MALHEUR RIVER BASIN TMDL

APPENDIX B: TEMPERATURE TMDL TECHNICAL DATA

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DEQ
State of Oregon
Department of
Environmental
Quality

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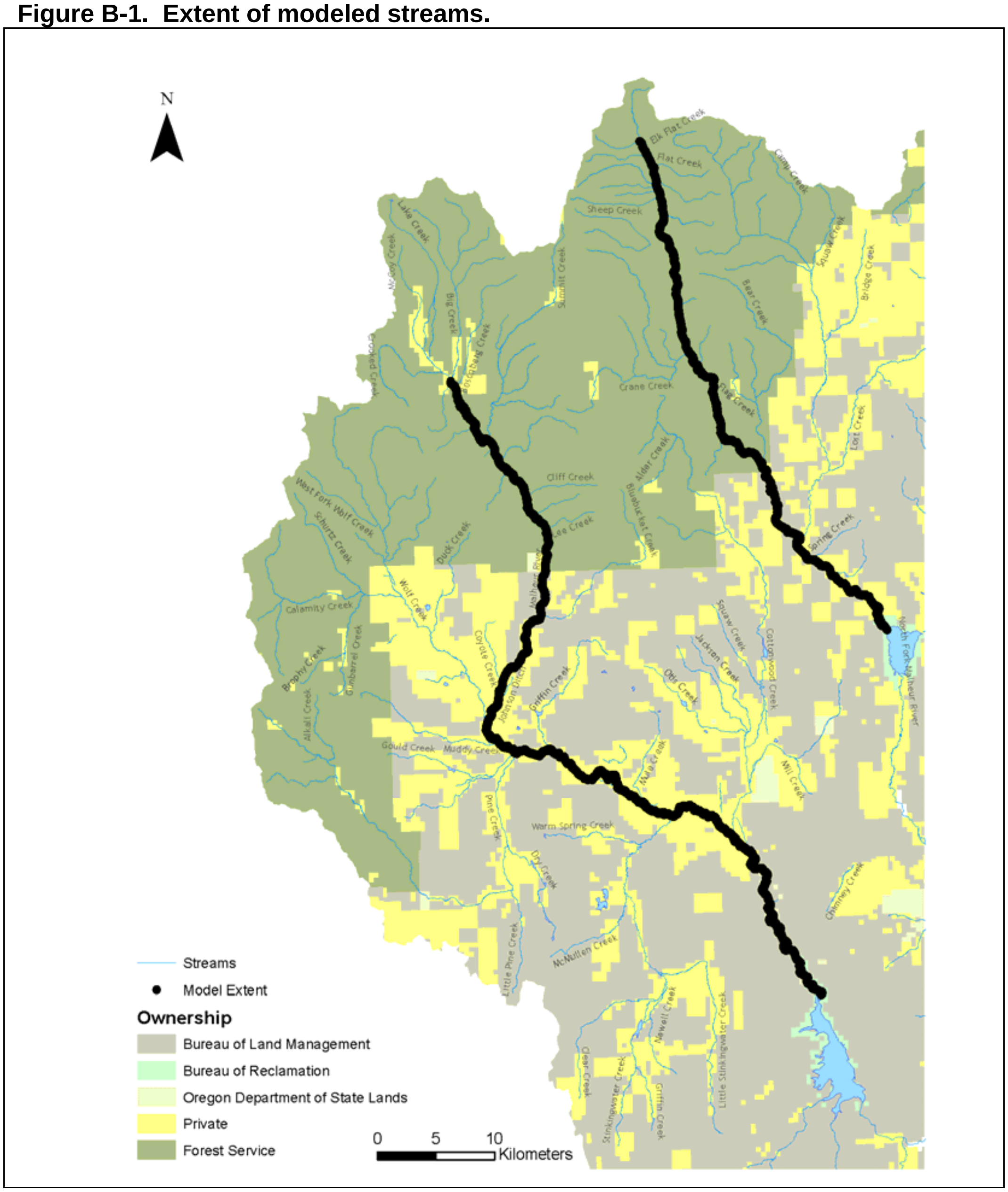
INTRODUCTION

This appendix documents the modeling and technical aspects of the temperature assessment for the Malheur River Basin temperature TMDL. The focus is on the Heat Source modeling and site potential vegetation development on the Malheur River and North Fork Malheur River.

MODEL EXTENT

The model simulations were conducted on the temperature impaired portions of the Malheur and North Fork Malheur Rivers. See **Figure B-1** for a map. On the Malheur River, the model extended from Warm Spring Reservoir to the Malheur headwaters at the confluence of Lake and Big Creeks. On the North Fork of the Malheur, the model extended from Beulah Reservoir to about 300 meters upstream of where Horseshoe Creek flows into the North Fork of the Malheur.

Figure B-1. Extent of modeled streams.



HABITAT DATA

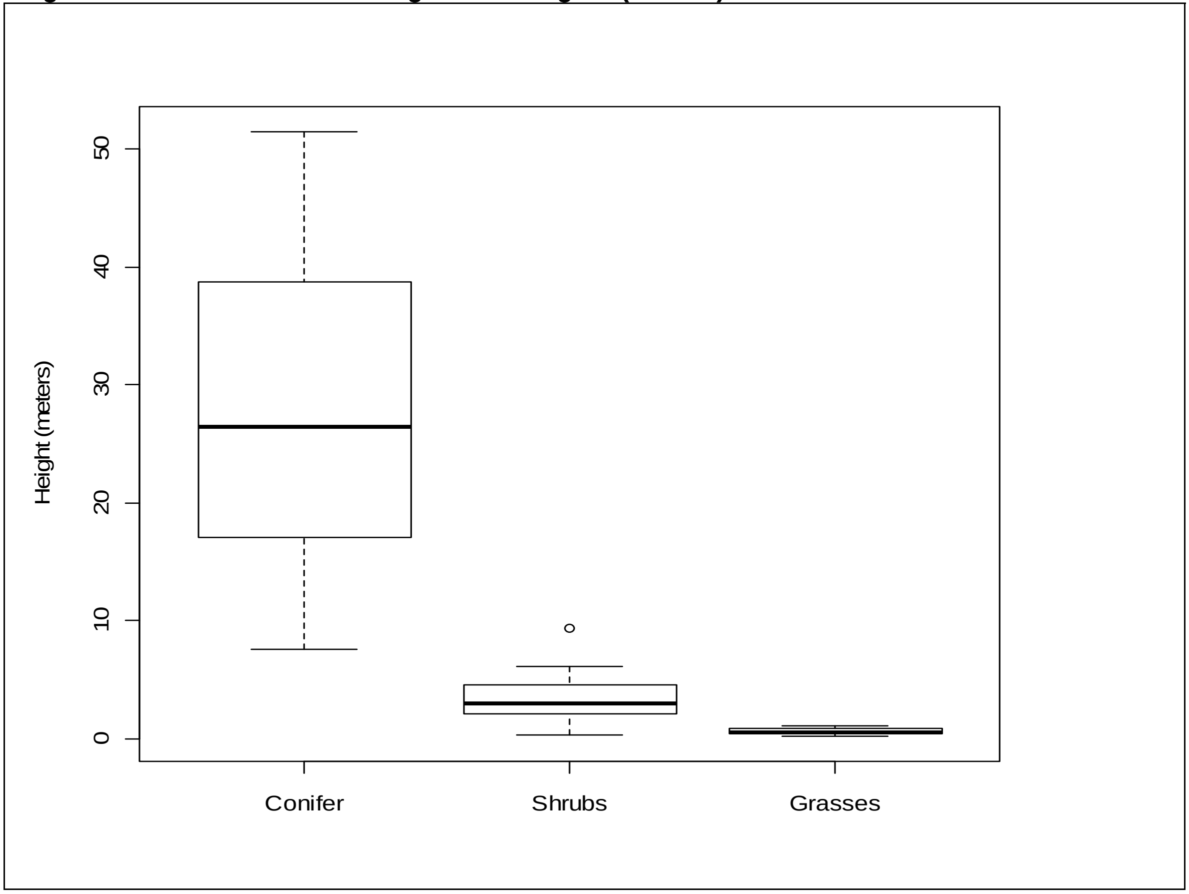
Vegetation height, type, and effective shade data was collected in June-August 2006, July 2007, July 2008 and August 2008.

Vegetation heights (shown in **Table B-1**) were collected at each site using a laser range finder. Small, medium and large trees were randomly chosen at each site. Unless otherwise specified, if there is a single number in **Table B-1**, this value represents the average estimated tree height in the area. The overall distribution of vegetation heights is shown in the Tukey box plots in **Figure B-2**. The rectangle box represents the interquartile range (ie. The 25th to the 75th percentile). The whiskers represent the minimum and maximum values unless. Outliers (shown as points) have a distance that is more than 1.5 times the interquartile range.

Table B-1. Field measured vegetation heights (meters).

Location	***Conifers***	***Shrubs***	***Grasses***
Big Creek at Rd 16 (mile marker 19)	Lodgepole 7.6, 13.1, 16.5, 17.1, Ponderosa 18.3	3.0, 2.4, 5.2	
Big Creek at Big Creek Campground	Lodgepole (old) 16.2 Ponderosa 33.5, 23.8, 40.0	4.6, 9.4, 5.8	*0.6-0.9*
Malheur River at Malheur Ford d/s along trail	Ponderosa 42.7, 28.0, 46.0, 15.2, 42.1	1.8-6.1	
Malheur River at Malheur Ford farther u/s of Ford	Ponderosa 51.5, 48.8, 31.4, 20.7		
NF Malheur River at NF Malheur Campground	Ponderosa (tall) 41.8, 38.7, 39.9, Ponderosa (med) 25.0, 25.3, 28.0	2.4- 4.0	*1.1*
NF Malheur River along NF Malheur trail 381	Ponderosa (old) 43.0 Lodgepole 26.5, 20.1, 27.4, 27.1, 28.3	Alder 1.8, 3.7, 2.4, 3.0, 3.7	
NF Malheur u/s quarter mile of Swamp Creek	Spruce 18.9, 14.9, Lodgepole 26.5, 16.5, 25.9, 7.6, 7.9 Ponderosa 33.5	Alder 2.1, 2.4	
Basin Creek u/s confluence with Willow Cr.			0.2
Cottonwood Creek trib near Bully Cr. Rd			0.5
NF Malheur River 30m d/s Little Malheur		Mostly Alder 2.4-3.7	
NF Malheur River 150m d/s Little Malheur		Mostly Alder 1.8-3.0	
NF Malheur River 200m u/s Little Malheur		2.4-6.1	
NF Malheur River above Beulah Reservoir		Willows 0.3-2.4 Alder 4.6-5 .5	
NF Malheur River on BLM near Water Gulch	Juniper (mature) 8.5	Willows <0.3 – 3.0 Alders<0.3 – 5.2	
Malheur River @ Carey Spring		Willow 1.8-2.1 (med)	

Figure B-2. Field Measured Vegetation heights (meters).



DERIVED DATA

Several landscape scale Geographic Information System (GIS) data sets were sampled to derive spatial (location) stream data. Sampling density was user-defined and generally matched any GIS data resolution and accuracy. The sampled parameters used in the modeling analysis include:

- Stream Position and Aspect
- Stream Elevation and Gradient
- Maximum Topographic Shade Angle (East, South, West)
- Stream Channel Wetted Width
- Vegetation and Land cover

The following sub-sections detail the methodologies and data used for each derived data type.

Digital Orthophotos

The State of Oregon Geospatial Enterprise Office acquired digital orthophotos for the entire state from the US Department of Agriculture's National Agriculture Imagery Program (NAIP). This imagery is an interim compressed version with a 1-meter pixel resolution, mosaiced according to county. The NAIP orthophotos have a horizontal accuracy of ±5 meters and are referenced to digital ortho quarter quads (DOQs) from the National Digital Ortho Program (NDOP). The NAIP orthophotos are formatted to the UTM NAD83 coordinate system. ODEQ used this imagery to derive stream bank channel edges and land cover.

Digitized Stream and Wetted Channel Width

Stream flowlines for the Malheur River and North Fork Malheur River were digitized at a 1:2,000 or smaller map scale from the NAIP orthophotos. The stream flowline is used to determine the location and flow path for modeling. The flow path was segmented every 50 meters to establish true river length.

The right and left banks (looking in the downstream direction) were digitized from the NAIP orthophotos at a 1:2,000 or smaller map scale. The digitized polylines correspond to the approximate location of the river's wetted edge and were used to measure the wetted width at each of the 50 meter segments.

Figure B-3 shows the digitized streamline and wetted channel edges on the Malheur River near Pine Creek Road at model river kilometer 62.5.

Digitized Near Stream Land Cover

The streams were buffered 100 meters from each bank edge. The buffer was then overlaid on the digital NAIP orthophotos so polygons could be created that corresponded to unique land cover types. The land cover was digitized at a 1:2,000 map scale or less (**Figure B-3**). Each polygon contains the generalized plant species or land cover type, height class, and density class.

Each land cover polygon was assigned a generalized height class of “small”, “medium” or “tall”. Density was characterized as “low”, “medium”, and “high”. Specific values for these classes were then assigned based on field measurements. Land cover types were classified as deciduous, conifer, shrub, grass, built areas, and other general descriptions.

The digitized near stream land cover is most accurate according to the date that the NAIP orthophotos were collected, which was in 2005.

Figure B-3. Digitized land cover.

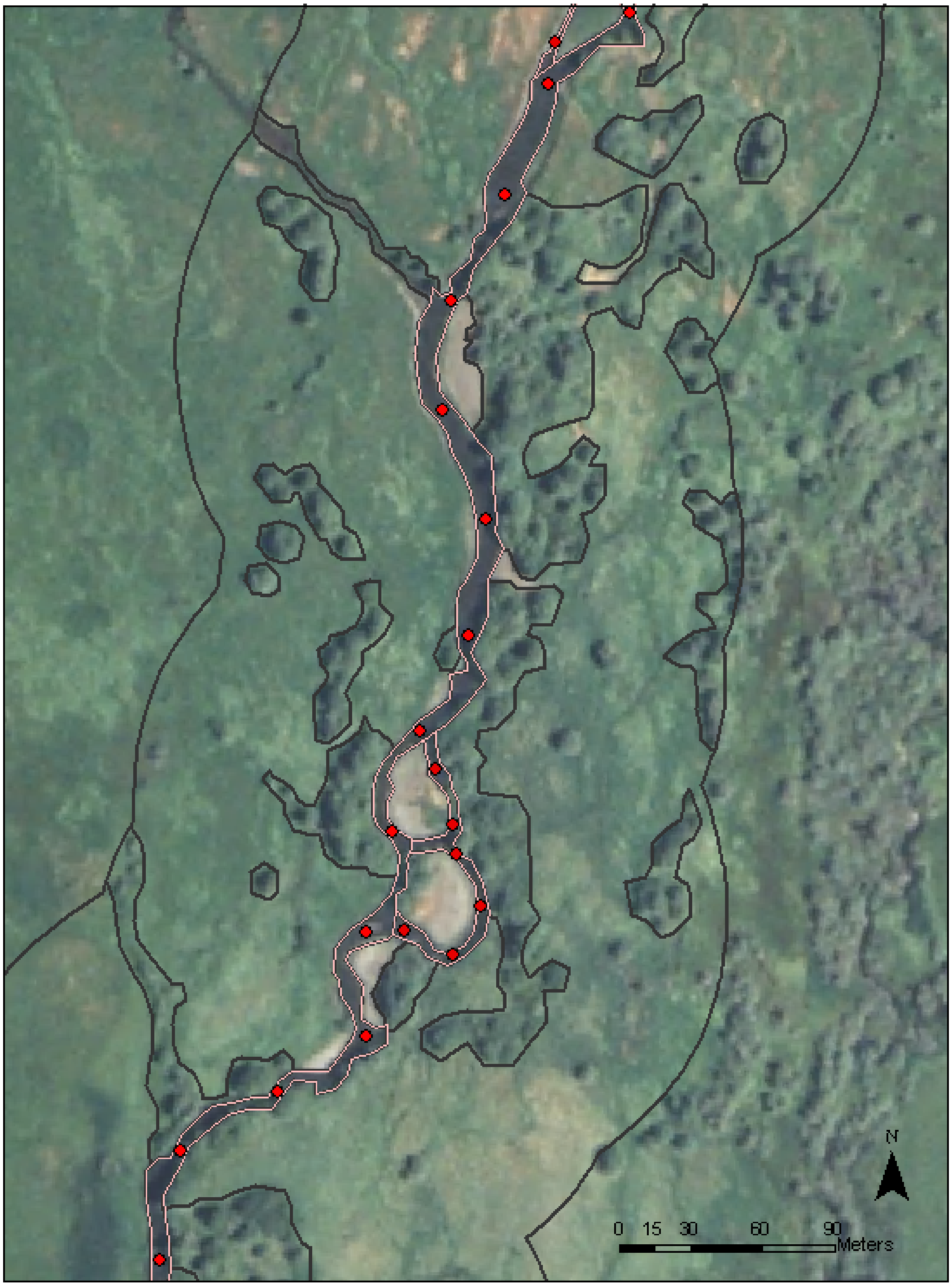


Table B-2 summarizes the numeric codes and descriptions used to uniquely identify each of the digitized land cover polygons. Height values and densities were estimated for each land cover code based on field measurements from **Table B-1**.

Table B-2. Digitized land cover polygon codes and descriptions.

