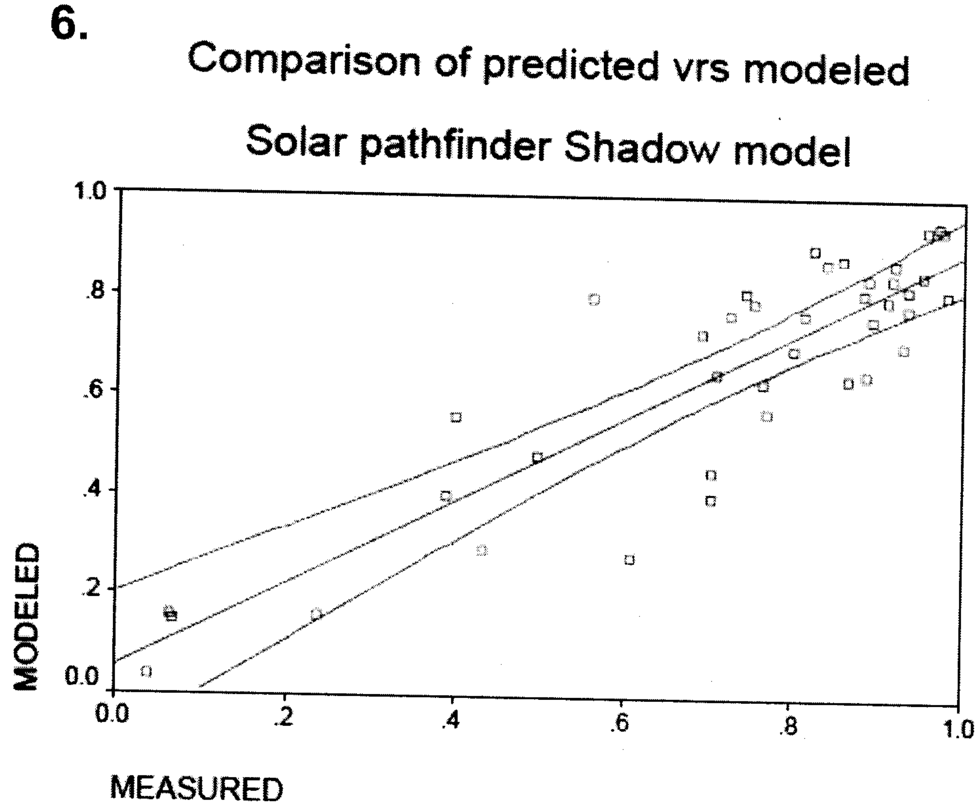


Figure 9. Angular Canopy Density and Buffer Width

6.



7.

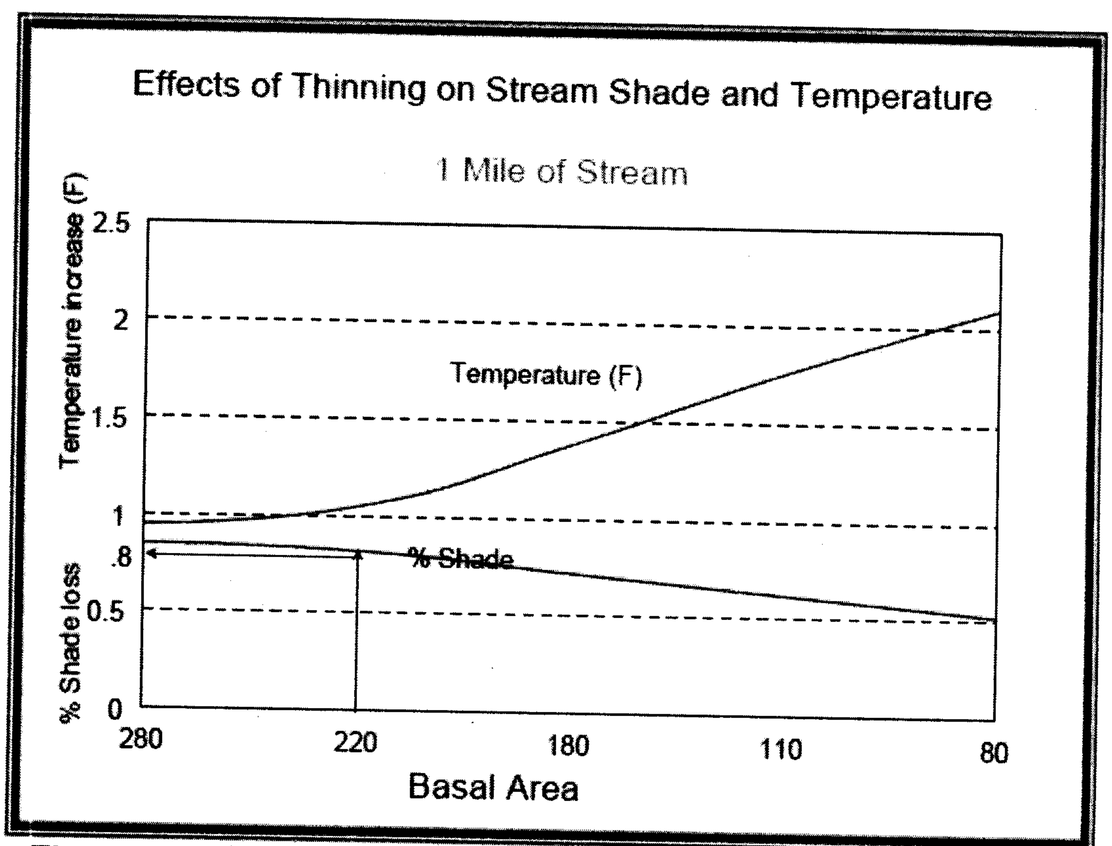


Figure 6. Modeled effects of thinning on stream temperature (SHADOW)

WDOE. 2005.

Willapa River Watershed Temperature Total Maximum Daily Load Study. Publication No. 04-03-24. Olympia, Washington.

1.

