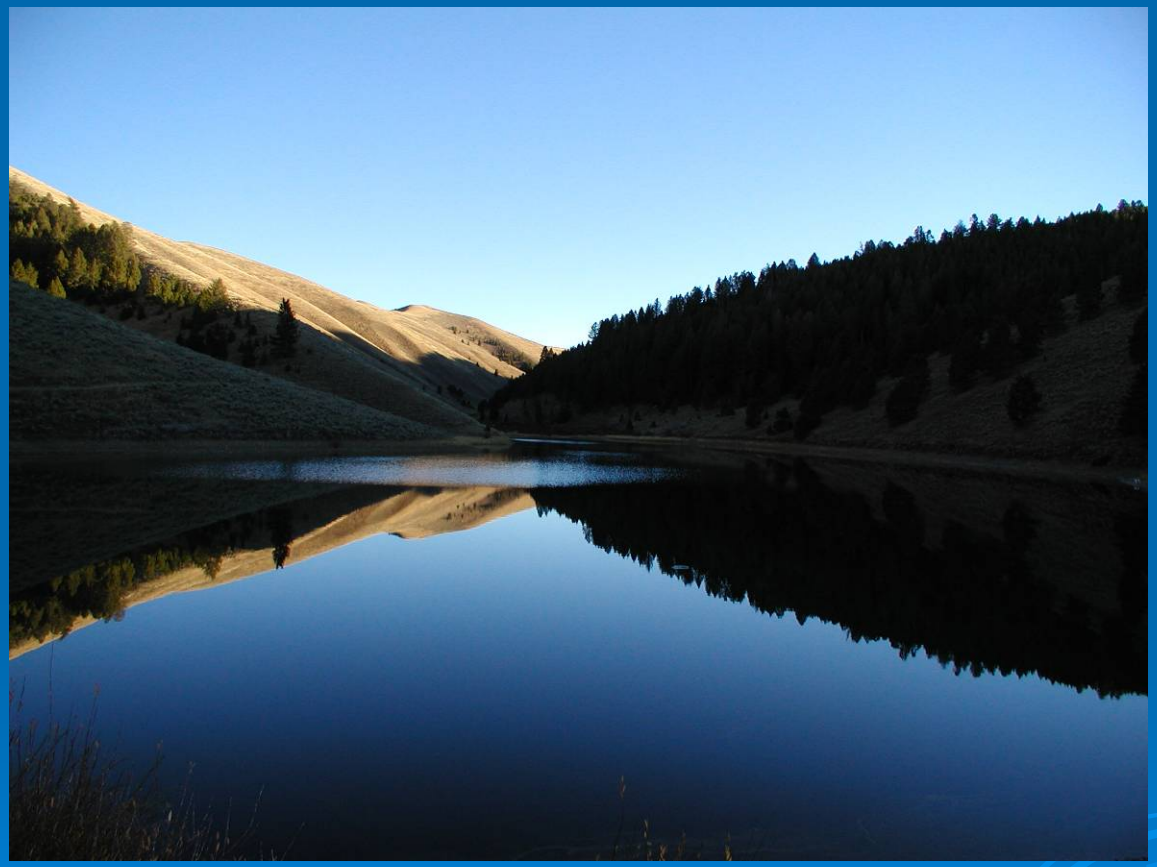
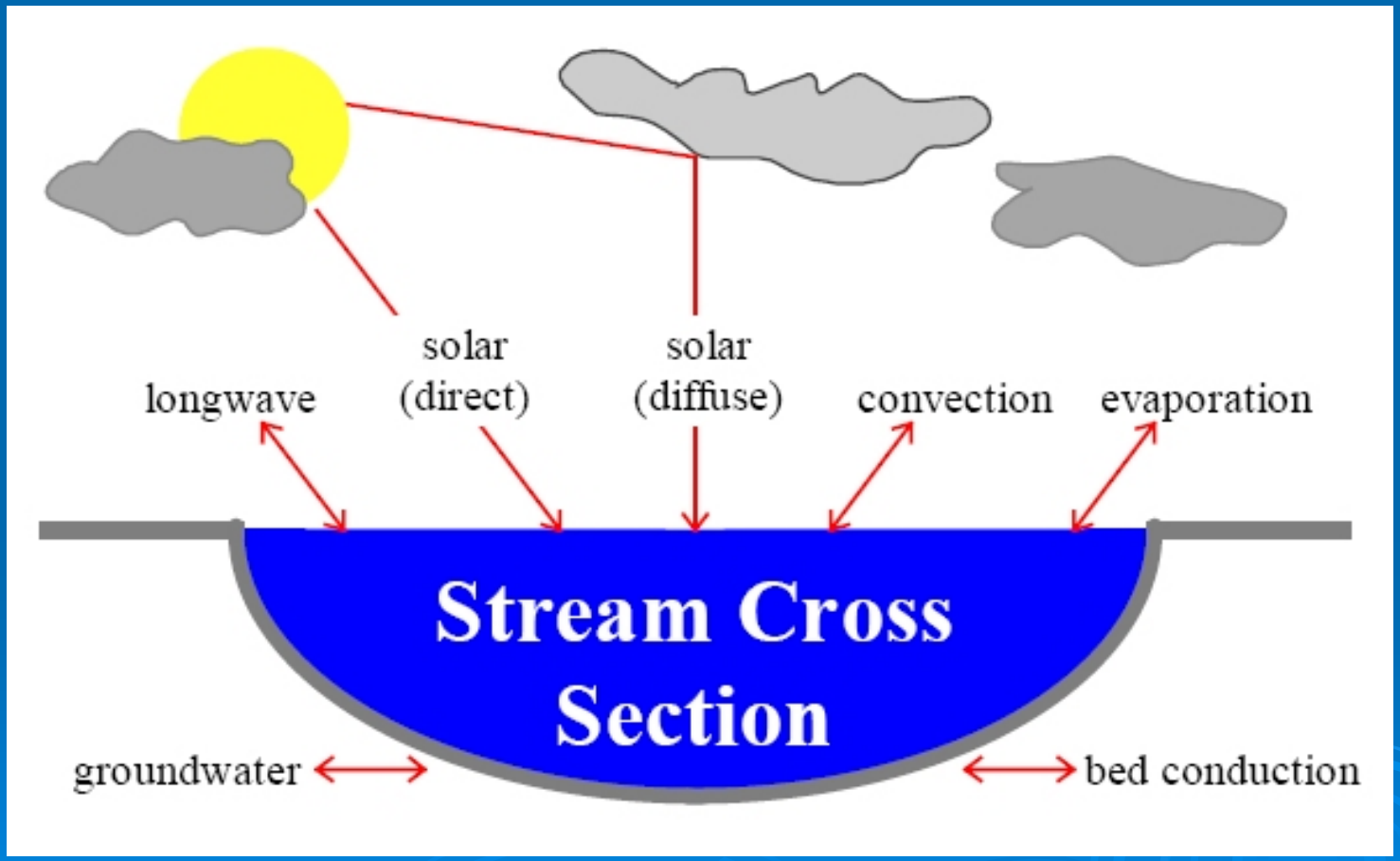
Potential Natural Vegetation Temperature TMDLs

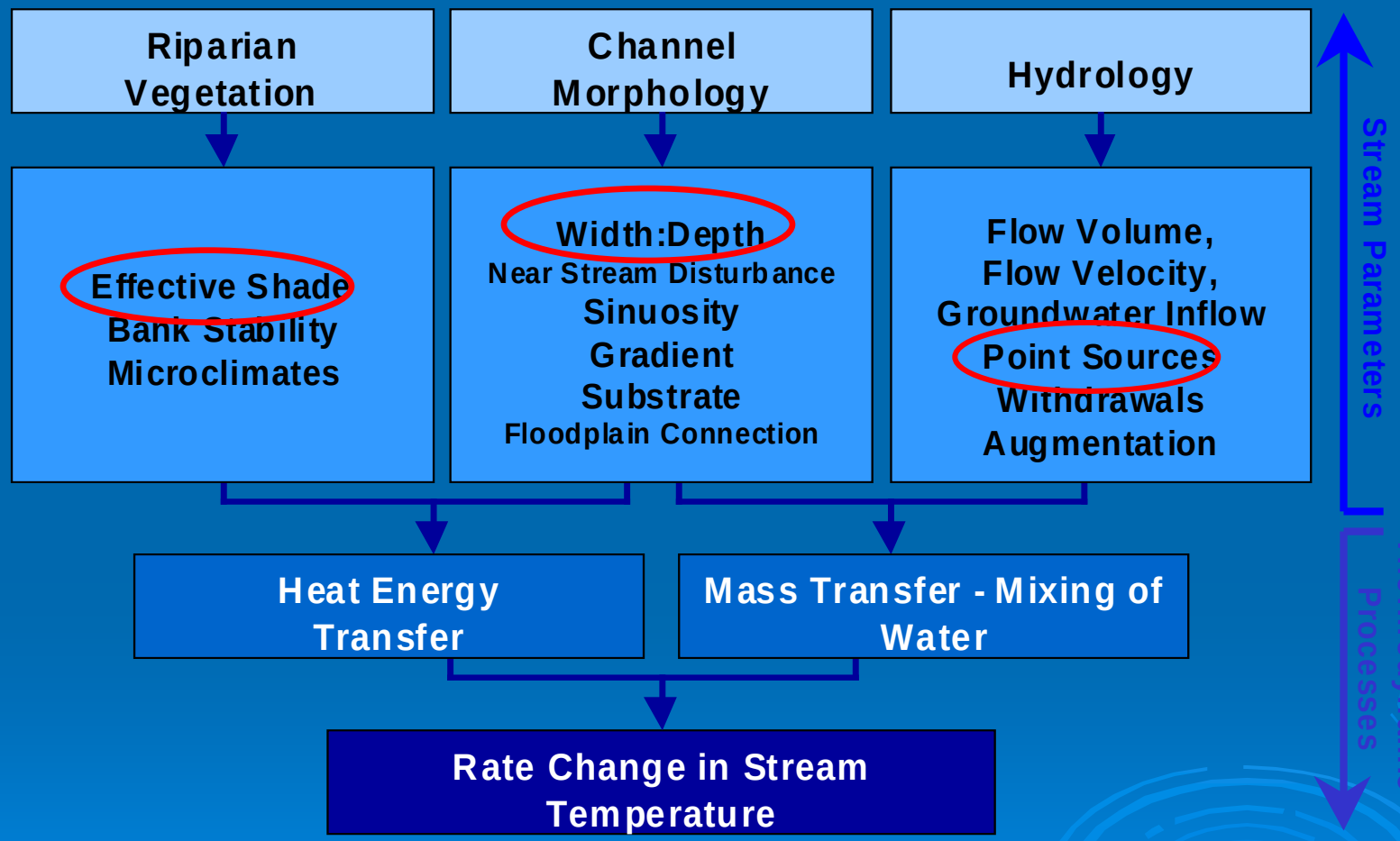


Mark Shumar & Jessica Moore, State Technical Services Office,
Idaho Department of Environmental Quality

Components of a Stream's Heat Budget



Stream Temperature Conceptual Model Flow Chart



Natural Stream Temperature

- Natural Shade (PNV)
- Natural Cross-section
- Natural Flow
- Natural Bed/Floodplain Connectivity

Potential Natural Vegetation

- Provides the expected effective shade (along with topography)
- Produces natural stream temperatures (assuming no point sources, dams, etc.)
- Equates to natural background conditions in Idaho WQS

Temperature TMDL

- Loading Capacity = Solar Load under PNV
  aka potential effective shade
- Existing Load = Solar Load under current
  effective shade
- Load Reduction = PNV Load – Existing Load

