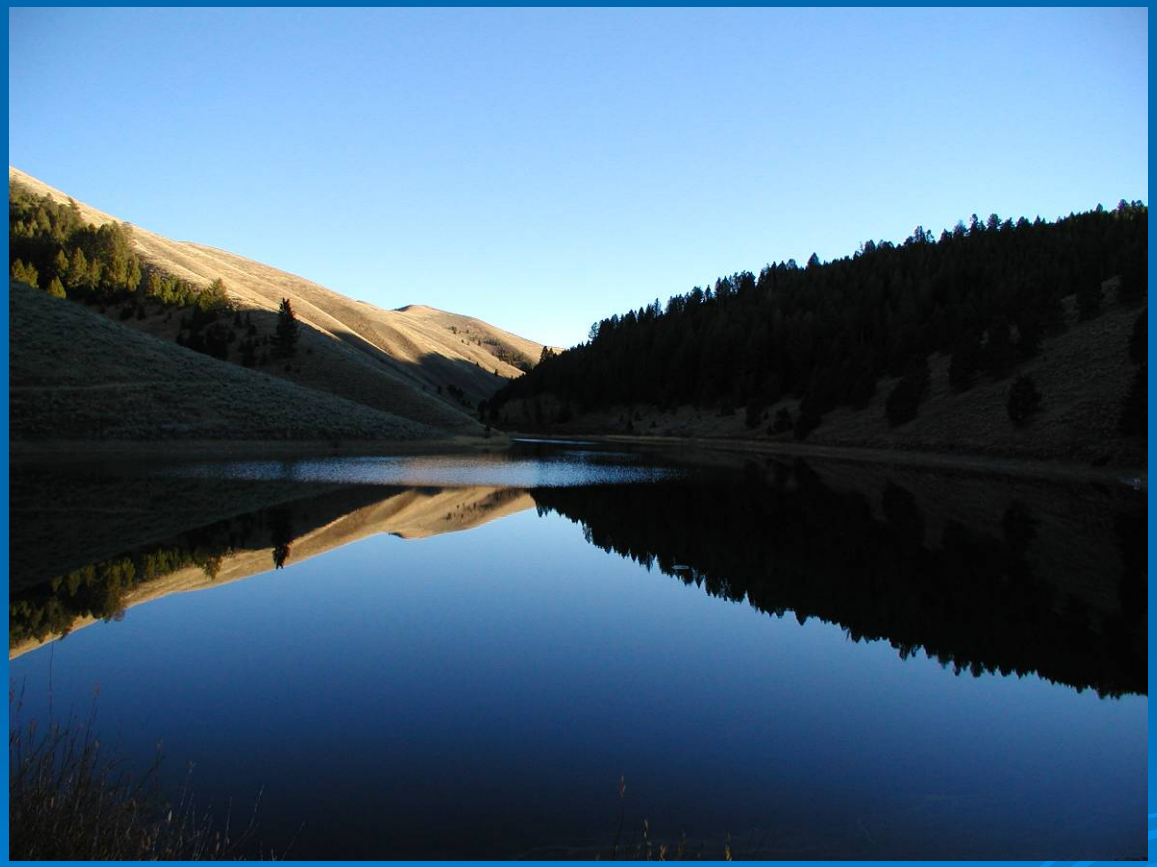
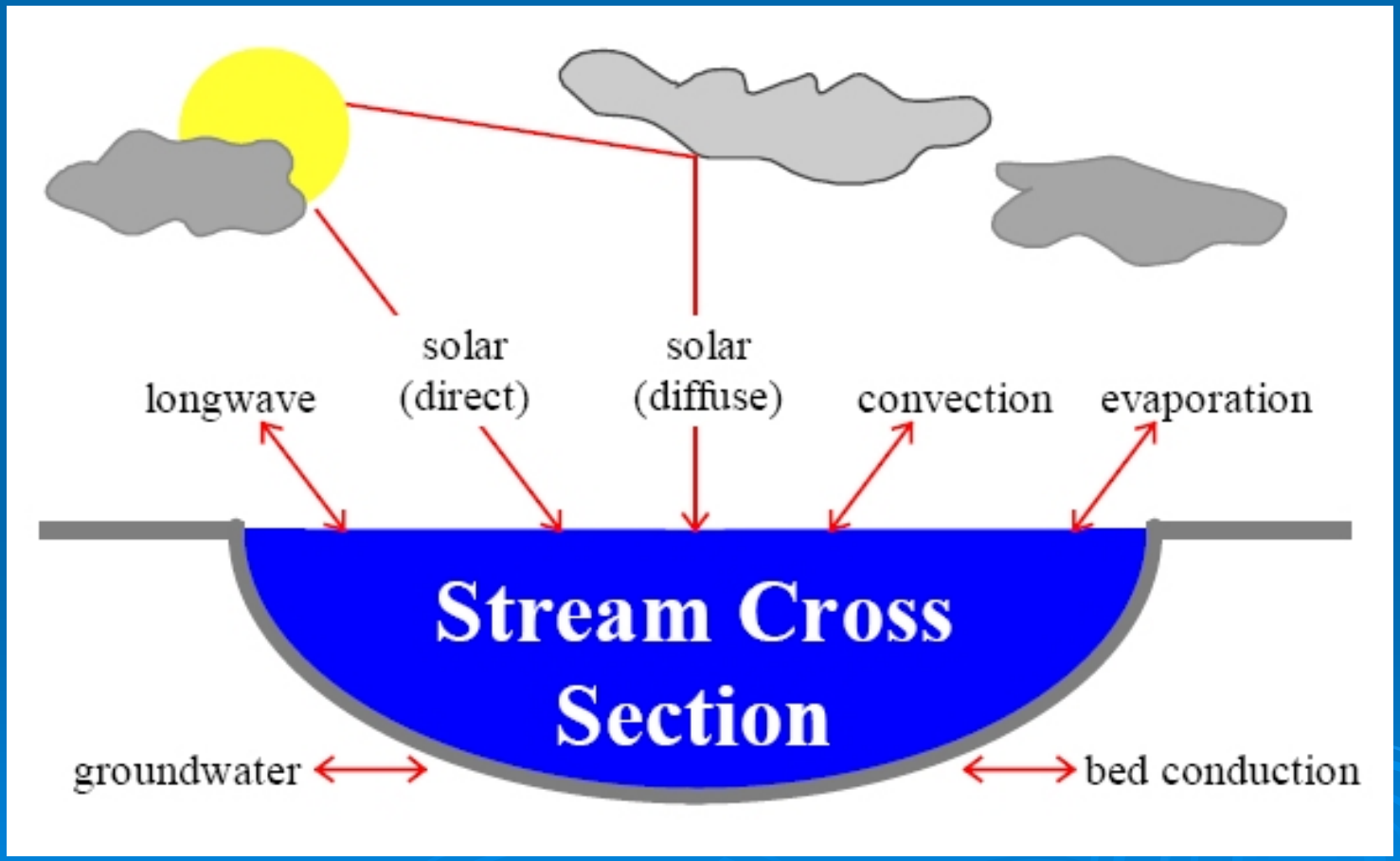
Potential Natural Vegetation Temperature TMDLs

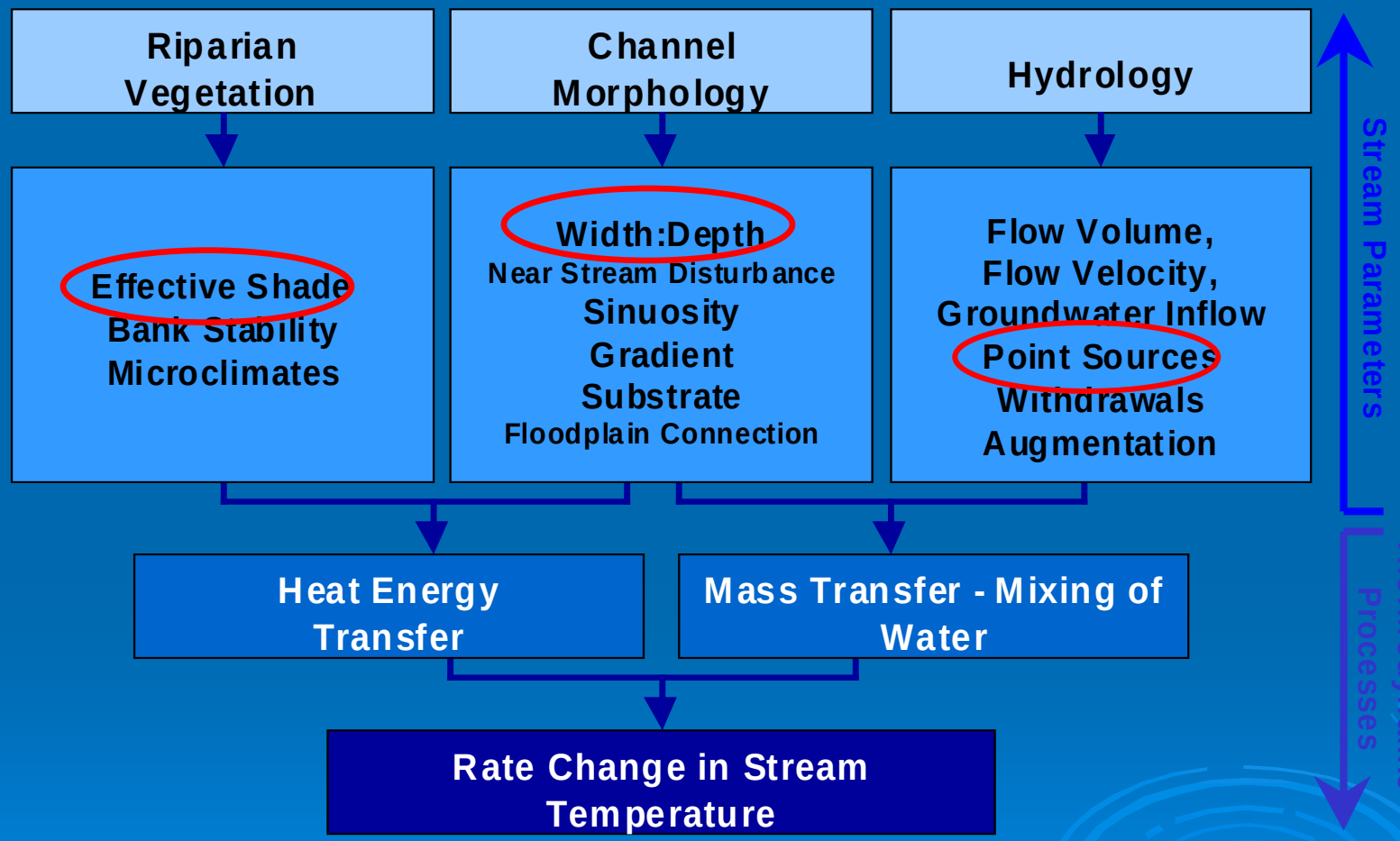


Mark Shumar & Jessica Moore, State Technical Services Office,
Idaho Department of Environmental Quality