Land cover	Land cover code	Height (m)	Density	Overhang (m)
Unpaved Road/Trail	1000	0	100%	0
Paved Road	1001	0	100%	0
Buildings	1500	3.5	95%	0
Cultivated/Agriculture	1700	0.3	100%	0
Floodplain Grasses	2000	0.3	100%	0
Upland Grasses	2700	0.25	100%	0
Upland Scrubland	2800	2	25%	0
Rock Outcrop (Van-Drewsey Rd)	2900	5	100%	0
Wetted Stream	3011	0	100%	0
Side Channels	3012	0	100%	0
Tributary Stream	3013	0	100%	0
Water/Oxbow/Alcove	3014	0	100%	0
Ditch/Canal	3015	0	100%	0
Conifer - Low Dense - Short	4000	5	25%	0.5
Conifer -Low Dense - Mid	4020	20	10%	1
Conifer - Low Dense - Mid	4050	20	25%	1
Conifer - Med Dense - Short	4500	5	60%	0.5
Conifer - Med Dense - Mid	4550	20	60%	1
Conifer - Med Dense - Tall	4570	36	60%	1
Conifer - High Dense - Mid	4750	20	85%	1
Conifer - High Dense - Mid	4770	36	85%	1.5
Conifer - High Dense - Mid	5000	2.2	30%	0.5
Conifer - High Dense - Tall	5020	4.6	30%	0.5
Deciduous/Shrub - Low Dense - Short	5050	15	30%	1
Deciduous/Shrub - Low Dense - Mid	5500	2.2	70%	0.5
Deciduous/Shrub - Low Dense - Mid	5520	4.6	70%	0.5
Deciduous/Shrub - Med Dense - Short	5550	15	70%	1
Deciduous/Shrub - Med Dense - Mid	5700	2.2	95%	0.5
Deciduous/Shrub - Med Dense - Mid	5720	4.6	95%	0.5
Deciduous/Shrub - High Dense - Short	5750	15	95%	1
Deciduous/Shrub - High Dense - Mid	5770	30	95%	1.5

TTOOLS SAMPLING DOCUMENTATION

TTools 7.5.5 is an ArcGIS tool maintained by ODEQ that is designed to automatically sample GIS spatial data sets and assemble input data for Heat Source modeling. This section documents the TTools sampling routines that were performed on the Malheur and North Fork Malheur River, in preparation for solar radiation modeling. TTools is available for download at the following website: http://www.deq.state.or.us/wq/tmdls/tools.htm.

Malheur River

Segmentation – The main channel was segmented into 50-meter reaches. Side channels were segmented into 25 meter reaches because of their smaller size.

Channel Widths – The distance between each of the digitized banks (perpendicular to the stream aspect) was measured for each stream segment.

Stream Elevation and Slope – The stream elevation at each segment was measured from a 10-meter DEM, using a radial 25-cell sampling routine. Some stream elevations were revised to correct for imperfections in the DEM.

Topographic Shade Angles – The maximum topographic shade angles to the east, south, and west were measured at each segment from the 10-meter DEM. The sampling routine extended 20 kilometers in each direction. The dots on **Figure B-4** depict the locations of landscape features that provide the maximum topographic shade.

Land Cover – The land cover types derived from the orthophotos were sampled in seven directions in a radial star pattern at every segment. There are four samples per direction. Main channel segments were sampled at 9 meters, 18 meters, 27 meters, and 36 meters from each stream segment in all seven directions. Side channel segments were sampled at 4 meters, 8 meters, 12 meters and 16 meters from each segment in all seven directions. Vegetation sample interval was based on the average wetted width to minimize water samples and capture vegetation at the channel edge. **Figure B-5** shows a graphical representation of sample locations along the Malheur River. Each dot represents a single land cover sample.

North Fork Malheur River

Segmentation – The main channel was segmented into 50-meter reaches. Side channels were segmented into 25 meter reaches because of their smaller size.

Channel Widths – The distance between each of the digitized banks (perpendicular to the stream aspect) was measured for each stream segment.

Stream Elevation and Slope – The stream elevation at each segment was measured from a 10-meter DEM, using a radial 25-cell sampling routine. Some stream elevations were revised to correct for imperfections in the DEM.

Topographic Shade Angles – The maximum topographic shade angles to the east, south, and west were measured at each segment from the 10-meter DEM. The sampling routine extended 20 kilometers in each direction.

Land Cover – The land cover types derived from the orthophotos was sampled in seven directions in a radial star pattern at every segment. There are four samples per direction. Main channel segments were sampled at 7 meters, 14 meters, 21 meters, and 28 meters from each stream segment in all seven directions. Side channel segments were sampled at 4 meters, 8 meters, 12 meters and 16 meters from each segment in all seven directions.

Figure B-4. The dots depict the locations of landscape features that provide the maximum topographic shade along the Malheur River near the confluence of Bluebucket Creek.

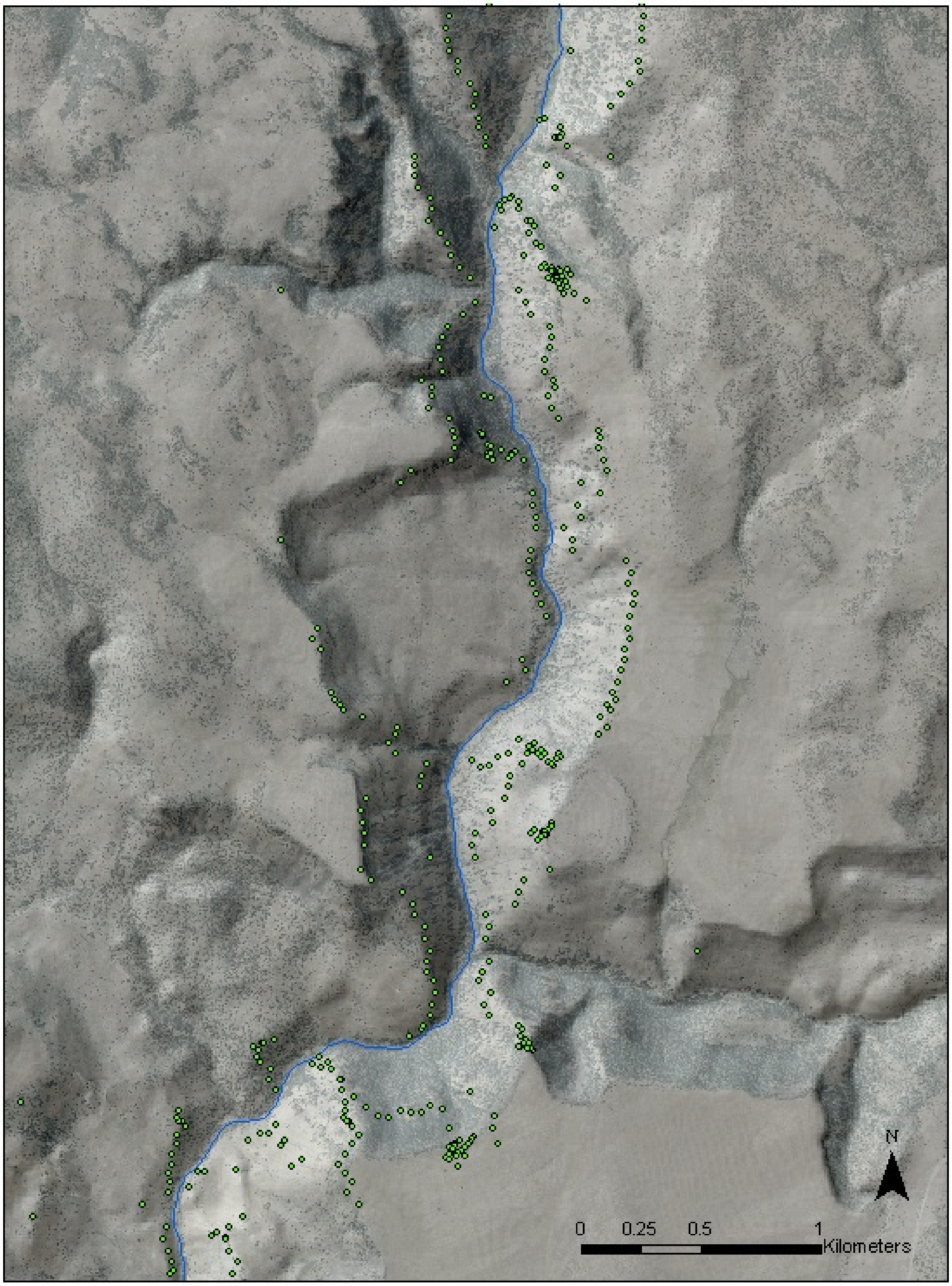
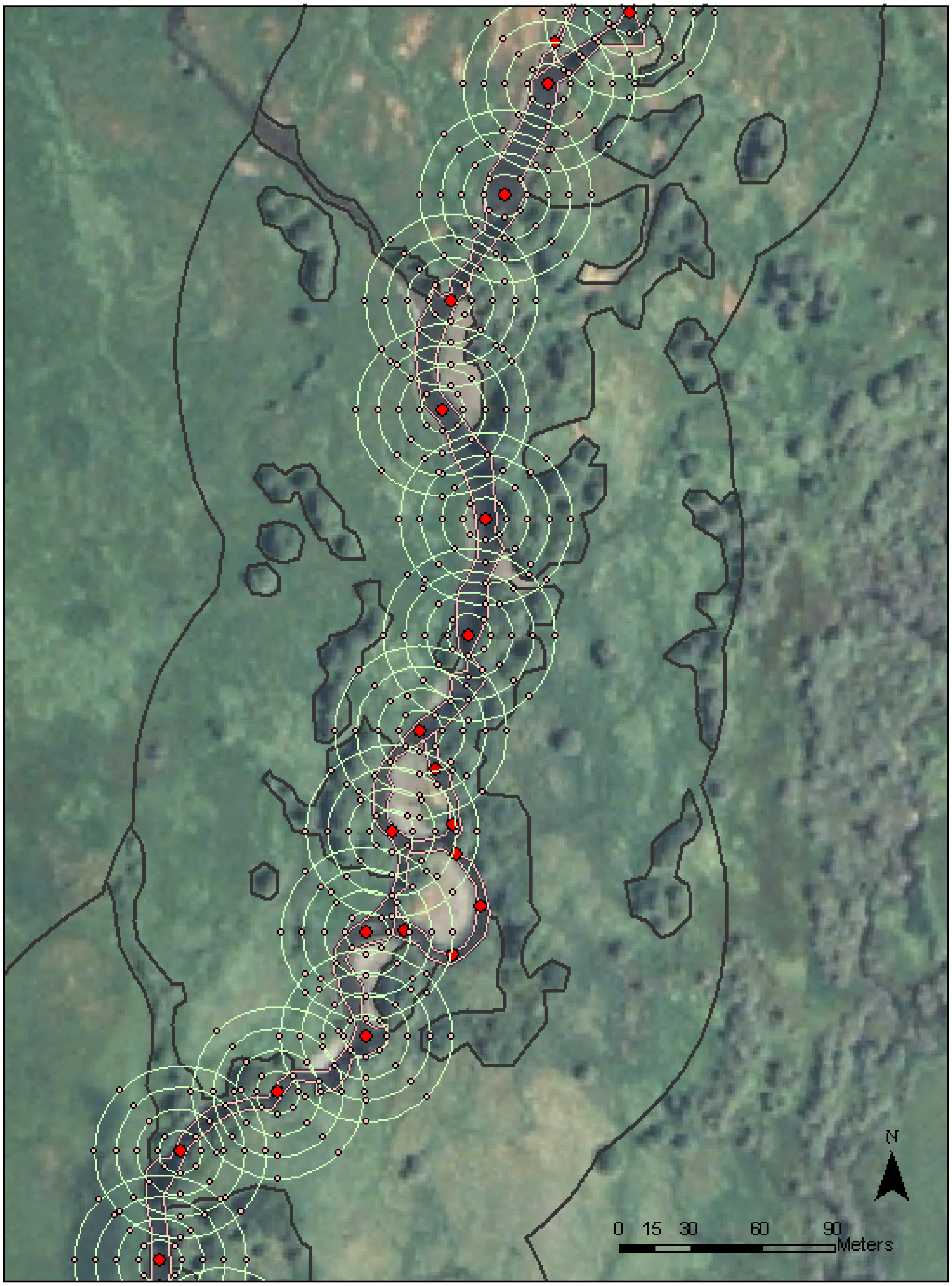


Figure B-5. Ttools land cover sample locations along the Malheur River



TTools Sampling Results

Figure B-6 and **Figure B-7** show the TTools-sampled wetted widths. The total channel width includes the wetted width of the main channel plus the averaged wetted width from any side channels in that segment. Side channels refer to small bifurcations or larger watercourses splitting off from the main channel as depicted in the aerial photos. Isolated oxbows and dry channels were not included in the total wetted channel width.

Figure B-6. Malheur River wetted channel widths.

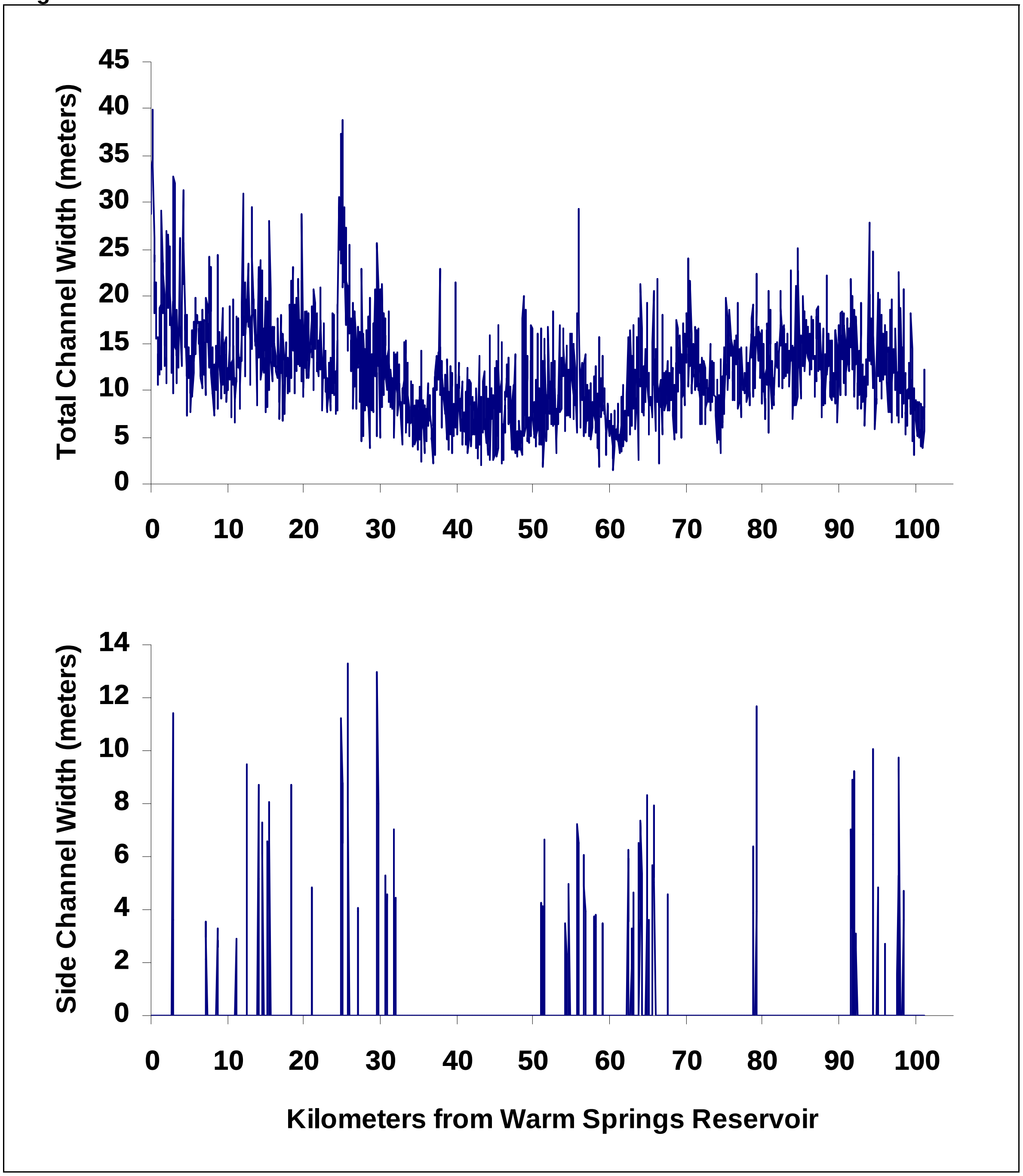


Figure B-7. North Fork Malheur River wetted channel widths.

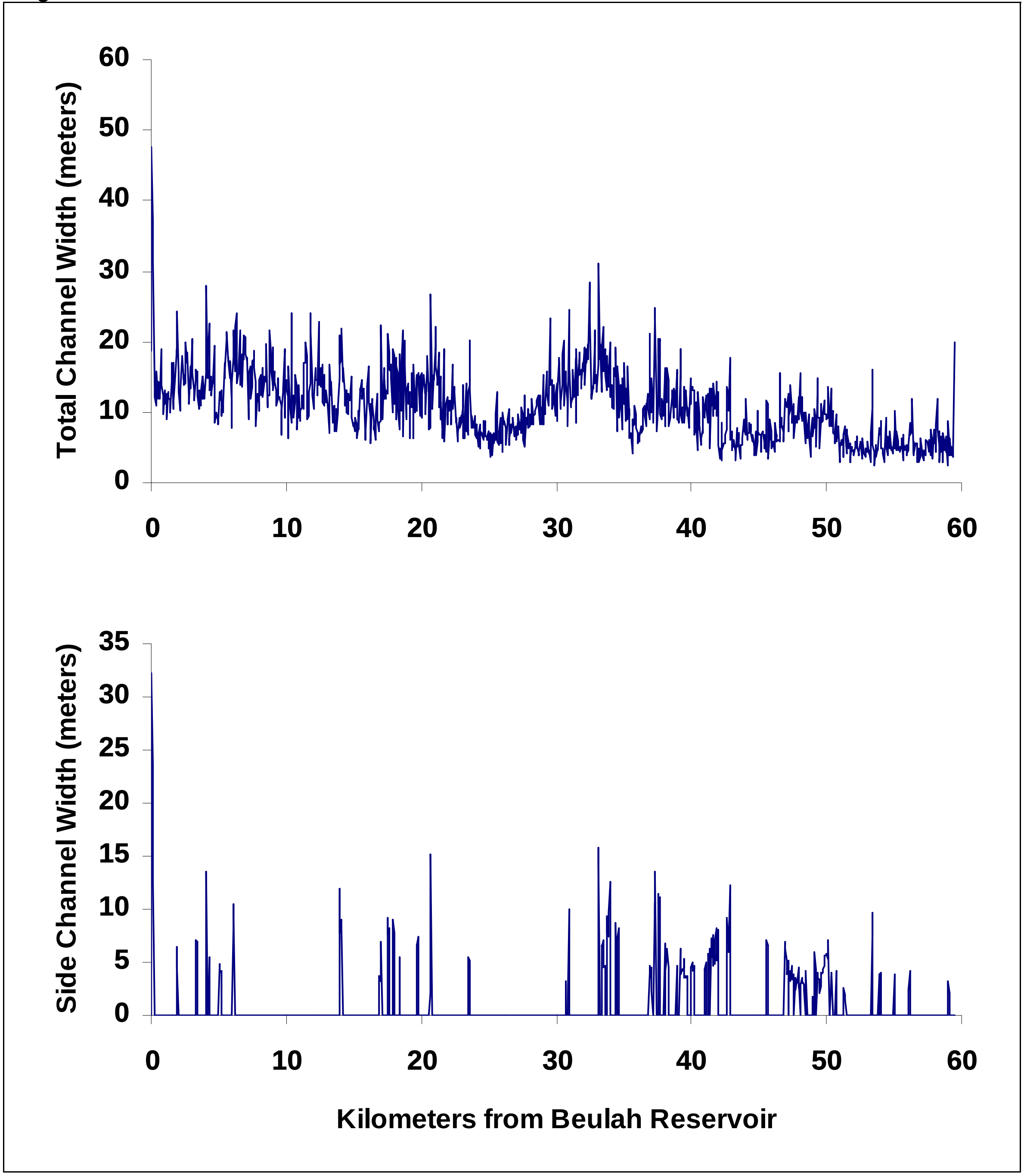


Figure B-8 and Figure B-9 summarize the TTools-sampled stream elevations and calculated gradients for each stream segment.