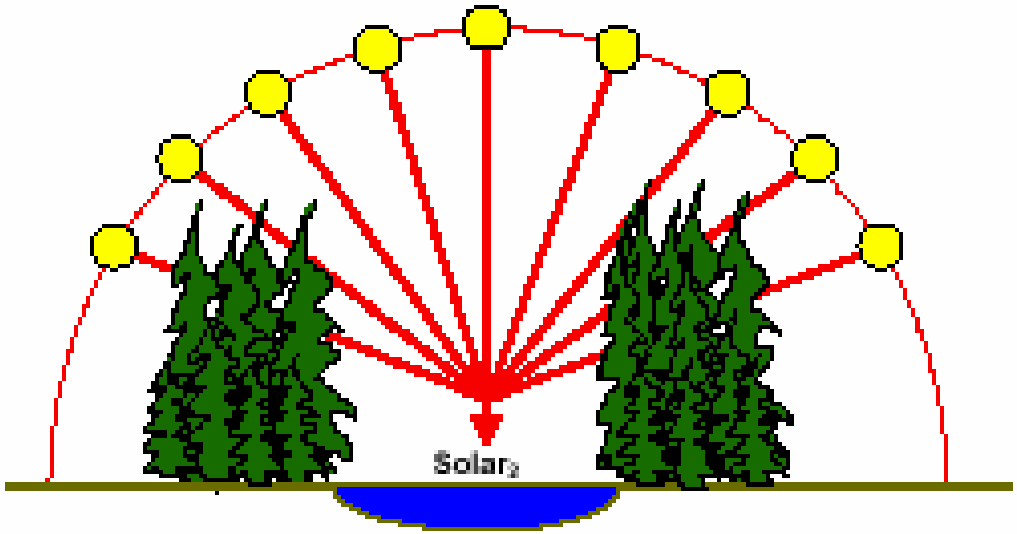
Temperature TMDL

- Existing Shade – estimated from aerial photos and measured with pathfinder
- Target Shade – modeled by plant community type
- Existing Bankfull Width – available measurements
- Natural Bankfull Width – estimated from regional curve

Effective Shade

Effective Shade Defined

$Solar_1$ – Potential daily direct beam solar radiation load adjusted for julian day, solar altitude, solar azimuth and site elevation.



$$\text{Effective Shade} = \frac{(Solar_1 - Solar_2)}{Solar_1}$$

Where,

$Solar_1$: Potential Daily Direct Beam Solar Radiation Load

$Solar_2$: Daily Direct Beam Solar Radiation Load Received at the Stream Surface

Existing Effective Shade

Topography

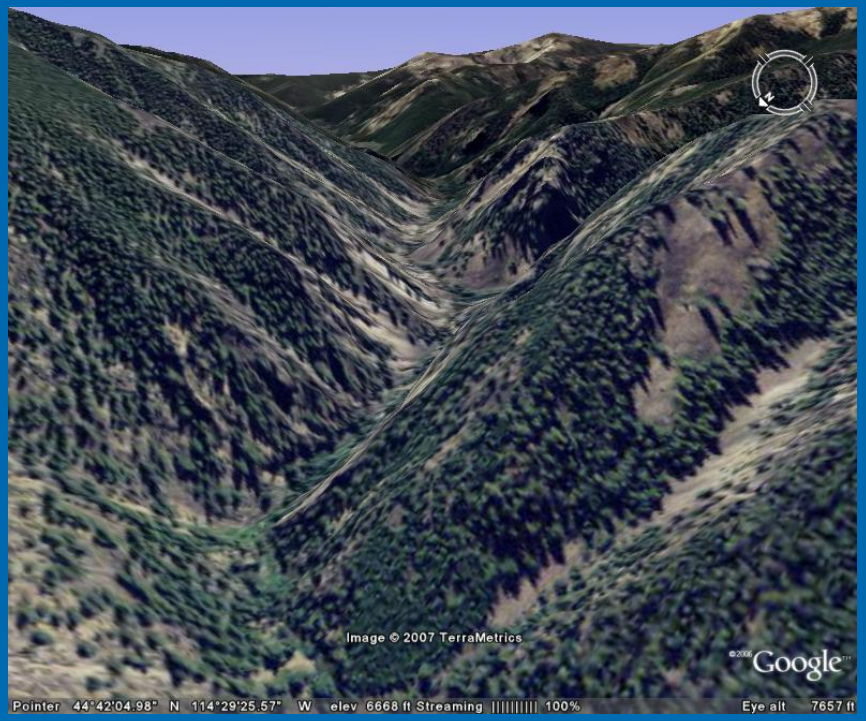
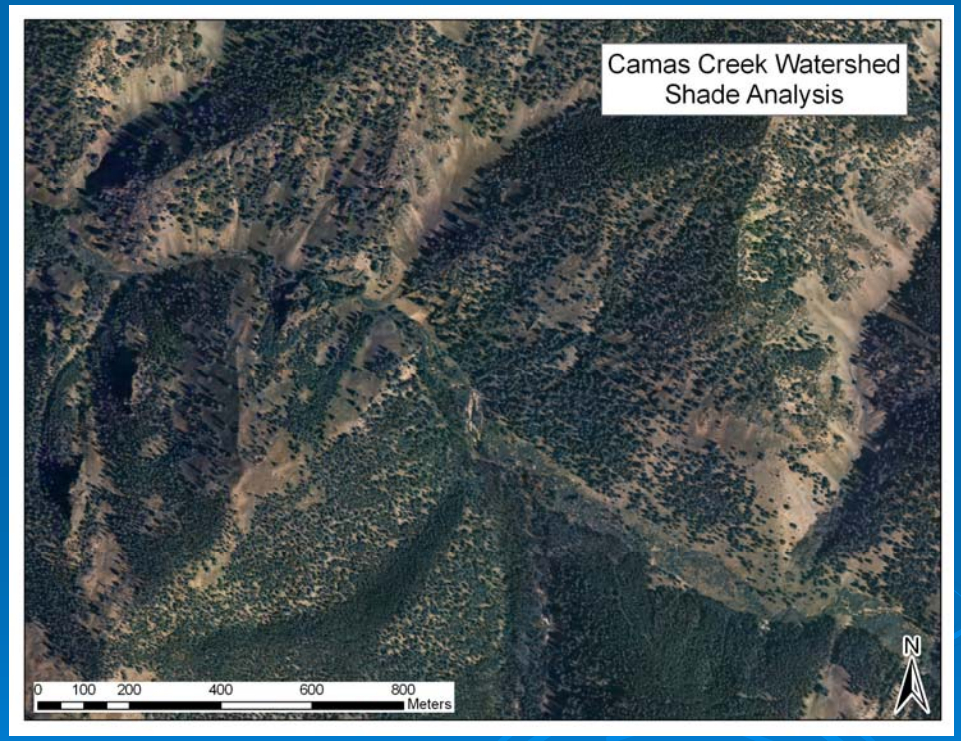
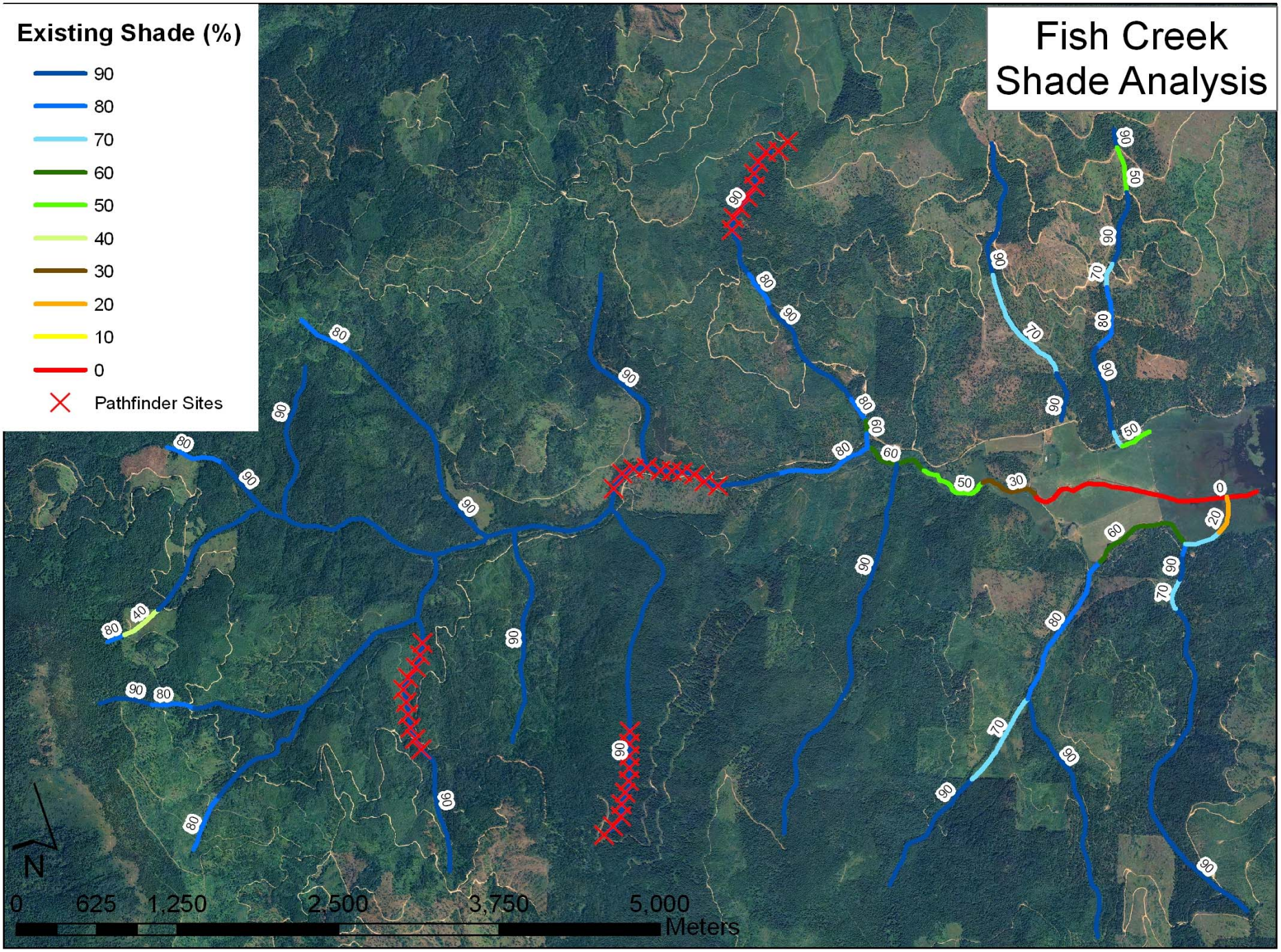