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

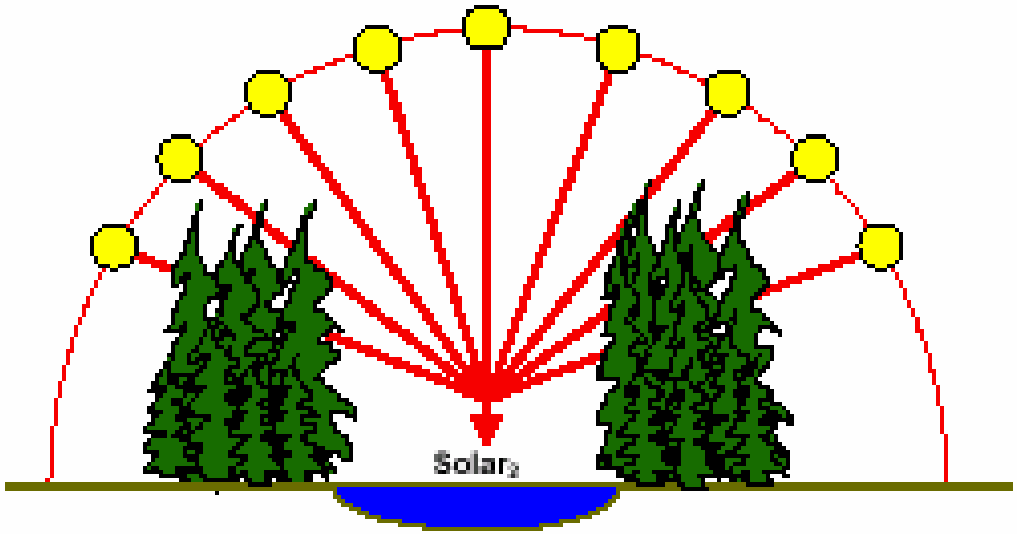
Temperature TMDL

- 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

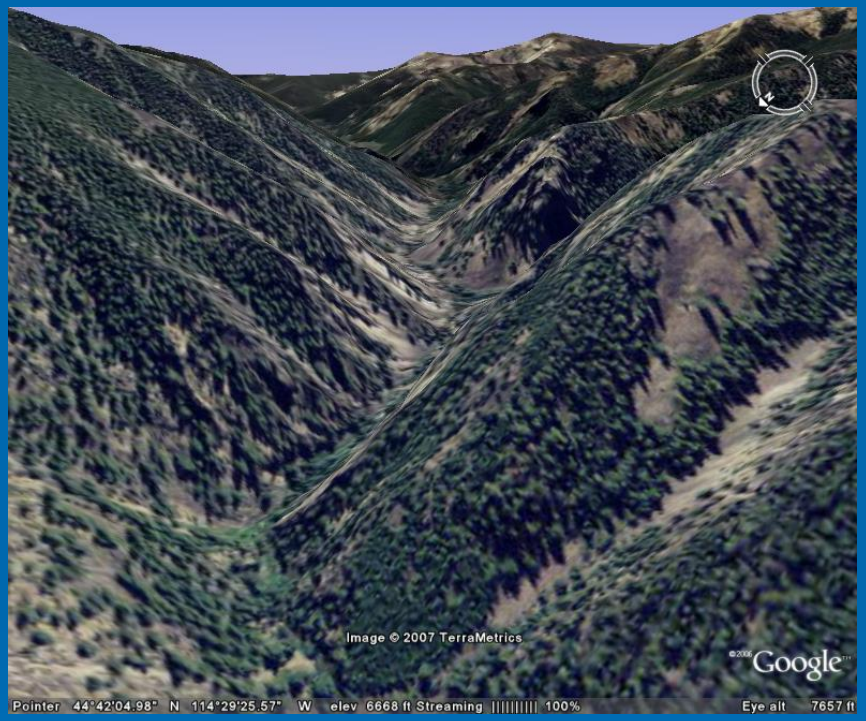
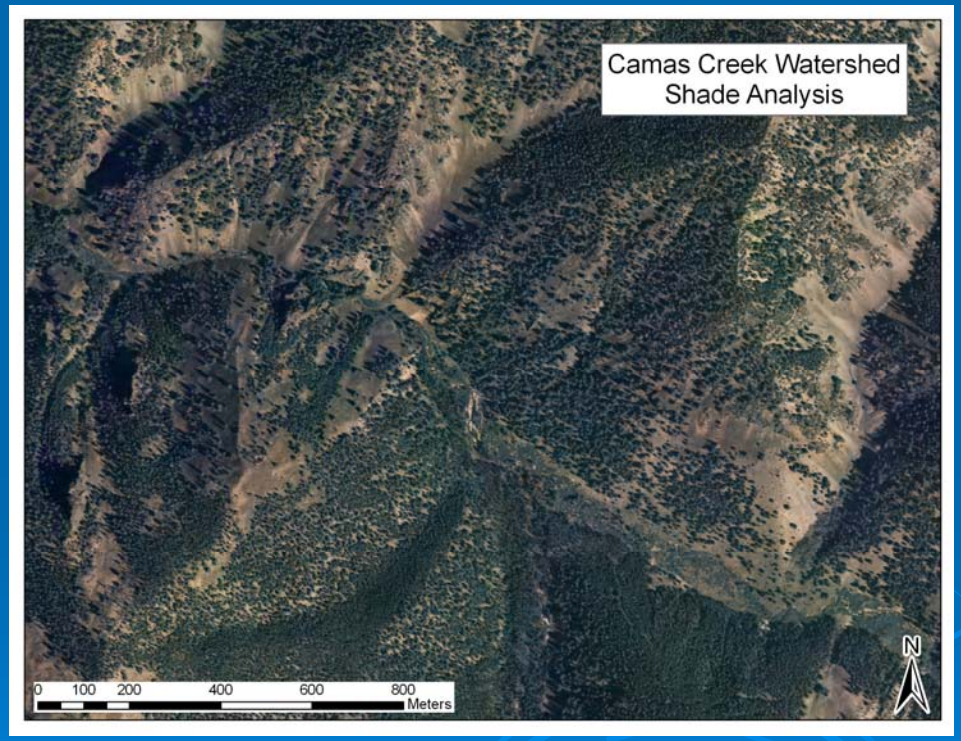
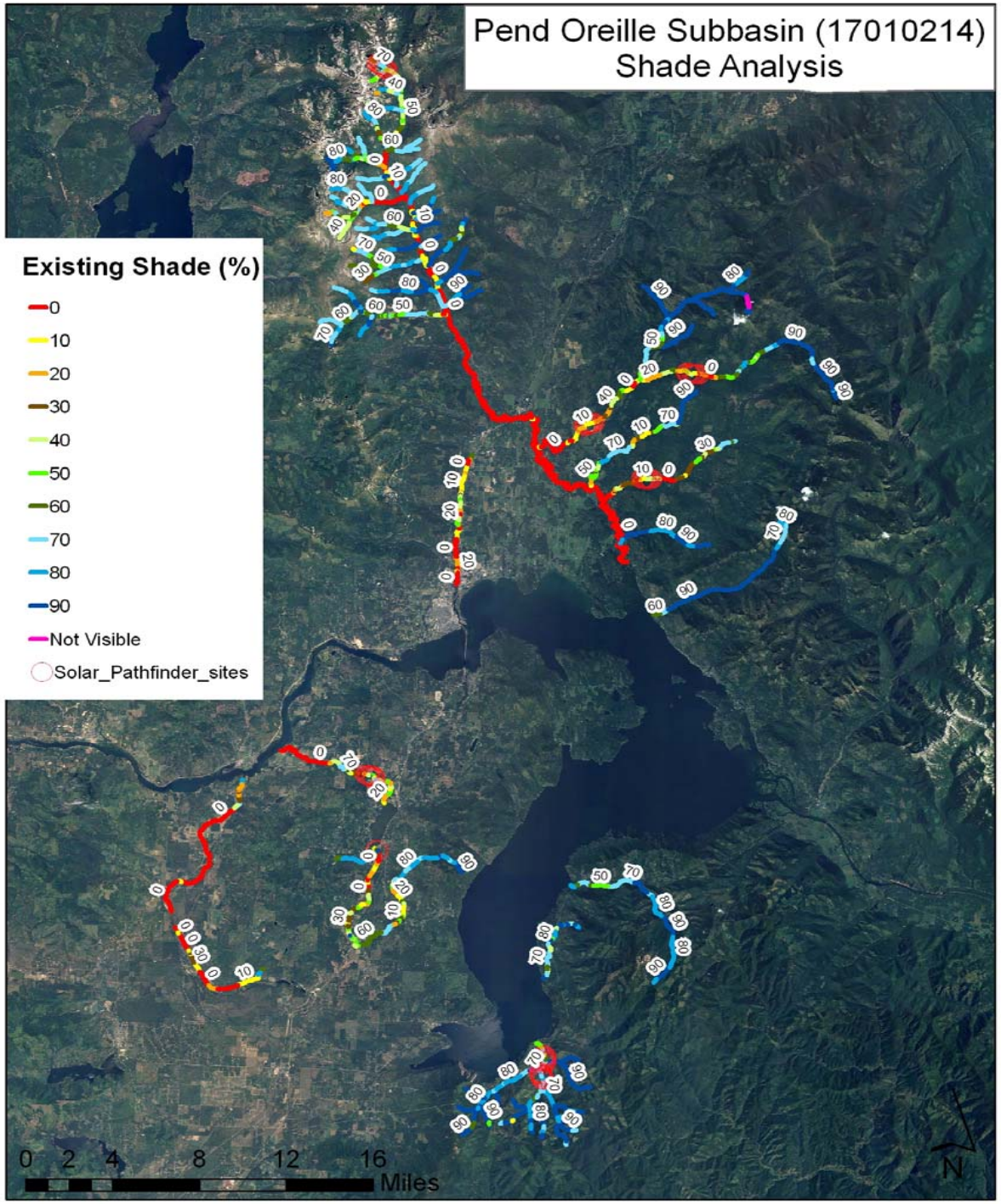


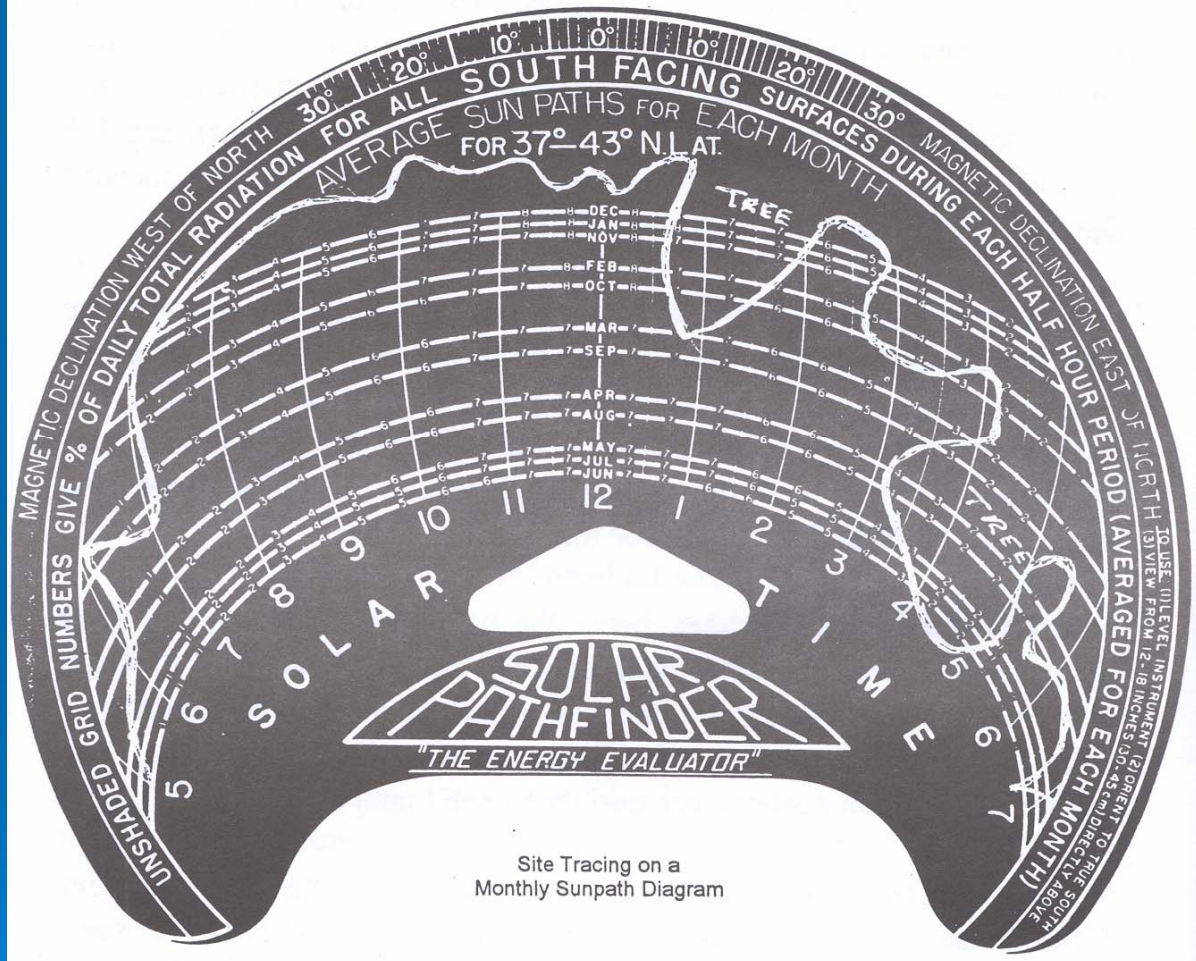
Image © 2007 TerraMetrics
Google
Pointer 44°42'04.98" N 114°29'25.57" W elev 6668 ft Streaming 100%
Eye alt 7657 ft


