Appendix F

Deschutes River Tributaries TMDLs Technical Analysis

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ACRONYMS/ABBREVIATIONS

Acronym/Abbreviation	Definition
°C	Degrees Celsius
µg/L	Micrograms per Liter
303(d)	Clean Water Act Section 303(d): Impaired Waters and Total Maximum Daily Loads
7-DADMax	7-Day Average of Daily Maximum Temperature
ac-ft/yr	Acre-feet per Year
BMP	Best Management Practice
BOD	Biochemical Oxygen Demand
CBOD	Carbonaceous Biochemical Oxygen Demand
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CWA	Clean Water Act
DEM	Digital Elevation Model
DMR	Discharge Monitoring Report
DO	Dissolved Oxygen
Ecology	Washington Department of Ecology
EIM	Environmental Information Management System
EMC	Event Mean Concentration
EPA	United States Environmental Protection Agency
GHCND	Global Historical Climatology Network Daily
GIS	Geographic Information System
in/yr	Inches per Year
kg/day	Kilograms per Day
kWh/day	Kilowatt-hours per Day
kWh/m^2/day	Kilowatt-hours per Square Meter per Day
LA	Load Allocation
LiDAR	Light Detection And Ranging
m	Meters
mg/L	Milligram per Liter
mg-N/L	Milligrams Nitrogen per Liter
mg-P/L	Milligrams Phosphorus per Liter
MS4	Municipal Separate Storm Sewer System
NA	Not Applicable
NHD	National Hydrography Dataset
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NSDZ	Near-Stream Disturbance Zone

Acronym/Abbreviation	Definition
NTU	Nephelometric Turbidity Unit
ODEQ	Oregon Department of Environmental Quality
PARIS	Water Quality Permitting and Reporting Information System
PLOAD	Pollutant Load Application Tool
QAPP	Quality Assurance Project Plan
SOD	Sediment Oxygen Demand
SPV	System Potential Vegetation
s.u.	Standard Units (for pH)
TKN	Total Kjeldahl Nitrogen
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WAC	Washington Administration Code
WLA	Waste Load Allocation
W/m^2	Watts per Square Meter
WSDOT	Washington State Department of Transportation

1.0 INTRODUCTION

This appendix is based a report prepared by Tetra Tech under contract with the Environmental Protection Agency, Region 10. All work was conducted in accordance with an approved Quality Assurance Project Plan (QAPP; Tetra Tech, 2019a). This appendix describes technical analyses conducted to support development of Total Maximum Daily Loads (TMDLs) to address nine tributaries impaired by a combination of temperature, dissolved oxygen (DO), and pH in the Deschutes River watershed (Figure 1). The Unnamed Spring was incorrectly aggregated with Listing ID 48713 for the 2012 listing cycle. The correct listing ID from the 2010 listing cycle, Listing ID 48923, is specified in the map in Figure 1.