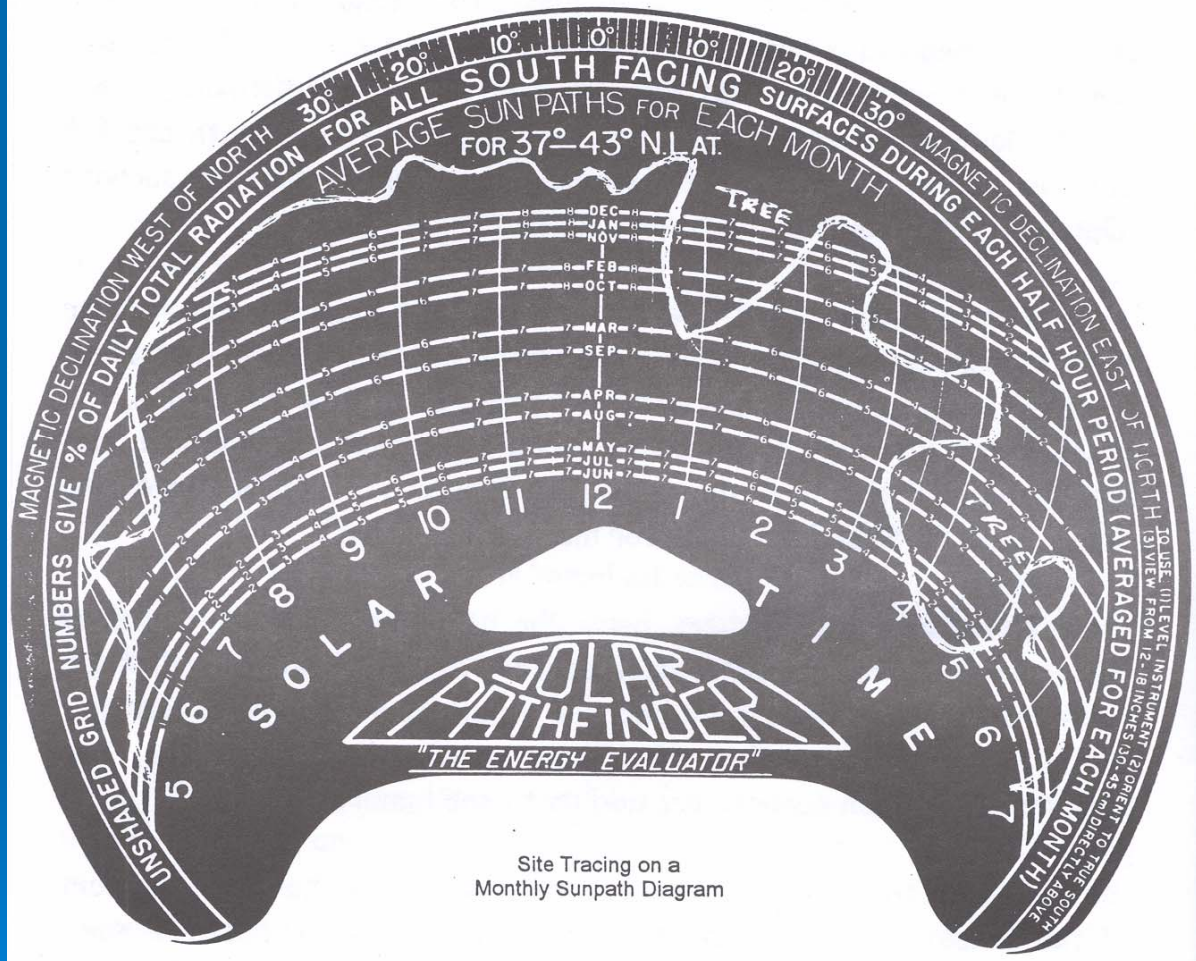
Image © 2007 TerraMetrics
Google
Pointer 44°42'04.98" N 114°29'25.57" W elev 6668 ft Streaming 100%
Eye alt 7657 ft


Camas Creek Watershed
Shade Analysis
0 100 200 400 600 800
Meters
N


Fish Creek
Shade Analysis
Existing Shade (%)
90
80
70
60
50
40
30
20
10
0
Pathfinder Sites
N
0
625
1,250
2,500
3,750
5,000
Meters

Existing Effective Shade

Monthly Sunpath Example



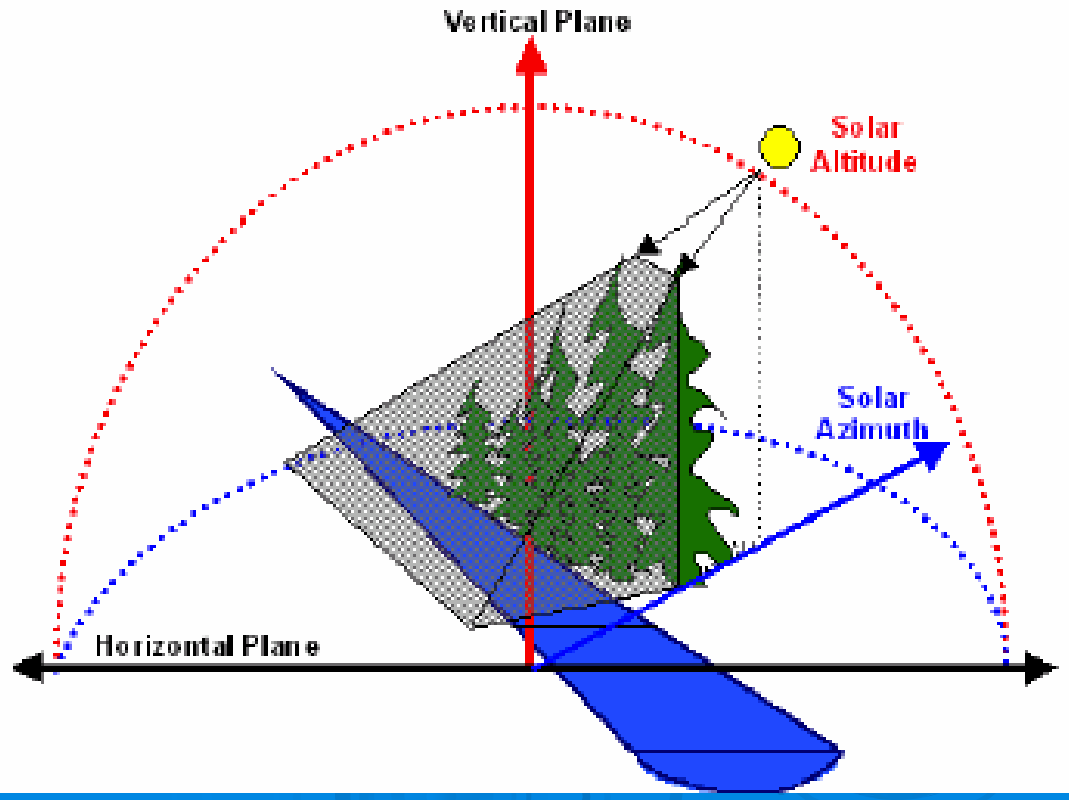
Site Tracing on a
Monthly Sunpath Diagram

Target Effective Shade

Geometric Relationship that Influence Shade Production

Solar Altitude and **Solar Azimuth** are two basic measurements of the sun's position. When a stream's orientation, geographic position, riparian condition and solar position are known, shading characteristics can be simulated.

Solar Altitude measures the vertical component of the sun's position
Solar Azimuth measures the horizontal component of the sun's position



Effective Shade Curve – Application in Ponderosa Pine/Common Chokecherry Habitat Type