Figure B-8. Malheur River stream elevations and slope.

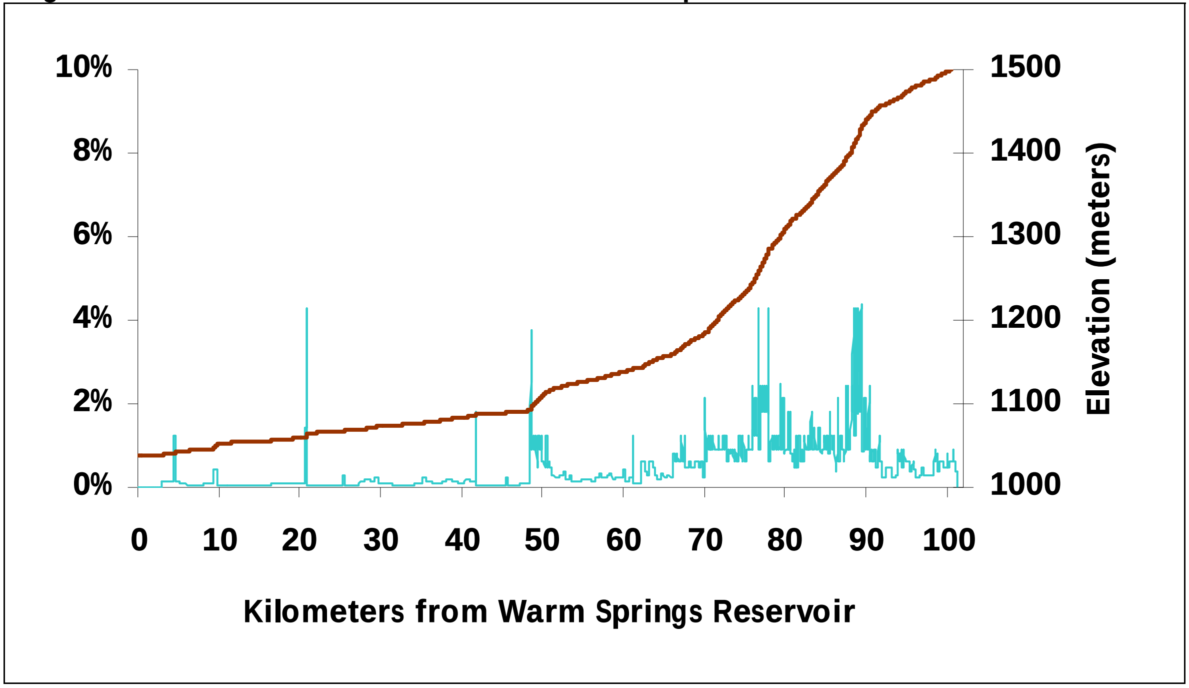


Figure B-9. North Fork Malheur River stream elevations and slope.

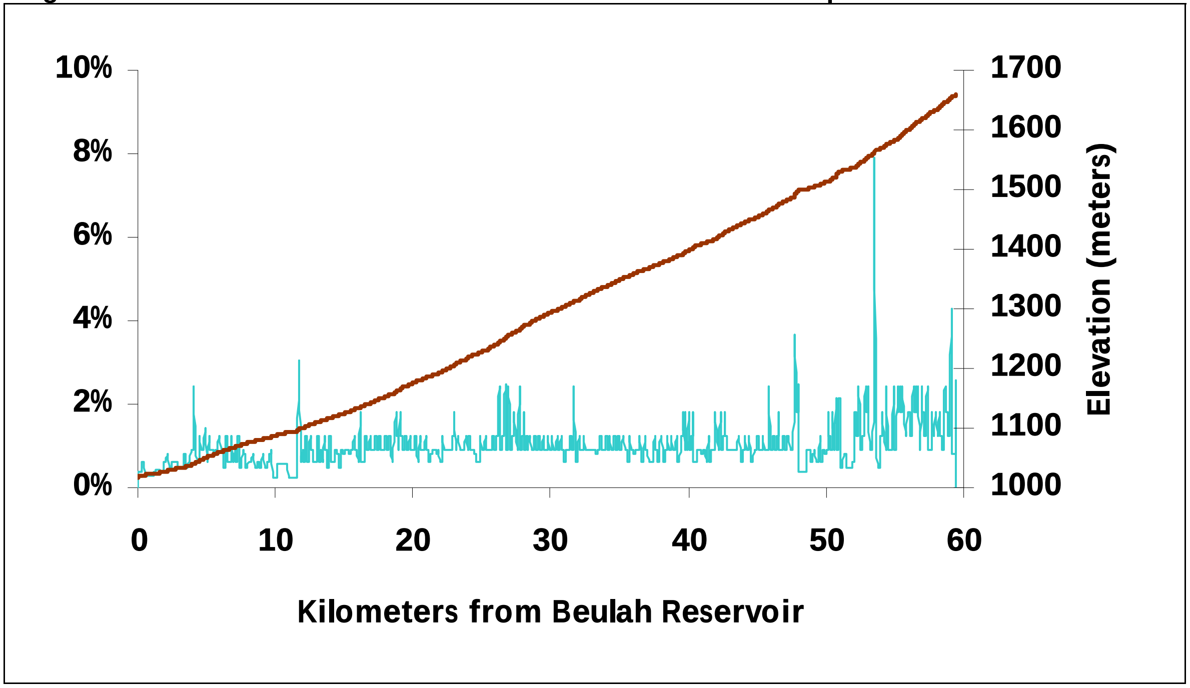


Figure B-10 and Figure B-11 summarizes the stream aspects (direction of flow) for each of the river segments.

Figure B-10. Malheur River stream aspects (direction of flow).

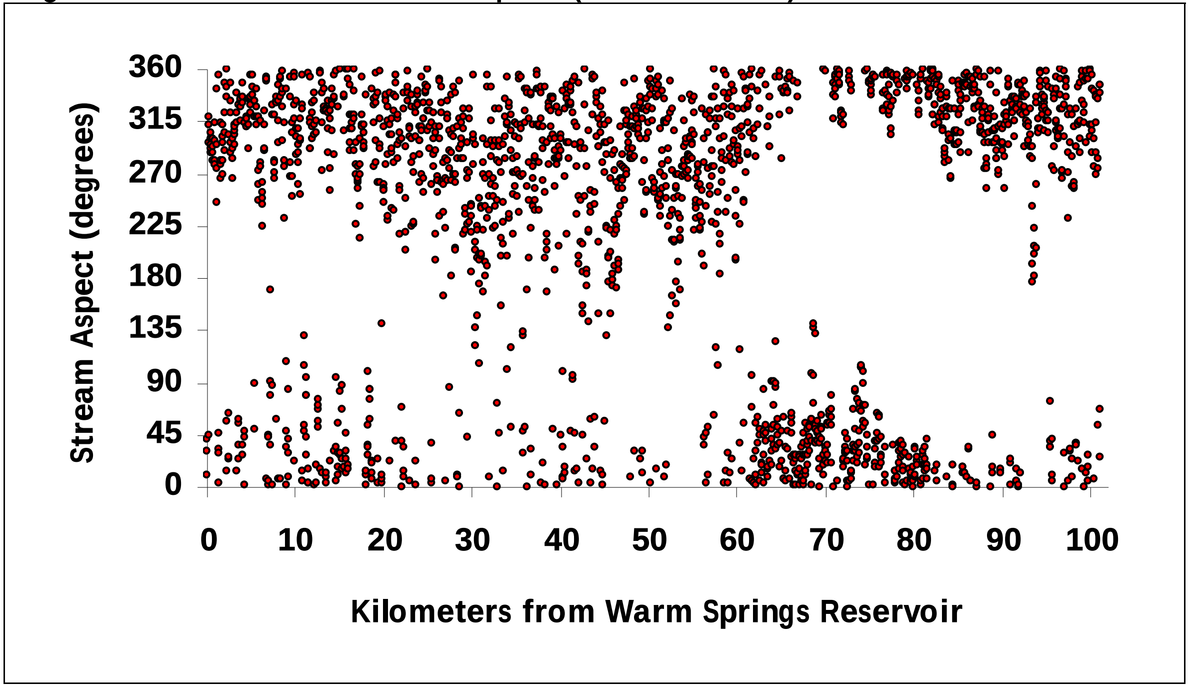


Figure B-11. North Fork Malheur River stream aspects (direction of flow).

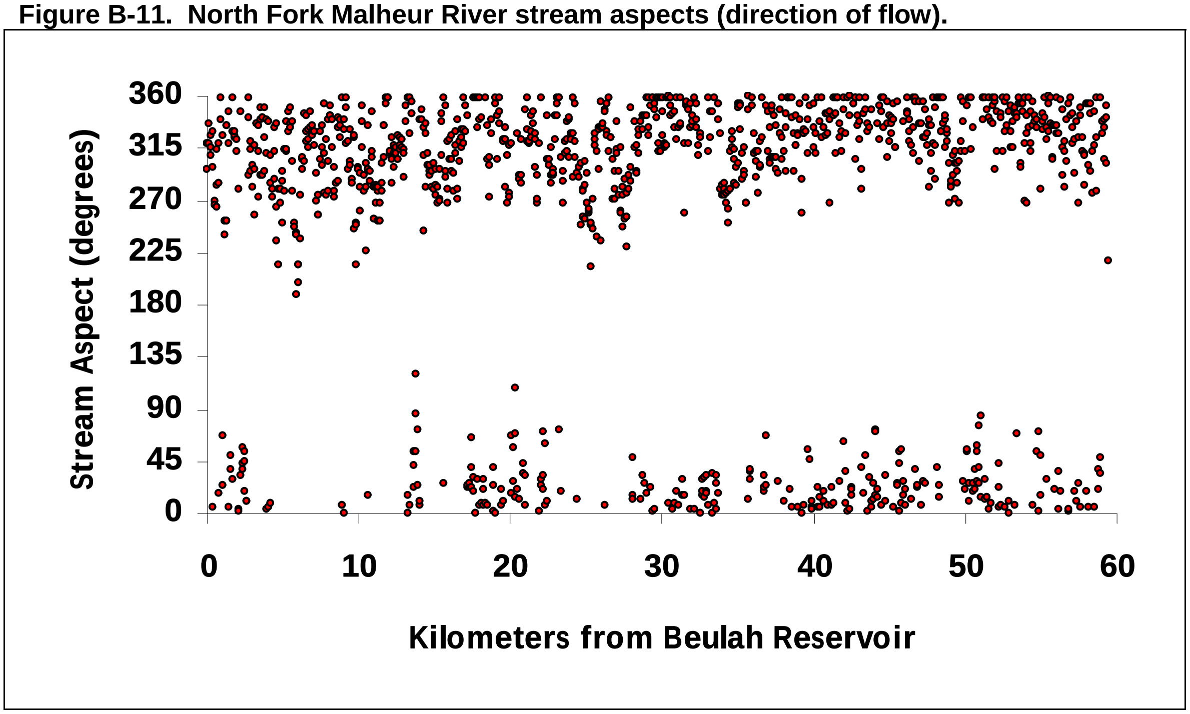


Figure B-12 and **Figure B-13** displays the TTools-sampled topographic shade angles. East, south and west topographic shade angles were sampled at each 50-meter segment and are used within the solar radiation model for determining the timing and amount of solar radiation loading at the stream surface.

Figure B-12. Malheur River Topographic shade angles.

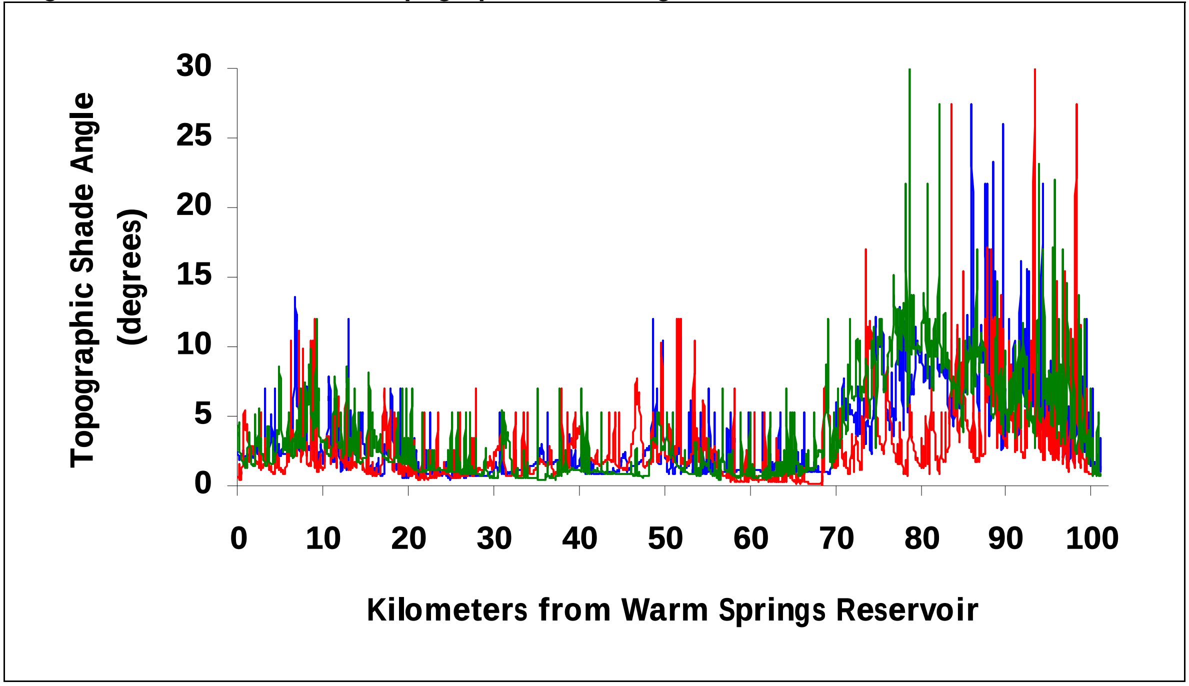
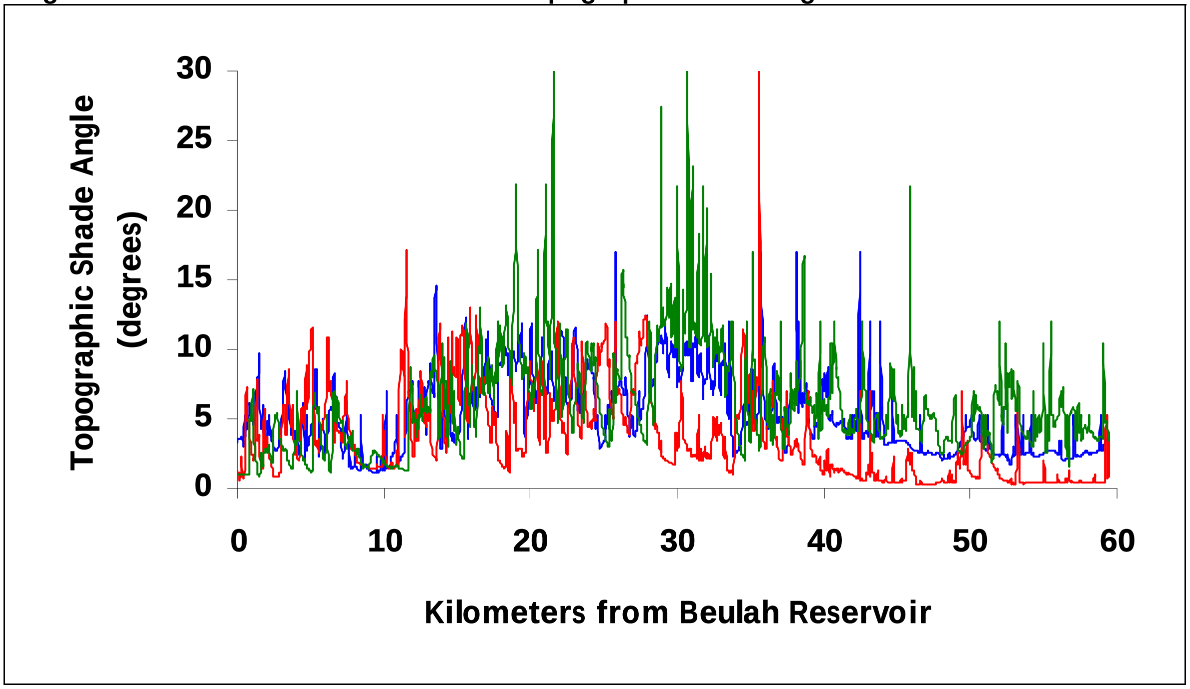


Figure B-13. North Fork Malheur River Topographic shade angles.