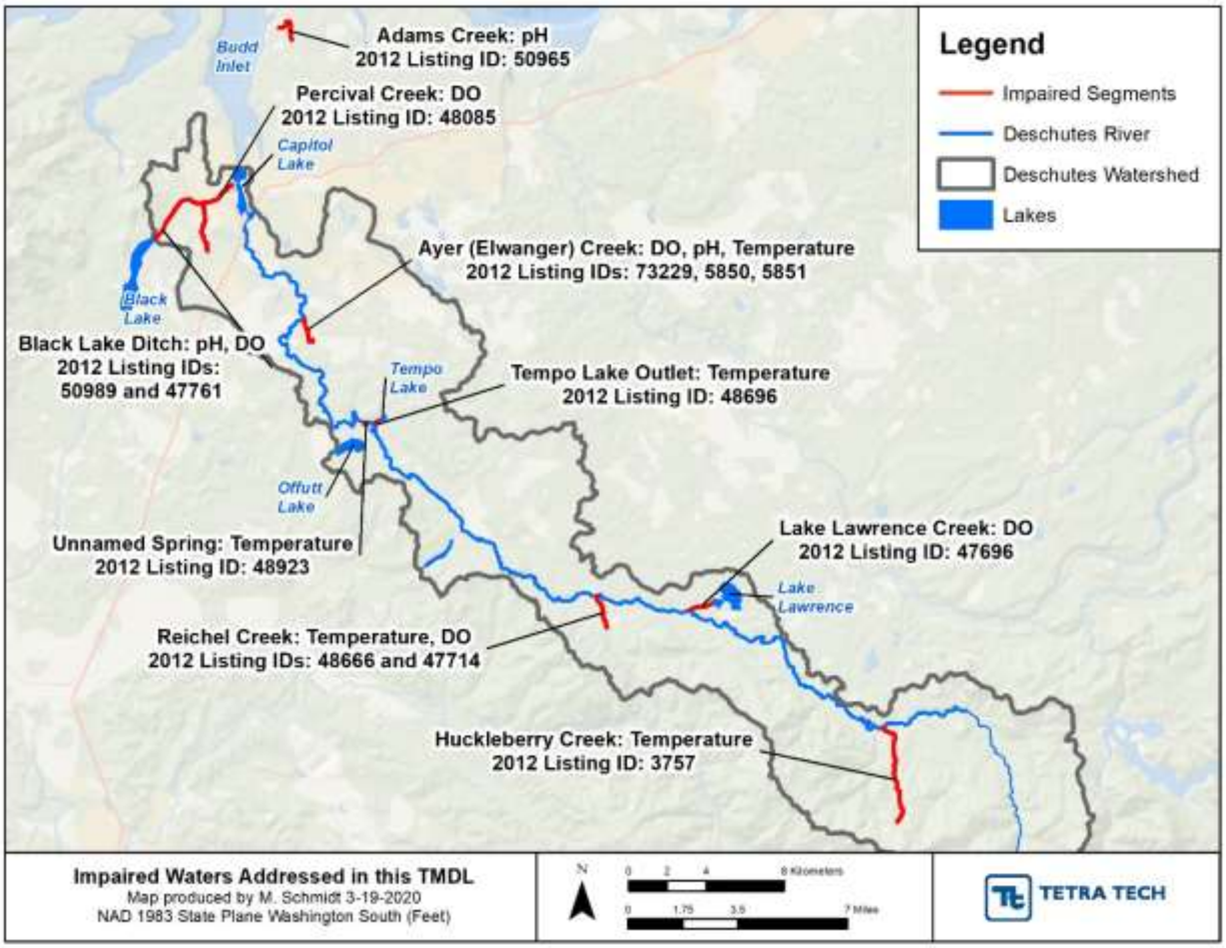


Figure 1. Waterbodies on the 2012 303(d) impaired waters list addressed in this report.

1.1 TECHNICAL APPROACH OVERVIEW

The regulations in the Code of Federal Regulations (CFR) at 40 CFR 130.2(i) allow appropriate surrogate measures to be used as the basis of a TMDL. Effective shade and corresponding maximum daily solar heat loads were assigned to the temperature impaired waterbodies as surrogate targets necessary to meet the numeric water temperature criteria. Because limiting light and nutrient availability hinders algal growth, which the Washington Department of Ecology (Ecology) identified as the driver of pH and DO water quality concerns in the

2015 Deschutes TMDLs, EPA established riparian shade, solar heat, and nutrient TMDLs to synergistically mitigate undesirable DO and pH fluctuations and support attainment of water quality criteria. This appendix includes details on the linkage between these targets and pH and/or DO, the approach used to establish the targets, and the analysis supporting the identification of TMDLs and assignment of allocations.

2.0 WATER TEMPERATURE

2.1 TECHNICAL APPROACH

Based on the well-documented relationship between riparian shade and stream temperature (Belt et al., 1992), reduced riparian shade along the stream corridor was identified as the most critical stressor causing temperatures to exceed water quality standards in the tributaries. This was verified for the mainstem using a QUAL2Kw model as part of the *2015 Deschutes TMDLs*. The QUAL2Kw modeling results for the Deschutes River temperature TMDLs showed that restoration of mature riparian vegetation provided the highest incremental improvement in reducing water temperatures. Secondary benefits expected to result from restoration of riparian vegetation, including improvements to channel morphology and microclimate conditions, were also evaluated by Ecology with the QUAL2Kw model. These were shown to be the second (channel improvements) and third (microclimate) most influential factors for improving water temperature in the Deschutes River. Restoring historic low flows was shown to be the least influential water quality management strategy. As such, the tributary temperature TMDLs focus on riparian vegetation for the attainment of the applicable temperature criteria.