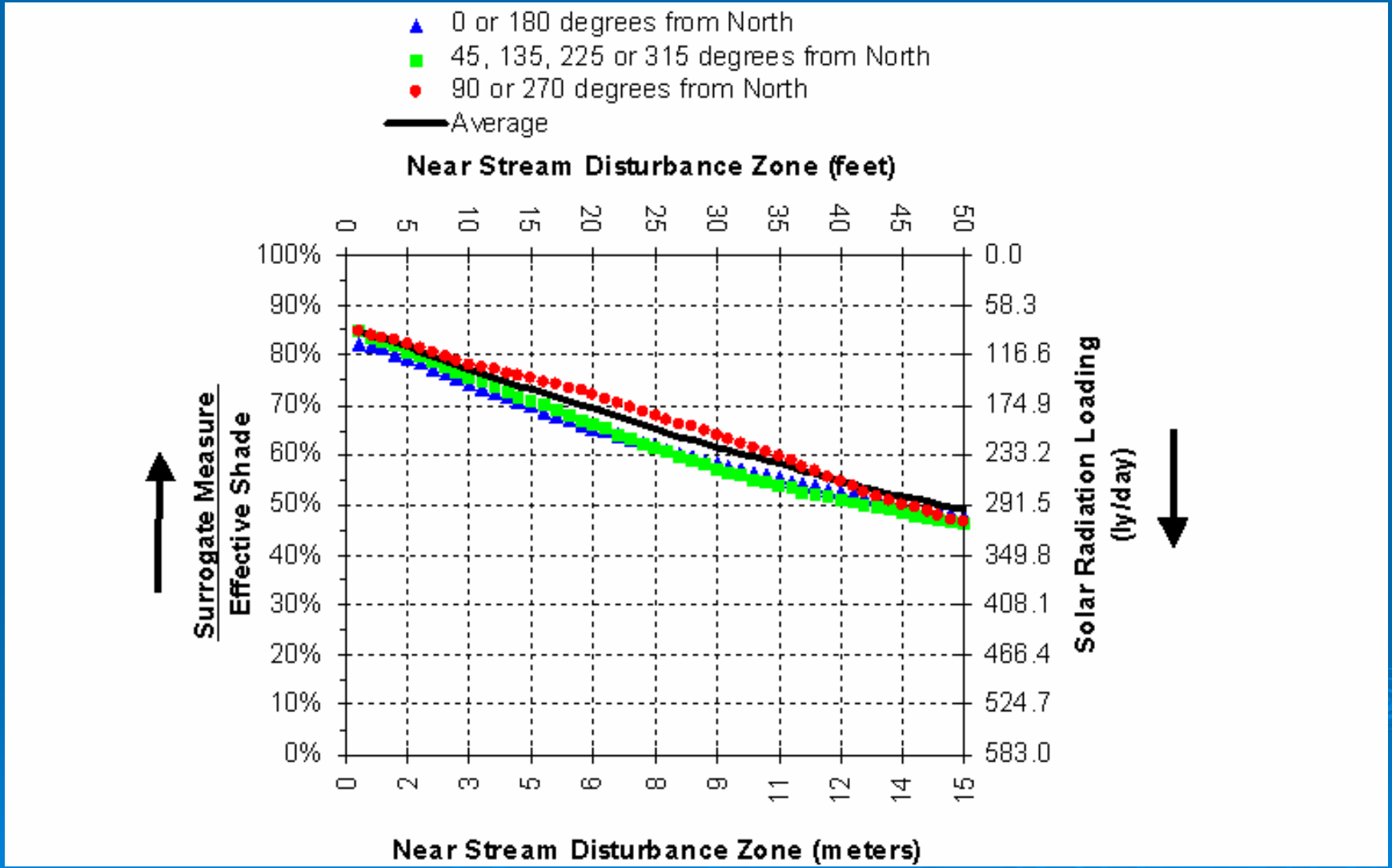


Table X-3. Summary ARU filter Group Characteristics

ARU filter Group A - Forest Riparian Group

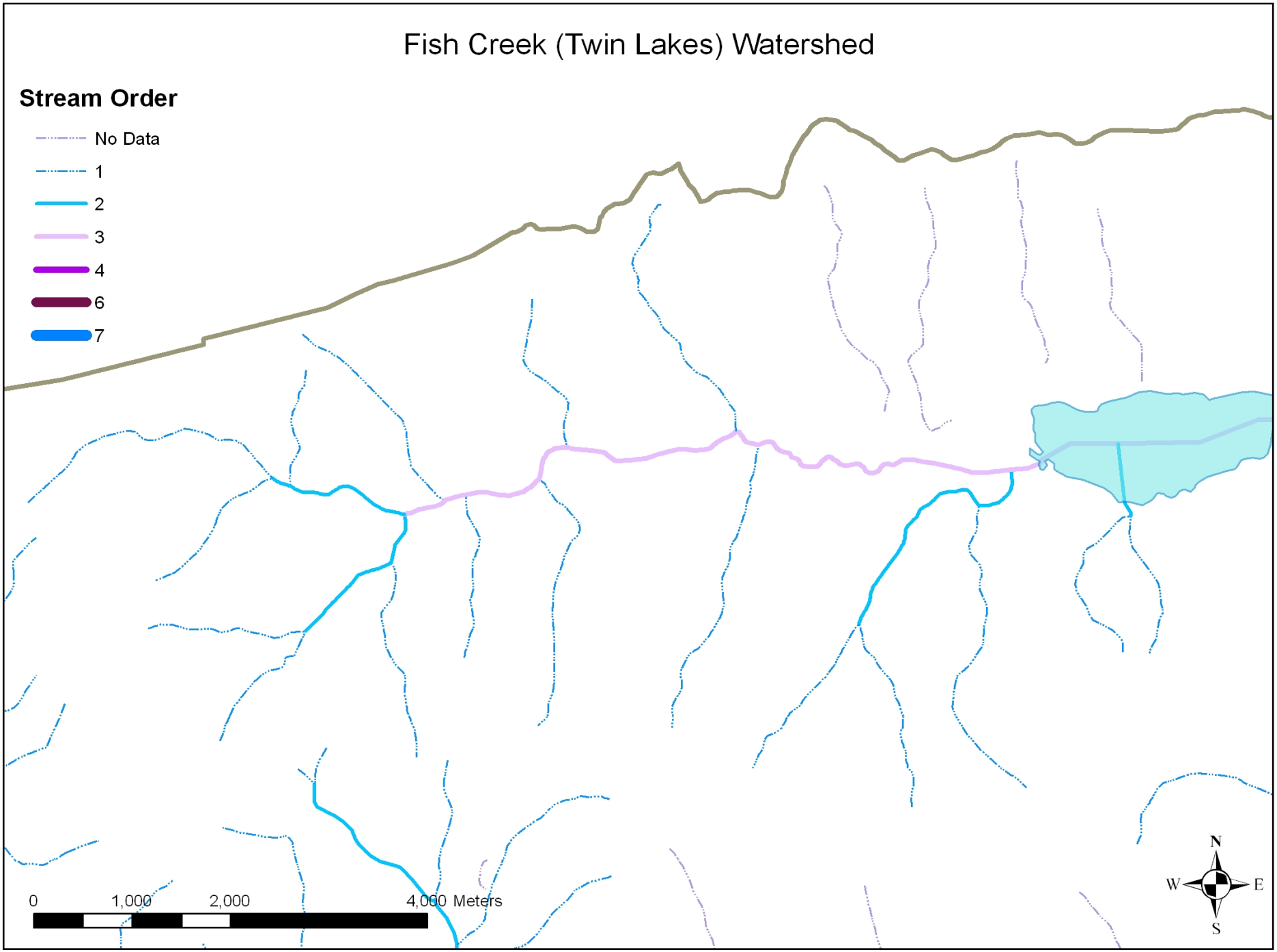
- Stream Order – 1st, 2nd, 3rd and 4th
- Stream gradient ≥ 3 percent

ARU filter Group B - Non-Forest Riparian Group 1

- Stream Order – 1st, 2nd, 3rd and 4th
- Stream gradient < 3 percent

ARU filter Group C - Non-Forest Riparian Group 2

- Stream Order – 5th and 6th


Fish Creek (Twin Lakes) Watershed
Stream Order
No Data
1
2
3
4
6
7
0
1,000
2,000
4,000 Meters
N
W
E
S

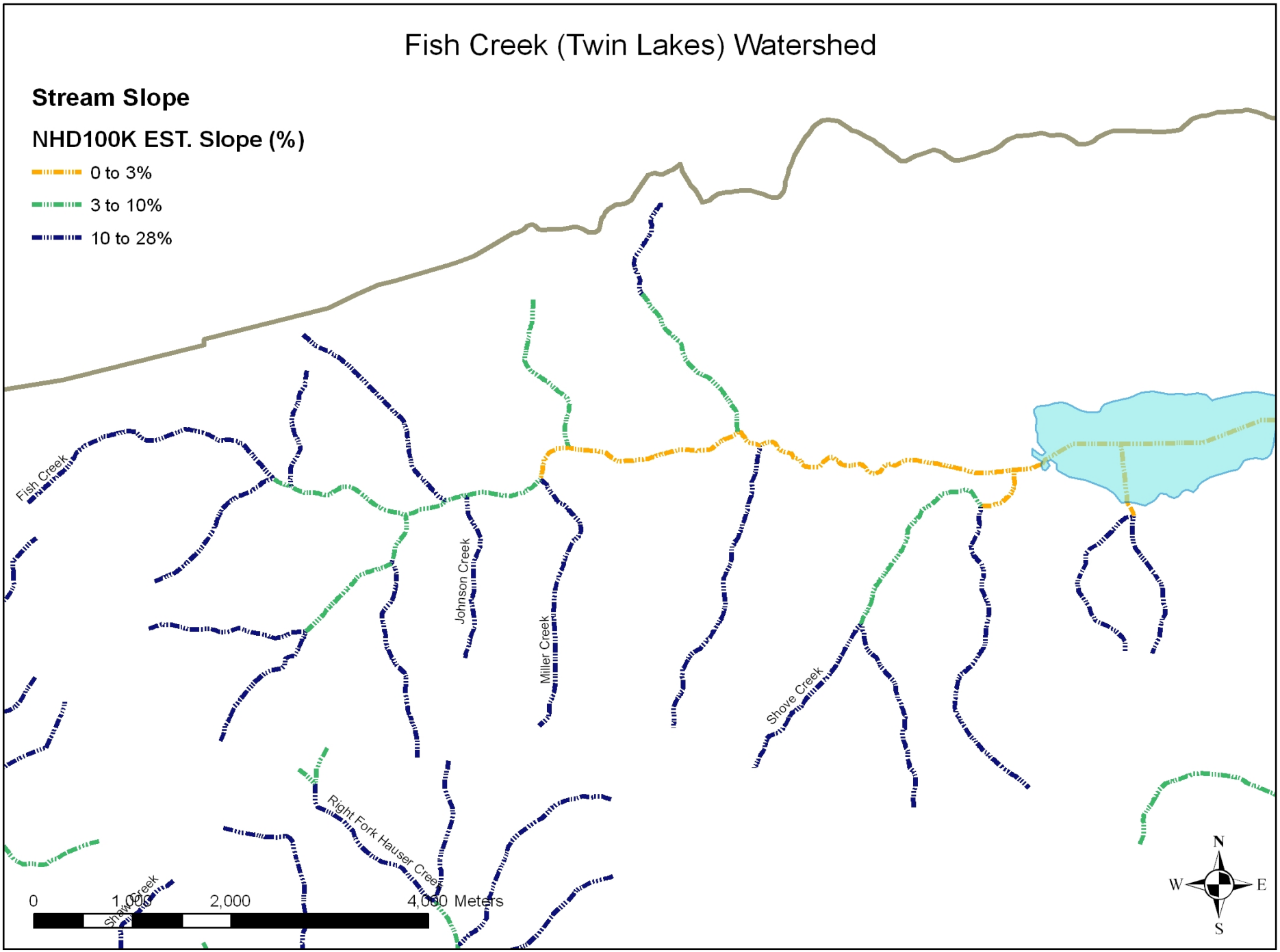

Fish Creek (Twin Lakes) Watershed
Stream Slope
NHD100K EST. Slope (%)
0 to 3%
3 to 10%
10 to 28%
Fish Creek
Johnson Creek
Miller Creek
Shove Creek
Right Fork Hauser Creek
Shaw Creek
0
1,000
2,000
4,000 Meters
N
W
E
S

Table X-4. VRU/HTG Assessment Groups in the Pend Oreille Basin (KPIZ 2003)	
Assessment Group	**Description**
Group A: VRU 1/HTG 1 (Warm/Dry), VRU 2/HTG 2 (Moderately Warm/Dry), and VRU 3/HTG 3 (Moderately Warm/ Moderately Dry).	This group contains the more warm and dry habitat types with VRU 1 being the warmest and driest to the more moderate conditions of VRU 3. These sites include warm, dry grasslands to moderately cool and dry upland sites. The dry, lower elevation open ridges are composed of mixed Douglas-fir and ponderosa pine in well-stocked and fairly open-grown conditions. Moderately moist, upland sites and dense draws also include larch and lodgepole pine, with lesser amounts of ponderosa pine. Tree regeneration occurs in patches and is largely absent in the understory, particularly in the driest sites. Annual precipitation ranges from 14" to 30", about 75% of that falling as rain. While the growing season is fairly long, high solar input and moderately shallow soils often result in soils that dry out early in the growing season, which results in low to moderate site productivity.
Group B: VRU 4/HTG 4 (Moderately Warm/Moist), VRU 5/HTG 5 (Moderately Cool/Moist), and VRU 6/HTG 6 (Moderately Cool/Wet).	This group occupies most of the moist sites along benches and stream bottoms. The moderating effects of the inland maritime climate ecologically influence this group. This group includes the more moderate sites of VRU 4 and scattered riparian and wet sites of VRU 6. This group is widespread throughout the forest and has the most biological productivity. Precipitation is moderate to high ranging from 30" to 55" per year.
Group C: VRU 7/HTG 7 (Cool/Moist) and VRU 8/HTG 8 (Cool/Wet).	This group occurs in the moist, lower subalpine forest setting and is common on northwest to east facing slopes, riparian and poorly drained subalpine sites, and moist frost pockets. This landscape is typically bordered by warmer sites (Group B) and cool, drier subalpine sites (Group D). This group includes characteristics of each. Average precipitation is estimated between 35" and 55" per year, less than half as rain. Vegetative productivity is moderate to high as a result of the high moisture-holding capacity and nutrient productivity of loess deposits, adequate precipitation, and a good growing season.
Group D: VRU 9/HTG 9 (Cool/ Moderately Dry), HTG 10 (Cold/Moderately Dry) and HTG 11 (Cold).	This group is typified by cool and moderately dry conditions with moderate solar input. The climate is characterized by a short growing season with early summer frosts. Annual precipitation ranges from 35"-70", mostly in the form of snow. Due to generally shallow soils (low water holding capacity), slope position, and aspect, soil moisture is often limited during late summer months. It is generally found on rolling, ridges and upper reaches of convex mountain slopes.

Table X-5. Pend Oreille Basin Historical Forest Vegetation Structure Estimates

Assessment Group	% of Area	Shrub/Seed/ SAP	Small/ Pole	Medium/ Immature	Large/ Mature	Old Growth
Warm/Dry (Group A)	17%	20%	8%	12%	17%	43%
Moist (Group B)	56%	25%	15%	27%	21%	12%
Cool/Moist (Group C)	16%	22%	13%	22%	23%	20%
Cool/Dry (Group D)	11%	22%	13%	22%	23%	20%
Historical Weighted Avg.		23.3%	13.3%	23.1%	20.9%	19.4%
National Forest Current		*28.4%*	*4.4%*	*39.2%*	*20.7%*	*7.4%*
% Change from Historic		*21.7%*	*-67.1%*	*69.7%*	*-0.8%*	*-62.1%*
Current as % of Historic		*121.7%*	*32.9%*	*169.7%*	*99.2%*	*37.9%*

Table X-6. Pend Oreille Basin Historical Forest Vegetation Composition Estimates

Assessment Group	PP	WP	WL	DF	GF/WH	WRC	LP	SAF	WBP
Warm/Dry (Group A)	60%	- -	10%	20%	- -	- -	10%	- -	- -
Moist (Group B)	1%	40%	25%	20%	5%	5%	3%	1%	- -
Cool/Moist (Group C)	- -	12%	15%	1%	- -	- -	12%	60%	- -
Cool/Dry (Group D)	- -	- -	- -	- -	- -	- -	20%	65%	15%
Historical Weighted Avg	10.8%	24.3%	18.1%	14.8%	2.8%	2.8%	7.3%	17.3%	1.7%
National Forest Current	2.2%	2.0%	3.8%	36.5%	16.9%	7.9%	4.3%	25.6%	0.2%
% Change from Historic	-80%	-91.8%	-79%	147.3%	503.6%	182.1%	-40%	47.9%	-88%
Current as % of Historic	20.4%	8.2%	21.0%	247.3%	603.6%	282.1%	60.0%	147.9%	12.1%

Nonforest Group 1

Table X-7. Canopy Cover and Constancy Conditions for Riparian "Overstory" Vegetation along VRU3C and VRU4C Streams.