SITE POTENTIAL VEGETATION

Site potential vegetation refers to the vegetation land cover which can grow and reproduce on a site given the natural plant biology, site elevation, soil characteristics, climate, and natural disturbance regime. Site potential vegetation does not include past or present anthropogenic activities that influence hydrology, stream morphology, biology, and/or natural disturbance regimes.

Site potential vegetation for the Malheur Basin was determined using a series of analysis steps. In brief the analysis steps are as follows:

1. Identify riparian and upland plant associations that occur in the basin.
2. Group the plant associations by Level IV ecoregion (Thoresen et al 2003) and if possible by landform or fluvial surface.
3. Classify plant associations into physiognomic vegetation classes (eg. conifer, shrubs, grasses, etc) using the primary shade producing overstory species.
4. Determine a composite height and density for each physiognomic vegetation class using height measurements from the field, literature, and knowledge from local experts.
5. Spatially apply (using a GIS) the vegetation classes along the modeled portions of the Malheur and North Fork Malheur River based on the landform rule set and ecoregion zones.
6. Develop effective shade curves to represent the vegetation classes for other streams.

Ecologists typically describe groupings of vegetation in terms of plant associations. Plant associations consist of plant communities with similar form, structure and floristics (Pfister et al 1977). Each plant association has individual species that are adapted to each other, have similar environmental requirements, and have some amount of integration together (Powell et al 2007).

Level IV Ecoregions (**Figure B-14**) are appropriate zones to characterize plant associations because they encompass similar geologies, physiography, vegetation, climate, soils, land use, wildlife distributions, and hydrology. (Thoresen et al 2003).

For the most part, the ecoregion level IV plant associations in **Table B-3** through **Table B-5** were taken directly from the citied literature (Crowe and Clausnitzer 1997 and Wells 2006). The literature used to identify level IV ecoregion plant associations shown in **Table B-7 (**Crowe et al 2004), originally identified the plant associations by level III ecoregion only. To classify these associations into level IV ecoregions, the elevation range and typical climate tolerances for each association was identified and then linked to the level IV ecoregions with elevation or climate regimes within those ranges. The elevation and climate ranges for each ecoregion represent areas 100 meters from streams. Since we are primarily concerned about condition near streams only, we wanted to eliminate upland areas. The climate ranges, shown in Table B-6, represent averages from 1971-2000.

The plant associations identified in **Table B-3** through **Table B-7** are not exhaustive and may not include every possible association that might be present. The elevations, gradients, and other descriptive attributes are approximate. Land managers should use this information and referenced documentation as a resource but always defer to site specific conditions when establishing or identifying site potential plant associations at the plot level.

Figure B-14. Level IV Ecoregions (Thoresen et al 2003)

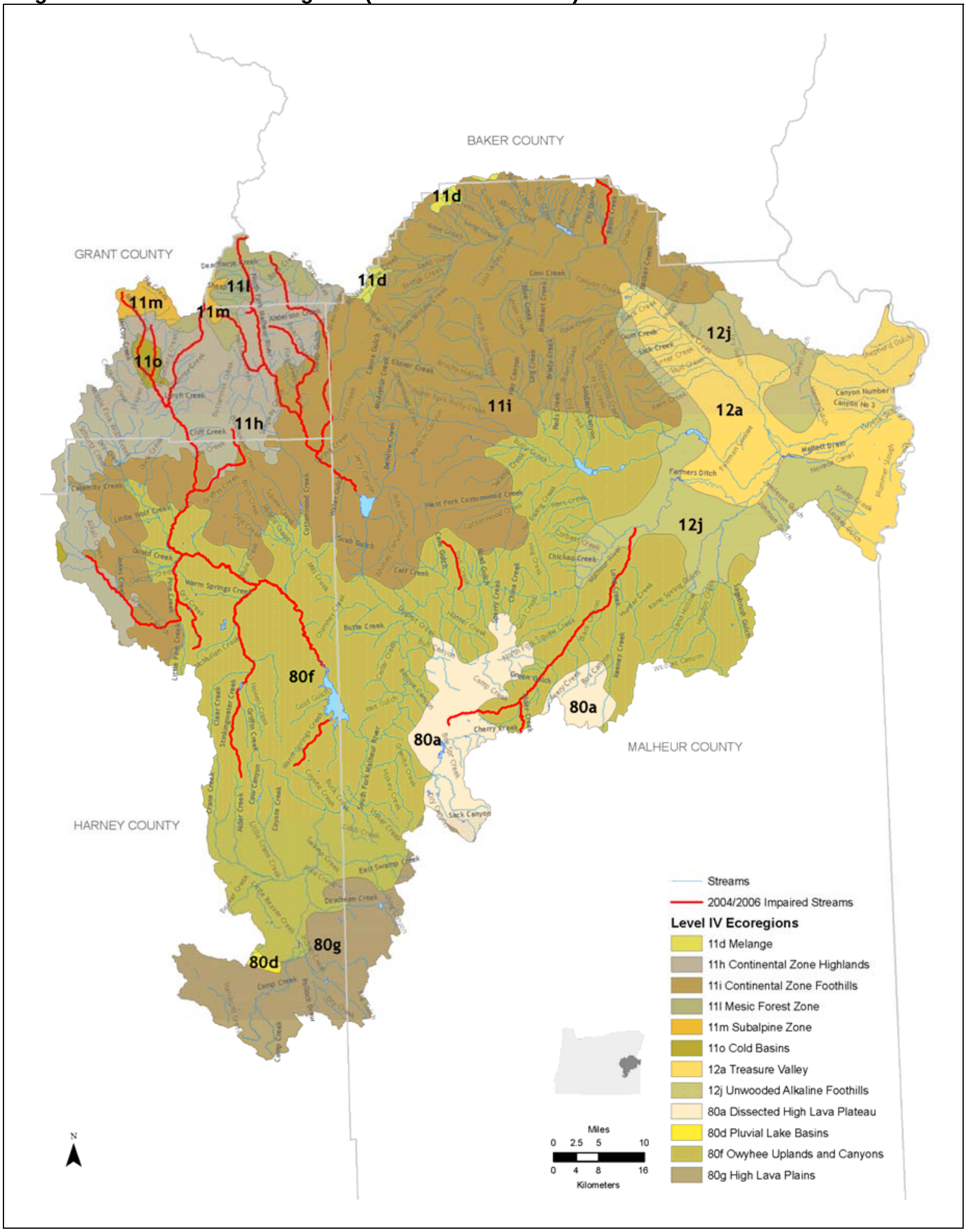


Table B-3. Possible site potential plant associations found in the Continental Zone Foothills 11i, Highlands 11h, and Cold Basins 11o Ecoregions (Crowe and Clausnitzer 1997).

Valley Morph.	Elevation (Feet)	Fluvial Surface	Soil Grain Size / Moisture Content	Plant Associations	TMDL Vegetation [code] class
Broad or moderately broad flat or trough shaped Valley gradient <2%	3,000 - 6,000	Alluvial Bars	Sand/Gravel/Cobble	Creeping spikerush Common horsetail	[2000] Floodplain grass
				Coyote willow Rigid willow	[5920/5925] Shrub
				Black cottonwood/Pacific willow	[5990] Cottonwood
		Floodplains and overflow channels	Silt Saturated Soils	Aquatic sedge Bladder sedge Inflated sedge	[2000] Floodplain grass
			Silt Partially Saturated Soils	Wooly sedge Tufted hairgrass Silver sagebrush/Tufted hairgrass Shrubby cinquefoil/Tufted hairgrass	[2000] Floodplain grass
			Silt Unsaturated Soils	Quaking aspen/Common snowberry	[5995] Aspen
				Ponderosa pine/Common snowberry	[4925/4950/4955/4970] Conifer Forest
			Gravel/sand/Silt/Clay Saturated Soils	Willow/Bladder sedge Willow/Aquatic sedge Mountain alder/Bladder sedge	[5920/5925] Shrub
			Gravel/sand/Silt/Clay Partially Saturated Soils	Willow/Woolly sedge	[5920/5925] Shrub
			Gravel/sand/Silt/Clay Unsaturated Soils	Willow/Kentucky bluegrass	[5920/5925] Shrub
		Terraces	All	Mountain big sagebrush/Cusick's bluegrass	[2800] Upland Scrubland
				Quaking Aspen/Common Snowberry	[5995] Aspen
				Black Cottonwood/Common Snowberry	[5990] Cottonwood
				Ponderosa Pine/Common Snowberry Douglas Fir/Common Snowberry	[4925/4950/4955/4970] Conifer Forest
	4,500-6,500	Streambanks		Mountain alder-Currants/Mesic forb Mountain alder/Red-osier dogwood/Mesic forb	[5925/5975] Shrub
		Floodplains	Saturated Soils	Bladder sedge Aquatic sedge	[2000] Floodplain grass
				Lodge pine/Aquatic sedge	[4950] Conifer Forest
			Partially Saturated Soils	Tufted hairgrass	[2000] Floodplain grass
				Lodgepole pine/Tufted hairgrass	[4950/4970] Conifer Forest
			Unsaturated Soils	Lodgepole pine/Kentucky bluegrass	[4950/4970] Conifer Forest
		Terraces	All	Subalpine fir/Grouse huckleberry Subalpine fir/Big huckleberry	[4950/4970] Conifer Forest
				XXXXXXXX	
	Headwaters (> 6,500)			Short beak sedge Bladder sedge Aquatic sedge Tufted hairgrass	[2000] Floodplain grass
				Quaking aspen/Mesic forb	[5995] Aspen

Table continued on next page.

Table B-3 continued. Possible site potential plant associations found in the Continental Zone Foothills 11i, Highlands 11h, and Cold Basins 11o Ecoregions (Crowe and Clausnitzer 1997).

Valley Morph.	Elevation (Feet)	Fluvial Surface	Soil Grain Size / Moisture Content	Plant Associations	TMDL Vegetation [code] class
Narrow to moderately wide V-shaped or trough spaded Valley gradient 2%-4%	3,000 - 6,000	Alluvial Bars	Sand/Gravel/Cobble	Common horsetail	[2000] Floodplain grass
		Floodplain	All	Mountain alder/Red-osier dogwood/Mesic Forb Mountain alder/Common snowberry Mountain alder/Common horsetail Mountain alder/Tall mannagrass Red-osier dogwood	[5925] Shrub
		Terraces	All	Mountain big sagebrush/Cusick's bluegrass	[2800] Upland Scrubland
				Ponderosa pine/Common snowberry Douglas fir/Common snowberry	[4925/4950/4955/4970] Conifer Forest
Narrow V shaped Valley gradient >4%	5,000 – 7,000	Streambanks	Sand/Gravel/Cobble	Mountain alder/Mesic forbs Mountain alder/Tall mannagrass	[5925] Shrub
Springs and Seeps	All	All	All	Big-leaved sedge Small-fruit bulrush Aquatic sedge Sheldon's sedge	[2000] Floodplain grass
				Mountain alder/Big-leaved sedge	[5920] Shrub

Table B-4. Possible site potential plant associations found in the Mesic Forest 11l Zone 1 Ecoregion (Crowe and Clausnitzer, 1997).

Valley Morph.	Fluvial Surface	Soil Grain Size / Moisture Content	Plant Associations	TMDL Vegetation [code] class
Narrow V shaped valleys with gradient >1% Elevation 4,000 - 7,500 ft	Streambanks and narrow floodplains	Sand/Gravel/Cobble	Arrowleaf groundsel Brook sadifrage Currants/Tall mannagrass Currants/Mesic Form	[2000] Floodplain grass
			Mountain alder-Currants/Mesic Forb Mountain alder/ Ladyfern	[5950] Shrub
			Subalpine fir/Arrowleaf groundsel Engelmann spruce/Arrowleaf groundsel	[4955] Conifer Forest
	Springs and seeps	All	Big leaved sedge Small-fruit bulrush Cusick's sedge Sheldon's sedge Aquatic sedge Bladder Sedge Brook saxifrage Swamp onion	[2000] Floodplain grass
			Red-osier dogwood/Brook saxifrage Mountain alder/Beg-leaved sedge	[5950] Shrub
Broad or moderately broad valleys with gradients <1% Elevation < 4,000 ft	Alluvial bars	Sand/Gravel/Cobble	Common horsetail	[2000] Floodplain grass
			Coyote willow Rigid willow	[5950] Shrub
			Black cottonwood/Pacific willow	[5990] Cottonwood
	Streambanks, floodplains and overflow channels	Alll	Small-fruit bulrush	[2000] Floodplain grass
			Mountain alder-Red-osier-dogowood/Mesic form Mountain alder/Dewey'sedge Red-osier dogwood Black hawthorne Red alder/Pacific ninebark	[5950] Shrub
			Black Cottonwood/ Mountain alder-Red-osier-dogowood Black cottonwood/Rocky mountain maple	[5990] Cottonwood
			Quaking aspen/ Common Snowberry Quaking aspen/Mesic Forb	[5995] Aspen
			Grand fir/Common Snowberry floodplain Grand fir/Rocky Mountain maple floodplain	[4955] Conifer Forest
	Terraces	Alll	Black hawthorne	[5950] Shrub
			Black cottonwood/common snowberry	[5990] Cottonwood
			Ponderosa pine/Common snowberry –floodplain Douglas fir/Common snowberry-floodplain Grand fir/Common Snowberry floodplain Grand fir/Rocky Mountain maple floodplain	[4955] Conifer Forest

Table continued on next page.

Table B-4 continued. Possible site potential plant associations found in the Mesic Forest 11l Zone 1 Ecoregion (Crowe and Clausnitzer, 1997).

Valley Morph.	Fluvial Surface	Soil Grain Size / Moisture Content	Plant Associations	TMDL Vegetation [code] class
Broad or moderately broad valleys With gradients <1% Elevaton 4,000 - 7,500 ft	Streambank of exposed or deposited substrate	All	Mountain alder/Currant	[5950] Shrub
	Floodplain	Saturated Soils	Aquatic Sedge Bladder sedge Inflated sedge Densely-tufted sedge Holm's sedge Woodrush sedge Few-flowered spikerush	[2000] Floodplain grass
		Partially Saturated Soils	Bluejoint reedgrass Tufted hairgrass Sheldon's sedge Swamp onion	[2000] Floodplain grass
			Lodgepole pine/Aquatic sedge	[4955] Conifer Forest
		Unsaturated Soils	Lodgepole pine/Tufted hairgrass	[4955] Conifer Forest
	Terraces	All	Lodgepole pine/Tufted hairgrass	[4955] Conifer Forest

Table B-5. Possible site potential plant associations found in the Subalpine 11m Ecoregion (Wells 2006).

Valley Elevation (Feet).	Soil Grain Size	Slope	Moisture Content	Landform Criteria	Plant Associations	TMDL Vegetation [code] class
5,250 - 7,000	Fine sandy loam or finer	Slope <3%	Soil not completely saturated for any part of the year or saturated for only a short period early in growing season	Slope <= 1	Holm's Rocky Mountain Sedge Tufted Hairgrass Smallwing Sedge	[2000] Floodplain grass
				Slope > 1 %	Bluejoint Reedgrass Brown Sedge	[2000] Floodplain grass
			Soil completely saturated for most to all of the year	All	Small-Fruit Bulrush Star Sedge Plant	[2000] Floodplain grass
					Mountain Alder/Tall Mannagrass	[5950] Shrub
		Slope >=3%	All	All	Northern Singlespike Sedge–Brook Saxifrage–Spring	[2000] Floodplain grass
	Coarser than very fine sandy loam and/or rock fragments > 20%	All	All	Streambanks and Floodplains < 6230 ft	Sitka Alder/Mesic Forb Plant Sitka Alder/Ladyfern	[5950] Shrub
				Streambanks and Fllodplains => 6230 ft	Mountain Alder/Tall Mannagrass	[5950] Shrub
				Terraces and moist meadows	Subalpine Fir/Big Huckleberry Shrubby Cinquefoil–Bog Birch Subalpine Fir-Engelmann Spruce/Labrador Tea	[4965] Conifer Forest
					Willow/Bluejoint Reedgrass	[5950] Shrub
				Rocky Bars	Coyote Willow Plant Association	[5950] Shrub

Table B-6. Ranges for various environmental attributes found within Basin and Range level IV ecoregions.

Level IV Ecoregion	Elevation Range (feet)	Mean Annual Precipitation Range (cm)	Mean Annual Minimum Temperature Range (Fahrenheit)	Mean Annual Maximum Temperature Range (Fahrenheit)
12a Treasure Valley	2106-3094	25 - 33	34.5 - 38.2	62.1 - 65.1
12j Unwooded Alkaline Foothills	2205-3609	26 - 38	33.7 - 37.7	60.1 - 64.8
80a Dissected High Lava Plateau	3924-5430	28 - 34	30.9 - 37.3	56.0 - 60.4
80d Pluvial Lake Basins	4039-4213	28 - 29	32.5 - 32.7	61.6 - 61.8
80f Owyhee Uplands and Canyons	2467-5794	22 - 41	29.7 - 38.9	54.2 - 64.5
80g High Lava Plains	3963-6004	28 - 47	32.2 - 37.2	55.9 - 62.0

Table B-7. Possible site potential plant associations found in the Treasure Valley 12a, Unwooded Alkaline Foothills 12j, Dissected High Lava Plateau, Pluvial Lake Basins 80d, Owyhee Uplands and Canyons 80f, and High Lava Plans 80g (Crowe et al 2004).