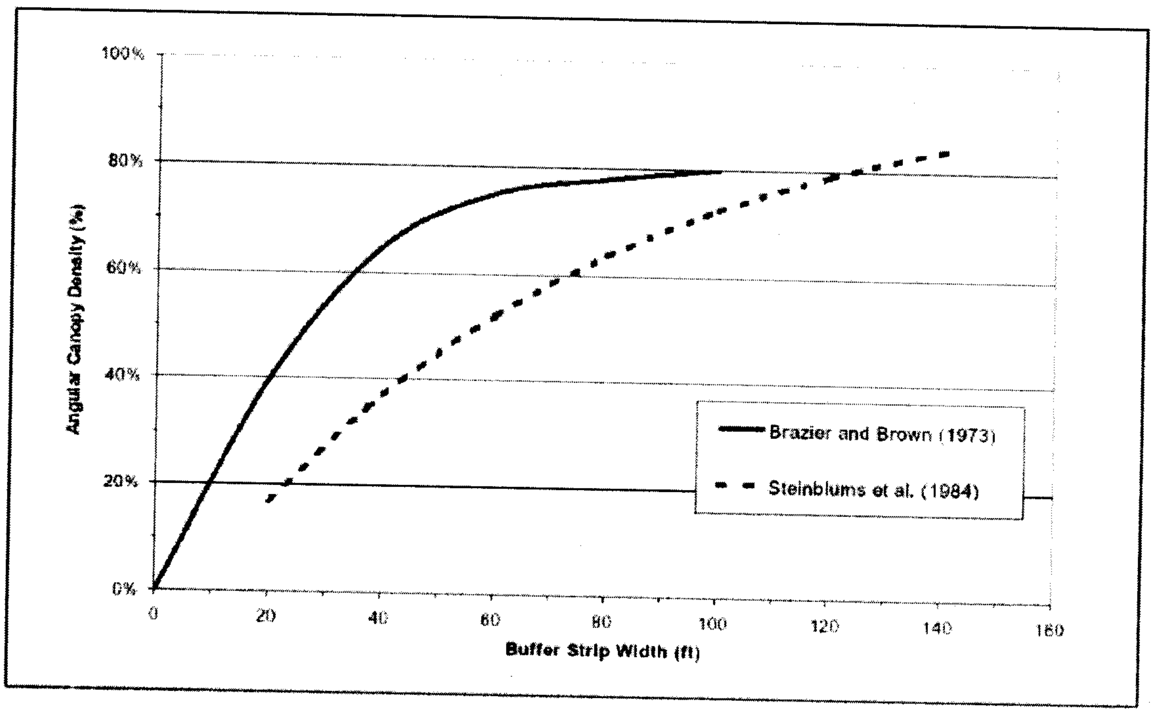


Figure 3. Relationship between angular canopy density (ACD) and riparian buffer width for small streams in old growth riparian stands (after Beschta et al., 1987 and CH2M Hill, 2000).

WDOE. 2007.

Modeling the effects of riparian buffer width on effective shade and stream temperature. Prepared by N. Cristea and J. Janisch. Publication No. 07-03-028. Washington State Department of Ecology. Olympia, Washington.

1.

Table 1. Shading effectiveness of various buffer widths (literature summary, after CH2M Hill, 2000, and Christensen, 2000).

Reference	Buffer investigated (meters)	Observations
Hewlett and Fortson 1982	15-30	Provided 60-80% shading.
Lynch et al. 1984	30	A 98-foot (30-m) buffer maintains water temperatures within 2°F (1°C) of their former average temperature in small streams (channel width less than 3 m). Provided 50-100% shading (equivalent to mature forest).

2.

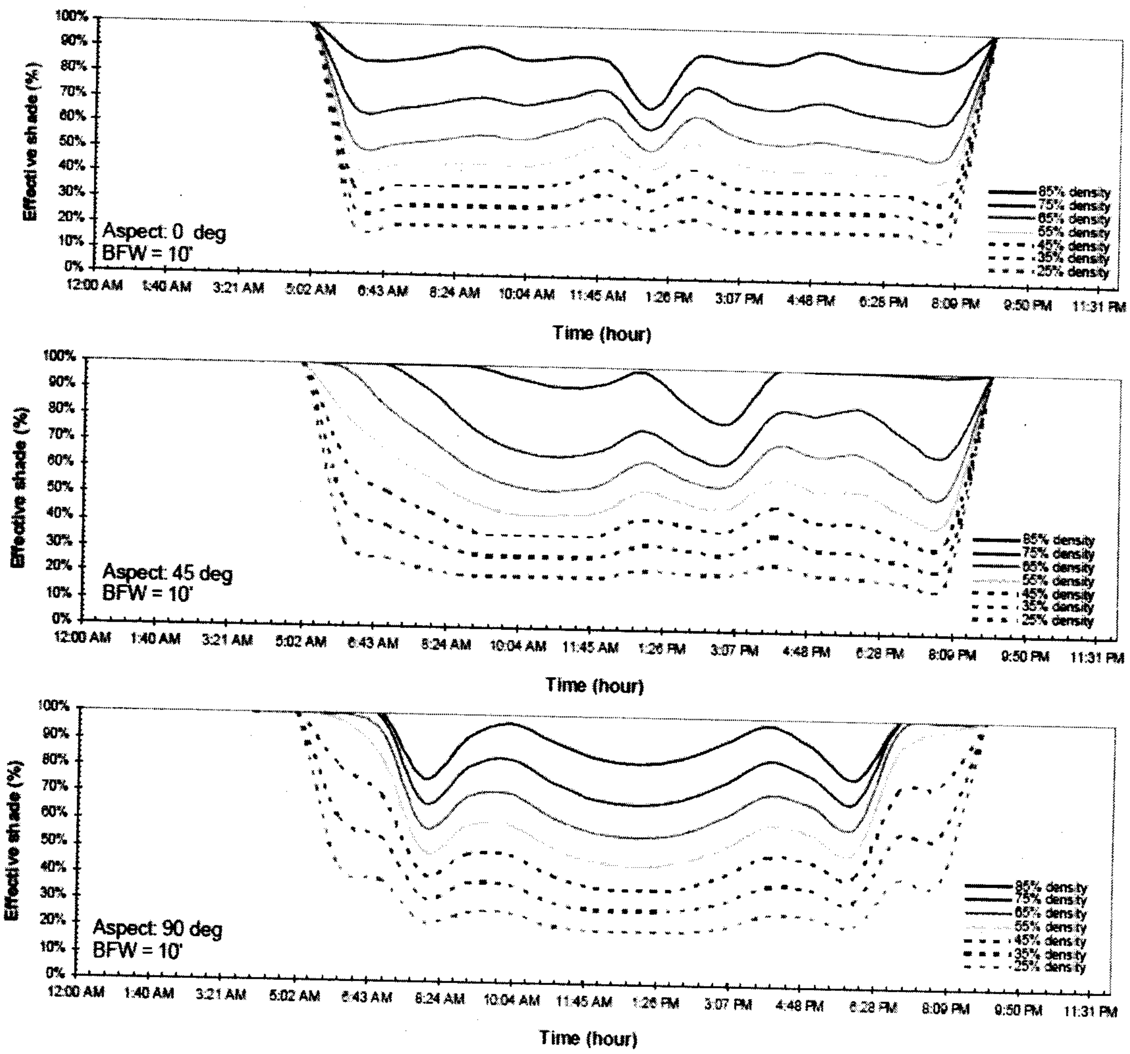


Figure 7. Daily effective shade for three channel orientations provided by a 120-foot buffer of canopy cover varying from 25% to 85%. Channel width is 10 feet.