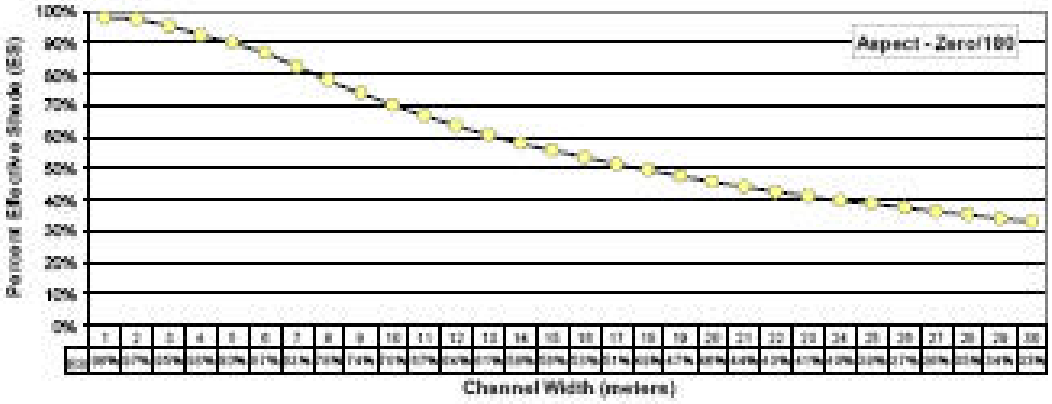
Common Name	Canopy Cover (CC)	Constancy	Weighted CC[10]	System Potential (SP) Height[11]	Weighting Factor[12]	Weighted SP Height
VRU 3C (n = 43 Ecodata plots)						
Grand Fir	20	51	10	100	14%	14
Engelmann Spruce	16	33	5	90	9%	8
Black Cottonwood	15	30	5	100	8%	8
Douglas Fir	8	35	3	91	10%	9
Western Redcedar	30	40	12	87	11%	10
Western Hemlock	19	56	11	85	16%	13
Rocky Mountain Maple	8	65	5	30	18%	5
Mountain Alder	21	21	4	30	6%	2
Sitka Alder	11	28	3	30	8%	2
Total			**58**	**Total**		**72**
VRU 4C (n = 34 Ecodata plots)						
Grand Fir	6	35	2	100	10%	10
Subalpine Fir	5	18	1	63	5%	3
Paper Birch	40	9	4	70	3%	2
Engelmann Spruce	13	44	6	90	13%	11
Balsam Poplar	30	3	1	80	1%	1
Black Cottonwood	16	24	4	100	7%	7
Douglas Fir	16	50	8	91	14%	13
Western Red Cedar	32	26	8	87	7%	6
Western Hemlock	5	26	1	85	7%	6
Rocky Mountain Maple	11	56	6	30	16%	5
Mountain Alder	34	35	12	30	10%	3
Sitka Alder	21	24	5	30	7%	2
Total			**58**	**Total**		**70**

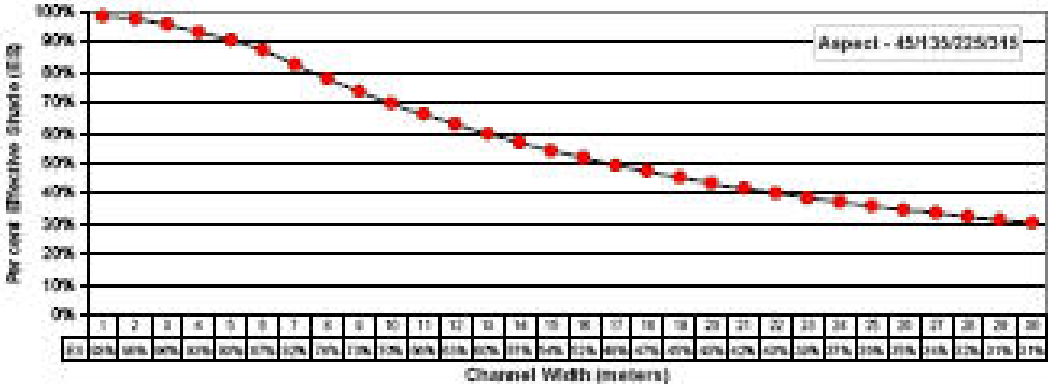
Nonforest Group 2

Table X-8. Canopy Cover and Constancy Conditions for Riparian "Overstory" Vegetation along VRU5C Streams.

Common Name	Canopy Cover (CC)	Constancy	Weighted CC[13]	System Potential (SP) Height[14]	Weighting Factor[15]	Weighted SP Height
VRU 5C (n = 9 Ecodata plots)						
Grand Fir	16	50	8	100	15%	15
Paper Birch	12	31	4	70	10%	7
Engelmann Spruce	5	31	2	90	10%	9
Black Cottonwood	28	63	18	100	19%	19
Douglas Fir	2	38	1	91	12%	11
Western Red Cedar	18	44	8	87	13%	12
Western Hemlock	6	25	2	85	8%	7
Mountain Alder	20	44	9	25	13%	3
Sitka Alder	11	28	3	30	8%	2
Total			**50**	**Total**		**82**

Figure X-8. System Potential Effective Shade for "Assessment Group B" (Moist) at Various Stream Aspect and Stream Width Conditions.





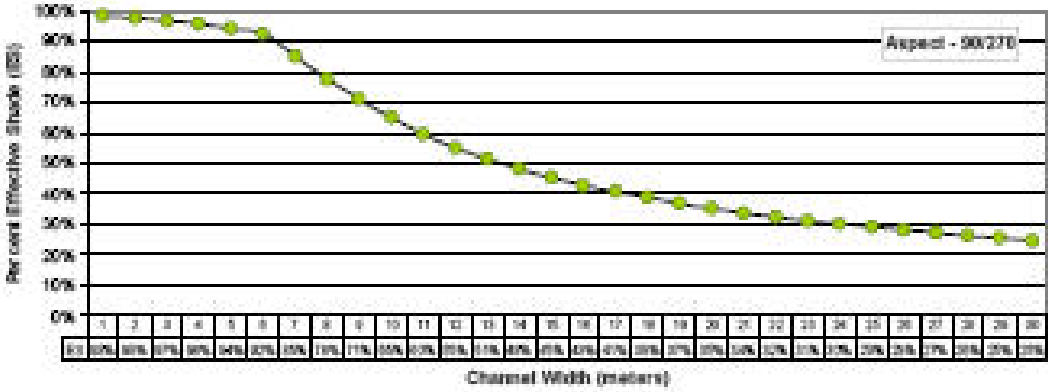
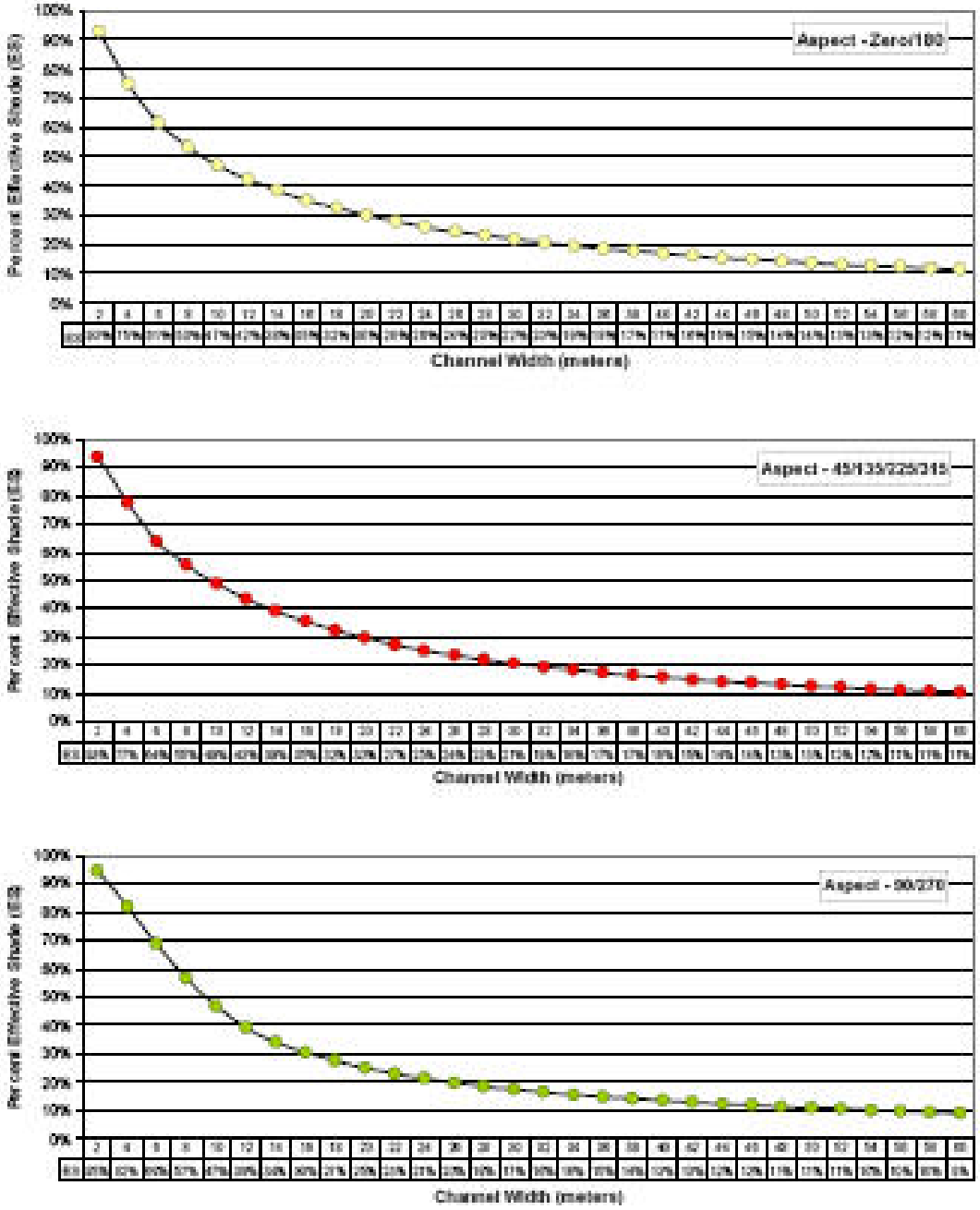