Plant Association	Elevation Range (feet)	Mean Annual Precipitation range (cm)	Mean Minimum Temperature (Fahrenheit)	Mean Maximum Temperature (Fahrenheit)	Level IV Ecoregion (X = present)						TMDL Vegetation [Code] Class
					12a	12j	80a	80d	80f	80g	
Broad-leaved cattail	2450-5060	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Narrowleaf bur-reed	4750-7220	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Northern mannagrass	4210-6700	not available	not available	not available			X	X	X	X	[2000] Floodplain Grasses
Creeping spikerush Stream/Perennial Pond	2860-6750	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Aquatic sedge	3060-7470	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Slender sedge	4600-5400	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Nebraska sedge	3770-5460	not available	not available	not available			X	X	X	X	[2000] Floodplain Grasses
Woolly sedge	3000-5440	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Holm's sedge	5600-8250	not available	not available	not available					X	X	[2000] Floodplain Grasses
Holm's sedge-black alpine sedge-tufted hairgrass	4700-7880	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Bladder sedge	3860-7470	not available	not available	not available			X	X	X	X	[2000] Floodplain Grasses
Eastside inflated sedge	3060-6340	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Few-flowered spikerush	4700-7600	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Baltic rush	3000-6550	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Nevada rush	4150-5300	not available	not available	not available			X	X	X	X	[2000] Floodplain Grasses
Three-square bulrush	2550-3400	not available	not available	not available	X	X			X		[2000] Floodplain Grasses
Small-fruited bulrush	3000-5845	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Tufted hairgrass	4500-7300	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Tufted hairgrass-Nebraska sedge	4550-5800	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Tufted hairgrass-Baltic rush Association	4070-5430	not available	not available	not available			X	X	X	X	[2000] Floodplain Grasses
Cusick' s bluegrass	4500-5200	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
Great Basin wildrye	1940-4620	not available	not available	not available	X	X	X	X	X	X	[2000] Floodplain Grasses
Arrowleaf groundsel	4700-7930	not available	not available	not available			X		X	X	[2000] Floodplain Grasses
California hellebore	4300-7880	not available	not available	not available			X		X	X	[2000] Floodplain Grasses

Table continued on next page.

Table B-7 Contd. Site potential vegetation Treasure Valley 12a, Unwooded Alkaline Foothills 12j, Dissected High Lava Plateau, Pluvial Lake Basins 80d, Owyhee Uplands and Canyons 80f, and High Lava Plans 80g (Crowe et al 2004).

Plant Association	Elevation Range (feet)	Mean Annual Precipitation range (cm)	Mean Minimum Temperature (Fahrenheit)	Mean Maximum Temperature (Fahrenheit)	Level IV Ecoregion (X = present)						TMDL Vegetation [Code] Class
					12a	12j	80a	80d	80f	80g	
Red-osier dogwood	2880-5500	12-36	29-40	51-63	X	X	X		X	X	[5900] Shrubs
Red-osier dogwood-Lewis' mockorange	1160-3140	10-12	32-38	31-64	X	X			X		[5900] Shrubs
Red-osier dogwood-Common chokecherry	2880-5100	13-23	31-35	58-61	X	X					[5900] Shrubs
Western birch-Lewis' mockorange	2080-3690	11-18	30-38	57-63	X	X					[5900] Shrubs
Black hawthorn-Wood's rose	~5000	not available	not available	not available			X		X	X	[5900] Shrubs
Rocky Mountain maple-western serviceberry-common chokecherry	1820-5580	12-62	25-41	45-65	X	X	X	X	X	X	[5900] Shrubs
Lewis' mockorange	2100-4202	15-28	29-39	55-63	X	X	X			X	[5900] Shrubs
Mountain alder/Woolly sedge	2960-5600	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Mountain alder/Common horsetail	3560-5620	not available	not available	not available		X	X	X	X	X	[5900] Shrubs
Mountain alder/Mesic Forbs	2810-6300	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Mountain alder-Douglas' spiraea	2250-5640	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Mountain alder-red-osier dogwood	2325-5260	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Shrubby cinquefoil	4400-5220	not available	not available	not available			X		X	X	[5900] Shrubs
Silver sagebrush/Tufted hairgrass	~5040	not available	not available	not available			X		X	X	[2800] Upland Scrub
Mountain big sagebrush/Cusick's bluegrass	4430-5540	not available	not available	not available			X		X	X	[2800] Upland Scrub
Dusky willow	3180-6940	not available	not available	not available		X	X	X	X	X	[5900] Shrubs
Booth willow-Geyer's willow/Bladder sedge	4080-5800	not available	not available	not available			X	X	X	X	[5900] Shrubs
Booth willow-Geyer's willow/Woolly sedge	3800-7000	not available	not available	not available			X	X	X	X	[5900] Shrubs
Booth willow-Lemmon willow/Mesic Forb	4560-7000	not available	not available	not available			X		X	X	[5900] Shrubs
Coyote willow-Dry alluvial bar	360-4800	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Coyote willow/Creeping spikerush-Three square bulrush	1520-4350	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Coyote willow-Shining willow-Red-osier dogwood	2700-5300	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Mackenzie's willow-Wood's rose	2720-4900	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Shining willow	4680-5400	not available	not available	not available			X		X	X	[5900] Shrubs
Shining willow/Wet graminoid	4400-5280	not available	not available	not available			X		X	X	[5900] Shrubs
Scouler willow	1510-6400	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Arroyo willow-Wood's rose-Red-osier dogwood	2540-5860	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Lemmon's willow-Wood's rose	2760-5650	not available	not available	not available	X	X	X	X	X	X	[5900] Shrubs
Black cottonwood – Alluvial bar	760-6260	11-62	23-41	46-65	X	X		X	X	X	[5990] Cottonwoods
Black cottonwood-White alder	1720-2520	15-23	34-38	56-64		X					[5990] Cottonwoods
Black cottonwood/Lewis' mockorange	1000-2560	13-28	33-38	56-62	X	X					[5990] Cottonwoods
Black cottonwood/Water birch	1840-2280	13-15	36-38	59-62		X					[5990] Cottonwoods
White alder – Alluvial bar	720-2880	10-14	33-41	60-65	X	X					[5900] Shrubs
White alder/Lewis' mockorange	1400-2640	13-28	32-40	56-61	X	X					[5900] Shrubs
White alder/Water birch	2000-3280	13-14	31-36	58-61	X	X					[5900] Shrubs

Plant associations from **Table B-3** though **Table B-7** were synthesized into general physiognomic vegetation classes types (eg. conifer, shrubs, grasses) with composite height and density attributes (shown in **Table B-8**). Height and density were derived from USDA's PLANTS database, Oregon State University's Rangeland Ecology and Management riparian plant fact sheets (OSU 2005), field measurements, photo interpretation, and local knowledge. The composite vegetation became the basis for the GIS layers used for effective shade modeling. Current condition land cover was converted into site potential land cover using the rule set described in **Table B-9** and in the sections discussing the floodplain/aspect matrix and nearest neighbor methodology.

Table B-8. Composite site potential land cover used in the effective shade modeling.

TMDL Landcover Class	Primary Species from Plant Associations	Model Code	Avg Height (meters)	Canopy Density	Overhang (meters)	Eco Regions
Floodplain Native Grasses	Aquatic sedge Arrowleaf groundsel Big leaved sedge Bladder sedge Bluejoint Reedgrass Brook sadifrage Brown Sedge Common horsetail Common cattail Creeping spikerush Currants Cusick's sedge Densely-tufted sedge Duckweed Few-flowered spikerush Holm's Rocky Mountain Sedge Holm's sedge Inflated sedge Mesic Forb Northern Singlespike Sedge–Brook Saxifrage–Spring Sheldon's sedge Short beak sedge Shrubby cinquefoil Silver sagebrush Small-fruit bulrush Smallwing Sedge Star Sedge Plant Swamp onion Tall mannagrass Tufted hairgrass Woodrush sedge Wooly sedge	2000	0.5	100%	0	All
Upland Native Grasses	Bluebunch wheatgrass Cusick's bluegrass Idaho fescue Kentucky bluegrass Sandberg bluegrass	2700	0.5	100%	0	All
Upland Scrub	Western Juniper Low sagebrush Mountain big sagebrush Wyoming big sagebrush	2800	2	25%	0	All
Rock Outcrop (Van-Drewsey Rd)	-	2900	5	100%	0	-
Wetted Stream	-	3011	0	100%	0	All
Side Channel	-	3012	0	100%	0	All
Tributary Stream	-	3013	0	100%	0	All
Water/Oxbow /Alcove	-	3014	0	100%	0	All

Table continued on next page.

Table B-8 continued. Composite site potential land cover used in the effective shade modeling.

TMDL Landcover Class	Primary Species from Plant Associations	Model Code	Avg Height (meters)	Canopy Density	Overhang (meters)	Eco Regions
Conifer	Ponderosa Pine	4920	20	60%	1	80f
Conifer	Ponderosa Pine	4925	27	55%	1.5	11i
Conifer	Douglas fir Lodgepole pine Ponderosa pine	4950	36	60%	1.5	11h, 11o
Conifer	Ponderosa Pine	4955	36	70%	1.5	11i
Conifer	Engelmann spruce Subalpine Fir	4965	33	80%	1.5	11m
Conifer	Douglas fir Lodgepole pine Ponderosa pine	4970	36	75%	1.5	11h
Conifer	Engelmann spruce Grand fir Lodgepole pine Ponderosa pine Subalpine fir	4975	37	80%	1.5	11l
Shrubs	Arroyo willow Common chokecherry Coyote willow Lemmon willow MacKenzie's willow Mountain alder Red-osier dogwood Rocky Mountain maple Scouler willow Shining willow Western serviceberry	5900	4.6	70%	1.5	12a, 12j, 80a, 80f,
Shrubs	Bebb willow Booth willow Coyote willow Geyer willow Lemmon willow Mountain alder Pacific willow Red-osier dogwood Rigid willow Shining willow Woods Rose	5920	6	70%	1.5	11i
Shrubs	Bebb willow Booth willow Coyote willow Geyer willow Lemmon willow Mountain alder Pacific willow Red-osier dogwood Rigid willow Shining willow Woods Rose	5925	6	75%	1.5	11h
Shrubs	Black hawthorne Booth willow Coyote willow Mountain alder Red alder Red-osier dogwood Rigid willow Sitka Alder Undergreen willow	5950	6	80%	1.5	11l, 11m, 11d
Shrubs	Mountain alder Red-osier dogwood	5975	7	80%	1.5	11o
Cottonwoods	Black cottonwood	5990	30	80%	1	All
Aspens	Quaking aspen	5995	30	70%	1	11h, 11i, 11l, 11o

Table B-9. Model lookup table for conversion of current condition land cover to site potential land cover.

Current Condition Land cover		Site Potential Land cover: Owyhee Uplands and Canyons (80f)	Continental Zone Foothills (11i)	Continental Zone Highlands (11h)	Cold Basins (11o)	Mesic Forest Zone (11l)
1000	Unpaved Road/Trail	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor
1001	Paved Road	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor
1500	Buildings	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor
1700	Cultivated/Agriculture	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation
2000	Floodplain Grasses	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation	Floodplain Vegetation
2700	Upland Grasses	No Change	No Change	No Change	No Change	4975 Conifer 80% Dense - 37m
2800	Upland Scrubland	No Change	No Change	No Change	No Change	4975 Conifer 80% Dense - 37m
2900	Rock Outcrop -Van-Drewsey Rd	No Change	No Change	No Change	No Change	No Change
3011	Wetted Stream	No Change	No Change	No Change	No Change	No Change
3012	Side Channels	No Change	No Change	No Change	No Change	No Change
3013	Tributary Stream	No Change	No Change	No Change	No Change	No Change
3014	Water/Oxbow/Alcove	No Change	No Change	No Change	No Change	No Change
3015	Ditch/Canal	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor	Nearest Neighbor
4000	Conifer - 25% Canopy ~5m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4020	Conifer - 10% Canopy ~20m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4050	Conifer - 25% Canopy ~20m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4500	Conifer - 60% Canopy ~5m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4550	Conifer - 60% Canopy ~20m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4570	Conifer - 60% Canopy ~36m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4750	Conifer - 85% Canopy ~20m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
4770	Conifer - 85% Canopy ~36m	4920 Conifer 60% Canopy - 20m	Continental Zone Foothills (11i) Aspect Matrix	Continental Zone Highlands (11h) Aspect Matrix	4950 Conifer 60% Canopy - 36m	4975 Conifer 80% Canopy - 37m
5000	Shrubs - 30% Canopy ~2.2m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5020	Shrubs - 30% Canopy ~4.6m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5050	Deciduous - 30% Canopy ~15m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5500	Shrubs - 70% Canopy ~2.2m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5520	Shrubs - 70% Canopy ~ 4.6m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5550	Deciduous - 70% Canopy ~15m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5700	Shrubs - 95% Canopy ~2.2m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5750	Deciduous - 95% Canopy ~15m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5720	Shrubs - 95% Canopy ~4.6m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5750	Deciduous - 95% Canopy ~15m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m
5770	Deciduous - 95% Canopy ~30m	5900 Deciduous/Shrubs 70% Canopy - 4.6m	5920 Deciduous/Shrubs 70% Canopy - 6m	5925 Deciduous/Shrubs 75% Canopy - 6m	5975 Deciduous/Shrubs 80% Canopy - 7m	5950 Deciduous/Shrubs 80% Canopy - 6m

Floodplain vegetation

In eastern Oregon's low gradient wide valley floodplains, the common type of site potential vegetation is a mixture of grasses, willows, sedges and deciduous tree types (Crowe et al, 2004). The type, extent, and distribution can depend on many factors, such as elevation, topography, climate, soil moisture, soil type, stream discharge, flood frequency, and disturbance. Available data and the limited resources for the TMDL process do not allow detailed study and mapping of locations likely to produce the varied mixture of floodplain vegetation. Instead, a composite of floodplain vegetation was modeled as five ranges described in **Table B-10**. Two types of vegetation classes made up this composite: grasses and shrubs. These two vegetation types were modeled at different mixtures to simulate the range of possibilities that may exist depending on site specific factors. As an example, under site potential simulation number 2, 75% of the area that is currently agriculture or floodplain grasses will continue to be floodplain grasses while the other 25% will become deciduous trees and shrubs. Refer to **Figure B-18** for an illustration.

Only vegetation that currently exists as either floodplain grasses or agriculture falls into the "floodplain" category. Locations on the floodplain that became grass and shrubs were determined randomly. This was done by creating a 17x17 meter grid across the floodplain area and randomly assigning the two vegetation types to individual grid cells based on the designated mixture for each simulation. The 17x17 meter grid size was chosen because it approximates the lower 25^{th} percentile patch size of the shrub communities that currently exist.

A mixture of 75% shrubs and 25% grasses (simulation 4) was chosen as the target site potential condition in these modeled floodplain areas. This mixture was chosen based on the historical description of vegetation from 1867 (next paragraph) and the density of existing patches of floodplain vegetation in areas with similar soil and stream morphology. Two example areas are shown in **Figure B-15** and **Figure B-17.**

On January 9, 1867, a US army officer wrote in his journal about the floodplain vegetation conditions on the Malheur River near present day Juntura. The following is quoted from page 196 in *The Deadliest Indian War in the West* (Michno 2007).

> *"The bottom was a half-mile wide, choked with willows and rose bushes and cut up by sloughs alternating with sand ridges."*
>
> *"I was very thankful that the affair terminated as it had, for the brush extends along the banks of the river varying from one quarter to half mile in width, the willows are so thick that a rabbit could scarcely get through it, matted with the worst kind of briers" The camp was a quarter mile into the thicket, "with but one serpentine path approaching it, over which the men would have to march single file, this ground again was intersected by almost impenetrable sloughs"*

The area the officer describes is generally a wide valley, low gradient floodplain with a sinuous meandering channel. This type of morphology is typical along a 50 km reach of the modeled portion of the Malheur River; mostly in private agricultural areas starting at model km 20 (near Highway 20) to model km 60 just upstream of Van-Drewsey Road.

In floodplain areas where the valley is more restrictive, or may be a small thin strip, the 75% shrub and 25% grasses mixture (simulation 4) was also used. We felt this mixture was appropriate for these modeled portions based on observations of the current mixtures of grass and shrubs at sites with minimal livestock grazing or areas that have had long term management protecting riparian vegetation, In these area we found there to be very thick, sometimes impenetrable, vegetation along the river very similar to the description from the US army officer in 1867.

Figure B-15. Examples of wide valley floodplain vegetation (Left: Ecoregion 11i -Little Malheur watershed. Right: Ecoregion 80f - Malheur River near Van-Drewsey Road).

On the North Fork of the Malheur River just upstream of the Little Malheur (**Figure B-16**), the right bank (east side) has a very steep slope which discourages livestock grazing and provides a good example of vegetation in a confined valley setting with a thin strip of floodplain.

Figure B-16. Examples of confined valley floodplain vegetation along the North Fork of the Malheur River upstream of the Little Malheur River (Ecoregion 11i).

Figure B-17. Floodplain vegetation along Big Creek in the 11o Cold Basin ecoregion.