WDOE (2007)

3. WDOE (2007)

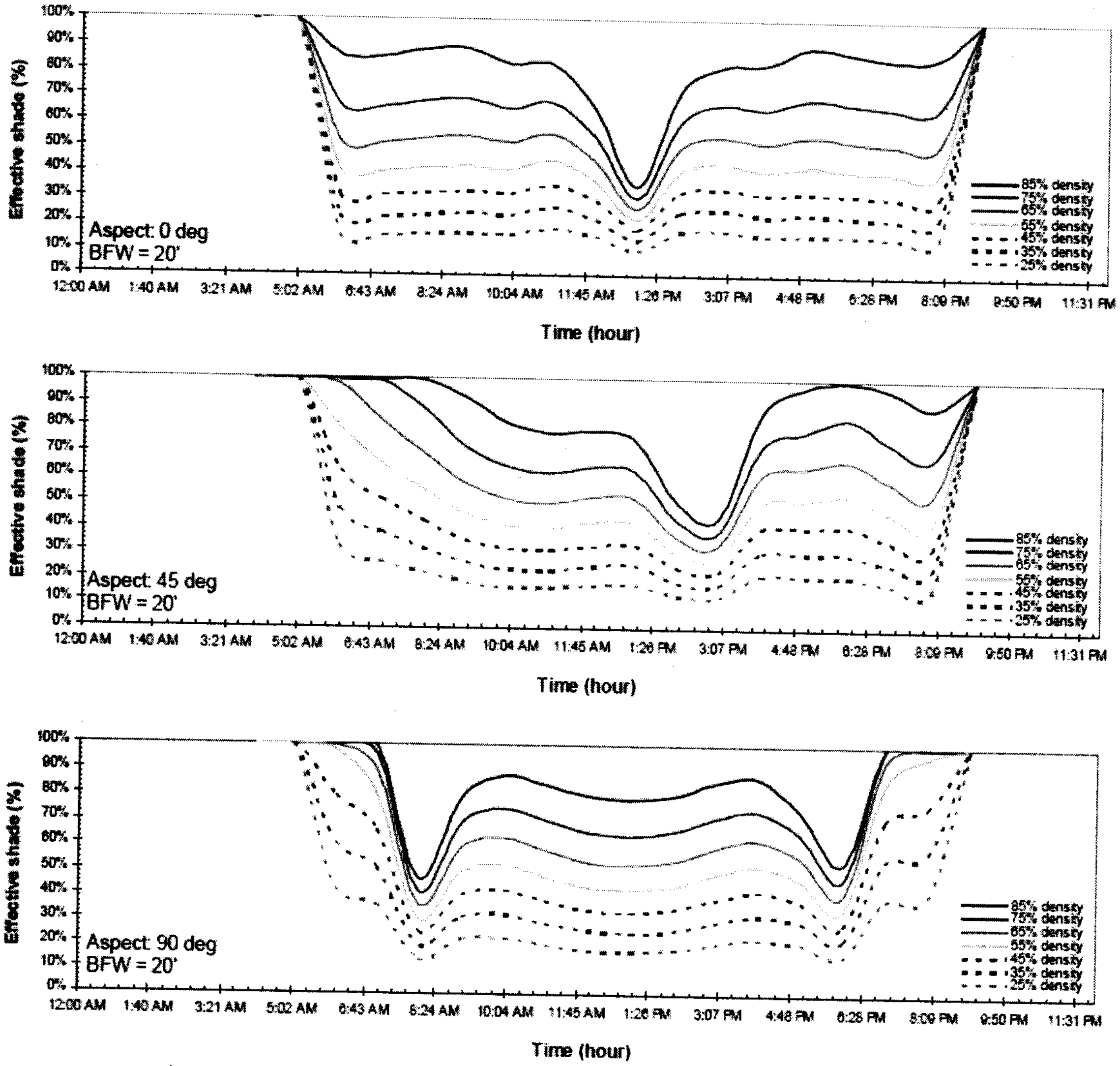


Figure 8. Daily effective shade for three channel orientations provided by a 120-foot buffer of canopy cover varying from 25% to 85%. Channel width is 20 feet.

4.

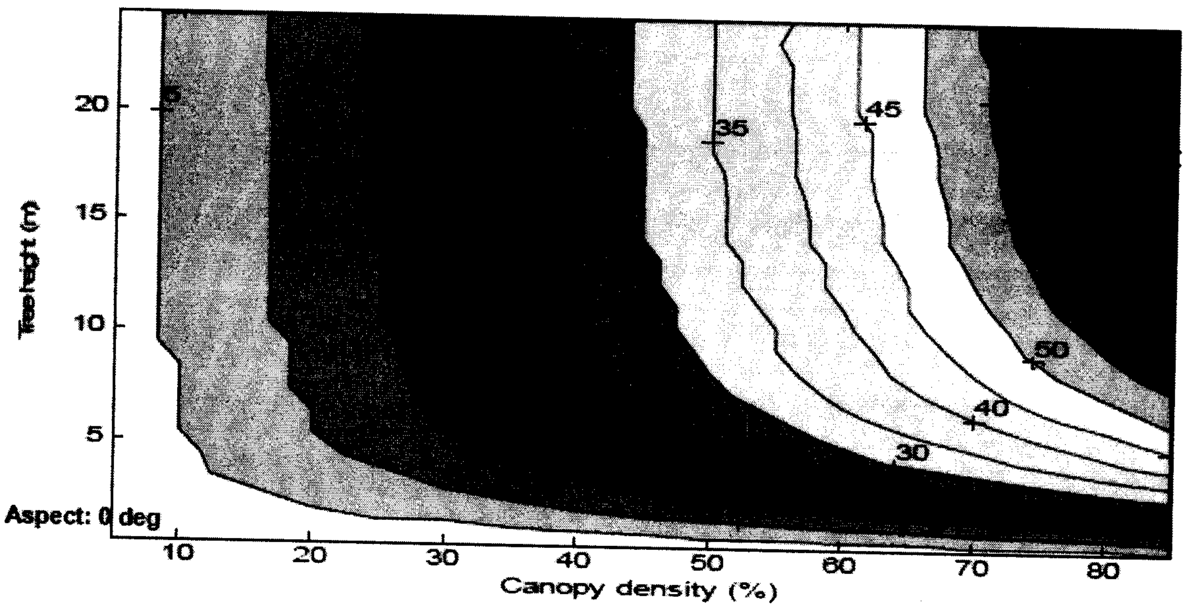


Figure 10. Contour lines of equal effective shade as a function of varying tree height and canopy cover for a single-sided 120-foot buffer (opposite bank unharvested) bordering a 20-foot-wide, north-south oriented channel. [tree height (m) v. canopy density (%)]

Table 7. Stream temperature simulations results (channel width = 10 ft). Shaded columns are differences between upstream and downstream temperature for the stated conditions. Values rounded to two decimals.