Shade models were developed to quantify effective shade for existing and system potential (i.e. restored mature) riparian vegetation for the tributaries impaired for water temperature. Effective shade is defined as the fraction of the potential solar shortwave radiation blocked by vegetation and topography before it reaches the stream surface. In addition, the shade models estimate the thermal heat load from solar radiation that reaches the exposed stream surface. Effective shade and solar heat loading targets are defined and applied as surrogate measures for these TMDLs. A similar approach has been applied in approved water temperature TMDLs for other Washington streams including the Green River (Coffin et al., 2011) and Salmon Creek (Stohr et al., 2011). Improvements to channel stability and morphology are inherently part of restoring riparian vegetation but are not explicitly part of the shade models.

The technical approach consisted of developing a site-specific shade model for each of the tributaries impaired for water temperature, as well as those impaired for DO and/or pH. Natural shade conditions will help achieve attainment of water quality criteria for DO and pH and reduce heat loading to the temperature-impaired Deschutes River. Ecology's shade modeling tool (Shade.xls) is a Microsoft Excel spreadsheet tool available on Ecology's website that applies methods originally developed by the Oregon Department of Environmental Quality (ODEQ) and Chen et al. (1998a; 1998b). The Shade.xls model quantifies solar heat loading and calculates percent effective shade along the stream corridor. Heat loads were developed for the TMDLs using the conceptual framework summarized in Table 1. The Shade.xls model evaluates solar radiation along streams using geographic information system (GIS) data derived with the TTools ArcGIS extension. TTools is an ArcMap Python add-in that uses spatial inputs to sample vegetation and topography data perpendicular to the stream channel at equal intervals longitudinally from upstream to downstream. It also samples longitudinal stream channel characteristics, such as the near-stream disturbance zone (NSDZ) and elevation. TTools can sample spatial data from the digitized edge of the water including ground elevation and land use type in the NSDZ and the riparian zone depending on available remote sensing data. Typically, spatial data inputs include Light Detection And Ranging (LiDAR) outputs, digital elevation models (DEMs), and riparian vegetation digitized from aerial imagery (digital orthophoto quadrangles and rectified aerial photos).

Table 1. Conceptual framework summary for waterbodies impaired for water temperature.

Category	Description
Models/Tools	Effective shade and thermal heat loads from solar radiation for existing and system potential riparian vegetation were evaluated through application of the Shade model (Shade.xls with inputs derived from TTools, an ArcGIS extension).
Endpoint	The modeling framework applied riparian shade and thermal heat loading as surrogate targets and the assessment endpoint. The ultimate endpoint is the numeric 7-DADMax temperature criterion.
Evaluated Stressors and Processes	The key stressors evaluated for the waterbodies impaired for temperature include incoming shortwave solar radiation and riparian shade loss. The spatial extent and density of existing and potential riparian shade characteristics were evaluated.
Key Model Parameters	Key parameters include latitude/longitude, time of year, stream geometry, topography, and vegetative buffer characteristics (e.g., species) of the existing and potential mature riparian vegetation.

As previously discussed, effective shade is the fraction of shortwave solar radiation that does not reach the stream surface due to interception by vegetative cover and/or topography. Effective shade at any location or time is influenced by latitude/longitude, time of year, stream geometry, channel orientation, topography, and riparian vegetation characteristics such as height, overhang, and density. Data inputs for the tributary Shade.xls models were readily available (e.g., aerial imagery, DEMs), and additional data (e.g., vegetation height and overhang) were estimated from LiDAR and other relevant data sources. The TTools output served as input for the Shade.xls models, which were then used to generate longitudinal effective shade profiles and daily solar radiation estimations below riparian cover.

Heat loads to the streams were calculated in units of watts per square meter (W/m^2) and were also converted to units of kilowatt-hours per square meter per day ($kWh/m^2/day$) and kilowatt-hours per day (kWh/day) to establish daily TMDLs for the temperature TMDLs. These units of measure, however, have limited value in guiding management and implementation activities needed to restore water quality. Thus, riparian shade targets that correspond with the solar heat loading targets were also defined to support implementation. The technical approach for applying these surrogate measures for water temperature is reasonable and protective of instream and downstream water quality for the following reasons:

- Applications of Ecology’s Shade.xls model have informed approved TMDLs across the state;
- Riparian vegetation provides increased effective stream shade that directly limits the heat load to the water surface, therefore reducing instream water temperatures;
- Shade loss was shown to be the most critical stressor in terms of heat loading to the Deschutes River based on QUAL2Kw modeling scenarios.