Table B-10. Floodplain vegetation height and density simulation attributes

<table>
<tr><th>Simulation</th><th>Land cover Composite</th><th>Owyhee Uplands and Canyons (80f)</th><th>Continental Zone Foothills (11i)</th><th>Continental Zone Highlands (11h)</th><th>Cold Basins (11o)</th><th>Mesic Forest Zone (11l)</th></tr>
<tr><td>Simulation 2</td><td>25% Deciduous/Shrubs
75% Floodplain Grasses</td><td rowspan="5">5900
Deciduous/Shrubs
70% Dense 4.6m

2000
Floodplain Grasses
100% Dense 0.5m</td><td rowspan="5">5920
Deciduous/Shrubs
70% Dense 6m

2000
Floodplain Grasses
100% Dense 0.5m</td><td rowspan="5">5925
Deciduous/Shrubs
75% Dense 6m

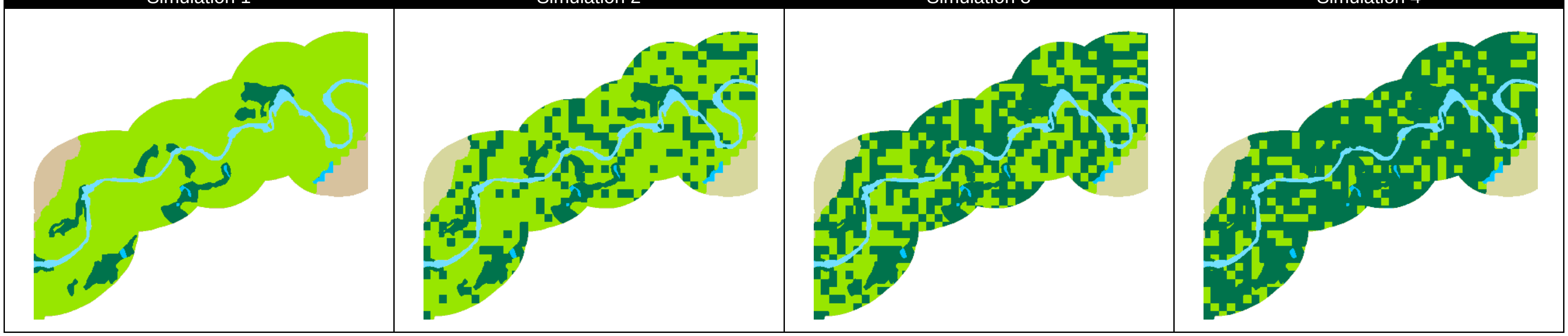
2000
Floodplain Grasses
100% Dense 0.5m</td><td rowspan="5">5975
Deciduous/Shrubs
80% Dense 7m

2000
Floodplain Grasses
100% Dense 0.5m</td><td rowspan="5">5950
Deciduous/Shrubs
80% Dense 6m

2000
Floodplain Grasses
100% Dense 0.5m</td></tr>
<tr><td>Simulation 3</td><td>50% Deciduous/Shrubs
50% Floodplain Grasses</td></tr>
<tr><td>Simulation 4</td><td>75% Deciduous/Shrubs
25% Floodplain Grasses</td></tr>
<tr><td>Simulation 5</td><td>100% Deciduous/Shrubs
0% Floodplain Grasses</td></tr>
<tr><td>Simulation 6</td><td>0% Deciduous/Shrubs
100% Floodplain Grasses</td></tr>
</table>

Figure B-18. Floodplain vegetation simulations

Current Conditions Simulation 1	75% Grasses 25% Deciduous/Shrubs Simulation 2	50% Grasses 50% Deciduous/Shrubs Simulation 3	25% Grasses 75% Deciduous/Shrubs Simulation 4



Aspect Matrix

In the continental zone foothills (11i) and continental zone highlands (11h) ecoregions, the aspect of the facing slope was used to determine the site potential vegetation for coniferous vegetation types that typically in upland areas. An aspect concept was used because generally a northeastern facing slope has more vegetation than a southwestern facing slope due to a more favorable microclimate. Northeastern facing slopes tend to have more vegetation because they receive less solar radiation than southwest facing slopes. The amount of solar radiation can influence the microclimate, particularly air temperature, humidity, and soil moisture (Rosenberg et al 1983, Swanson et al 1988).

Aspect (represented as an arc degree) was determined in ArcGIS using a 10 meter DEM. To simplify processing, the arc degrees were grouped into zones based on the eight general compass directions such as north or northeast. **Table B-11** describes which site potential vegetation types were assigned to which aspect zones.

Table B-11. Aspect Zones

Current Condition Land cover		Aspect	GIS Aspect Zone	Continental Zone Foothills (11i)	Continental Zone Highlands (11h)
4000 - 4770	Conifers	Flat/South/Southwest facing slopes (157.5° - 247.5°)	0, 5, 6	4925 Conifer 55% Dense 27m	4950 Conifer 60% Dense 36m
		East/West/Northwest/Southeast facing slopes (67.5° - 157.5°) (247.5° - 337.5°)	3, 7, 8, 4	4925 Conifer 55% Dense 27m	4950 Conifer 60% Dense 36m
		North/Northeast facing slopes (337° -67.5°)	1, 2, 9	4955 Conifer 70% Dense 36m	4970 Conifer 75% Dense 36m

Nearest Neighbor

The site potential vegetation for roads, buildings, ditches, and canals was determined by assigning them the site potential vegetation of its nearest neighbor. To complete this task, the ArcGIS "eliminate" arctool was used to merge these features into the neighboring polygon with the largest shared border. Some polygons remained because the largest border was the outside edge of the shapefile. To eliminate these polygons, the tool was run a second time to merge remaining polygons with its neighbor that had the largest area. Prior to running the eliminate tool, some long and very large irregular shaped polygons, such as roads, were split into smaller polygons along ecoregion borders, aspects, or transitions between upland and floodplain areas. This was done so they could more accurately represent the nearest neighbor within those zones.

SOLAR RADIATION SIMULATIONS

Figure B-19. Afternoon sun shines on the Malheur River

Many studies have shown the effects of solar radiation loading, and consequently, the importance of stream surface shade in moderating localized increases in water temperature (Beschta, 1997, and Johnson, 2004, Moore et al. 2005). Overall solar radiation is the most significant factor in the heat budget of streams.

Because solar radiation has a large impact on thermal regimes, solar radiation was used as the surrogate to evaluate the degree of impairment. The mathematical model Heat Source Version 8.0.2 was used to model solar radiation. Heat Source simulates open channel hydraulics, flow routing, heat transfer, effective shade, and stream temperatures (Boyd and Kasper, 2003).

Seven different model simulations (described in **Table B-12**) were conducted to determine the amount of effective shade and solar radiation load received on the Malheur River upstream of Warm Springs Reservoir and on the North Fork of the Malheur upstream of Beulah Reservoir. The simulations primarily consist of a current condition simulation, various scenarios estimating a restored natural condition, and a simulation evaluating the influence of topography. The TMDL loading capacity and allocations were based on the results from simulation number four.

Table B-12. Model simulations.

Sim 1	**Current Conditions**. The simulation models effective shade and solar radiation load received based on current channel widths, vegetation and anthropogenic land cover that was present at the time the aerial photograph was produced (July 2005).
Sim 2	**Site Potential Vegetation**. The simulation models effective shade and solar radiation load received based on current channel widths and site potential vegetation with the floodplain consisting of 75% grasses and 25% shrubs.
Sim 3	**Site Potential Vegetation**. The simulation models effective shade and solar radiation load received based on current channel widths and site potential vegetation with the floodplain consisting of 50% grasses and 50% shrubs
Sim 4	**Site Potential Vegetation**. The simulation models effective shade and solar radiation load received based on current channel widths and site potential vegetation with the floodplain consisting of 25% grasses and 75% shrubs. This model run is the natural conditions estimate used to establish the TMDL loading capacity (background) and load allocations.
Sim 5	**Site Potential Vegetation**. The simulation models effective shade and solar radiation load received based on current channel widths and site potential vegetation with the floodplain consisting of 0% grasses and 100% shrubs.
Sim 6	**Site Potential Vegetation**. The simulation models effective shade and solar radiation load received based on current channel widths and site potential vegetation with the floodplain consisting of 100% grasses and 0% shrubs.
Sim 7	**Topographic Shade**. This simulation models the effective shade and solar radiation load received from natural topographic features using current condition channel widths and the removal of all vegetation and anthropogenic land cover such as houses and buildings.

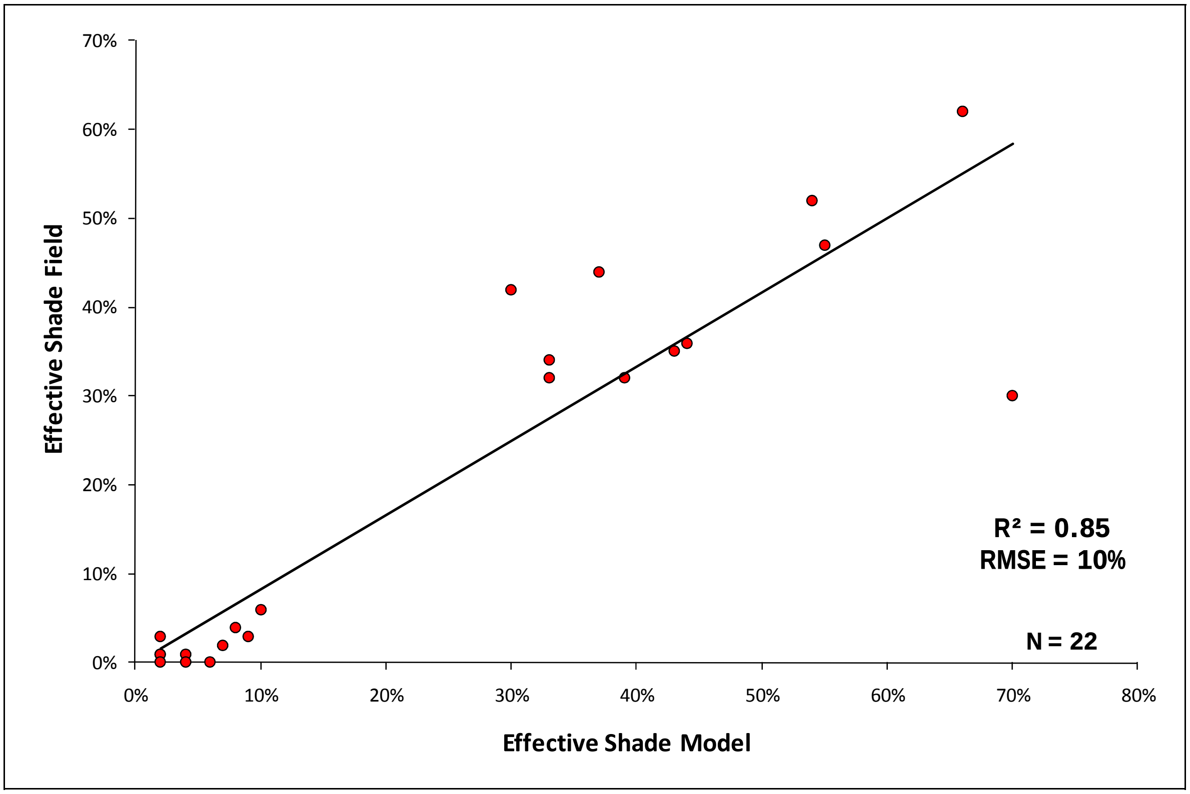
Model Validation

Model validation was conducted by comparing simulated current condition effective shade results with 22 ground level measured effective shade values. The ground level effective shade was collected during the various site visits from July through September using a Solar Pathfinder®. The measured effective shade values represent site conditions in July. The effective shade values reported in **Table B-13** and **Figure B-20** show a comparison of the measured and simulated effective shade on both modeled streams. The linear correlation coefficient is very good (R^2 = 0.85, n =22). The root mean square error (RMSE) is 10 percentage points.

Table B-13. Measured and simulated effective shade values.

Site Name	Model KM	Field Date	Lat	Long	Field	Model
Malheur River at Malheur Ford farther u/s of Ford	92.40	7/24/07	44.09406	-118.58049	44%	37%
Malheur River at Malheur Ford u/s of Ford	92.10	7/24/07	44.09206	-118.57896	35%	43%
Malheur River at Malheur Ford d/s along trail	91.40	7/24/07	44.08633	-118.57692	62%	66%
Malheur River at Malheur Ford farther d/s along trail	91.30	7/24/07	44.08578	-118.57669	30%	70%
Malheur River d/s Bluebucket Creek	74.90	7/16/08	43.96320	-118.53416	32%	33%
Malheur River u/s Bluebucket Creek	74.90	7/16/08	43.96382	-118.53373	34%	33%
Malheur River farther d/s Bluebucket Creek	74.85	7/16/08	43.96322	-118.53416	52%	54%
Malheur River @ Carey Spring	12.10	9/3/08	43.73219	-118.30019	1%	2%
NF Malheur u/s of Road 1370	59.25	7/25/07	44.32453	-118.41611	47%	55%
NF Malheur u/s quarter mile of Swamp Creek	55.40	7/25/07	44.29629	-118.40103	36%	44%
NF Malheur River at NF Malheur Campground	43.50	7/25/07	44.20822	-118.38236	42%	30%
NF Malheur River along NF Malheur trail 381	40.35	7/25/07	44.18271	-118.37767	32%	39%
NF Malheur River 200m u/s Little Malheur	14.40	8/20/08	44.01922	-118.25957	4%	8%
NF Malheur River 50m u/s Little Malheur	14.35	8/20/08	44.01915	-118.25858	2%	7%
NF Malheur River 30m d/s Little Malheur	14.30	8/20/08	44.01925	-118.25802	3%	9%
NF Malheur River 150m d/s Little Malheur	14.15	8/20/08	44.01807	-118.25738	6%	10%
NF Malheur River on BLM near Water Gulch 50m u/s	4.30	9/3/08	43.97151	-118.18710	0%	6%
NF Malheur River on BLM near Water Gulch	4.25	9/3/08	43.97151	-118.18710	1%	4%
NF Malheur River on BLM near Water Gulch 50m d/s	4.20	9/3/08	43.97151	-118.18710	0%	4%
NF Malheur River above Beulah Reservoir 50m u/s	0.45	9/3/08	-	-	1%	2%
NF Malheur River above Beulah Reservoir	0.45	9/3/08	43.94875	-118.17071	3%	2%
NF Malheur River above Beulah Reservoir 50m d/s	0.40	9/3/08	-	-	0%	2%

Figure B-20. Correlation of measured and simulated effective shade for all modeled streams.



Simulation Results Summary

Figure B-21. Frequency distribution of effective shade modeling results on the Malheur River.

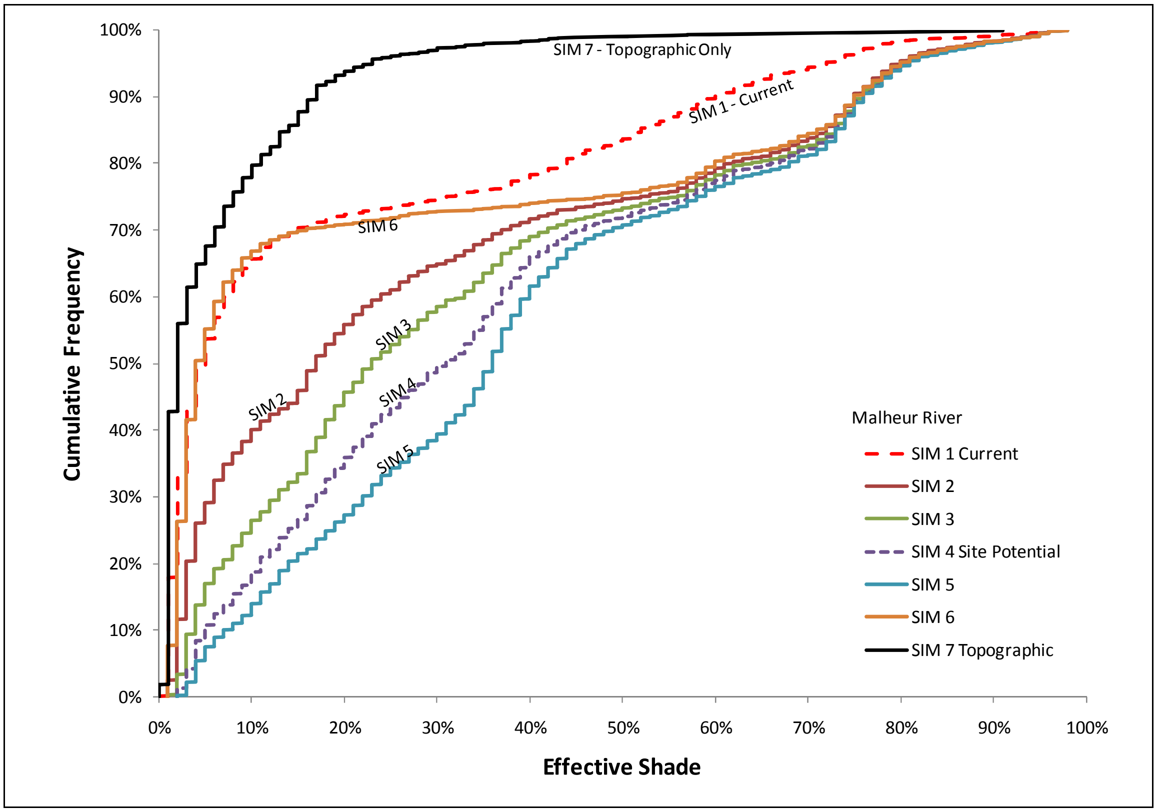


Figure B-22. Frequency distribution of effective shade modeling results on the North Fork Malheur River.