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


Pend Oreille Subbasin (17010214)
Shade Analysis
Existing Shade (%)
0
10
20
30
40
50
60
70
80
90
Not Visible
Solar_Pathfinder_sites
0 2 4 8 12 16
Miles
N

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

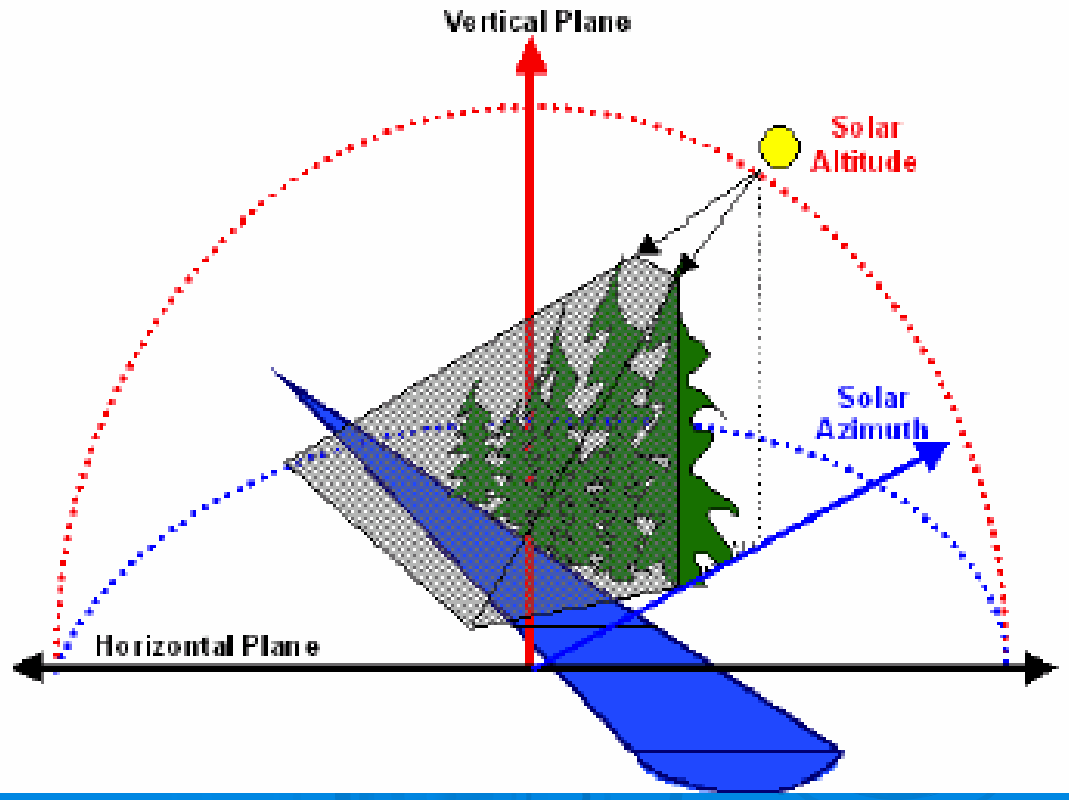


Table X-3. Summary ARU filter Group Characteristics

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

Figure X-3. "ARU filter" Groups in the Pend Oreille Basin.

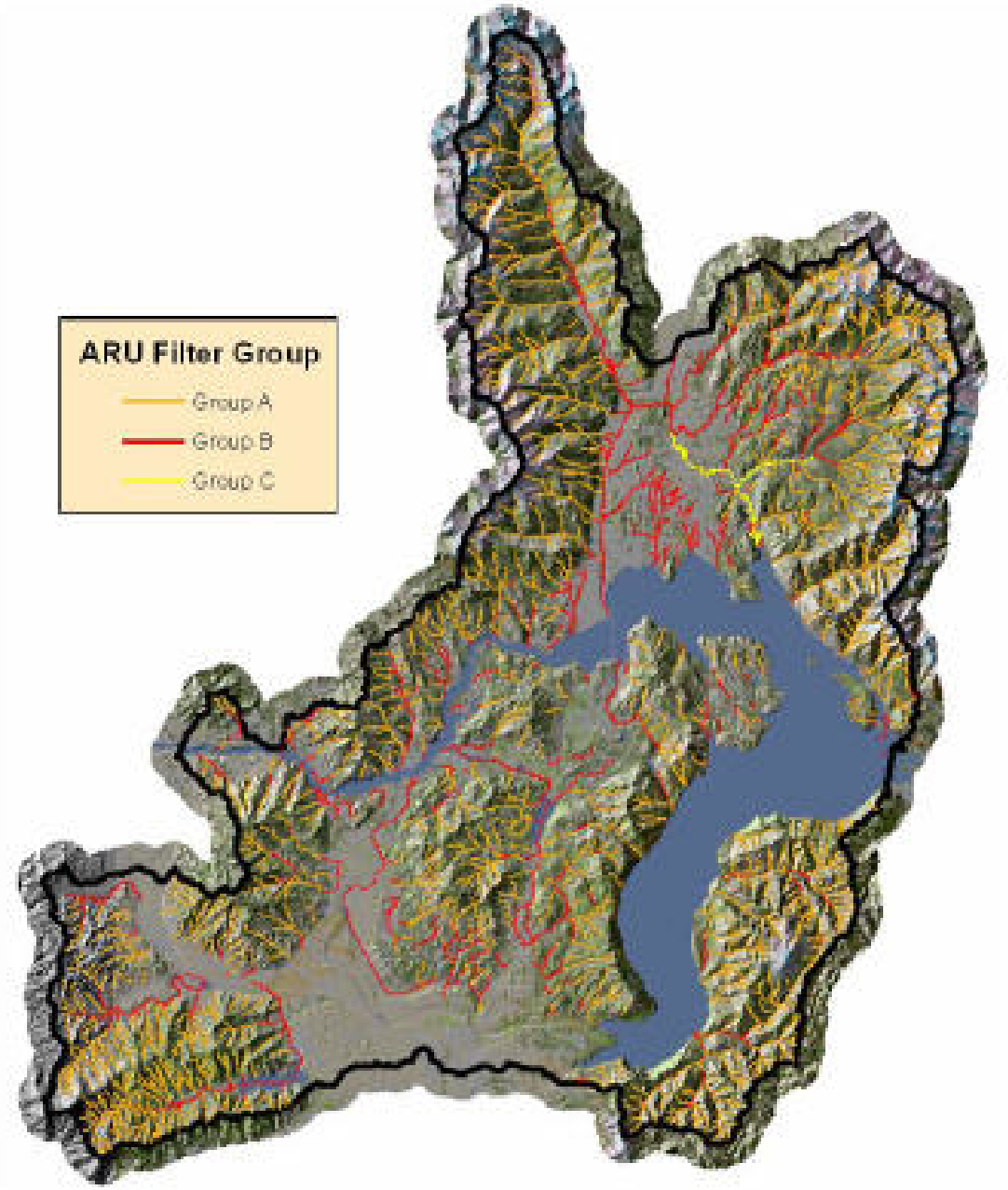


Figure X-5. Vegetation Response Units in the Pend Oreille Basin

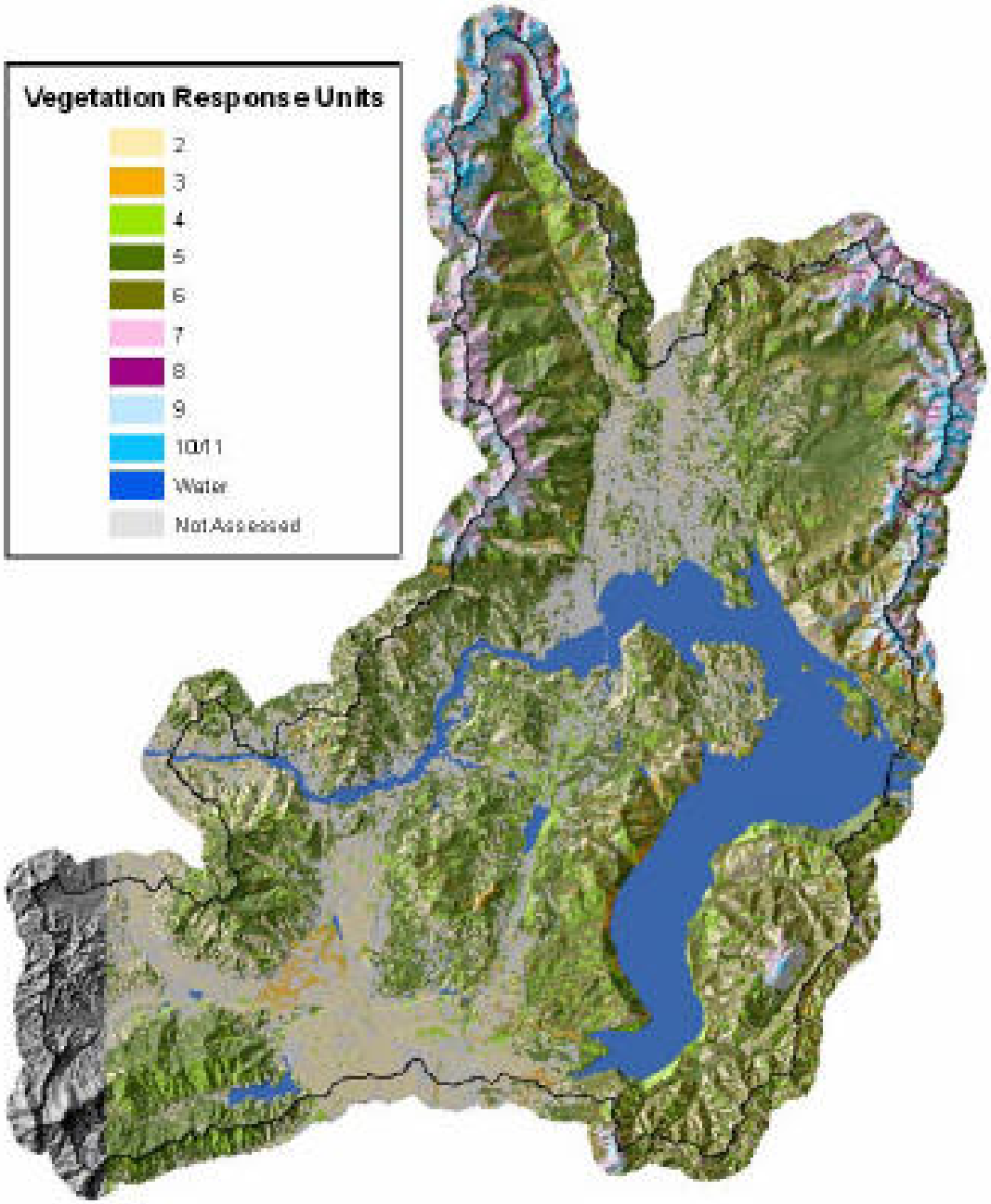


Table X-5. Pend Oreille Basin Historical Forest Vegetation Structure Estimates

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.