2.1.1 Geospatial and Monitoring Data

Data used in the technical analyses included GIS spatial datasets for drainage area delineations, land use/cover, permitted urban stormwater boundaries, Washington State Department of Transportation (WSDOT) operated roadways, vegetation and bare earth elevations, and aerial imagery (Table 2). GIS data were used to develop catchment boundaries for the waterbodies and to differentiate between regulated Municipal Separate Storm Sewer Systems (MS4s), which are subject to wasteload allocations (WLAs), and unregulated (non-MS4) areas, which are subject to load allocations (LAs). National Land Cover Dataset (NLCD) 2011 land use/cover applied in the assessments is shown in Figure 2.

Instream water temperature monitoring records were queried for all tributaries listed as impaired for water temperature, except for Percival Creek and Black Lake Ditch, which already have Ecology-developed Shade.xls models and targets. Those query results are summarized in Table 3. Water temperature monitoring records were available from the Washington Environmental Information Management (EIM) online database and from Thurston County. Water temperature observations were available for Ayer Creek at a frequency of about twice per month from July to December 2004. Water temperature was typically evaluated daily between 7/24/2003 to 10/23/2003 for Huckleberry Creek (minimum, maximum and average reported in EIM), and about every other week between July and December of 2004. Water temperature was sampled at Reichel Creek daily between 7/1/2003 to 10/22/2003 and 4/29/2004 to 9/28/2004 (minimum, maximum and average reported in EIM) and about once per month in recent years, where the highest individual record is 23.9 ºC. Tempo Lake Outlet was monitored between 5/21/2003 to 9/23/2003 and the Unnamed Spring to Deschutes River was monitored between 7/8/2003 and 6/29/2004. Ecology suspects there are quality issues with the data available through EIM for Unnamed Spring to Deschutes River. Nevertheless, summary metrics are provided for the data available.

Table 2. Geospatial data sources.

Purpose	GIS Datasets
Development of watershed boundaries and catchment areas	Catchment boundaries shapefile from NHDPlus V2[1] Flow accumulation analysis (Tetra Tech, 2019b)
Defining MS4 and non-regulated areas	MS4 boundaries shapefile from Ecology
	Land use/cover raster and imperviousness from NLCD 2011
	National highways shapefile from WSDOT
Development of Shade model inputs	Bare earth elevation (last-return) LiDAR rasters, vegetation elevation (first-return) LiDAR rasters
Development of Shade model inputs using remote sensing information	Streaming aerial imagery (Google Earth, ArcGIS Online World Imagery)