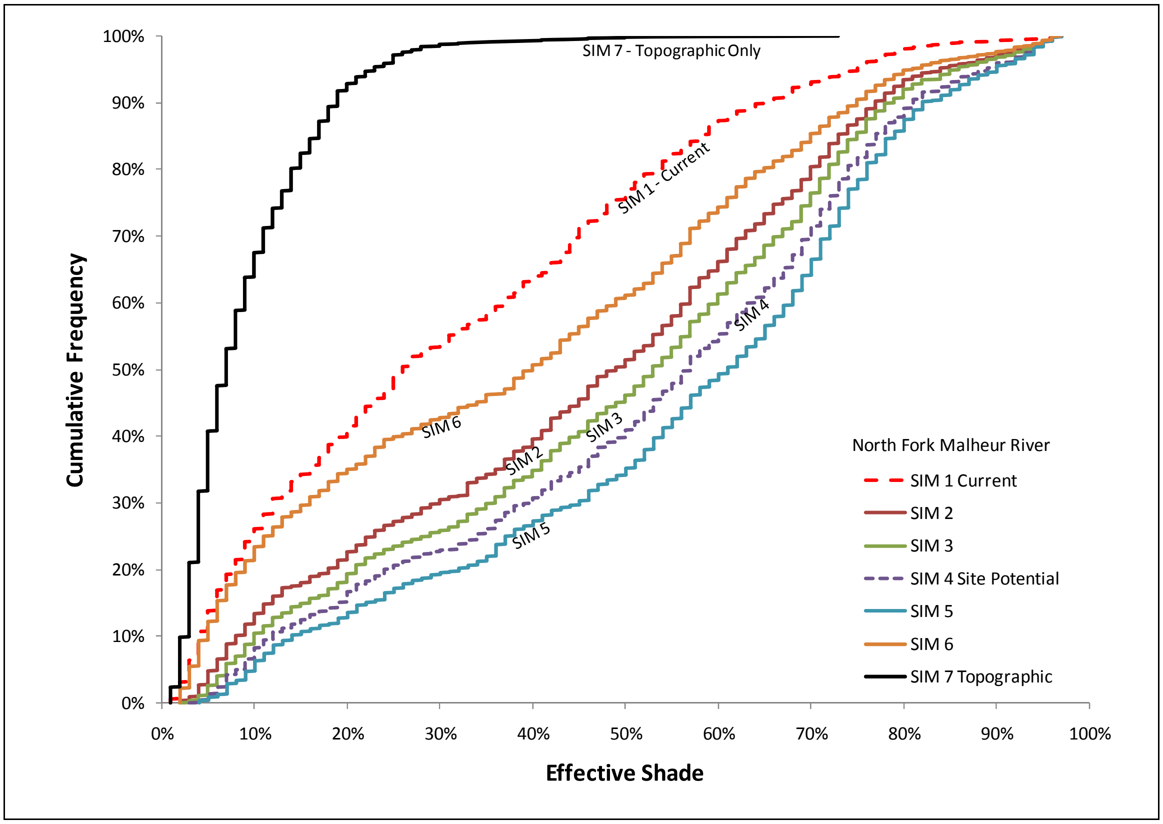


Figure B-23. Site potential effective shade on the Malheur River with various mixtures of floodplain grasses and shrubs

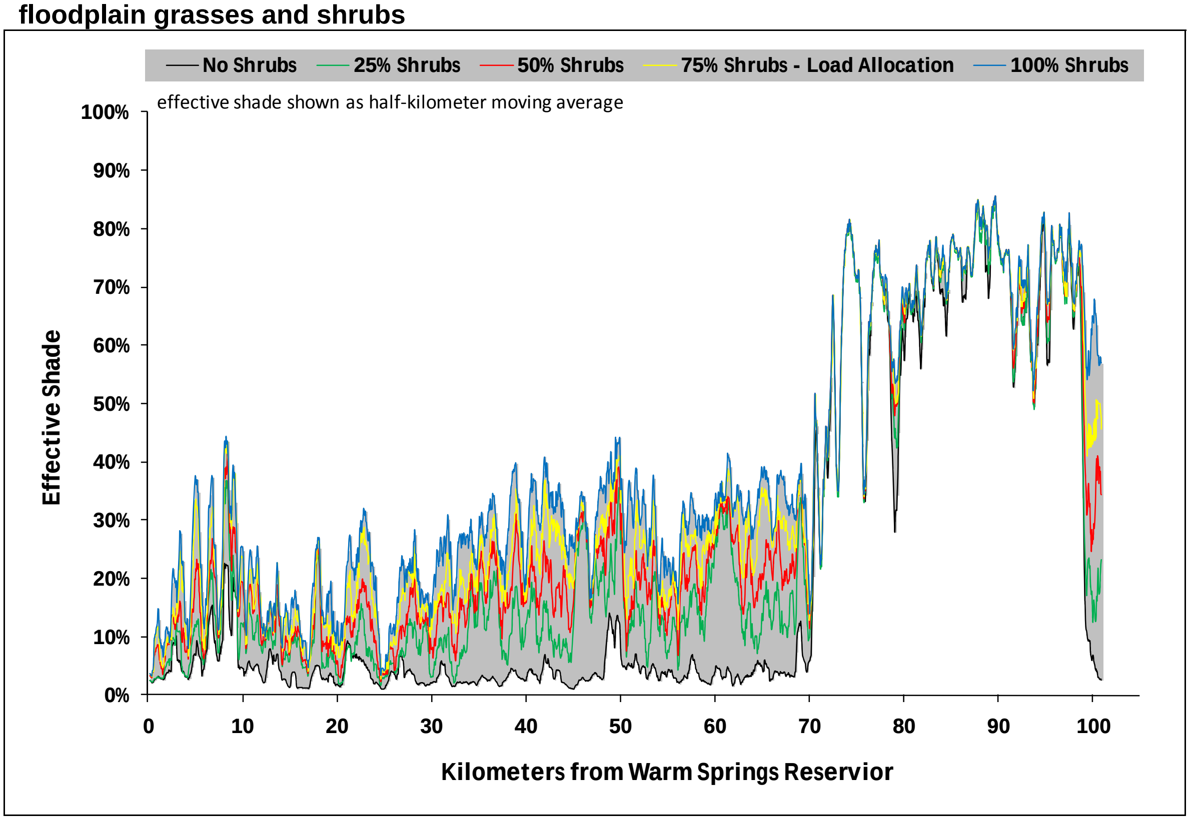
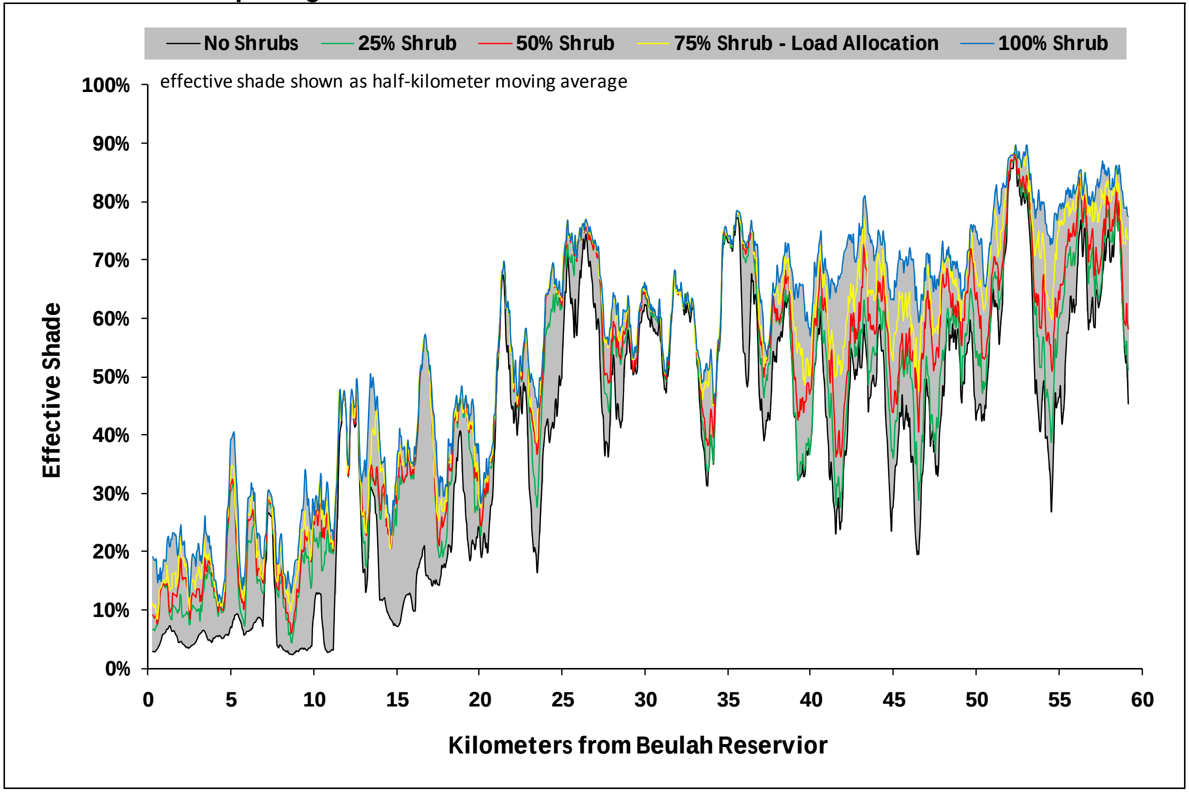
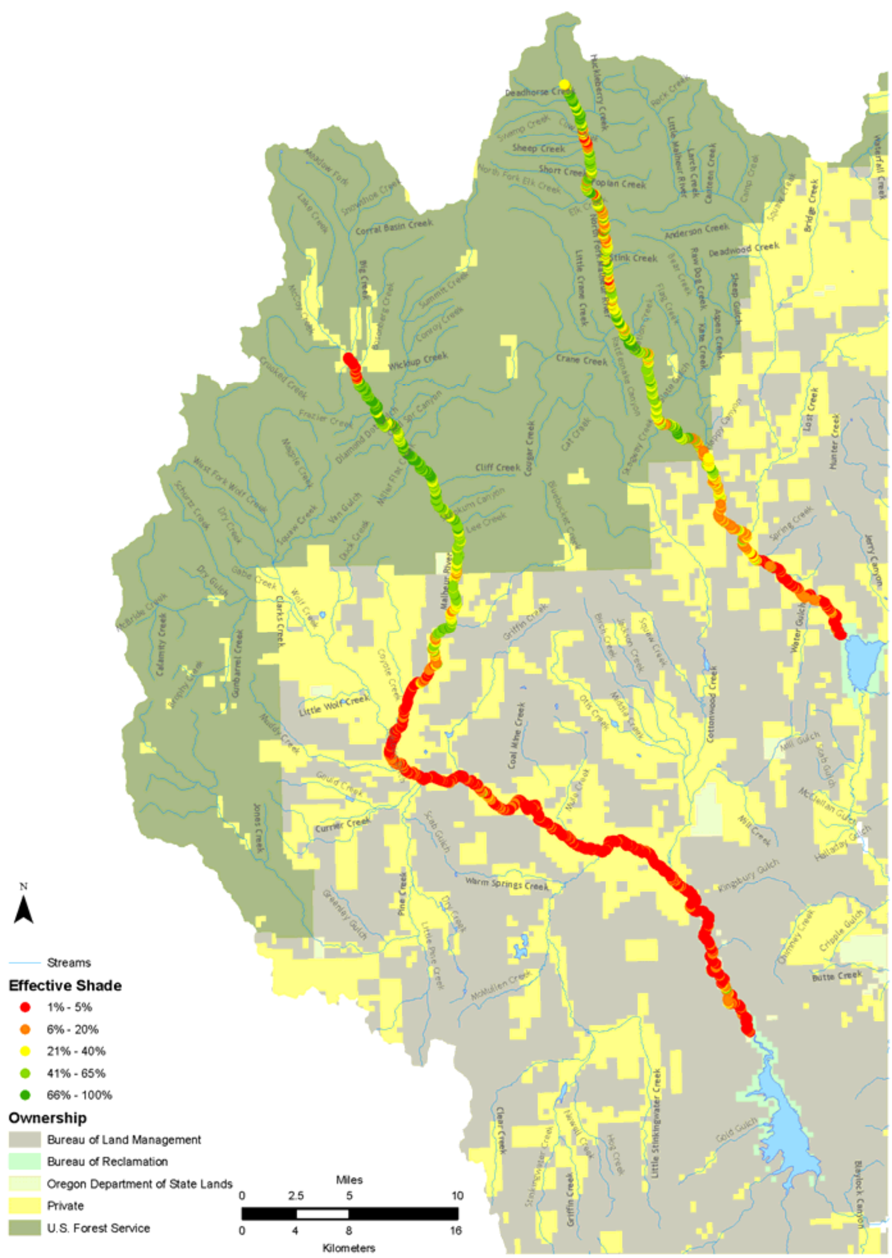


Figure B-24. Site potential effective shade on the North Fork Malheur River with various mixtures of floodplain grasses and shrubs



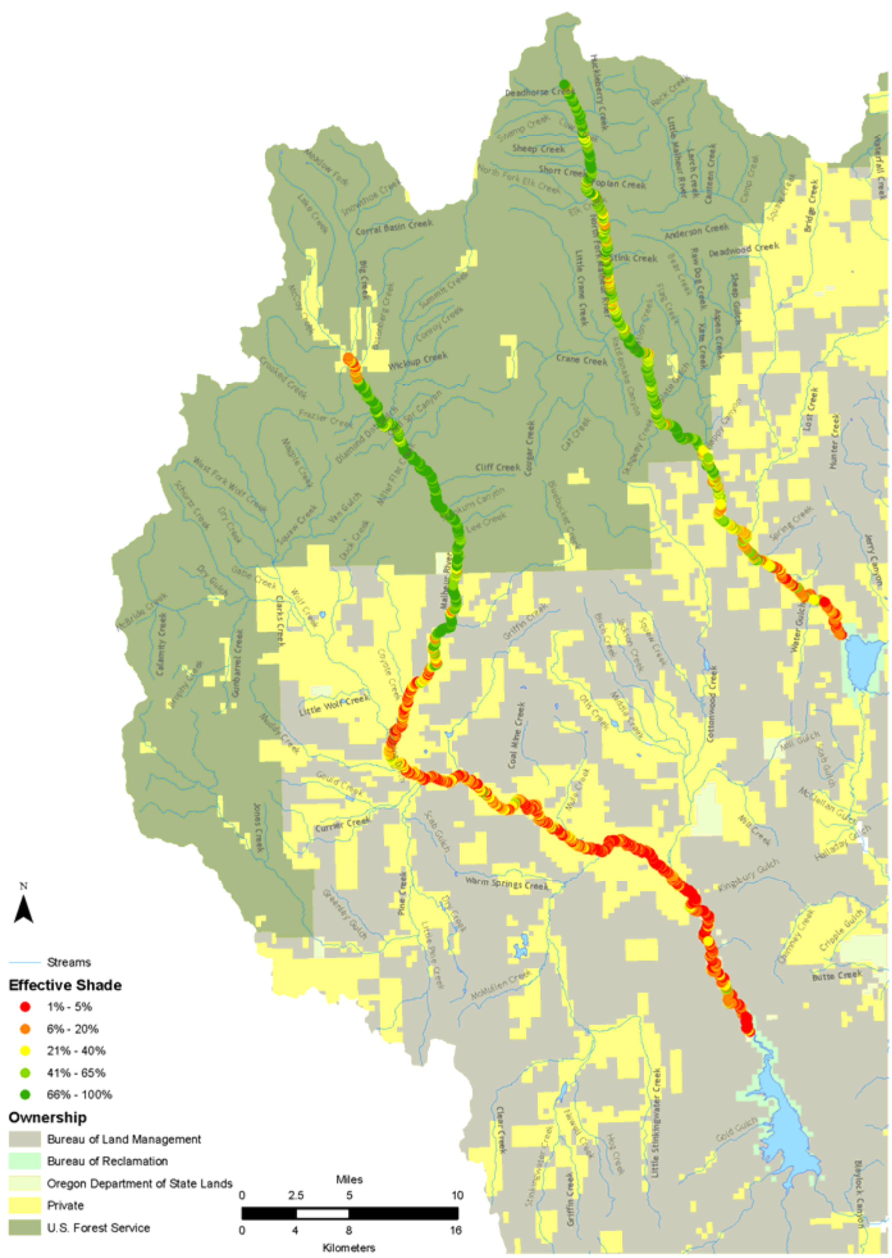
Simulation 1- Current Conditions

Figure B-25. Effective shade results for simulation 1 - current conditions.



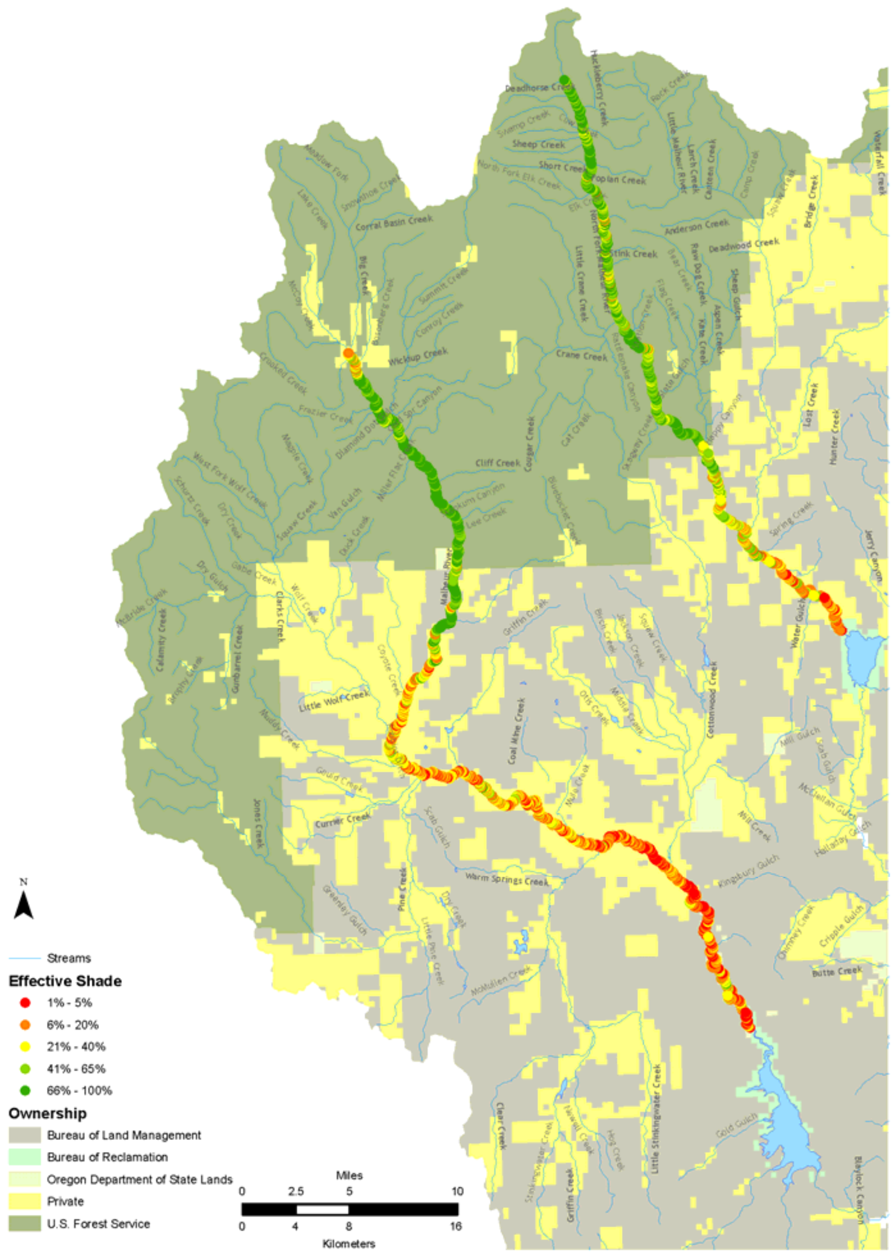
Simulation 2

Figure B-26. Effective shade results for simulation 2 – site potential with the floodplain containing 75% grasses and 25% shrubs.