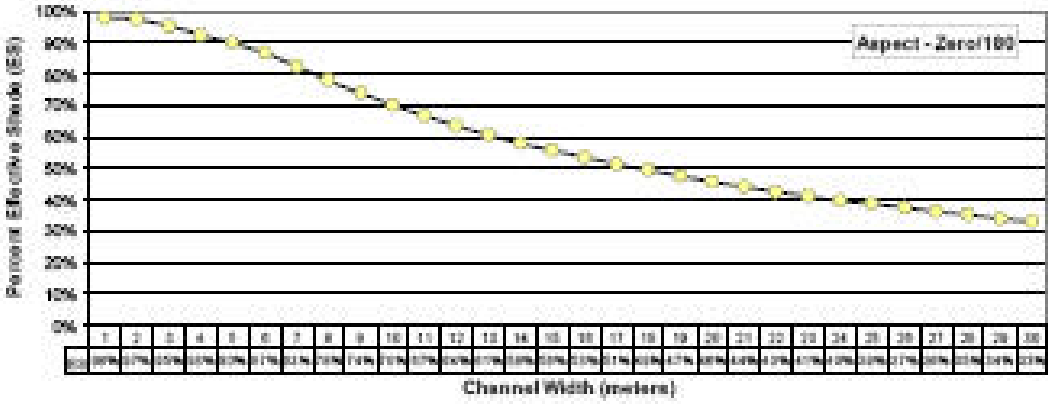
Common Name	Canopy Cover (CC)	Constancy	Weighted CC[10]	System Potential (SP) Height[11]	Weighting Factor[12]	Weighted SP Height
VRU 3C (n = 43 Ecodata plots)						
Grand Fir	20	51	10	100	14%	14
Engelmann Spruce	16	33	5	90	9%	8
Black Cottonwood	15	30	5	100	8%	8
Douglas Fir	8	35	3	91	10%	9
Western Redcedar	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**

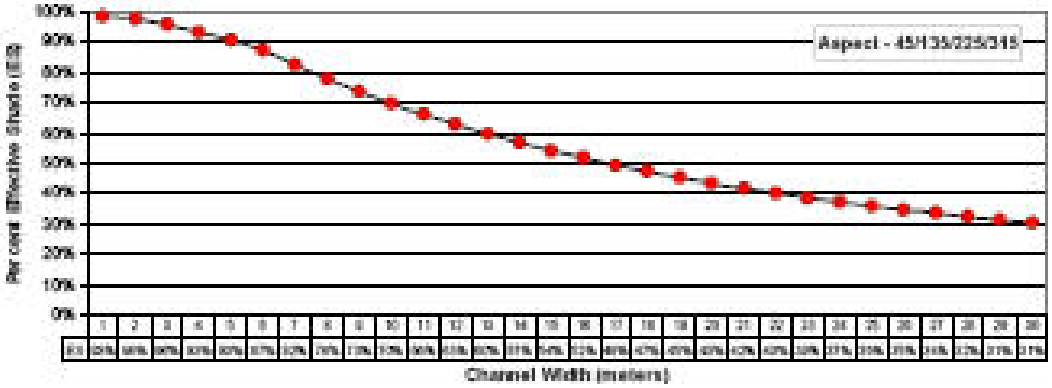
Nonforest Group 2

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.





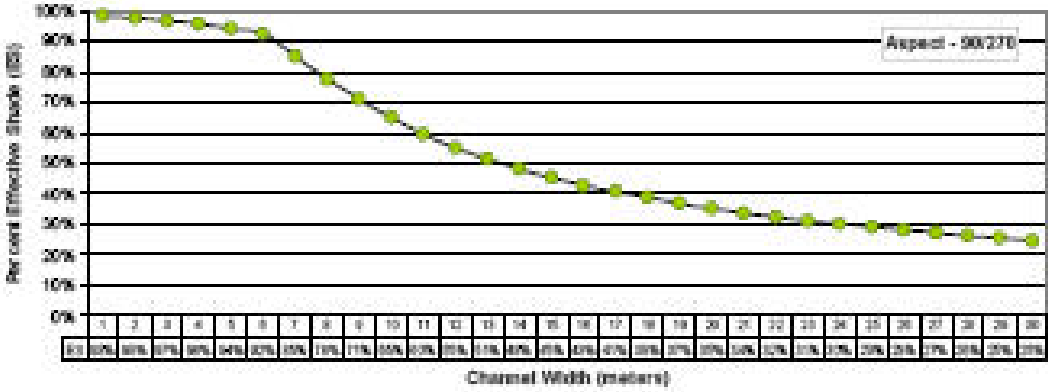
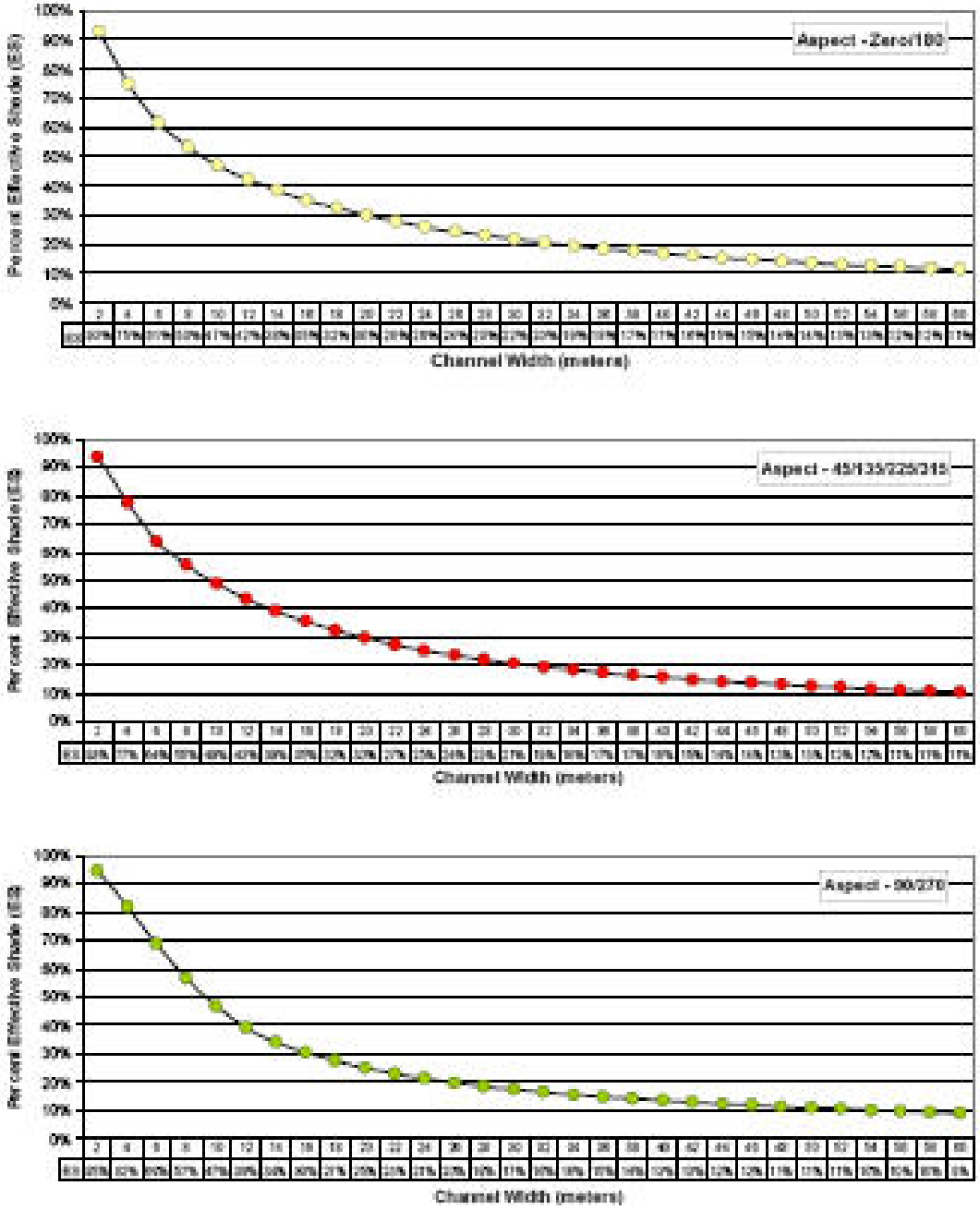


Figure X-16. System Potential Effective Shade for "Non-Forest" Assessment Group 1 at Various Stream Aspect and Stream Width Conditions.



Shade Targets – Forest

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**

Forest	10m	11m	12m	13m	14m	15m	20m	24m	25m
Group B - VRUs 4,5,6 0/180	70	67	64	61	58	56	46	40	39
45/135/225/315	70	66	63	60	57	54	43	37	36
90/270	65	60	55	51	48	45	35	30	29
Target (%)	**68**	**64**	**61**	**57**	**54**	**52**	**41**	**36**	**35**

Forest	1m	2m	3m	4m	5m	6m	7m	8m	9m
Group C - VRUs 7, 8 0/180	98	97	94	91	88	84	79	74	70
45/135/225/315	98	97	95	91	88	84	78	74	69
90/270	98	98	96	95	93	87	79	72	65
Target (%)	**98**	**97**	**95**	**92**	**90**	**85**	**79**	**73**	**68**

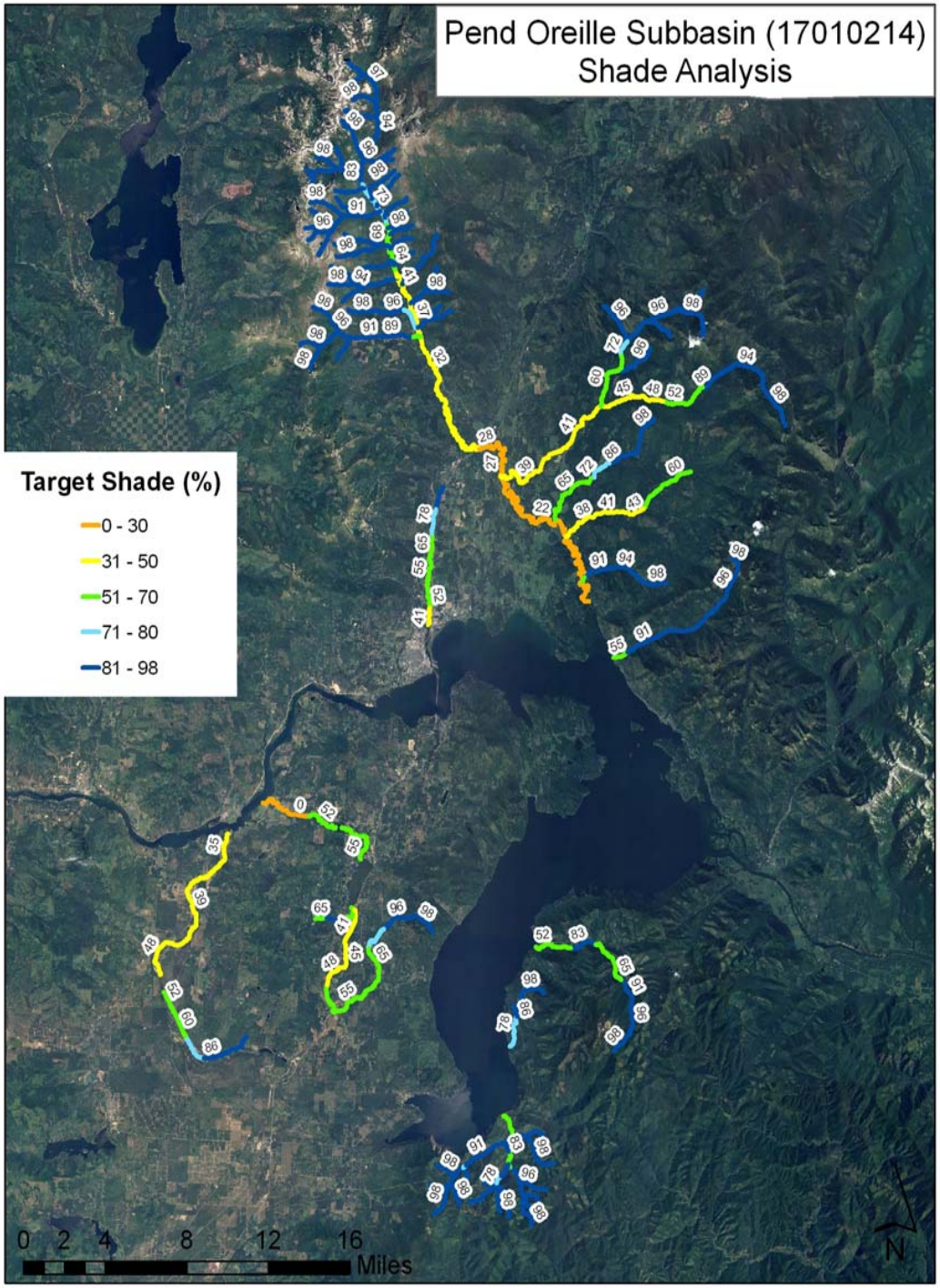
Forest	1m	2m	3m	4m	5m	6m	7m	8m	9m
Group D - VRUs 9, 10/11 0/180	98	96	92	88	84	79	74	69	65
45/135/225/315	98	96	93	89	85	79	74	69	64
90/270	98	97	96	93	88	80	72	64	58
Target (%)	**98**	**96**	**94**	**90**	**86**	**79**	**73**	**67**	**62**