Stream width = 10 ft			Temperature response / harvest unit									
Parameter investigated	***Baseline value***	Model run	500'		750'		1000'		1250'		1500'	
			Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)
		Baseline condition ($T_{max\ upstream}$ = 14.6°C)	**14.73**	**0.13**	**14.79**	**0.19**	**14.86**	**0.26**	**14.91**	**0.31**	**14.96**	**0.36**
Riparian buffer	50' (Brazier and Brown, 1973)	50' (Steinblums, 1984)	14.81	0.21	14.90	0.30	15.01	0.41	15.11	0.51	15.21	0.61
		30' (Brazier and Brown, 1973)	14.78	0.18	14.86	0.26	14.96	0.36	15.04	0.44	15.12	0.52
		30' (Steinblums, 1984)	14.86	0.26	14.96	0.36	15.13	0.53	15.25	0.65	15.37	0.77
		75' (Brazier and Brown, 1973)	14.69	0.09	14.73	0.13	14.78	0.18	14.81	0.21	14.85	0.25
		75' (Steinblums, 1984)	14.76	0.16	14.83	0.23	14.92	0.32	14.98	0.38	15.04	0.44
Flow	Q = 0.2 m^3/s (7.1 cfs)	Q = 0.24 m^3/s (8.5 cfs)	14.71	0.11	14.76	0.16	14.82	0.22	14.86	0.26	14.91	0.31
		Q = 0.28 m^3/s (9.9)	14.69	0.09	14.73	0.13	14.79	0.19	14.82	0.22	14.86	0.26
		Q = 0.32 m^3/s (11.3 cfs)	14.68	0.08	14.72	0.12	14.76	0.16	14.80	0.20	14.83	0.23
		Q = 0.36 m^3/s (12.7 cfs)	14.67	0.07	14.70	0.10	14.75	0.15	14.78	0.18	14.81	0.21
Stream roughness	n=0.04	n = 0.06	14.73	0.13	14.79	0.19	14.86	0.26	14.91	0.31	14.96	0.36
		n = 0.08	14.73	0.13	14.78	0.18	14.85	0.25	14.91	0.31	14.96	0.36
		n = 0.10	14.73	0.13	14.78	0.18	14.85	0.25	14.90	0.30	14.95	0.35
		n = 0.12	14.73	0.13	14.78	0.18	14.85	0.25	14.90	0.30	14.95	0.35
		n = 0.14	14.73	0.13	14.78	0.18	14.85	0.25	14.90	0.30	14.95	0.35
		n = 0.16	14.73	0.13	14.78	0.18	14.85	0.25	14.90	0.30	14.95	0.35
Groundwater input, constant temperature T = 10 deg C	No groundwater input was assumed	0.01 m^3/s/100m (0.35 cfs), T=10 deg C	14.55	-0.05	14.53	-0.07	14.51	-0.09	14.49	-0.11	14.47	-0.13
		0.012 m^3/s/100m (0.42 cfs), T=10 deg C	14.52	-0.08	14.49	-0.11	14.44	-0.16	14.41	-0.19	14.38	-0.22
		0.014 m^3/s/100m (0.49 cfs), T=10 deg C	14.49	-0.11	14.44	-0.16	14.38	-0.22	14.34	-0.26	14.30	-0.30
		0.016 m^3/s/100m (0.56 cfs), T=10 deg C	14.45	-0.15	14.40	-0.20	14.32	-0.28	14.27	-0.33	14.22	-0.38
		0.018 m^3/s/100m (0.63 cfs), T=10 deg C	14.42	-0.18	14.35	-0.25	14.26	-0.34	14.20	-0.40	14.14	-0.46
Constant groundwater input, variable T	No groundwater input was assumed	0.01 m^3/s/100m (0.35 cfs), T = 14 deg C	14.70	0.10	14.75	0.15	14.80	0.20	14.83	0.23	14.87	0.27
		0.01 m^3/s/100m (0.35 cfs), T = 12 deg C	14.63	0.03	14.64	0.04	14.65	0.05	14.66	0.06	14.67	0.07
		0.01 m^3/s/100m (0.35 cfs), T = 10 deg C	14.55	-0.05	14.53	-0.07	14.51	-0.09	14.49	-0.11	14.47	-0.13
		0.01 m^3/s/100m (0.35 cfs), T = 8 deg C	14.48	-0.12	14.43	-0.17	14.36	-0.24	14.32	-0.28	14.27	-0.33
		0.01 m^3/s/100m (0.35cfs), T = 6 deg C	14.40	-0.20	14.32	-0.28	14.22	-0.38	14.14	-0.46	14.07	-0.53
Hyporheic exchange	No hyporheic exchange was assumed	hyporheic zone (d) = approx 300% stream depth Q = 80% of surface flow / 100m	14.73	0.13	14.78	0.18	14.85	0.25	14.90	0.30	14.95	0.35
Reach gradient	2%	4%	14.73	0.13	14.79	0.19	14.86	0.26	14.91	0.31	14.97	0.37
		6%	14.73	0.13	14.79	0.19	14.86	0.26	14.91	0.31	14.97	0.37
		8%	14.73	0.13	14.79	0.19	14.86	0.26	14.92	0.32	14.97	0.37
Increased headwater temperature diel range	Tmin = 13 deg C Tmax = 14.6 deg C Tmean = 13.8 deg C	Tmin = 12.2 deg C, Tmax = 14.6 deg C, Tmean = 12.2 deg C	14.72	0.12	14.77	0.17	14.83	0.23	14.88	0.28	14.93	0.33

'-' sign indicates a decrease in temperature; '+' sign indicates an increase in temperature

WDOE (2007)

6.

Table 8: Stream temperature simulations results (channel width = 20 ft). Shaded columns are differences between upstream and downstream temperature for the stated conditions. Values rounded to two decimals.