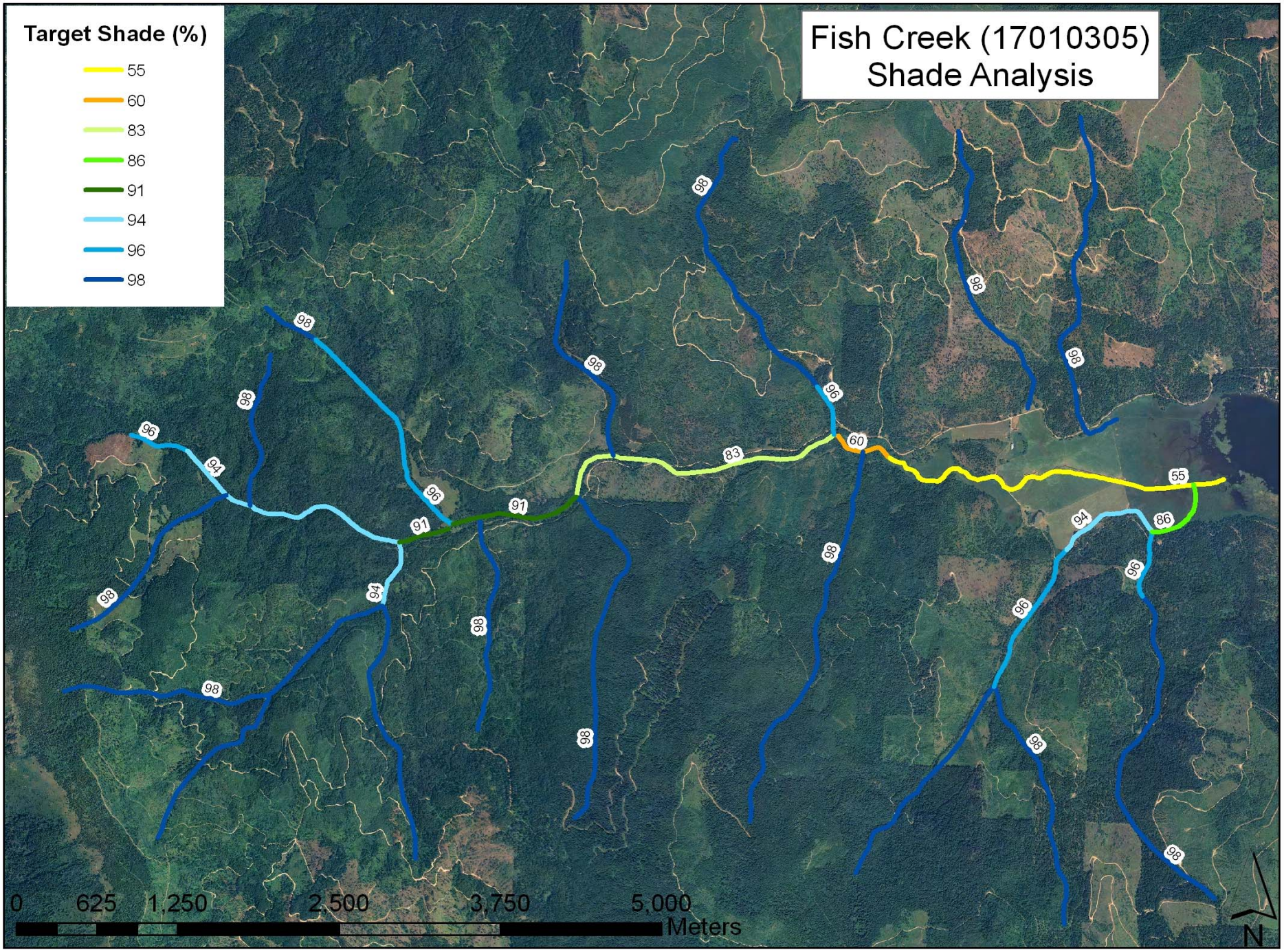
Figure X-16. System Potential Effective Shade for "Non-Forest" Assessment Group 1 at Various Stream Aspect and Stream Width Conditions.



Shade Targets

Forest	1m	2m	3m	4m	5m	6m	7m	8m	9m
Group B - VRUs 4,5,6 0/180	98	97	95	93	90	87	83	78	74
45/135/225/315	98	98	96	93	90	87	82	78	73
90/270	98	98	97	96	94	92	85	78	71
Target (%)	**98**	**98**	**96**	**94**	**91**	**89**	**83**	**78**	**73**

Non-Forest	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m
Group 1 - Hardwoods 0/180		93		75		61		53		47
45/135/225/315		93		77		64		55		49
90/270		95		82		69		57		47
Target (%)	**97**	**94**	**86**	**78**	**72**	**65**	**60**	**55**	**52**	**48**


Fish Creek (17010305)
Shade Analysis
Target Shade (%)
55
60
83
86
91
94
96
98
0
625
1,250
2,500
3,750
5,000
Meters
N

Bankfull Width

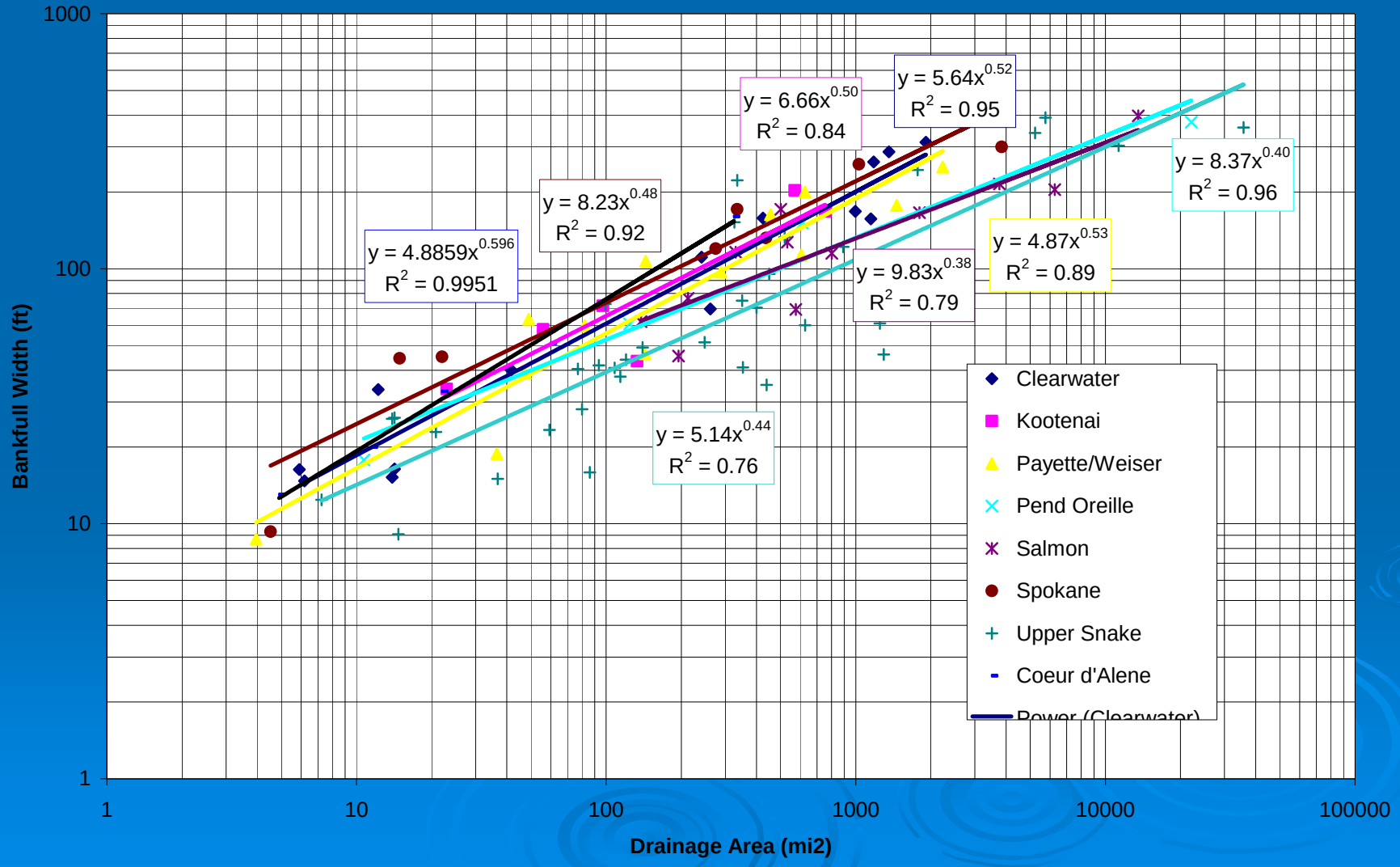


Table 1. Bankfull Width (m) as Estimated From the Spokane Regional Curve and Existing Measurements.

Location	area (sq mi)	Spokane (m)	existing (m)
Fish Creek Mainstem			
Fish Creek @ mouth	19.4	10	~8
Fish Creek ab meadow	14.8	9	
Fish Creek bl Miller Creek	9.3	7	7.1
Fish Creek @ ID/WA border	1.7	3	
South-side Tributaries			
Youngs Draw @ mouth	1.84	3	
Shove Creek @ mouth	2.72	4	
Swansons Chute @ mouth	0.85	2	
Miller Creek @ mouth	1.14	3	1.7*
Johnson Creek @ mouth	0.35	2	
Unnamed complex (west of Johnson)	2.61	4	
east fork	0.6	2	2.8
middle fork	0.62	2	
west fork	1.75	3	
Unnamed (western most)	0.55	2	
North-side Tributaries			
1st Unnamed (eastern most)@mouth	0.58	2	
2nd Unnamed @ mouth	0.91	2	
3rd Unnamed (opposite Swansons)@ mouth	1.23	3	1.1*
4th Unnamed (opposite Miller)@mouth	1.08	3	
5th Unnamed (opposite Johnson)@mouth	1.05	3	
6th Unnamed (western most)@mouth	0.24	1	

*headwaters sampling locations

Loading Analysis

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**Fish Creek**
470	0.8	1.14	0.96	0.228	-0.91	3	3	1410	1607.4	1410	321.48	-1285.92	Forest Group B
1970	0.9	0.57	0.94	0.342	-0.23	4	4	7880	4491.6	7880	2694.96	-1796.64	
ID17010305PN014_02							**Subtotal**	**9,290**	**6,099**	**9,290**	**3,016**	**-3,083**	
1480	0.9	0.57	0.91	0.513	-0.06	5	5	7400	4218	7400	3796.2	-421.8	
1580	0.9	0.57	0.83	0.969	0.399	7	7	11060	6304.2	11060	10717.14	4412.94	
800	0.8	1.14	0.83	0.969	-0.171	7	7	5600	6384	5600	5426.4	-957.6	
500	0.6	2.28	0.6	2.28	0	7	7	3500	7980	3500	7980	0	Nonforest Group 1
580	0.5	2.85	0.55	2.565	-0.285	8	8	4640	13224	4640	11901.6	-1322.4	
460	0.3	3.99	0.55	2.565	-1.425	8	8	3680	14683.2	3680	9439.2	-5244	
1840	0	5.7	0.55	2.565	-3.135	8	8	14720	83904	14720	37756.8	-46147.2	
ID17010305PN014_03							**Subtotal**	**50,600**	**136,697**	**50,600**	**87,017**	**-49,680**	
							Total	**59,890**	**142,796**	**59,890**	**90,034**	**-52,763**	**-37**
													% Reduction

MOS

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**Fish Creek**
470	0.9	0.57	0.96	0.228	-0.34	3	3	1410	803.7	1410	321.48	-482.22	Forest Group B
1970	0.9	0.57	0.94	0.342	-0.23	4	4	7880	4491.6	7880	2694.96	-1796.64	
ID17010305PN014_02							**Subtotal**	**9,290**	**5,295**	**9,290**	**3,016**	**-2,279**	
1480	0.9	0.57	0.91	0.513	-0.06	5	5	7400	4218	7400	3796.2	-421.8	
1580	0.8	1.14	0.83	0.969	-0.171	7	7	11060	12608.4	11060	10717.14	-1891.26	
800	0.8	1.14	0.83	0.969	-0.171	7	7	5600	6384	5600	5426.4	-957.6	
500	0.6	2.28	0.6	2.28	0	7	7	3500	7980	3500	7980	0	Nonforest Group 1
580	0.5	2.85	0.55	2.565	-0.285	8	8	4640	13224	4640	11901.6	-1322.4	
460	0.5	2.85	0.55	2.565	-0.285	8	8	3680	10488	3680	9439.2	-1048.8	
1840	0.5	2.85	0.55	2.565	-0.285	8	8	14720	41952	14720	37756.8	-4195.2	
ID17010305PN014_03							**Subtotal**	**50,600**	**96,854**	**50,600**	**87,017**	**-9,837**	
							Total	**59,890**	**102,150**	**59,890**	**90,034**	**-12,116**	**-12**
													% Reduction