Shade Targets - Nonforest

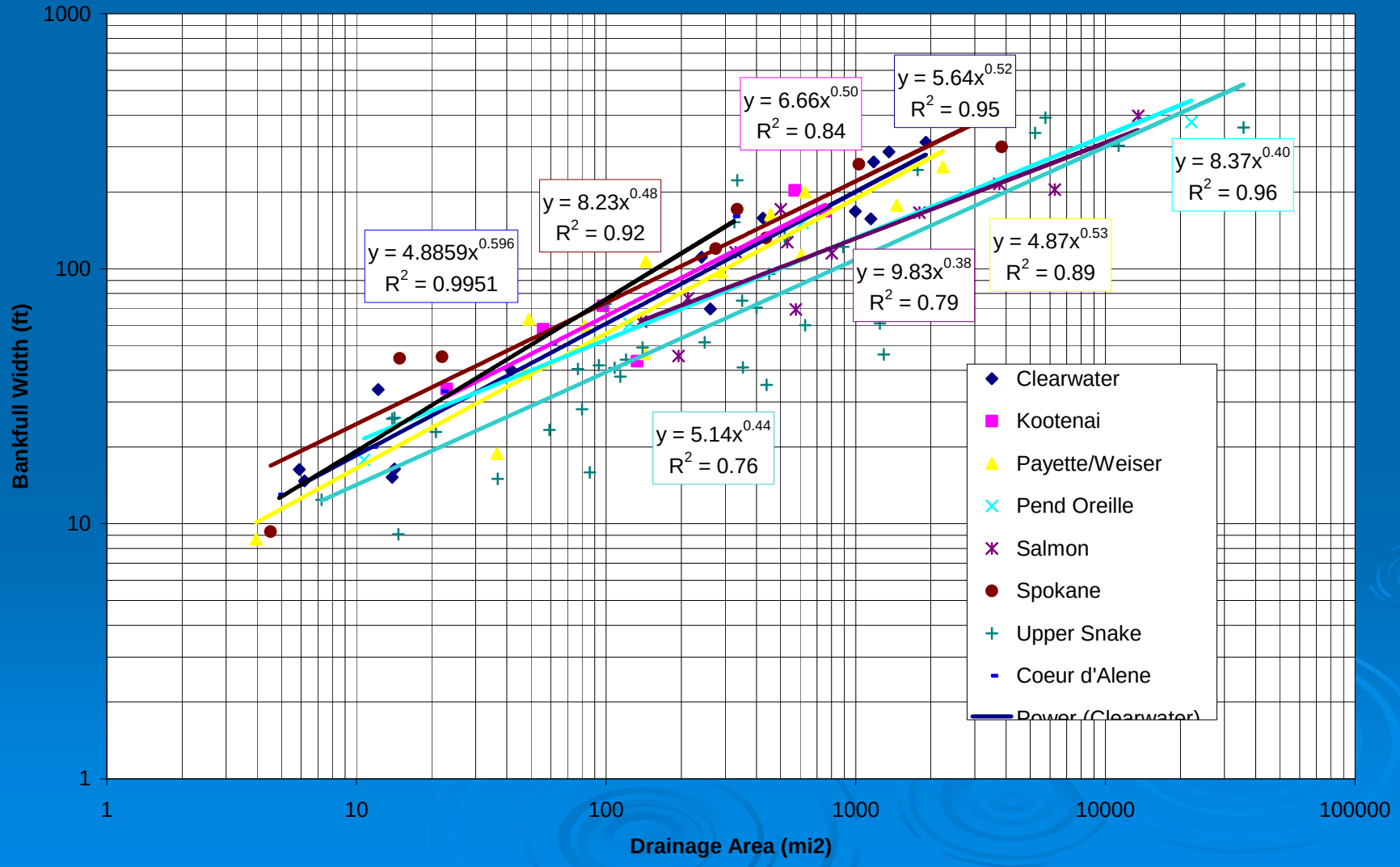
Non-Forest	1m	2m	3m	4m	5m	6m	7m	8m	9m	10m	11m
Group 1 - Hardwoods 0/180		93		75		61		53		47	
45/135/225/315		93		77		64		55		49	
90/270		95		82		69		57		47	
Target (%)	**97**	**94**	**86**	**78**	**72**	**65**	**60**	**55**	**52**	**48**	**45**

Non-Forest	12m	13m	14m	15m	16m	17m	18m	19m	20m	21m	22m
Group 1 - Hardwoods 0/180	42		38		35		32		30		28
45/135/225/315	43		39		35		32		30		27
90/270	39		34		30		27		25		23
Target (%)	**41**	**39**	**37**	**35**	**33**	**32**	**30**	**29**	**28**	**27**	**26**

Non-Forest	10m	11m	12m	24m
Group 2 - Hardwoods 0/180	41		37	23
45/135/225/315	43		39	23
90/270	44		37	20
Target (%)	**43**	**41**	**38**	**22**


Pend Oreille Subbasin (17010214)
Shade Analysis
Target Shade (%)
0 - 30
31 - 50
51 - 70
71 - 80
81 - 98
0 2 4 8 12 16
Miles
N

Bankfull Width



Location	area (sq mi)	PendOreille (m)	Existing (m)
1st West-side Pack Tributary @ mouth	1.33	3	
Beehive Creek @ mouth	0.91	2	
Slide Creek @ mouth	1.13	3	
Thor Creek @ mouth	1.82	3	
Zuni Creek @ mouth	1.14	3	
West Branch Creek @ mouth	5.22	5	
1st Tributary to W. Branch @ mouth	0.46	2	
2nd Tributary to W. Branch @ mouth	1.18	3	
3rd Tributary to W. Branch @ mouth	0.77	2	
1st West-side Pack Trib bl W.Branch	0.51	2	
1st East-side Pack Trib bl W.Branch	0.7	2	
2nd East-side Pack Trib bl W.Branch	1.34	3	
McCormick Creek @ mouth	6.7	5	9.5
1st Trib from McCormick Lake @ confluence	0.27	2	
1st Trib from Fault Lake @ confluence	0.62	2	
1st Tributary to McCormick @ mouth	1.22	3	
2nd Tributary to McCormick @ mouth	0.84	2	
Gunsight Creek @ mouth	0.98	3	
4th Tributary to McCormick @ mouth	0.25	1	
1st East-side Pack Trib bl McCormick	0.27	2	
Torrent Creek @ mouth	0.7	2	
Zee Creek @ mouth	0.39	2	
Youngs Creek @ mouth	1.1	3	3
Homestead Creek @ mouth	2.85	4	
Homestead Creek ab Youngs Creek	1.63	3	
Tributary to Homestead Creek @ mouth	0.34	2	
1st East-side Pack Trib bl Homestead	0.46	2	
1st West-side Pack Trib bl Homestead	0.76	2	
2nd East-side Pack Trib bl Homestead	0.23	1	
Jeru Creek @ mouth	5.24	5	7.3
Upper fork to Jeru Creek ab confluence	1.07	3	
Lower fork to Jeru Creek ab confluence	1.33	3	
Forked Tributary to Jeru @ mouth	2.55	4	
Pearson Creek @ mouth	3.04	4	
Martin Creek @ mouth	3.39	4	5.3
Tributary to Martin Creek @ mouth	0.79	2	
Blane Creek @ mouth	1.46	3	
Upper fork to Blane Creek	0.39	2	
Lower fork to Blane Creek	0.91	2	
Lindsey Creek @ mouth	2.94	4	
Tributary to Lindsey Creek @ mouth	0.57	2	
Hellroaring Creek @ mouth	10.9	7	4.9
Hellroaring Creek bl fork @ 3730ft	5.46	5	
Hellroaring Creek bl hdwtr forks @ 4290ft	1.64	3	
Upper hdwtr fork Hellroaring @ confluence	0.48	2	
Lower hdwtr fork Hellroaring @ confluence	1.13	3	
3rd tributary to Hellroaring @ mouth	2.49	4	
4th tributary to Hellroaring @ mouth	0.97	3	
Pack River bl Rapid Lightning Cr.	270	24	
Pack River bl Grouse Cr.	198	21	37
Pack River bl gage (Hwy 95)	121	17	
Pack River bl Hellroaring Cr.	71.9	14	28.7, 44.3, 30.8*
Pack River bl Jeru Cr.	46.8	12	22.8, 22.7, 22*
Pack River ab McCormick Cr.	24.3	9	21, 12.2*
Pack River ab West Branch	14.8	7	13.6

Location	area (sq mi)	PendOreille (m)	Existing (m)
Grouse Creek @ mouth	56.1	13	9.5, 22.3
Grouse Creek bl NF	46.8	12	18.4, 20
Grouse Creek bl SF	22.2	9	16.6, 18, 27.6
Grouse Creek ab SF	14.6	7	10.4
NF Grouse Creek @ mouth	15.3	8	6.3, 8.3
1st Tributary to NF Grouse @ mouth	1.53	3	
2nd Tributary to NF Grouse @ mouth	1	3	
Dyree Creek @ mouth	1.94	3	
4th Tributary to NF Grouse @ mouth	2	3	
Gold Creek (Pack) @ mouth	12.7	7	
Gold Creek bl fork @ 2530ft	6.64	5	4.8
Gold Creek bl 1st fork @2680ft	2.63	4	2.1
Rapid Lightning Creek @ mouth	48.3	12	
Rapid Lightning Creek bl Spring	36.1	11	15, 11.5
Rapid Lightning Creek ab Spring	30.3	10	
Rapid Lightning Creek bl Trapper	12.8	7	
Rapid Lightning Creek ab Trapper	6.75	5	6.4
Trout Creek @ mouth	9.69	6	6.4
Trout Creek bl Shertz Creek	3.7	4	
Sand Creek (PO) @ slough	37.3	11	12.5
Sand Creek ab Little Sand	23.5	9	
Sand Creek @ Bronx	14.8	7	6.4
Sand Creek bl Jack Creek	3.6	4	5.1
Trestle Creek @ mouth	19	8	9.4
Trestle Creek bl 2nd trib @ 2770ft	11.9	7	9.6
Trestle Creek ab trib @ 3040ft	5.27	5	6.8
Granite Creek @ mouth	26.6	9	12.1, 8.2
Granite Creek ab Dry/Toms Gulch	8.85	6	8.7
Granite Creek ab Packsaddle Cr.	4.65	5	
Cedar Creek @ mouth	7.46	6	4.2
Cedar Creek ab Canyon Creek	3.04	4	
Gold Creek (PO) @ mouth	21.8	9	7.7, 8.2
Gold Creek ab Kick Bush/Cheer Cr.	17.7	8	8.3
Gold Creek ab W. Gold Cr.	10.4	7	7.7
Gold Creek ab Chloride Gulch	4.74	5	
1st Tributary to Gold Creek @ mouth	0.46	2	
2nd Tributary to Gold Creek @ mouth	0.38	2	
3rd Tributary to Gold Creek @ mouth	1.12	3	
Chloride Gulch @ mouth	4.25	5	
Chloride Gulch ab 1st Tributary	1.46	3	
1st Tributary to Chloride Gulch @ mouth	0.29	2	
2nd Tributary to Chloride Gulch @ mouth	0.83	2	
3rd Tributary to Chloride Gulch @ mouth	0.64	2	
West Gold Creek @ mouth	6.94	6	3.5, 6.5, 5.6, 4.8
West Gold Creek ab 1st Tributary	1.34	3	
1st Tributary to West Gold @ mouth	0.49	2	
2nd Tributary to West Gold @ mouth	0.52	2	
3rd Tributary to West Gold @ mouth	0.71	2	
4th Tributary to West Gold @ mouth	0.83	2	
Kick Bush Creek @ mouth	3.4	4	
Kick Bush Creek ab Cheer Cr.	2.1	3	
Cheer Creek @ mouth	0.76	2	1.9
Upper Cocolalla Creek ab Lake	44.5	12	5.7, 5
Upper Cocolalla Creek @ Careywood	26.7	9	
Upper Cocolalla Creek ab Micro Cr.	3.93	4	3.6
Lower Cocolalla Creek bl Lake	68	14	7.6
Lower Cocolalla Creek ab slough	81.3	15	
Fish Creek @ mouth	9.55	6	7.2
Fish Creek bl fork	8.1	6	
Hoodoo Creek @ mouth	84.3	15	
Hoodoo Creek ab Hoodoo Lake	24	9	9.9
Hoodoo Creek ab 1st lake	3.9	4	