Stream width = 20 ft			Temperature response / harvest unit									
			500'		750'		1000'		1250'		1500'	
Parameter investigated	***Baseline value***	Model run	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)	Daily max	ΔT (deg C)
		Baseline condition ($T_{max\ upstream}$ = 14.6°C)	**14.75**	**0.15**	**14.81**	**0.21**	**14.96**	**0.36**	**15.08**	**0.48**	**15.20**	**0.60**
Riparian buffer	50' (Brazier and Brown, 1973)	50' (Steinblums, 1984)	14.84	0.24	14.94	0.34	15.07	0.47	15.17	0.57	15.27	0.67
		30' (Brazier and Brown, 1973)	14.83	0.23	14.93	0.33	15.06	0.46	15.15	0.55	15.24	0.64
		30' (Steinblums, 1984)	14.89	0.29	15.02	0.42	15.18	0.58	15.31	0.71	15.44	0.84
		75' (Brazier and Brown, 1973)	14.70	0.10	14.79	0.19	14.95	0.35	15.07	0.47	15.19	0.59
		75' (Steinblums, 1984)	14.77	0.17	14.85	0.25	14.98	0.38	15.11	0.51	15.23	0.63
Flow	Q = 0.4 m^3/s (14.2 cfs)	Q = 0.48 m^3/s (16.9 cfs)	14.72	0.12	14.78	0.18	14.86	0.26	14.96	0.36	15.06	0.46
		Q = 0.56 m^3/s (19.8 cfs)	14.71	0.11	14.75	0.15	14.81	0.21	14.88	0.28	14.96	0.36
		Q = 0.64 m^3/s (22.6 cfs)	14.69	0.09	14.73	0.13	14.78	0.18	14.82	0.22	14.89	0.29
		Q = 0.72 m^3/s (25.4 cfs)	14.68	0.08	14.72	0.12	14.76	0.16	14.80	0.20	14.83	0.23
Stream roughness	n=0.04	n = 0.06	14.75	0.16	14.81	0.21	14.95	0.35	15.07	0.47	15.19	0.59
		n = 0.08	14.75	0.15	14.81	0.21	14.95	0.35	15.06	0.46	15.18	0.58
		n = 0.10	14.75	0.15	14.81	0.21	14.94	0.34	15.06	0.46	15.17	0.57
		n = 0.12	14.75	0.15	14.81	0.21	14.94	0.34	15.05	0.45	15.17	0.57
		n = 0.14	14.74	0.14	14.80	0.20	14.93	0.33	15.05	0.45	15.16	0.56
		n = 0.16	14.74	0.14	14.80	0.20	14.93	0.33	15.04	0.44	15.16	0.56
Groundwater input, constant temperature T = 10 deg C	No groundwater input was assumed	0.01 $m^3/s/100m$ (0.35 cfs), T=10 deg C	14.57	-0.03	14.56	-0.04	14.60	0.00	14.64	0.04	14.68	0.08
		0.012 $m^3/s/100m$ (0.42 cfs), T=10 deg C	14.54	-0.06	14.51	-0.09	14.53	-0.07	14.56	-0.04	14.59	-0.01
		0.014 $m^3/s/100m$ (0.49 cfs), T=10 deg C	14.50	-0.10	14.46	-0.14	14.47	-0.13	14.49	-0.11	14.50	-0.10
		0.016 $m^3/s/100m$ (0.56 cfs), T=10 deg C	14.47	-0.13	14.42	-0.18	14.41	-0.19	14.41	-0.19	14.42	-0.18
		0.018 $m^3/s/100m$ (0.63 cfs), T=10 deg C	14.44	-0.16	14.37	-0.23	14.35	-0.25	14.34	-0.26	14.34	-0.26
Constant groundwater input, variable T	No groundwater input was assumed	0.01 $m^3/s/100m$ (0.35 cfs), T = 14 deg C	14.72	0.12	14.77	0.17	14.89	0.29	14.98	0.38	15.08	0.48
		0.01 $m^3/s/100m$ (0.35 cfs), T = 12 deg C	14.64	0.04	14.66	0.06	14.74	0.14	14.81	0.21	14.88	0.28
		0.01 $m^3/s/100m$ (0.35 cfs), T = 10 deg C	14.57	-0.03	14.56	-0.04	14.60	0.00	14.64	0.04	14.68	0.08
		0.01 $m^3/s/100m$ (0.35 cfs), T = 8 deg C	14.49	-0.11	14.45	-0.15	14.45	-0.15	14.47	-0.13	14.48	-0.12
		0.01 $m^3/s/100m$ (0.35cfs), T = 6 deg C	14.42	-0.18	14.35	-0.25	14.31	-0.29	14.29	-0.31	14.28	-0.32
Hyporheic exchange	No hyporheic exchange was assumed	hyporheic zone (d) = approx 300% stream depth Q = 80% of surface flow / 100m	14.74	0.14	14.80	0.20	14.93	0.33	15.04	0.44	15.15	0.55
Reach gradient	2%	4%	14.75	0.15	14.82	0.22	14.97	0.37	15.09	0.49	15.21	0.61
		6%	14.76	0.16	14.82	0.22	14.97	0.37	15.10	0.50	15.21	0.61
		8%	14.76	0.16	14.82	0.22	14.98	0.38	15.10	0.50	15.22	0.62
Increased headwater temperature diel range	Tmin = 13 deg C Tmax = 14.6 deg C Tmean = 13.8 deg C	Tmin = 12.2 deg C, Tmax = 14.6 deg C. Tmean = 12.2 deg C	14.73	0.13	14.79	0.19	14.89	0.29	15.00	0.40	15.10	0.50

'-' sign indicates a decrease in temperature; '+' sign indicates an increase in temperature

7.

A	B	C	D	E	F	G	H	I	J	K	L	M	N
WDOE (2007)													
Cristea and Janisch													
Table 7.							Decrement in rate of temp.		Decrement in rate of temp.		Diff. in rate of temp.		
Stream temperature simulations results (channel width = 10 ft).		Temperature response/harvest unit			Temp. increase/mile		change from 30' to 50' buffer		change from 50' to 75' buffer		change between Steinblums		
and flow is 7.1 cfs											and Brazier/Brown		
Parameter investigated	**Model run**	**0'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	
		°C	**°C**	**°C**	**°C/mile**	**°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**°C/mile**	**°C/mile**	
Riparian buffer	30' Brazier and Brown 1973	14.60	14.78	15.12	1.90	1.83	-0.53	-0.56					
	50' Brazier and Brown 1973	14.60	14.73	14.96	1.37	1.27			-0.42	-0.39			
	75' Brazier and Brown 1973	14.60	14.69	14.85	0.95	0.88							
	30' Steinblums 1984	14.60	14.86	15.37	2.75	2.71	-0.53	-0.56			0.84	0.88	
	50' Steinblums 1984	14.60	14.81	15.21	2.22	2.15			-0.53	-0.60	0.84	0.88	
	75' Steinblums 1984	14.60	14.76	15.04	1.69	1.55					0.74	0.67	
Table 8.							Decrement in rate of temp.		Decrement in rate of temp.		Diff. in rate of temp.		
Stream temperature simulations results (channel width = 20 ft).		Temperature response/harvest unit			Temp. increase/mile		change from 30' to 50' buffer		change from 50' to 75' buffer		change between Steinblums		
and flow is 14.2 cfs											and Brazier/Brown		
Parameter investigated	**Model run**	**0'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	**500'**	**1500'**	
		°C	**°C**	**°C**	**°C/mile**	**°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**Δ°C/mile**	**°C/mile**	**°C/mile**	
Riparian buffer	30' Brazier and Brown 1973	14.60	14.83	15.24	2.43	2.25	-0.84	-0.14					
	50' Brazier and Brown 1973	14.60	14.75	15.20	1.58	2.11			-0.53	-0.04			
	75' Brazier and Brown 1973	14.60	14.70	15.19	1.06	2.08							
	30' Steinblums 1984	14.60	14.89	15.44	3.06	2.96	-0.53	-0.60			0.63	0.70	
	50' Steinblums 1984	14.60	14.84	15.27	2.53	2.36			-0.74	-0.14	0.95	0.25	
	75' Steinblums 1984	14.60	14.77	15.23	1.80	2.22					0.74	0.14	

CURRICULUM VITAE

Dale A. McCullough
Senior Fishery Scientist
Columbia River Inter-Tribal Fish Commission
729 NE Oregon St., Suite 200
Portland, Oregon 97232
503-238-0667 (main)
503-731-1306 (direct)
www.critfc.org
e-mail: mccd@critfc.org

Education

B.S. Zoology, Ohio University, Athens, Ohio, 1970
M.S. Biology, Idaho State University, Pocatello, Idaho, 1975
Ph.D. Fisheries, Oregon State University, Corvallis, Oregon 1988

Memberships

Phi Beta Kappa 1970
Phi Kappa Phi 1970
Sigma Xi 1974

Employment

Senior Fishery Scientist, February 1994-present, Columbia River Inter-Tribal Fish Commission. Member of NOAA Fisheries Interior Columbia River Technical Recovery Team since October 2001; Oregon Department of Environmental Quality Water Temperature Committee; EPA Regional Water Temperature technical committee; development of screening process for potential use on land management actions under Section 7 and 10 consultation by NMFS; monitoring plan for use in federal land management; development of model of fish habitat quality/fish survival; water temperature effects on salmonids; carrying capacity of salmon in the Columbia River; watershed analysis; salmon habitat monitoring. Supervisor Phil Roger. Work in cooperation with other CRITFC/tribal staff and contractors to achieve tribal fish habitat restoration goals. Assist in providing leadership with departmental management staff.