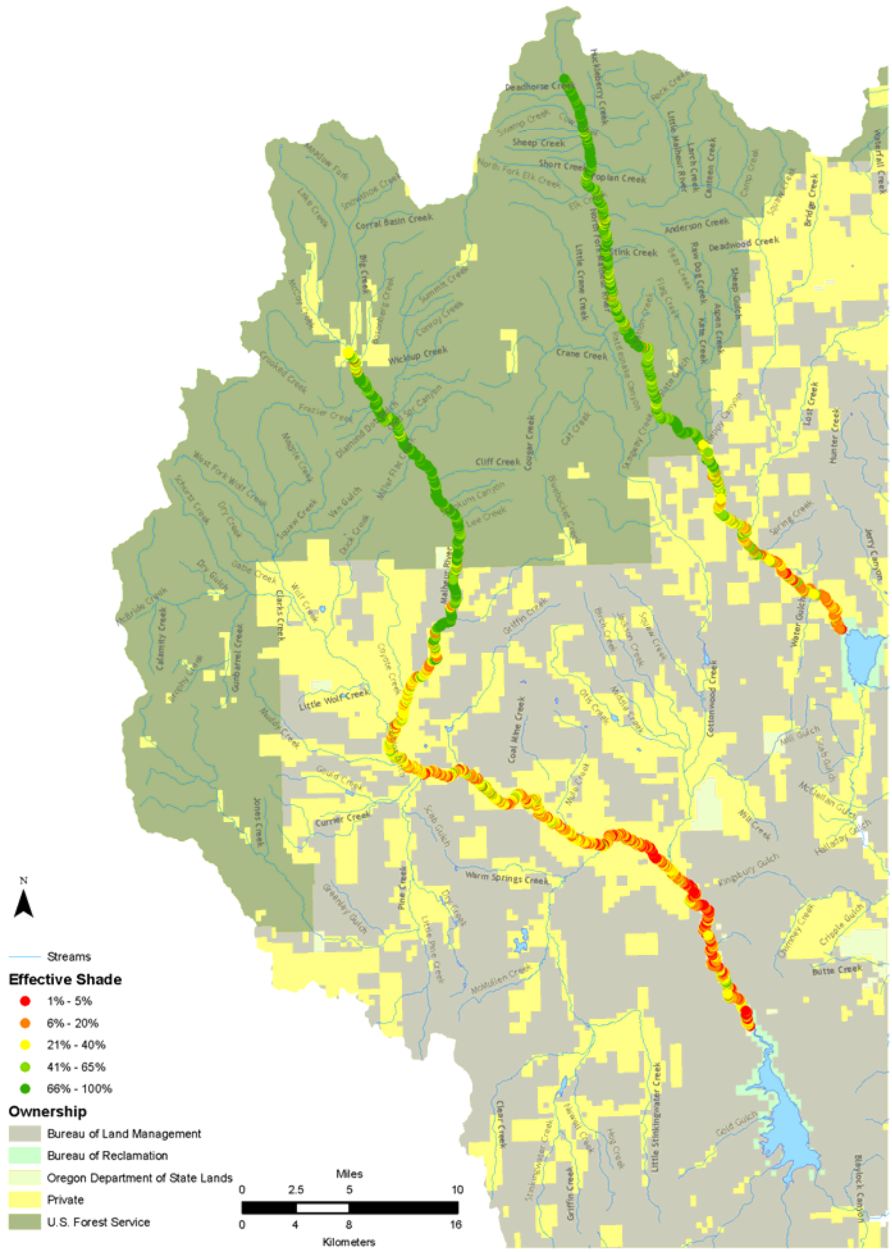
Simulation 3

Figure B-27. Effective shade results for simulation 3 – site potential with the floodplain containing 50% grasses and 50% shrubs.



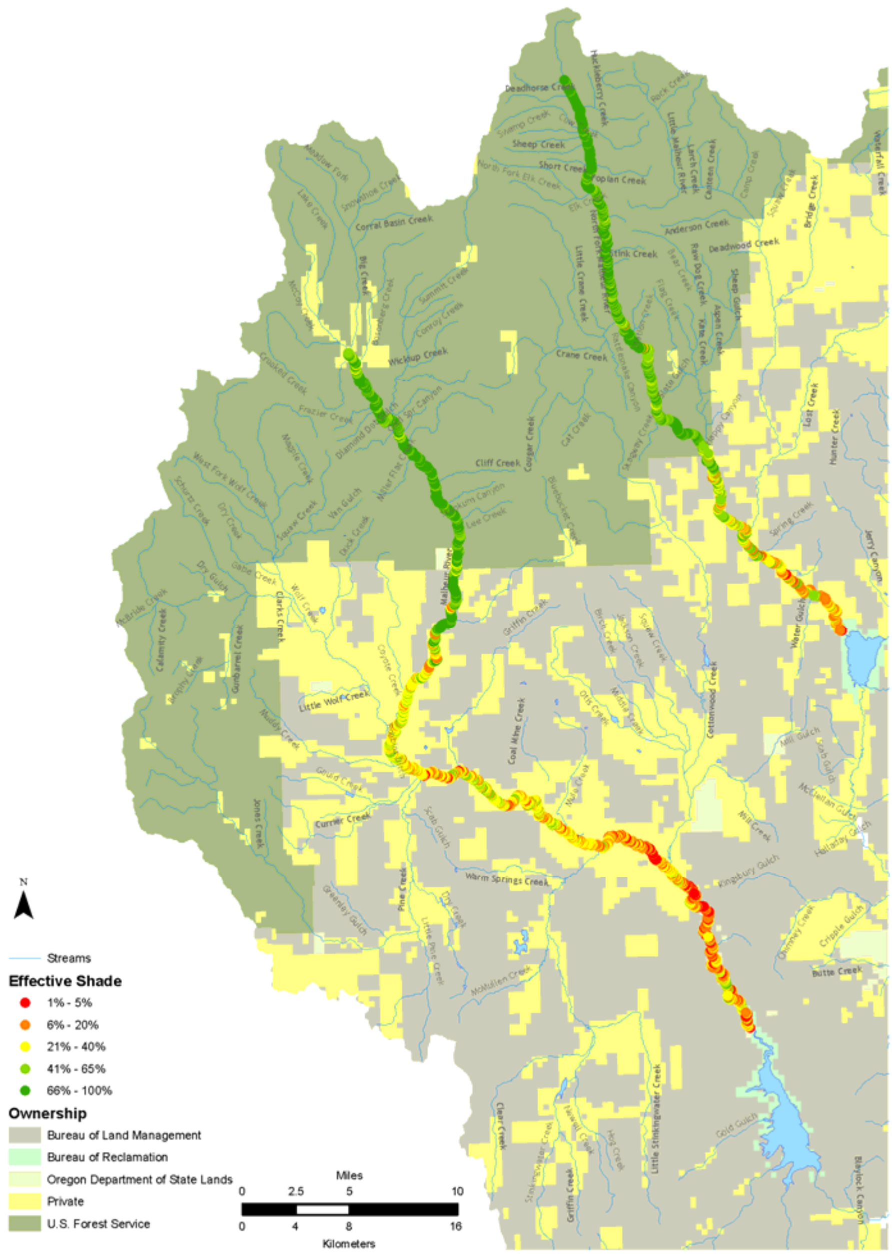
Simulation 4

Figure B-28. Effective shade results for simulation 4 – site potential with the floodplain containing 25% grasses and 75% shrubs.



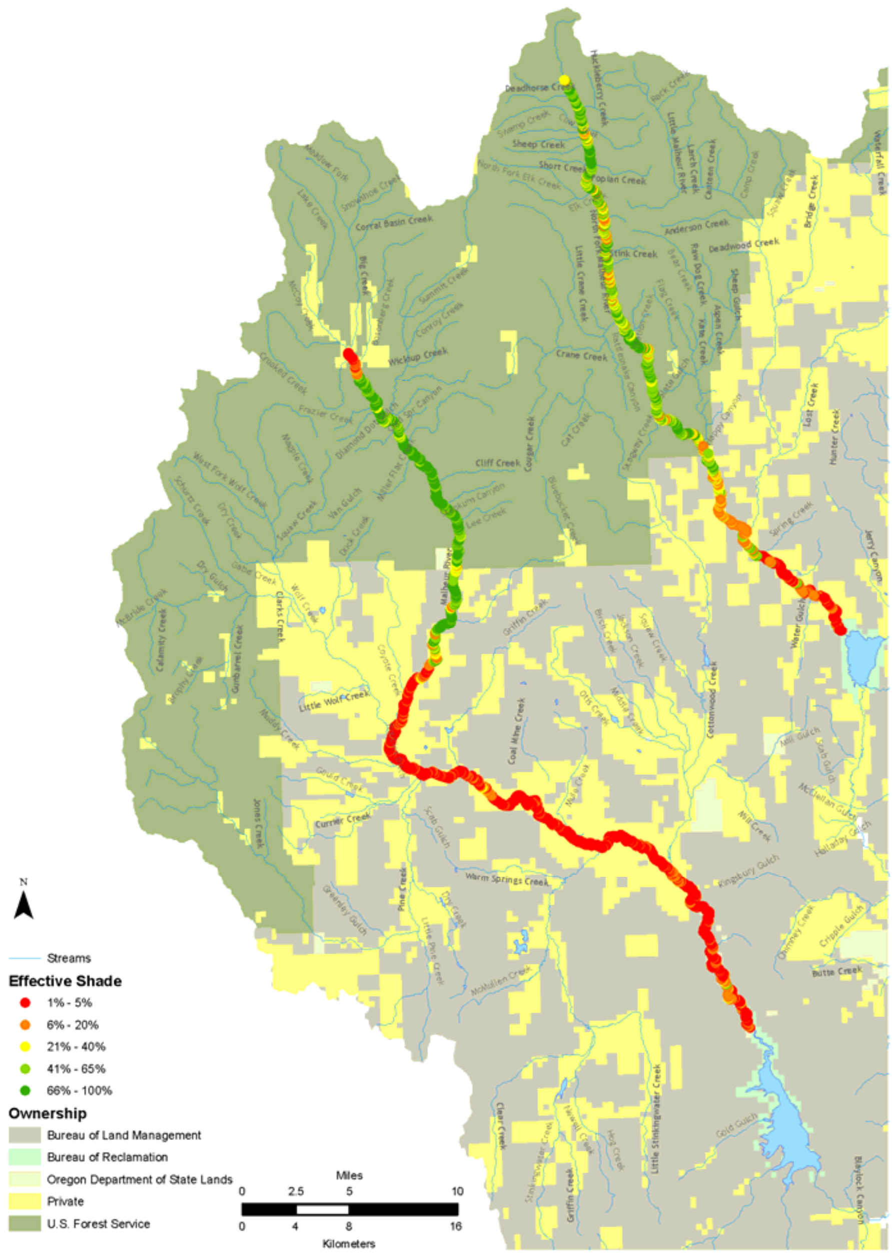
Simulation 5

Figure B-29. Effective shade results for simulation 5 – site potential with the floodplain containing 0% grasses and 100% shrubs.



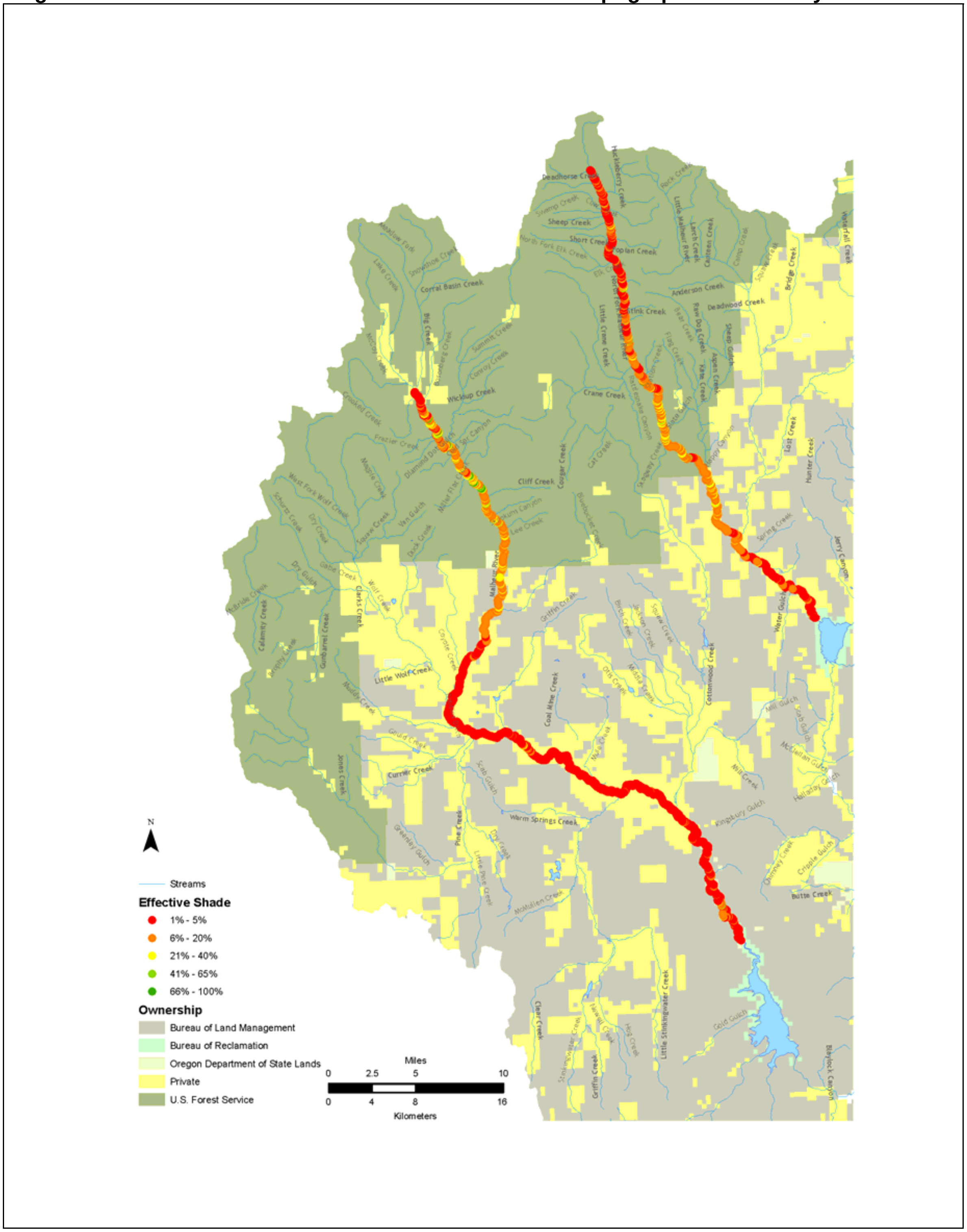
Simulation 6

Figure B-30. Effective shade results for simulation 6 – site potential with the floodplain containing 100% grasses and 0% shrubs.



Simulation 7

Figure B-31. Effective shade results for simulation 7 – topographic shade only.



REFERENCES

Beschta RL, 1997. Riparian Shade and Stream Temperature: An Alternative Perspective. *Rangelands* 19(2):25-28.

Boyd M. and Kasper B. 2003. Analytical Methods for Dynamic Open Channel Heat and Mass Transfer: Methodology for Heat Source Model Version 7.0

Crowe EA and Clausnitzer RR. 1997. *Mid-Montane Wetland Plat Associations of the Malheur, Umatilla and Wallowa-Whitman National Forests*. Technical Paper R6 NR-ECOL-TP-22-97. Baker City, OR: US Department of Agriculture, Forest Service, Wallowa-Whitman National Forest.

Crowe EA, Kovalchik BL, Kerr MJ. 2004. *Riparian and Wetland Vegetation of Central and Eastern Oregon*. Oregon State University, Portland, OR.

Johnson SL. 2004. Factors influencing stream temperature in small streams: substrate effects and a shading experiment. *Canadian Journal of Fish and Aquatic Sciences* 61: 913-923.

Moore RD, Spittlehouse DL, Story A. 2005. Riparian Microclimate and stream temperature response to forest harvesting: A review. *Journal of the American Water Resources Association* 14(4):813-834.

Pfister RD, Kovalchik BL, Arno SF, Presby RC. 1977. *Forest Types of Montana*. General Technical Report INT-34. Ogden, UT. US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.

Powell DC, Johnson CG Jr, Crowe EA, Wells A, Swanson DK. 2007. *Potential vegetation hierarchy for the Blue Mountains section of northeastern Oregon, southeastern Washington, and west central Idaho*. General. Technical. Report. PNW-GTR-709. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Rosenberg NJ, Blad BL, Verma SB. 1983. Microclimate- the biological environment. John Wiley and Sons, Inc., New York, New York.

Swanson FJ, Kratz TK, Caine N, Woodmansee RG. 1988. Landform effects on ecosystem patterns and processes. *BioScience* 38: 92–98.

Thorson TD, Bryce SA, Lammers DA, Woods AJ, Omernik JM, Kagan J, Pater DE, Comstock JA. 2003. Ecoregions of Oregon (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, U.S. Geological Survey (map scale 1:1,500,000). http://www.epa.gov/wed/pages/ecoregions/or_eco.htm.

OSU. 2005. Oregon State University Rangeland Ecology and Management Riparian Plant Fact Sheets. Last Accessed at http://oregonstate.edu/dept/range/Riparian%20PDFs.php

Wells AF. 2006. *Deep Canyon and Subalpine riparian and wetland plant associations of the Malheur , Umatilla, and Wallowa-Whitman National Forests.* General Technical Report PNW-GTR-682. Portland, OR. US Department of Agriculture, Forest Service, Pacific Northwest Research Station.