North-side Tributaries

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**North-side Tributaries**
150	0.9	0.57	0.98	0.114	-0.46	1	1	150	85.5	150	17.1	-68.4	*eastern-most tributary*
370	0.5	2.85	0.98	0.114	-2.736	1	1	370	1054.5	370	42.18	-1012.32	
610	0.9	0.57	0.98	0.114	-0.456	1	1	610	347.7	610	69.54	-278.16	
200	0.7	1.71	0.98	0.114	-1.596	1	1	200	342	200	22.8	-319.2	
550	0.8	1.14	0.98	0.114	-1.026	2	2	1100	1254	1100	125.4	-1128.6	
710	0.9	0.57	0.98	0.114	-0.456	2	2	1420	809.4	1420	161.88	-647.52	
140	0.7	1.71	0.98	0.114	-1.596	2	2	280	478.8	280	31.92	-446.88	
240	0.5	2.85	0.98	0.114	-2.736	2	2	480	1368	480	54.72	-1313.28	
1120	0.9	0.57	0.98	0.114	-0.456	1	1	1120	638.4	1120	127.68	-510.72	*2nd tributary*
960	0.7	1.71	0.98	0.114	-1.596	2	2	1920	3283.2	1920	218.88	-3064.32	
410	0.9	0.57	0.98	0.114	-0.456	2	2	820	467.4	820	93.48	-373.92	
1140	0.9	0.57	0.98	0.114	-0.456	1	1	1140	649.8	1140	129.96	-519.84	*3rd tributary*
290	0.8	1.14	0.98	0.114	-1.026	2	2	580	661.2	580	66.12	-595.08	
1020	0.9	0.57	0.98	0.114	-0.456	2	2	2040	1162.8	2040	232.56	-930.24	
210	0.8	1.14	0.96	0.228	-0.912	3	3	630	718.2	630	143.64	-574.56	
100	0.6	2.28	0.96	0.228	-2.052	3	3	300	684	300	68.4	-615.6	
110	0.8	1.14	0.96	0.228	-0.912	3	3	330	376.2	330	75.24	-300.96	
1770	0.9	0.57	0.98	0.114	-0.456	2	2	3540	2017.8	3540	403.56	-1614.24	*4th tributary*
470	0.8	1.14	0.98	0.114	-1.026	1	1	470	535.8	470	53.58	-482.22	*5th tributary*
1890	0.9	0.57	0.96	0.228	-0.342	3	3	5670	3231.9	5670	1292.76	-1939.14	
1280	0.9	0.57	0.98	0.114	-0.456	1	1	1280	729.6	1280	145.92	-583.68	*western-most tributary*
							Total	**24,450**	**20,896**	**24,450**	**3,577**	**-17,319**	**-83**
													% Reduction

North-side Tributaries (MOS)

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**North-side Tributaries**
150	0.9	0.57	0.98	0.114	-0.46	1	1	150	85.5	150	17.1	-68.4	*eastern-most tributary*
370	0.9	0.57	0.98	0.114	-0.456	1	1	370	210.9	370	42.18	-168.72	
610	0.9	0.57	0.98	0.114	-0.456	1	1	610	347.7	610	69.54	-278.16	
200	0.9	0.57	0.98	0.114	-0.456	1	1	200	114	200	22.8	-91.2	
550	0.9	0.57	0.98	0.114	-0.456	2	2	1100	627	1100	125.4	-501.6	
710	0.9	0.57	0.98	0.114	-0.456	2	2	1420	809.4	1420	161.88	-647.52	
140	0.9	0.57	0.98	0.114	-0.456	2	2	280	159.6	280	31.92	-127.68	
240	0.9	0.57	0.98	0.114	-0.456	2	2	480	273.6	480	54.72	-218.88	
1120	0.9	0.57	0.98	0.114	-0.456	1	1	1120	638.4	1120	127.68	-510.72	*2nd tributary*
960	0.9	0.57	0.98	0.114	-0.456	2	2	1920	1094.4	1920	218.88	-875.52	
410	0.9	0.57	0.98	0.114	-0.456	2	2	820	467.4	820	93.48	-373.92	
1140	0.9	0.57	0.98	0.114	-0.456	1	1	1140	649.8	1140	129.96	-519.84	*3rd tributary*
290	0.9	0.57	0.98	0.114	-0.456	2	2	580	330.6	580	66.12	-264.48	
1020	0.9	0.57	0.98	0.114	-0.456	2	2	2040	1162.8	2040	232.56	-930.24	
210	0.9	0.57	0.96	0.228	-0.342	3	3	630	359.1	630	143.64	-215.46	
100	0.9	0.57	0.96	0.228	-0.342	3	3	300	171	300	68.4	-102.6	
110	0.9	0.57	0.96	0.228	-0.342	3	3	330	188.1	330	75.24	-112.86	
1770	0.9	0.57	0.98	0.114	-0.456	2	2	3540	2017.8	3540	403.56	-1614.24	*4th tributary*
470	0.9	0.57	0.98	0.114	-0.456	1	1	470	267.9	470	53.58	-214.32	*5th tributary*
1890	0.9	0.57	0.96	0.228	-0.342	3	3	5670	3231.9	5670	1292.76	-1939.14	
1280	0.9	0.57	0.98	0.114	-0.456	1	1	1280	729.6	1280	145.92	-583.68	*western-most tributary*
							Total	**24,450**	**13,937**	**24,450**	**3,577**	**-10,359**	**-74**
													% Reduction

South-side Tributaries

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**South-side Tributaries**
2890	0.9	0.57	0.98	0.114	-0.46	1	1	2890	1647.3	2890	329.46	-1317.84	*Youngs Draw*
250	0.7	1.71	0.96	0.228	-1.482	3	3	750	1282.5	750	171	-1111.5	Forest Group B
200	0.9	0.57	0.96	0.228	-0.342	3	3	600	342	600	136.8	-205.2	
90	0.8	1.14	0.96	0.228	-0.912	3	3	270	307.8	270	61.56	-246.24	
290	0.7	1.71	0.86	0.798	-0.912	3	3	870	1487.7	870	694.26	-793.44	Nonforest Group 1
310	0.2	4.56	0.86	0.798	-3.762	3	3	930	4240.8	930	742.14	-3498.66	
2080	0.9	0.57	0.98	0.114	-0.456	1	1	2080	1185.6	2080	237.12	-948.48	*Shove Creek*
1100	0.9	0.57	0.98	0.114	-0.456	1	1	1100	627	1100	125.4	-501.6	Forest Group B
780	0.7	1.71	0.98	0.114	-1.596	2	2	1560	2667.6	1560	177.84	-2489.76	
1260	0.8	1.14	0.96	0.228	-0.912	3	3	3780	4309.2	3780	861.84	-3447.36	
880	0.6	2.28	0.94	0.342	-1.938	4	4	3520	8025.6	3520	1203.84	-6821.76	
3200	0.9	0.57	0.98	0.114	-0.456	2	2	6400	3648	6400	729.6	-2918.4	*Swansons Chute*
2850	0.9	0.57	0.98	0.114	-0.456	2	2	5700	3249	5700	649.8	-2599.2	*Miller Creek*
1760	0.9	0.57	0.98	0.114	-0.456	2	2	3520	2006.4	3520	401.28	-1605.12	*Johnson Creek*
540	0.9	0.57	0.94	0.342	-0.228	4	4	2160	1231.2	2160	738.72	-492.48	*Unnamed (west of Johnson)*
2160	0.9	0.57	0.98	0.114	-0.456	2	2	4320	2462.4	4320	492.48	-1969.92	*east fork*
420	0.9	0.57	0.98	0.114	-0.456	1	1	420	239.4	420	47.88	-191.52	*west fork*
340	0.8	1.14	0.98	0.114	-1.026	1	1	340	387.6	340	38.76	-348.84	
2050	0.9	0.57	0.98	0.114	-0.456	2	2	4100	2337	4100	467.4	-1869.6	
470	0.8	1.14	0.98	0.114	-1.026	1	1	470	535.8	470	53.58	-482.22	*middle fork*
1050	0.9	0.57	0.98	0.114	-0.456	2	2	2100	1197	2100	239.4	-957.6	
140	0.8	1.14	0.98	0.114	-1.026	1	1	140	159.6	140	15.96	-143.64	*Unnamed (western most)*
340	0.4	3.42	0.98	0.114	-3.306	1	1	340	1162.8	340	38.76	-1124.04	
1200	0.9	0.57	0.98	0.114	-0.456	2	2	2400	1368	2400	273.6	-1094.4	
							Total	**50,760**	**46,107**	**50,760**	**8,928**	**-37,179**	**-81**
													% Reduction

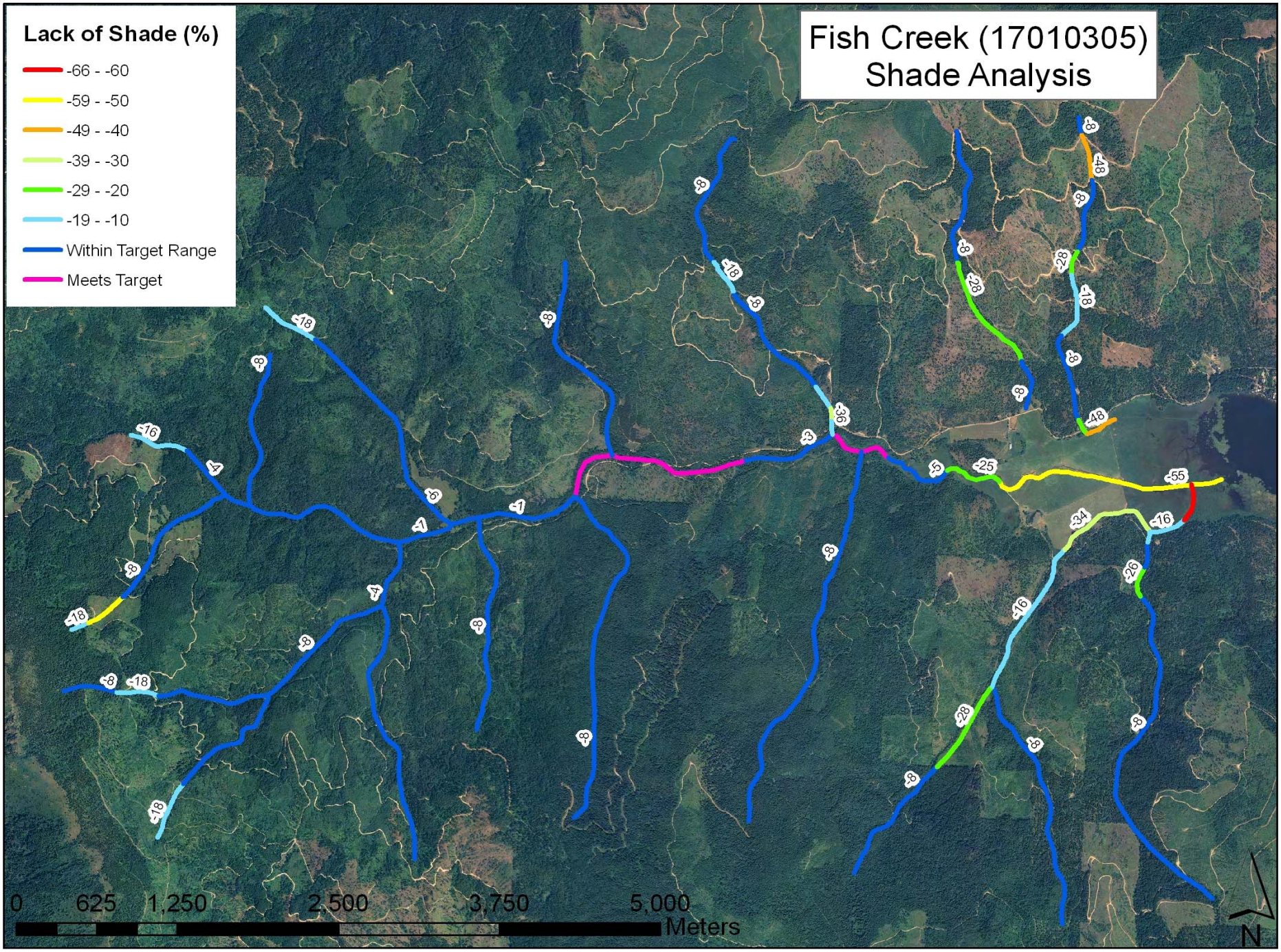
South-side Tributaries (MOS)

Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**South-side Tributaries**
2890	0.9	0.57	0.98	0.114	-0.46	1	1	2890	1647.3	2890	329.46	-1317.84	*Youngs Draw*
250	0.9	0.57	0.96	0.228	-0.342	3	3	750	427.5	750	171	-256.5	Forest Group B
200	0.9	0.57	0.96	0.228	-0.342	3	3	600	342	600	136.8	-205.2	
90	0.9	0.57	0.96	0.228	-0.342	3	3	270	153.9	270	61.56	-92.34	
290	0.8	1.14	0.86	0.798	-0.342	3	3	870	991.8	870	694.26	-297.54	Nonforest Group 1
310	0.8	1.14	0.86	0.798	-0.342	3	3	930	1060.2	930	742.14	-318.06	
2080	0.9	0.57	0.98	0.114	-0.456	1	1	2080	1185.6	2080	237.12	-948.48	*Shove Creek*
1100	0.9	0.57	0.98	0.114	-0.456	1	1	1100	627	1100	125.4	-501.6	Forest Group B
780	0.9	0.57	0.98	0.114	-0.456	2	2	1560	889.2	1560	177.84	-711.36	
1260	0.9	0.57	0.96	0.228	-0.342	3	3	3780	2154.6	3780	861.84	-1292.76	
880	0.9	0.57	0.94	0.342	-0.228	4	4	3520	2006.4	3520	1203.84	-802.56	
3200	0.9	0.57	0.98	0.114	-0.456	2	2	6400	3648	6400	729.6	-2918.4	*Swansons Chute*
2850	0.9	0.57	0.98	0.114	-0.456	2	2	5700	3249	5700	649.8	-2599.2	*Miller Creek*
1760	0.9	0.57	0.98	0.114	-0.456	2	2	3520	2006.4	3520	401.28	-1605.12	*Johnson Creek*
540	0.9	0.57	0.94	0.342	-0.228	4	4	2160	1231.2	2160	738.72	-492.48	*Unnamed (west of Johnson)*
2160	0.9	0.57	0.98	0.114	-0.456	2	2	4320	2462.4	4320	492.48	-1969.92	*east fork*
420	0.9	0.57	0.98	0.114	-0.456	1	1	420	239.4	420	47.88	-191.52	*west fork*
340	0.9	0.57	0.98	0.114	-0.456	1	1	340	193.8	340	38.76	-155.04	
2050	0.9	0.57	0.98	0.114	-0.456	2	2	4100	2337	4100	467.4	-1869.6	
470	0.9	0.57	0.98	0.114	-0.456	1	1	470	267.9	470	53.58	-214.32	*middle fork*
1050	0.9	0.57	0.98	0.114	-0.456	2	2	2100	1197	2100	239.4	-957.6	
140	0.9	0.57	0.98	0.114	-0.456	1	1	140	79.8	140	15.96	-63.84	*Unnamed (western most)*
340	0.9	0.57	0.98	0.114	-0.456	1	1	340	193.8	340	38.76	-155.04	
1200	0.9	0.57	0.98	0.114	-0.456	2	2	2400	1368	2400	273.6	-1094.4	
							Total	**50,760**	**29,959**	**50,760**	**8,928**	**-21,031**	**-70**
													% Reduction

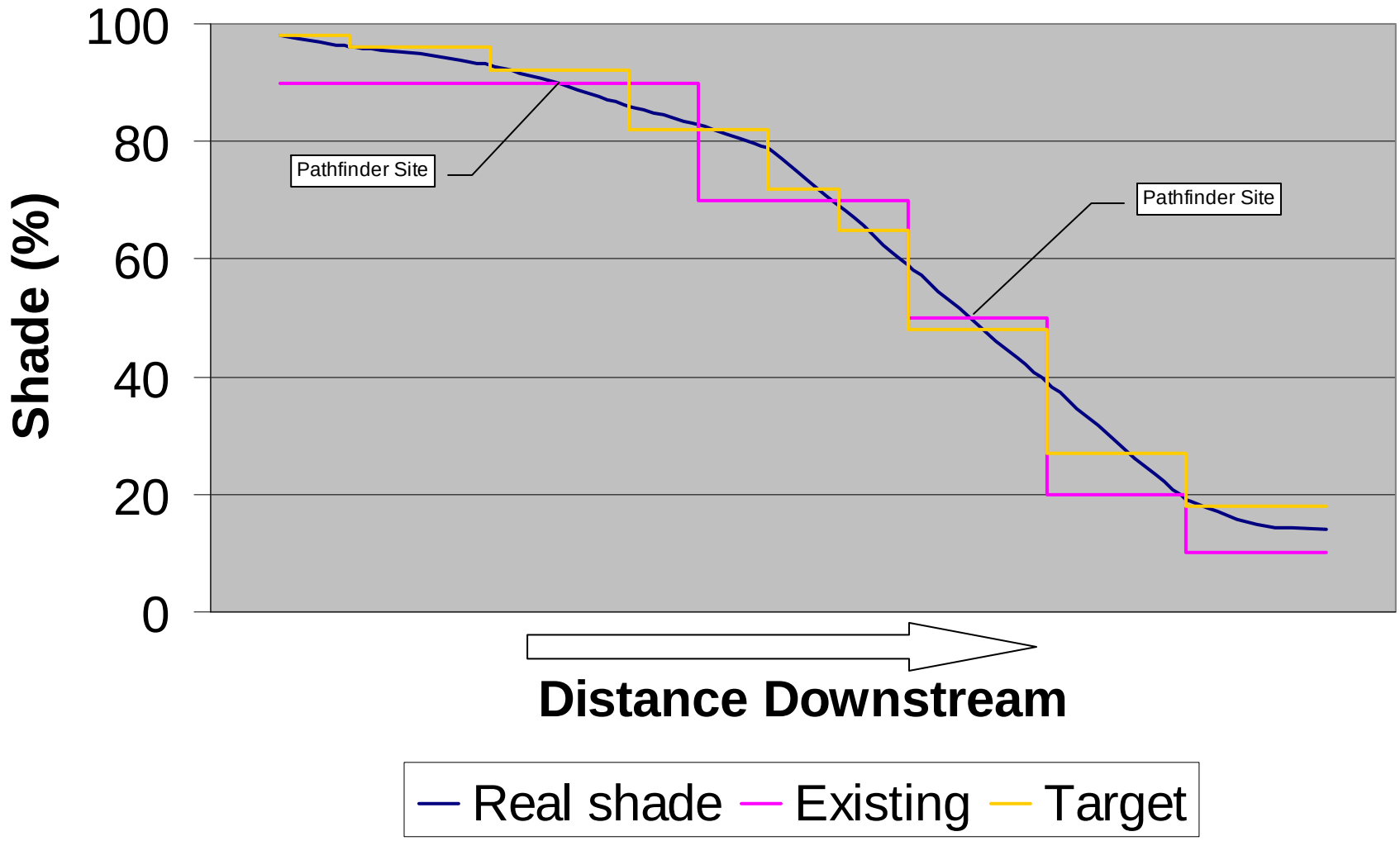
Excess Solar Load

Table 7. Excess Solar Loads and Percent Reductions for Fish Creek.

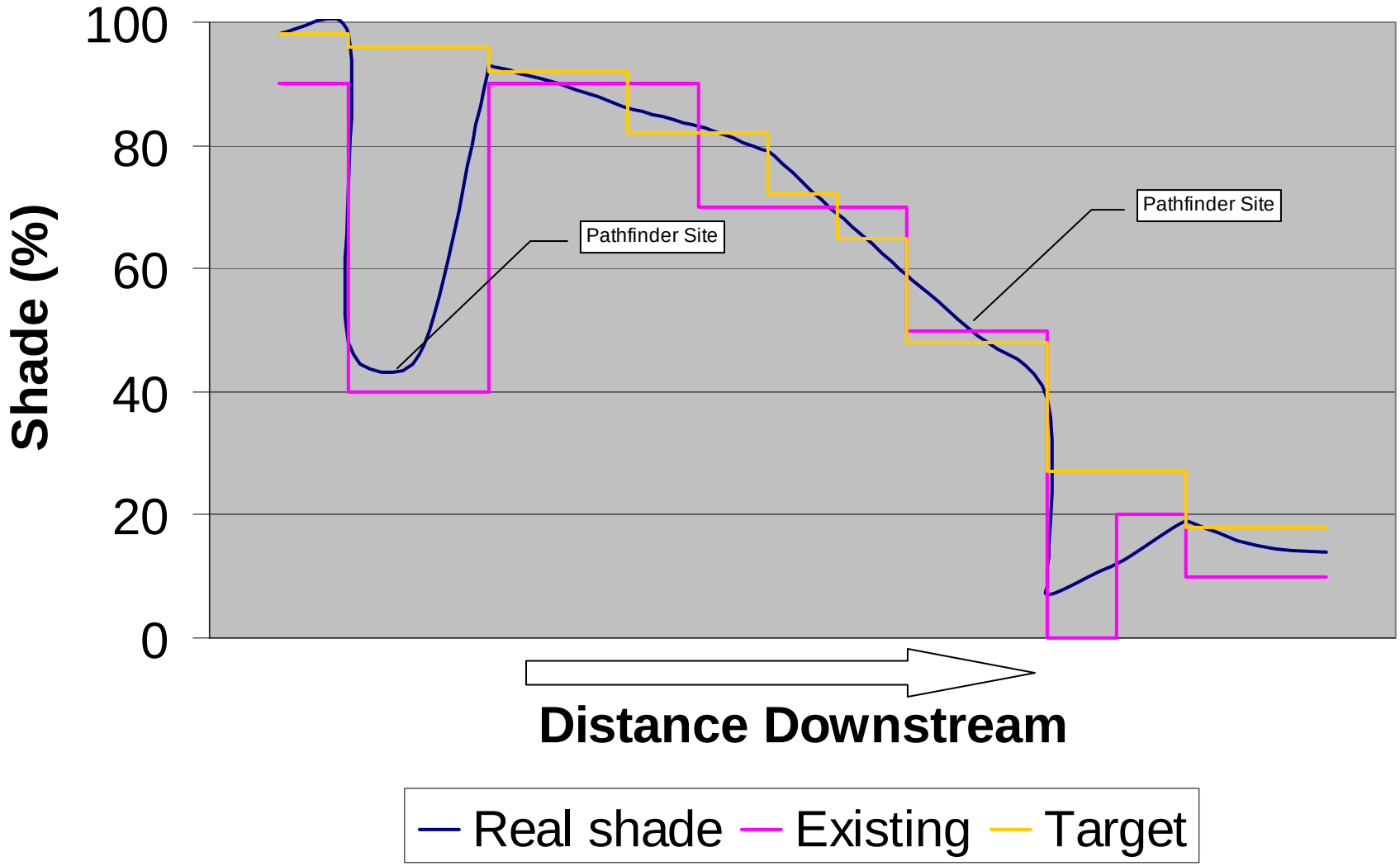
Water Body	Excess Load (kWh/day)	Percent Reduction
Fish Creek	52,763 (12,116 MOS)	28 – 37%
South-side Tributaries	37,179 (21,031 MOS)	35 – 81%
North-side Tributaries	17,319 (10,359 MOS)	33 – 83%


Fish Creek (17010305)
Shade Analysis
Lack of Shade (%)
-66 - -60
-59 - -50
-49 - -40
-39 - -30
-29 - -20
-19 - -10
Within Target Range
Meets Target
0
625
1,250
2,500
3,750
5,000
Meters
N

Shade Estimates



Shade Estimates



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