Managing Scientist, September 1990-January 1994, Columbia River Inter-Tribal Fish Commission. Act as supervisor for fish production team; duties include project planning and coordination, preparation of workplans and budgets, personnel reviews and other assorted personnel matters. Continuation of development of methodology for classification of watersheds and streams for application as a tool in setting fish habitat standards, planning monitoring programs, and assessing fish production potential. Development of rationale for assessment of fish habitat carrying capacity; participate in TFW Ambient Monitoring Committee; Oregon AFS Watershed Classification Committee for maintenance of biodiversity; EPA cumulative effects review committee; Oregon Department of Environmental Quality Temperature Committee for triennial water quality review; development of steelhead spawning data base for John Day River; development of screening process for potential use on land management actions under Section 7 and 10 consultation by NMFS. Supervisor Phil Mundy.

Fishery Scientist, September 1985- September 1990, Columbia River Inter-Tribal Fish Commission. Technical analysis of land/aquatic management procedures (especially US Forest Service land management plans); review and development of monitoring and cumulative effects analysis procedures; acquisition and interpretation of fish habitat data; evaluation of fish production potential in freshwater environments; technical review and editing of professional journal and public agency publications; represent Commission on technical committees charged with fish habitat protection and monitoring such as Washington's Timber/Fish/Wildlife Program; development of theoretical principles and practical procedures for classification of watersheds and streams. Supervisor Phil Roger.

Research assistant, July 1983- September 1985, College of Oceanography, Oregon State University. Radiochemical analyses of marine and river sediments using solvent extraction, ion exchange, electrodeposition, precipitation. Analysis of alpha, beta, and gamma radiation spectra using multichannel analyzers. Neutron activation. Estimation of sediment budget for McNary Reservoir. Project leader Thomas Beasley.

Computer analyst, Anadromous, Inc., Corvallis, OR. September 1984- September 1985. Statistical analysis of coded wire tag data for salmon returns to aquaculture company. Wrote computer programs for data analysis. Supervisor Ronald Gowan.

Consultant, May 1-June 15, 1982, Oregon State University, Fisheries Department. Designed equipment and procedures for sampling aquatic invertebrates and sediments from the Willamette River by SCUBA for a U.S. Army Corps of Engineers project. Assisted collection of fish and measurement of physical and chemical water characteristics. Project leader H. Li.

Research assistant, March 1978- May 1982, Oregon State University. Development of a system and methodology for classification of watersheds and streams under Environmental Protection Agency funding. Project leader C.E. Warren.

Research assistant, January 1977- June 1977, Idaho State University. Worked with large team of scientists from Idaho State University, Michigan State University, Stroud Water Research Center, and Oregon State University on River Continuum project on Salmon River in Idaho. Collection of benthic organic matter, periphyton, and benthic invertebrates using SCUBA. Project leaders G.W. Minshall, K.W. Cummins, R. Vannote, J. Sedell.

Research assistant, December 1974- December 1976, Oregon State University, Corvallis, OR. Independent research on bioenergetics of the snail *Juga plicifera* under IBP funding. Also worked with research team on River Continuum project in the H.J. Andrews Experimental Forest. Measurement of primary production, standing crop of benthic organic matter, drift; collection of invertebrate samples; respirometry. Extensive use of SCUBA in sampling large and small streams. Project leader J. Sedell.

Research assistant, January 1974- November 1974, Idaho State University, Pocatello, ID. Conducted research under International Biological Program (IBP) on bioenergetics of aquatic insects in Deep Creek, Idaho. Worked with team charting energy flow through the Deep Creek ecosystem as a representative of cold desert streams. Project leader G.W. Minshall.

NORCUS (Northwest College and University Association for Science) scholarship, October 1972-October

1973, Battelle Northwest, Richland, WA. Conducted extended research for M.S. degree on ERDA reserve at Rattlesnake Springs. Project leader, C.E. Cushing.

Teaching assistant, September 1970- June 1972, Idaho State University. Taught introductory labs in biology, ecology. Department Chairman, A.D. Linder.

Publications

McCullough, D.A. 1975. Bioenergetics of three aquatic invertebrates determined by radioisotopic analyses. Idaho State University. 326 p.

McCullough, D.A. 1975. Bioenergetics of three aquatic invertebrates determined by radioisotopic analyses. BNWL-1928. Battelle Northwest Laboratories. U.S. ERDA contract E(45-1):1830, 225 p.

Minshall, G.W., J.T. Brock, D.A. McCullough, R. Dunn, M.R. McSorley, and R. Pace. 1975. Process studies related to the Deep Creek Ecosystem. U.S./IBP Desert Biome, R.M. 75-46.

McCullough, D.A., G.W. Minshall, and C.E. Cushing. 1979. Bioenergetics of lotic filter-feeding insects *Simulium* spp. (Diptera) and *Hydropsyche occidentalis* (Trichoptera) and their function in controlling organic transport in streams. Ecology 60(3):585-596.

McCullough, D.A., G.W. Minshall, and C.E. Cushing. 1979. Bioenergetics of a stream "collector" organism *Tricorythodes minutus* (Insecta: Ephemeroptera). Limnol. Oceanogr. 24(1):45-58.

Beasley, T.M., C.D. Jennings, and D.A. McCullough. 1985. Sediment accumulation rates in the lower Columbia River. J. Environmental Radioactivity.

McCullough, D.A. 1987. A systems classification of watersheds and streams. Ph.D. thesis. Oregon State University. 217 p.

McCullough, D.A. 1987. A compilation of habitat/fisheries data for the Clearwater National Forest. Columbia River Inter-Tribal Fish Commission. Unpublished manuscript.

McCullough, D.A., J. Weber, J. Sedell, D. Heller, R. Williams, and L. Wasserman. 1990. A proposal for managing and monitoring streams for fish production in Region 6. Draft manuscript. Columbia River Inter-Tribal Fish Commission and U.S. Forest Service. 37 p.

McCullough, D.A. 1990. Classification of streams within a landscape perspective. 158 p. In: Coordinated Information System Project, Annual Progress Report, January 5, 1989- December 31, 1990. Prepared by Columbia River Inter-Tribal Fish Commission for Bonneville Power Commission.