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)	**Pack River Shade Curves**
340	0.6	2.2	0.98	0.11	-2.09	1	1	340	748	340	37.4	-710.6	forest group D
1180	0.7	1.65	0.98	0.11	-1.54	2	1	2360	3894	1180	129.8	-3764.2	forest group C
1370	0.4	3.3	0.97	0.165	-3.135	4	2	5480	18084	2740	452.1	-17631.9	
160	0	5.5	0.97	0.165	-5.335	5	2	800	4400	320	52.8	-4347.2	
170	0.6	2.2	0.95	0.275	-1.925	5	3	850	1870	510	140.25	-1729.75	
250	0.4	3.3	0.95	0.275	-3.025	5	3	1250	4125	750	206.25	-3918.75	
250	0.5	2.75	0.96	0.22	-2.53	5	3	1250	3437.5	750	165	-3272.5	forest group B
250	0.6	2.2	0.96	0.22	-1.98	6	3	1500	3300	750	165	-3135	
110	0.4	3.3	0.96	0.22	-3.08	6	3	660	2178	330	72.6	-2105.4	
80	0.6	2.2	0.96	0.22	-1.98	6	3	480	1056	240	52.8	-1003.2	
760	0.4	3.3	0.96	0.22	-3.08	7	3	5320	17556	2280	501.6	-17054.4	
700	0.5	2.75	0.94	0.33	-2.42	8	4	5600	15400	2800	924	-14476	
250	0.4	3.3	0.94	0.33	-2.97	9	4	2250	7425	1000	330	-7095	
380	0.5	2.75	0.94	0.33	-2.42	9	4	3420	9405	1520	501.6	-8903.4	
190	0.4	3.3	0.94	0.33	-2.97	9	4	1710	5643	760	250.8	-5392.2	
610	0.6	2.2	0.91	0.495	-1.705	10	5	6100	13420	3050	1509.75	-11910.25	
310	0.3	3.85	0.91	0.495	-3.355	10	5	3100	11935	1550	767.25	-11167.75	
110	0.1	4.95	0.91	0.495	-4.455	11	5	1210	5989.5	550	272.25	-5717.25	
380	0.5	2.75	0.91	0.495	-2.255	11	5	4180	11495	1900	940.5	-10554.5	
320	0.2	4.4	0.89	0.605	-3.795	11	6	3520	15488	1920	1161.6	-14326.4	
130	0	5.5	0.89	0.605	-4.895	12	6	1560	8580	780	471.9	-8108.1	
140	0.1	4.95	0.89	0.605	-4.345	12	6	1680	8316	840	508.2	-7807.8	
300	0.3	3.85	0.89	0.605	-3.245	12	6	3600	13860	1800	1089	-12771	
170	0.1	4.95	0.89	0.605	-4.345	12	6	2040	10098	1020	617.1	-9480.9	
1990	0	5.5	0.83	0.935	-4.565	14	7	27860	153230	13930	13024.55	-140205.45	
590	0.1	4.95	0.78	1.21	-3.74	18	8	10620	52569	4720	5711.2	-46857.8	
3350	0	5.5	0.73	1.485	-4.015	21	9	70350	386925	30150	44772.75	-342152.25	
1030	0.1	4.95	0.68	1.76	-3.19	22	10	22660	112167	10300	18128	-94039	
220	0	5.5	0.68	1.76	-3.74	22	10	4840	26620	2200	3872	-22748	
1300	0.1	4.95	0.64	1.98	-2.97	22	11	28600	141570	14300	28314	-113256	
130	0.2	4.4	0.64	1.98	-2.42	22	11	2860	12584	1430	2831.4	-9752.6	
1680	0	5.5	0.64	1.98	-3.52	23	11	38640	212520	18480	36590.4	-175929.6	
1610	0.1	4.95	0.41	3.245	-1.705	23	12	37030	183298.5	19320	62693.4	-120605.1	nonforest 1
900	0	5.5	0.39	3.355	-2.145	24	13	21600	118800	11700	39253.5	-79546.5	
390	0.1	4.95	0.39	3.355	-1.595	25	13	9750	48262.5	5070	17009.85	-31252.65	
230	0	5.5	0.39	3.355	-2.145	26	13	5980	32890	2990	10031.45	-22858.55	
620	0.1	4.95	0.37	3.465	-1.485	27	14	16740	82863	8680	30076.2	-52786.8	
1180	0	5.5	0.37	3.465	-2.035	29	14	34220	188210	16520	57241.8	-130968.2	
17090	0	5.5	0.32	3.74	-1.76	32	17	546880	3007840	290530	1086582.2	-1921257.8	
2340	0	5.5	0.28	3.96	-1.54	36	20	84240	463320	46800	185328	-277992	
240	0.1	4.95	0.28	3.96	-0.99	36	20	8640	42768	4800	19008	-23760	
4200	0	5.5	0.27	4.015	-1.485	37	21	155400	854700	88200	354123	-500577	
23370	0	5.5	0.22	4.29	-1.21	37	24	864690	4755795	560880	2406175.2	-2349619.8	nonforest 2
							Total	**2,051,860**	**11,074,635**	**1,180,680**	**4,432,086**	**-6,642,549**	**-60**
													% Reduction

MOS 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)	**Pack River Shade Curves**
340	0.9	0.55	0.98	0.11	-0.44	1	1	340	187	340	37.4	-149.6	forest group D
1180	0.9	0.55	0.98	0.11	-0.44	1	1	1180	649	1180	129.8	-519.2	forest group C
1370	0.9	0.55	0.97	0.165	-0.385	2	2	2740	1507	2740	452.1	-1054.9	
160	0.9	0.55	0.97	0.165	-0.385	2	2	320	176	320	52.8	-123.2	
170	0.9	0.55	0.95	0.275	-0.275	3	3	510	280.5	510	140.25	-140.25	
250	0.9	0.55	0.95	0.275	-0.275	3	3	750	412.5	750	206.25	-206.25	
250	0.9	0.55	0.96	0.22	-0.33	3	3	750	412.5	750	165	-247.5	forest group B
250	0.9	0.55	0.96	0.22	-0.33	3	3	750	412.5	750	165	-247.5	
110	0.9	0.55	0.96	0.22	-0.33	3	3	330	181.5	330	72.6	-108.9	
80	0.9	0.55	0.96	0.22	-0.33	3	3	240	132	240	52.8	-79.2	
760	0.9	0.55	0.96	0.22	-0.33	3	3	2280	1254	2280	501.6	-752.4	
700	0.9	0.55	0.94	0.33	-0.22	4	4	2800	1540	2800	924	-616	
250	0.9	0.55	0.94	0.33	-0.22	4	4	1000	550	1000	330	-220	
380	0.9	0.55	0.94	0.33	-0.22	4	4	1520	836	1520	501.6	-334.4	
190	0.9	0.55	0.94	0.33	-0.22	4	4	760	418	760	250.8	-167.2	
610	0.9	0.55	0.91	0.495	-0.055	5	5	3050	1677.5	3050	1509.75	-167.75	
310	0.9	0.55	0.91	0.495	-0.055	5	5	1550	852.5	1550	767.25	-85.25	
110	0.9	0.55	0.91	0.495	-0.055	5	5	550	302.5	550	272.25	-30.25	
380	0.9	0.55	0.91	0.495	-0.055	5	5	1900	1045	1900	940.5	-104.5	
320	0.8	1.1	0.89	0.605	-0.495	6	6	1920	2112	1920	1161.6	-950.4	
130	0.8	1.1	0.89	0.605	-0.495	6	6	780	858	780	471.9	-386.1	
140	0.8	1.1	0.89	0.605	-0.495	6	6	840	924	840	508.2	-415.8	
300	0.8	1.1	0.89	0.605	-0.495	6	6	1800	1980	1800	1089	-891	
170	0.8	1.1	0.89	0.605	-0.495	6	6	1020	1122	1020	617.1	-504.9	
1990	0.8	1.1	0.83	0.935	-0.165	7	7	13930	15323	13930	13024.55	-2298.45	
590	0.7	1.65	0.78	1.21	-0.44	8	8	4720	7788	4720	5711.2	-2076.8	
3350	0.7	1.65	0.73	1.485	-0.165	9	9	30150	49747.5	30150	44772.75	-4974.75	
1030	0.6	2.2	0.68	1.76	-0.44	10	10	10300	22660	10300	18128	-4532	
220	0.6	2.2	0.68	1.76	-0.44	10	10	2200	4840	2200	3872	-968	
1300	0.6	2.2	0.64	1.98	-0.22	11	11	14300	31460	14300	28314	-3146	
130	0.6	2.2	0.64	1.98	-0.22	11	11	1430	3146	1430	2831.4	-314.6	
1680	0.6	2.2	0.64	1.98	-0.22	11	11	18480	40656	18480	36590.4	-4065.6	
1610	0.4	3.3	0.41	3.245	-0.055	12	12	19320	63756	19320	62693.4	-1062.6	nonforest 1
900	0.3	3.85	0.39	3.355	-0.495	13	13	11700	45045	11700	39253.5	-5791.5	
390	0.3	3.85	0.39	3.355	-0.495	13	13	5070	19519.5	5070	17009.85	-2509.65	
230	0.3	3.85	0.39	3.355	-0.495	13	13	2990	11511.5	2990	10031.45	-1480.05	
620	0.3	3.85	0.37	3.465	-0.385	14	14	8680	33418	8680	30076.2	-3341.8	
1180	0.3	3.85	0.37	3.465	-0.385	14	14	16520	63602	16520	57241.8	-6360.2	
17090	0.3	3.85	0.32	3.74	-0.11	17	17	290530	1118540.5	290530	1086582.2	-31958.3	
2340	0.2	4.4	0.28	3.96	-0.44	20	20	46800	205920	46800	185328	-20592	
240	0.2	4.4	0.28	3.96	-0.44	20	20	4800	21120	4800	19008	-2112	
4200	0.2	4.4	0.27	4.015	-0.385	21	21	88200	388080	88200	354123	-33957	
23370	0.2	4.4	0.22	4.29	-0.11	24	24	560880	2467872	560880	2406175.2	-61696.8	nonforest 2
							Total	**1,180,680**	**4,633,827**	**1,180,680**	**4,432,086**	**-201,741**	**-4**
													% Reduction

Trout Creek 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)	**Trout Creek Shade Curves**
1330	0.9	0.55	0.98	0.11	-0.44	1	1	1330	731.5	1330	146.3	-585.2	forest group B
400	0.8	1.1	0.98	0.11	-0.99	2	2	800	880	800	88	-792	
710	0.9	0.55	0.98	0.11	-0.44	2	2	1420	781	1420	156.2	-624.8	
400	0.9	0.55	0.86	0.77	0.22	3	3	1200	660	1200	924	264	nonforest group 1
2190	0.8	1.1	0.94	0.33	-0.77	4	4	8760	9636	8760	2890.8	-6745.2	forest group B
2400	0.9	0.55	0.91	0.495	-0.055	5	5	12000	6600	12000	5940	-660	
370	0.8	1.1	0.65	1.925	0.825	6	6	2220	2442	2220	4273.5	1831.5	nonforest group 1
							Total	**27,730**	**21,731**	**27,730**	**14,419**	**-7,312**	**-34**
													% Reduction

MOS **MOS**

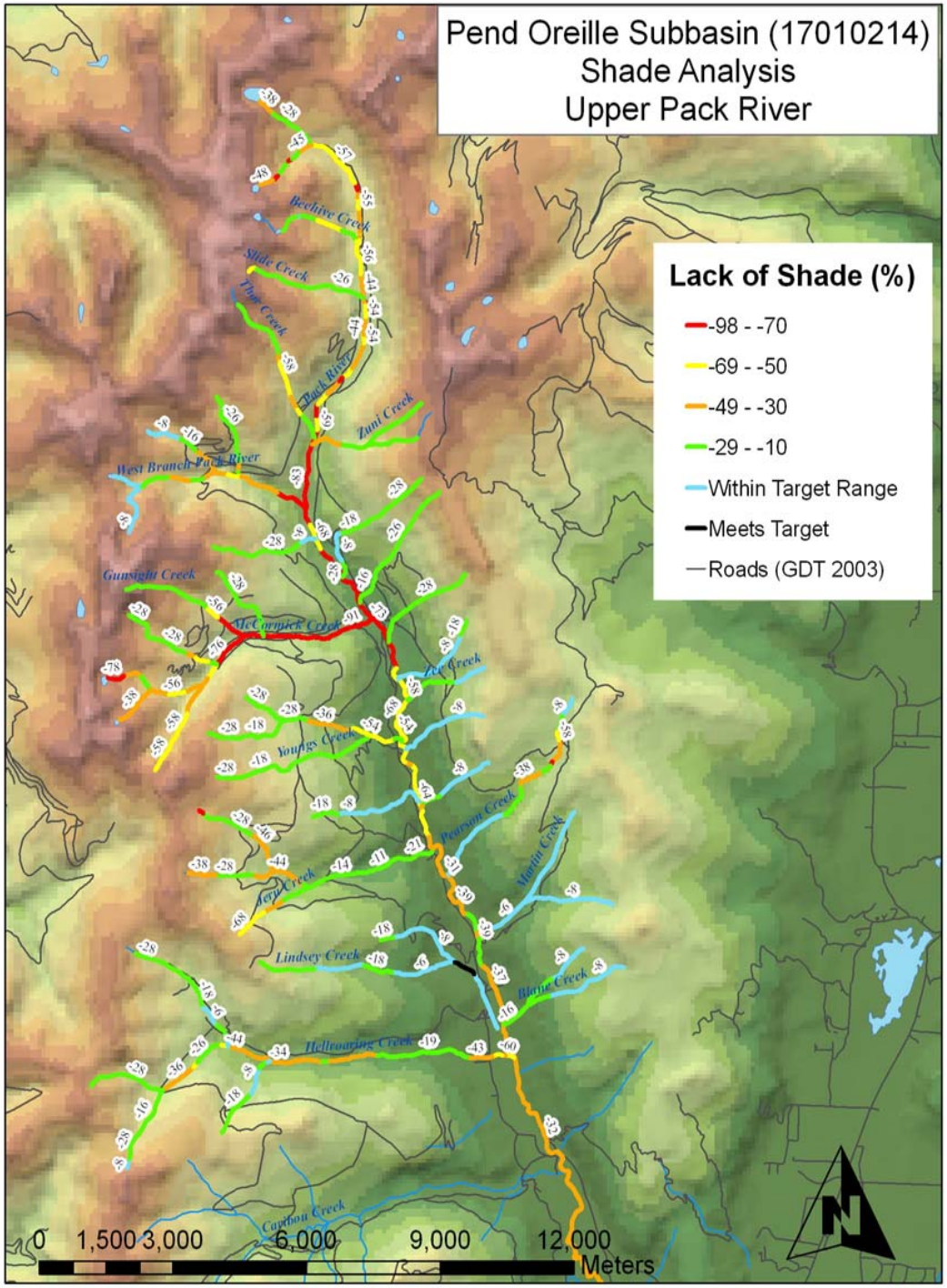
Segment Length (meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Existing Stream Width (m)	Natural Stream Width (m)	Existing Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Segment Area (m^2)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	**Trout Creek Shade Curves**
1330	0.9	0.55	0.98	0.11	-0.44	1	1	1330	731.5	1330	146.3	-585.2	forest group B
400	0.9	0.55	0.98	0.11	-0.44	2	2	800	440	800	88	-352	
710	0.9	0.55	0.98	0.11	-0.44	2	2	1420	781	1420	156.2	-624.8	
400	0.8	1.1	0.86	0.77	-0.33	3	3	1200	1320	1200	924	-396	nonforest group 1
2190	0.9	0.55	0.94	0.33	-0.22	4	4	8760	4818	8760	2890.8	-1927.2	forest group B
2400	0.9	0.55	0.91	0.495	-0.055	5	5	12000	6600	12000	5940	-660	
370	0.6	2.2	0.65	1.925	-0.275	6	6	2220	4884	2220	4273.5	-610.5	nonforest group 1
							Total	**27,730**	**19,575**	**27,730**	**14,419**	**-5,156**	**-26**
													% Reduction

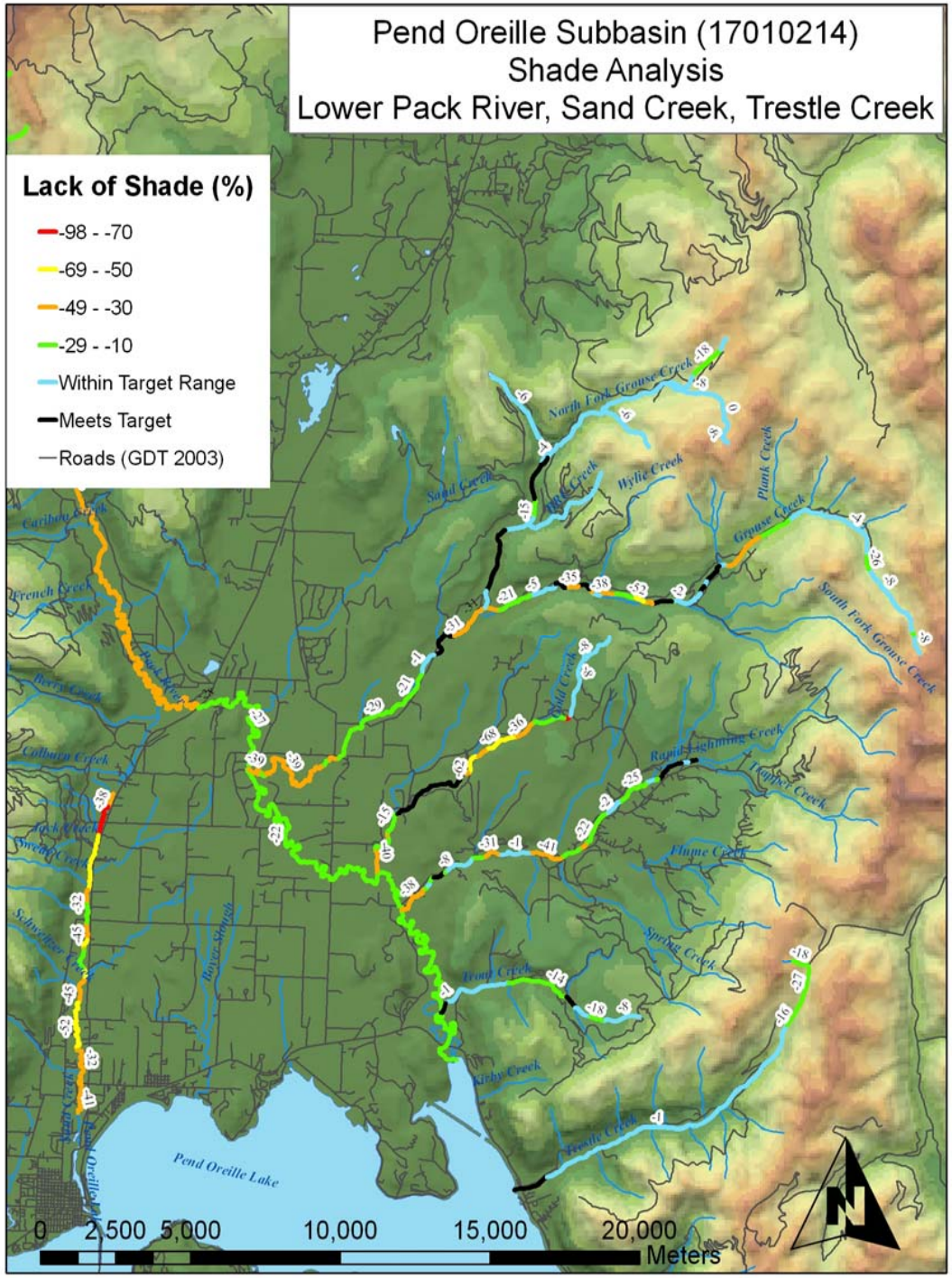
Excess Load

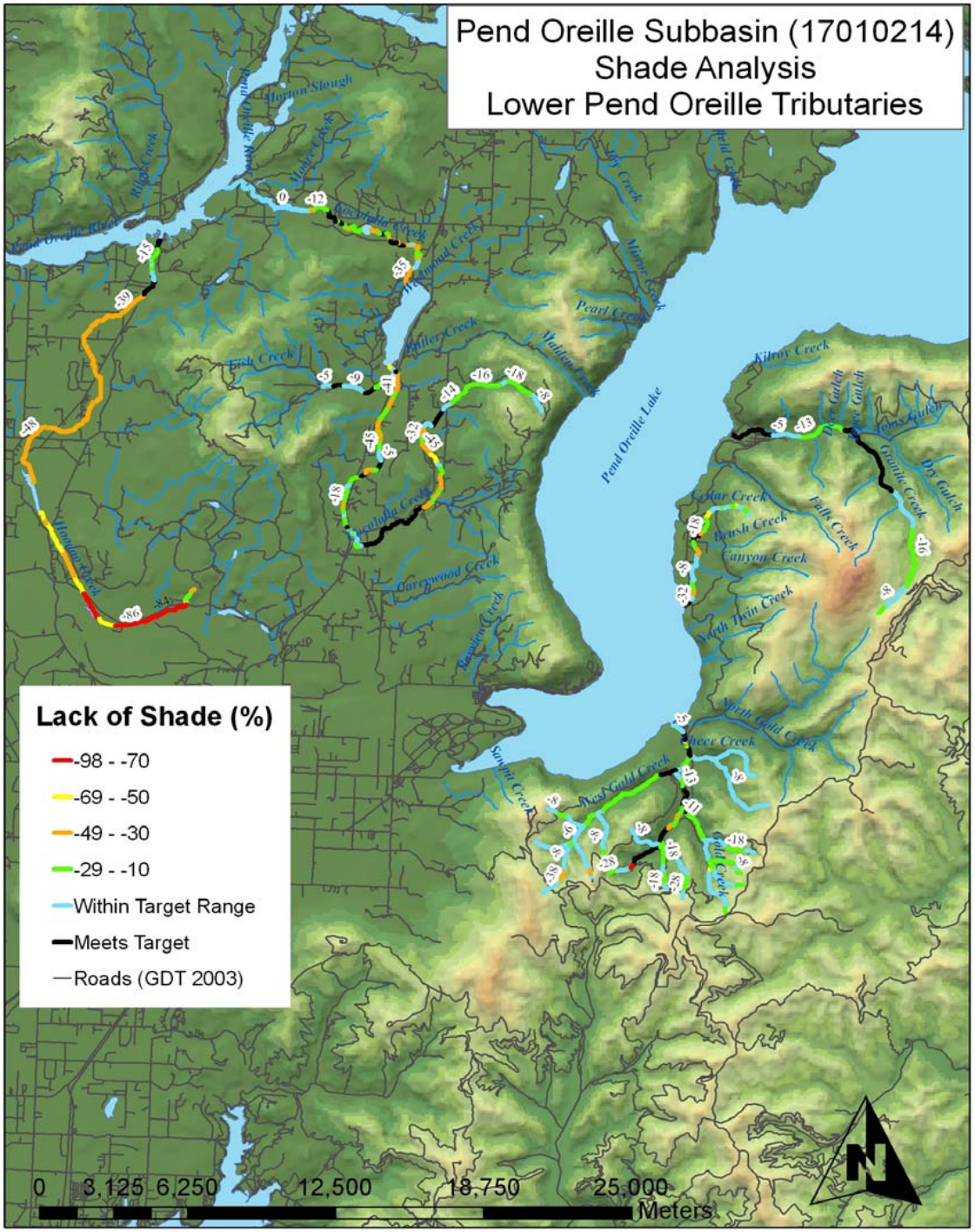
Water Body	Excess Load (kWh/day)	Percent Reduction
Grouse Creek	994,318 (83,672 MOS)	50 – 54%
Sand Creek	268,696 (13,716 MOS)	55 – 58%
Rapid Lightning Creek	211,879 (27,640 MOS)	31 – 35%
North Gold Creek	57,774 (11,123 MOS)	32 – 40%
Trestle Creek	20,214 (7,405 MOS)	18 – 29%
North Fork Grouse Creek	14,187 (25,429 MOS)	0 – 13%
Trout Creek	7,312 (5,156 MOS)	10 – 34%

Water Body	Excess Load (kWh/day)	Percent Reduction
Hoodoo Creek	483,857 (96,365 MOS)	13 – 16%
Upper Cocolalla Creek	158,974 (39,360 MOS)	20 – 26%
Lower Cocolalla Creek	46,042 (12,310 MOS)	0.05 – 0.17%
West Gold Creek	24,776 (15,161 MOS)	24 – 61%
‘South’ Gold Creek	17,123 (11,419 MOS)	7 – 21%
Chloride Gulch	16,474 (9,220 MOS)	26 – 58%
Fish Creek	16,060 (7,607 MOS)	16 – 31%
Cedar Creek	14,401 (6,542 MOS)	23 – 43%
Upper Tribs to Gold Creek	7,861 (4,594 MOS)	35 – 84%
Kick Bush & Cheer Creeks	6,565 (6,565 MOS)	0 – 71%
Granite Creek	5,546 (18,350 MOS)	0 – 4%