McCullough, D.A. 1991. Problems in the classification of watershed and stream systems: hierarchical classification by physical potential within an ecoregion context. Manuscript in preparation.

McCullough, D.A. 1991. The basis for estimates of carrying capacity. Columbia River Inter-Tribal Fish Commission. Unpublished manuscript. 44 p.

McCullough, D.A. 1996. Stream carrying capacity and smolt production. p. 45-70. In: G.E. Johnson D.A. Neitzel, and W.V. Mavros, and N.B. Peacock (eds.). Proceedings from a workshop on ecological carrying capacity of salmonids in the Columbia River Basin: Measure 7.1A of the Northwest Power Planning Council's 1994 Fish and Wildlife Program. Report 3 of 4. Final report. US Department of Energy, Bonneville Power Administration. Project Number 93-012, Agreement Number DE-AI79-86BP62611. (available at http://www.efw.bpa.gov /Environment/EW/EWP/DOCS/REPORTS/HABITAT/H62611-8.pdf)

Hawkins, C.P., J.L. Kershner, P.A. Bisson, M.D. Bryant, L.M. Decker, S.V. Gregory, D.A. McCullough, C.K. Overton, G.H. Reeves, R.J. Steedman, and M.K. Young. 1993. A hierarchical approach to classifying habitats in small streams. . Fisheries (Bethesda) 18(6): 6-12.

Li, H., W.K. Currens, D. Bottom, S. Clarke, J. Dambacher, C. Frissell, P. Harris, R. Hughes, D. McCullough, A. McGie, K. Moore, R. Nawa, and S. Thiele. 1995. Safe havens: genetic refuges and evolutionary significant units. p. 371-380. In: J.D. Nielson (ed.). Evolution and the aquatic ecosystem: defining unique units in population conservation. American Fisheries Society Symposium 17. American Fisheries Society, Bethesda, MD.

McCullough, D.A., S. Spalding, D. Sturdevant, M. Hicks. 2001. Summary of technical literature examining the physiological effects of temperature. EPA Regional Temperature Technical Committee technical issue paper. Available at http://yosemite.epa.gov/R10/WATER.NSF/webpage/Water+Issues+in+Region+10

McCullough, D.A. and F.A. Espinosa, Jr. 1996. A monitoring strategy for application to salmon-bearing watersheds. Tech. Report 96-5. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 170 p. + appendices. (available at www.critfc.org)

Rhodes, J.J., D.A. McCullough, and F.A. Espinosa, Jr. 1994. A coarse screening process for evaluation of the effects of land management activities on salmon spawning and rearing habitat in ESA consultations. Tech. Report 94-4. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 127 pp. + appendices. (available at www.critfc.org)

Cuenco, M.L. and D.A McCullough. 1995. Framework for estimating salmon survival as a function of habitat condition. Tech. Report 96-4. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 107 pp. + appendices.

McCullough, D.A. 1995. Scientific literature on the temperature requirements of salmonid fishes. Appendix D. In: 1992-1994 Water quality standards review. Final issue papers. Oregon Department of Environmental Quality, Portland, Oregon. (available at http://www.fishlib.org/Bibliographies/waterquality.html)

Espinosa, F.A., Jr., J.J. Rhodes, and D.A. McCullough. 1997. The failure of existing plans to protect salmon habitat on the Clearwater National Forest in Idaho. J. Env. Management 49(2):205-230.

McCullough, D.A. 1999. A review and synthesis of effects of alterations to the water temperature regime on freshwater life stages of salmonids, with special reference to chinook salmon. EPA 910-R-99-010. Prepared for the USEPA, Region 10, Seattle, Washington. 279 p. (available at www.critfc.org)

McCullough, D.A. 1999. Monitoring of streambank stability and streamside vegetation in a livestock exclosure on the Warm Springs River, Oregon: Comparison of ground-based surveys with aerial

photographic analysis. Prepared for the Confederated Tribes of the Warm Springs Reservation of Oregon under a special services contract to the Bonneville Power Administration, Project number (BPA) 96FC96721. 182 p. (available at www.critfc.org)

McCullough, D.A. and S. Spalding. 2002. Multiple lines of evidence for determining upper optimal temperature thresholds for bull trout. Prepared for EPA Regional Temperature Committee, Environmental Protection Agency, Region X, Seattle, WA. 25 p. (available at www.critfc.org).

Poole, G.C., J.B. Dunham, M. Hicks, D. Keenan, J. Lockwood, W. Materna, D.A. McCullough, C. Mebane, J. Risley, S. Sauter, S. Spalding, and D. Sturdevant. 2001. Technical synthesis: scientific issues related to temperature criteria for salmon, trout, and char native to the Pacific Northwest. US Environmental Protection Agency Report #EPA 910-R-01-007. Seattle, Washington. 24 p.

McCullough, D., S. Spalding, D. Sturdevant, and M. Hicks. 2001. Summary of technical literature examining the physiological effects of temperature. Technical Issue Paper 5. Temperature Water Quality Criteria Guidance Development Project. EPA-910-D-01-005. Environmental Protection Agency, Region X. Seattle, WA. (available at http://yosemite.epa.gov/R10/WATER.NSF).

Poole, G.C., J.B. Dunham, D.M. Keenan, D.A. McCullough, C. Mebane, S.T. Sauter, J.C. Lockwood, D.A. Essig, M.P. Hicks, D.J. Sturdevant, E.J. Materna, S.A. Spalding, J. Risley, and M. Deppman. 2004. The case for regime-based water quality standards. BioScience 54(2):155-161.

McCullough, D.A. and M.J. Greene. 2005. Monitoring fine sediment: Grande Ronde and John Day Rivers. Final report to Bonneville Power Administration. Project No. 1997-034-00. CRITFC Technical Report 5-1. www.critfc.org.

Thesis Research Experience

M.S. Extensive experience in application of radioisotope methodology in determination of energy flow pathways in aquatic invertebrates. Conducted bioenergetics research at Idaho State University, Battelle Northwest, and Oregon State University. This research is important in understanding the role and persistence of invertebrate species in the aquatic community and estimating the impact of invertebrates on food resources.

Ph.D. Development of a system for classification of watersheds and streams through use of a hierarchical system of biophysical capacities. The Tillamook Forest on the north coast of Oregon was used as a prototype area for testing methodologies. This work is important in understanding the relationship between stream habitat and watershed character in designing efficient monitoring programs and in effectively managing ecological units.

Presentations

Presentation of bioenergetics research for year 1973 to AEC review panel, Richland, WA.

Bioenergetics of the mayfly *Tricorythodes minutus*. AAAS Meeting. 1975. Corvallis, Oregon.

Principles and methods of determination of energy budgets of aquatic insects. Invited lecture given to class of G.W. Minshall. 1977.

A systems classification of watersheds and streams. Given to Environmental Protection Agency, Corvallis, Oregon, July 1983.