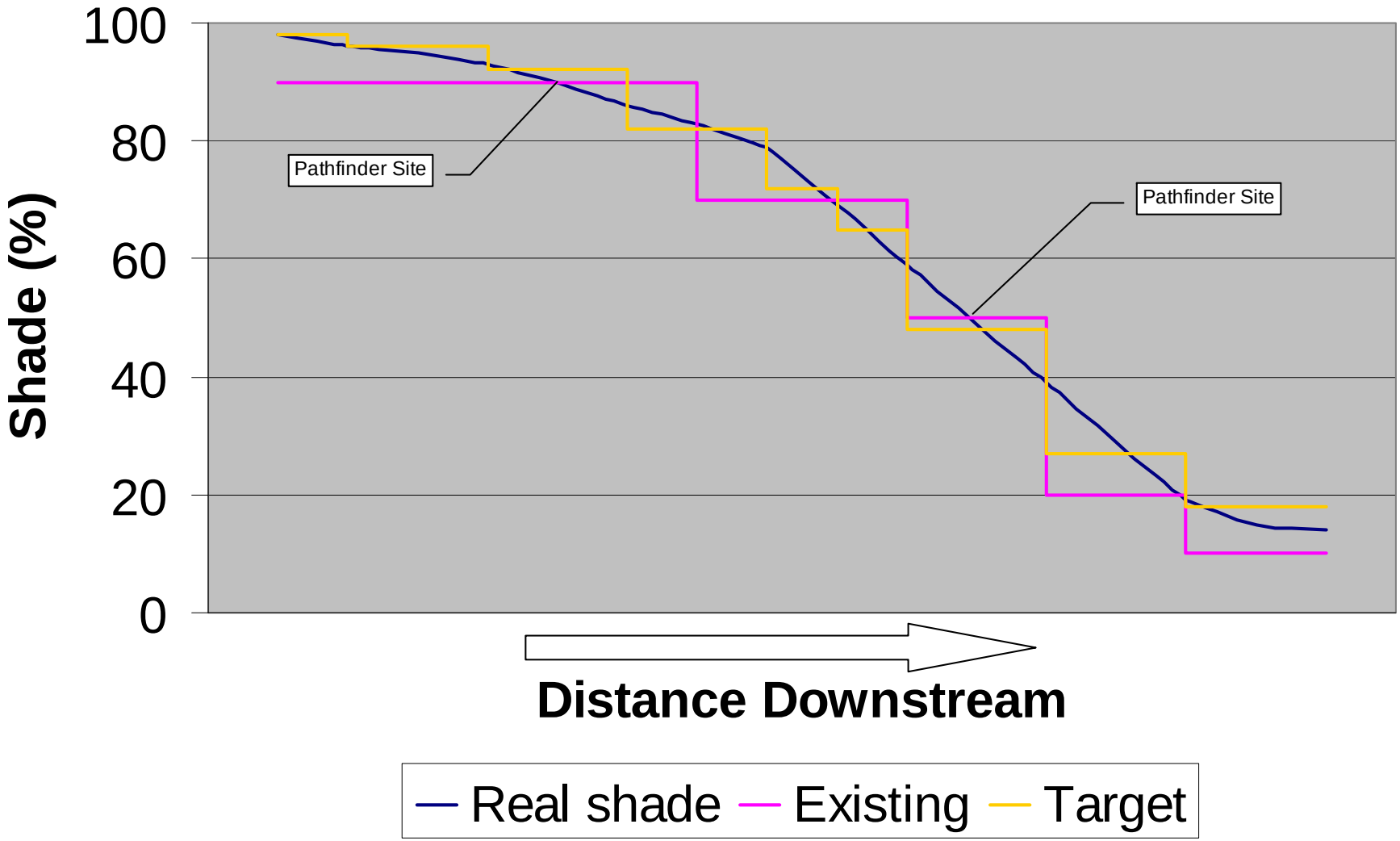
Water Body	Excess Load (kWh/day)	Percent Reduction
Pack River, source to mouth	6,642,549 (201,741 MOS)	58 – 60%
McCormick Creek	191,305 (3,634 MOS)	94 – 96%
Hellroaring Creek	78,533 (9,766 MOS)	64 – 73%
West Branch Creek	47,106 (6,648 MOS)	75 – 87%
1st Tributary to McCormick	32,945 (2,899 MOS)	88 – 96%
Homestead Creek	26,245 (4,426 MOS)	75 – 90%
Forked Tributaries to Jeru	25,320 (4,387 MOS)	75 – 91%
Jeru Creek	23,690 (3,224 MOS)	69 – 80%
Gunsight Creek	16,814 (2,101 MOS)	82 – 93%
Thor Creek	14,306 (2,530 MOS)	76 – 93%
Zuni Creek	12,740 (3,110 MOS)	70 – 92%
Pearson Creek	11,727 (4,236 MOS)	49 – 77%
Youngs Creek	10,938 (3,117 MOS)	63 – 88%
Forked Tributaries to Hellroaring Creek	10,691 (3,249 MOS)	63 – 90%
Lindsey Creek	9,307 (8,510 MOS)	4 – 47%
2nd East-side Pack Trib below West Branch	8,664 (2,350 MOS)	62 – 85%
Slide Creek	8,561 (2,258 MOS)	64 – 87%
2nd Trib to McCormick Creek	7,359 (1,716 MOS)	72 – 94%
1st West-side Pack Tributary	7,097 (1,025 MOS)	78 – 92%
Martin Creek	6,615 (5,059 MOS)	18 – 77%
Beehive Creek	5,921 (1,307 MOS)	13 – 16%
Blane Creek	5,858 (3,097 MOS)	40 – 85%
1st East-side Pack Trib below West Branch	5,544 (2,464 MOS)	50 – 90%
3rd Trib to Hellroaring Creek	5,204 (2,394 MOS)	43 – 80%
1st East-side Pack Trib below McCormick Creek	4,134 (1,461 MOS)	59 – 92%
1st West-side Pack Trib below West Branch	3,953 (1,236 MOS)	64 – 93%
4th Trib to McCormick Creek	2,911 (832 MOS)	67 – 93%
Zee Creek	2,812 (1,426 MOS)	44 – 89%
1st West-side Pack Trib below Homestead Creek	2,451 (2,121 MOS)	11 – 82%
4th Trib to Hellroaring Creek	2,423 (1,296 MOS)	39 – 84%
Torrent Creek	2,000 (1,813 MOS)	8 – 82%
1st East-side Pack Trib below Homestead Creek	1,751 (1,751 MOS)	0 – 80%
2nd East-side Pack Trib below Homestead Creek	1,462 (818 MOS)	39 – 88%


Pend Oreille Subbasin (17010214)
Shade Analysis
Upper Pack River
Lack of Shade (%)
-98 - -70
-69 - -50
-49 - -30
-29 - -10
Within Target Range
Meets Target
Roads (GDT 2003)
Beehive Creek
Slide Creek
Pine Creek
Pack River
Zuni Creek
West Branch Pack River
Gunsight Creek
McCormick Creek
Ice Creek
Youngs Creek
Pearson Creek
Martin Creek
Jerry Creek
Lindsey Creek
Blaine Creek
Hellroaring Creek
Cayuse Creek
0 1,500 3,000 6,000 9,000 12,000
Meters
N

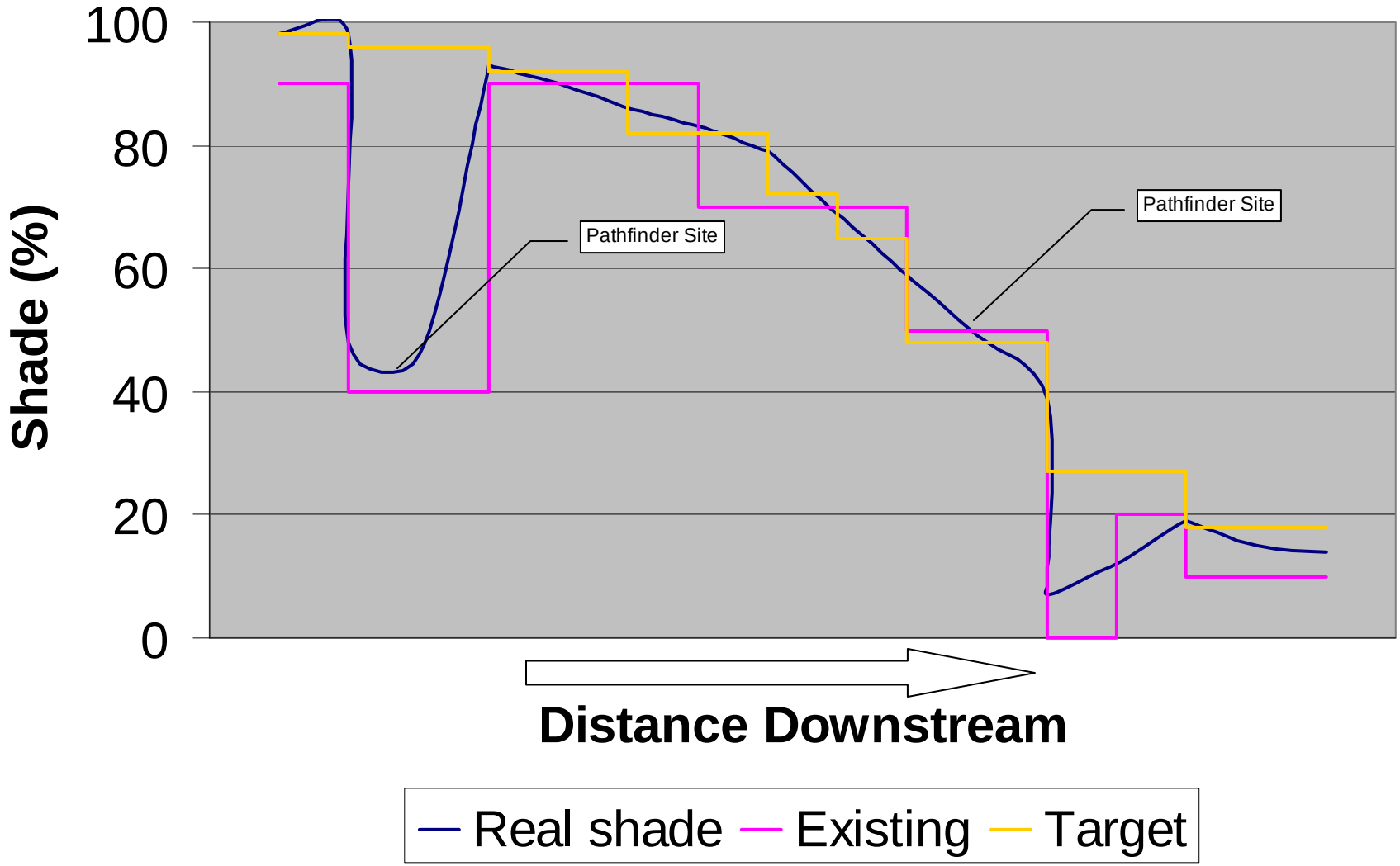

Pend Oreille Subbasin (17010214)
Shade Analysis
Lower Pack River, Sand Creek, Trestle Creek
Lack of Shade (%)
-98 - -70
-69 - -50
-49 - -30
-29 - -10
Within Target Range
Meets Target
Roads (GDT 2003)
Pend Oreille Lake
0 2,500 5,000 10,000 15,000 20,000
Meters


Pend Oreille Subbasin (17010214)
Shade Analysis
Lower Pend Oreille Tributaries
Lack of Shade (%)
-98 - -70
-69 - -50
-49 - -30
-29 - -10
Within Target Range
Meets Target
Roads (GDT 2003)
0 3,125 6,250 12,500 18,750 25,000
Meters
N
Pend Oreille Lake
Morton Slough
Pearl Creek
Kilroy Creek
Granite Creek
Dry Gulch
Fulls Creek
Brush Creek
Canyon Creek
North Twin Creek
North Gold Creek
West Gold Creek
Gold Creek
Sawmill Creek
Carrywood Creek
Fish Creek
Cocolalla Creek
Maidem Creek
Pend Oreille River

Shade Estimates



Shade Estimates



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