Systematic classification of watersheds and streams of Oregon. Delivered February 1984 to Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Forest Service Management of fish habitat in the Columbia River basin. Delivered to Bonneville Power Administration Symposium, Airport Sheraton, Portland, OR. 1986.

The tribal perspective on Forest Service Research and management of anadromous fish in the Pacific Northwest. Delivered to Forest Service Region 6 symposium, Rippling River. 1986.

Effects of forest practices on fish habitat in the Northwest. Delivered to a forestry class at Mt. Hood Community College. 1987.

Washington's TFW Process. Panel discussion on new developments in fisheries management in the Pacific Northwest. Oregon Chapter of the American Fisheries Society. Ashland, OR. 1988.

Principles and methods of stream classification for TFW. TFW sponsored workshop on stream/watershed classification for ambient monitoring programs. Pack Forest, Eatonville, WA. 1988.

Delivered talk to Hancock Field Station OMSI Field Class on "The role of the courts and the Inter-Tribal Fish Commission in restoration of anadromous fish in the Columbia River Basin." Hancock Field Station is near Fossil, OR. 1989. Requested by H. Li.

Presentation to OMSI Field Class at Oregon State University, Corvallis on "Fisheries issues on the Columbia River and the role of the Columbia River Inter-Tribal Fish Commission. 1990. Requested by H. Li.

American Society of Limnology and Oceanography, Edmonton, Canada, July 1993. Towards a science-based management of Columbia basin watersheds for water temperature control and protection of fish production

Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon, Stream team, January 24, 1994. The role of temperature in regulating survival of Oregon's freshwater biota.

North Pacific International Chapter, American Fisheries Society, February 9-11, 1994. Wenatchee, Washington. Effects of water temperature on chinook survival and evaluation of evidence from the laboratory and field with management implications.

International River Quality Symposium, Poland-USA Joint Conference. Portland State University, Portland, Oregon, March 21-25, 1994. Technical concerns in selection of temperature criteria to protect oregon's freshwater biota.

Columbia River Inter-Tribal Fish Commission, Portland, Oregon, April 6, 1994. Technical concerns in selection of temperature criteria to protect Oregon's freshwater biota.

"Carrying capacity of tributaries and mainstem of the columbia river:concepts and management responses." Workshop on ecological carrying capacity for Columbia Basin salmon habitats. 2-day workshop at Columbia River Red Lion Inn, Portland, OR. September 6-7, 1995. Hosted by Battelle Northwest. Funded by Bonneville Power Administration.

"Use of biologically based temperature requirements as a guide to appropriate numeric indices for stream management." 1998. Stream temperature monitoring and assessment workshop. January 12-14, 1998. Forest Science Project, Humboldt State University Foundation, PO Box 1180, Arcata, CA. Co-sponsored by USEPA and California Forestry Association.

Independent Multidisciplinary Science Team for Governor Kitzhaber's Oregon Plan for restoration of salmon. Presentation on Water temperature standards: history, philosophy, and biological assessments, with Dr. Robert Beschta; September 10, 1998.

Retrospective on Water Temperature Effects on Salmonids of the Columbia River: A Contrast between 1971 and 1998. Presentation in EPA sponsored workshop (Mainstem Columbia/Snake River Temperature Workshop), Portland, Oregon. Mary Lou Soscia, convener. Don Martin and Dale McCullough, presenters. December 1998.

CBFWA/NWPPC Subbasin Planning Workshop. December 9, 1999. Concepts of subbasin planning: a tribal perspective.

"The effects of elevated water temperature on survival and production of adult salmon in the Snake River system." Given to the US Army Corps of Engineers Technical Management Team (TMT), June 15, 2000, Portland, OR.

"Balancing the effects of elevated water temperatures on mainstem survival of adults and smolts." Given to the Fish Production Advisory Committee, at the Fish Passage Center, Portland, OR. June 20, 2000.

"A conceptual model for the effects of water temperature alterations to a stream system on salmonid production at a watershed scale." Presentation to Oregon's Independent Multidisciplinary Science Team. Corvallis, Oregon. October 6, 2000.

"Effects of temperature and dissolved gases on fish health." Presentation at Columbia River Basin Tribal Water Quality Conference 2000, Spokane, WA. November 15, 2000.

"Physiological effects and management responses to seasonal droughts for salmonids." Presentation to workshop "Drought 2000, Lessons learned," Montana American Fisheries Society Annual Meeting, Butte, Montana. January 23, 2001.

Panel Discussion at Special Session: "Predation on Threatened Salmonids: State of the Science and Management," Thursday, February 15, 2002, 1:40 pm - 5:00 pm. The Wildlife Society - Oregon Chapter / American Fisheries Society - Oregon Chapter Joint Meeting, Doubletree Hotel, Jantzen Beach, Portland, Oregon.

"Overview of Columbia River Salmon and Restoration Issues." July 19, 2005 lecture to Environmental

Sciences class at Lewis and Clark College, Portland, Oregon for Professor Heather Erickson.

The Columbia River Estuarine Research Conference, 2006. Astoria, April 19-20, 2006. "A Framework for Salmon Recovery? Management Roadblocks and Needed Direction."

"Prospects for Recovery of ESA-listed Spring Chinook in the Upper Grande Ronde Basin as a Case Study in the Failure of Federal and State Agencies to Apply Best Available Science to Water Quality/Quantity Management." National Research Council Committee on the Hydrologic Impacts of Forest Management, October 2-3, 2006. H.J. Andrews Experimental Forest, Blue River, Oregon.

Training

"Photogrammetry and aerial photographic interpretation." March 11-15, 1991. College of Forestry, Oregon State University.

FORPLAN. 2-day course on the USFS program for forest planning. Oregon State University. Taught by Dr. K.N. Johnson. 1986.

Introduction to ARCVIEW. 2-day course in GIS, an ESRI-certified course offered by Atterbury Consultants, November 13-14, 1995.

Aerial Photo Analysis and Mapping. March 25-28, 1997. Oregon State University, College of Forestry.

Management problems of the technical person in a leadership role. October 27, 1997. Fred Pryor Seminars, Beaverton, OR.

Expert witness seminar. 1988. US Fish and Wildlife Service, National Ecology Research Center. 1-d session. Colorado State University, course EL305.

Workshop on the use of the SSTEMP stream reach temperature model. Tom Payne and Associates. January 14, 1998, Sacramento, CA.

Additional Employment

September 17, 2004. Peer Review of State of Idaho Evaluation of Seasonal-Cold-Water Temperature Criteria. Technical review completed for Versar, Springfield, Virginia, subcontractor to USEPA. Contracting officer, Kelly McAloon.

September 20, 2005-April 10, 2006. Technical advisory committee for the Colorado Department of Public Health and Environment, Denver, Colorado. Preparation of technical memos and presentation at a CDPHE Commission meeting in support of development of temperature standards for the State of Colorado. Contracting officer, Sarah Johnson.

June-July, 2007. Contractor to Connecticut River Watershed Council for review of Entergy Vermont Yankee Nuclear Power Plant's proposal to Vermont for a temperature variance in the Connecticut River.