[1] http://www.horizon-systems.com/nhdplus/nhdplusv2_home.php

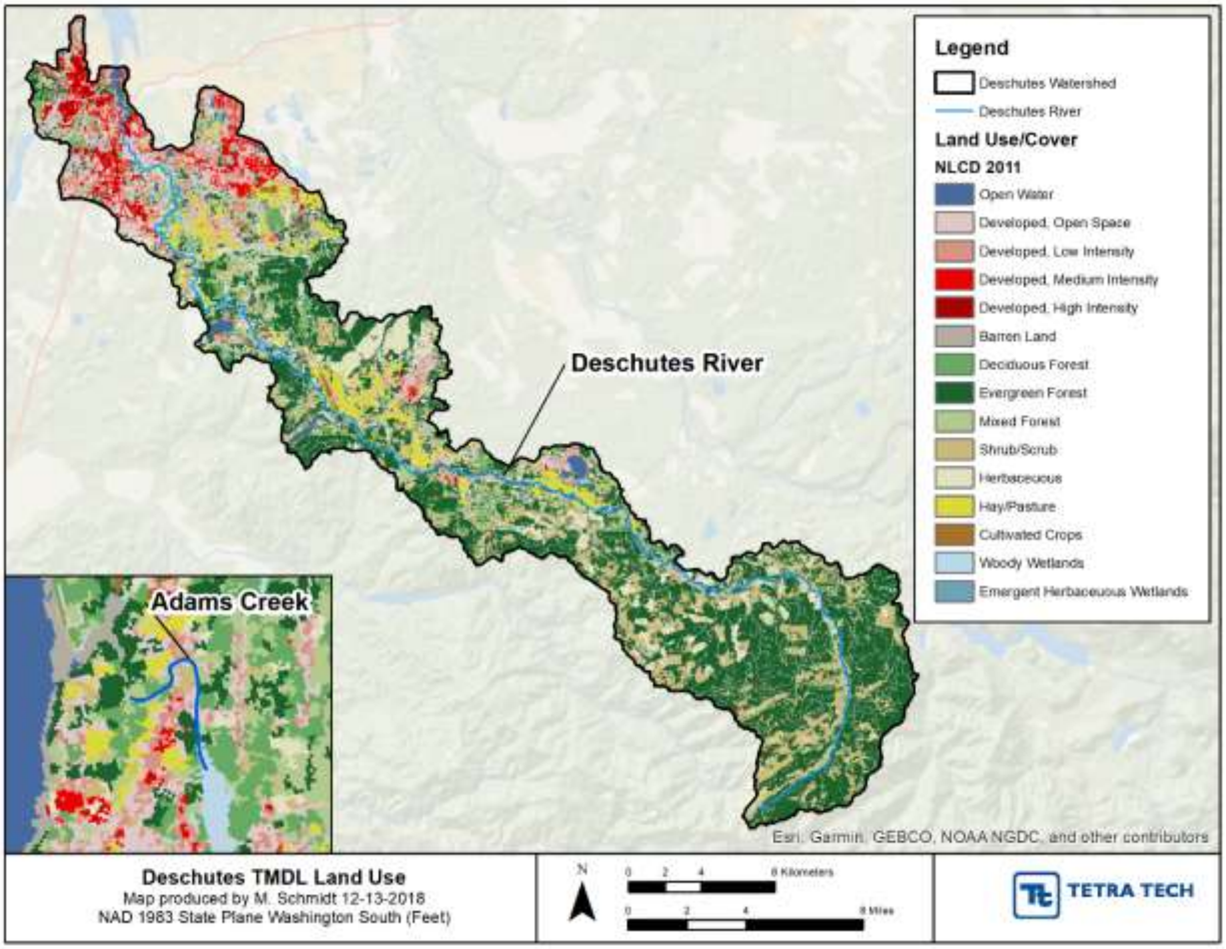


Figure 2. NLCD 2011 land use/cover in the Deschutes River watershed with an inset map showing the Adams Creek area north of the watershed.

Table 3. Monitoring records for tributaries impaired for water temperature (°C).

Waterbody	Data Sources	Period of Record	7 DADMax[1]	Count[2]	Mean	Min	Max
Ayer Creek	EIM	7/21/2004 – 12/28/2004	17.5	11	11.8	4.5	18.8
Huckleberry Creek	EIM	7/2/2003 – 12/28/2004	16.0	288	13.0	4.6	16.3
Reichel Creek	EIM and Thurston County	7/1/2003 – 9/10/2018	16.0	490	13.4	0.4	20.0
Tempo Lake Outlet	EIM	5/21/2003 – 9/23/2003	17.5	378	15.4	10.7	25.1
Unnamed Spring to Deschutes River	EIM	7/8/2003 – 6/29/2004	17.5	420	9.5	8.5	21.0[3]

[1]The water temperature standard is expressed as the 7-day average of daily maximum temperatures (7-DADMax), however, the statistics shown in the table are derived from individual grab samples (e.g., individual maximum observation of water temperature).

[2]Typically the minimum, maximum, and average daily temperatures are reported in EIM for Huckleberry Creek, Reichel Creek, Tempo Lake Outlet, and Unnamed Spring to Deschutes River. The sample count listed in the table does not aggregate these.

[3]Ecology suspects there may be quality issues associated with the data for the Unnamed Spring to Deschutes River.

2.2 TECHNICAL ANALYSIS

To assess topographic and vegetative shade that blocks solar radiation, Shade.xls models were developed with inputs derived from the TTools ArcGIS Extension. Shade models for Black Lake Ditch and Percival Creek were previously developed by Ecology (Roberts et al., 2012) to support TMDL development for the *2015 Deschutes TMDLs*. Because Ecology did not previously develop Shade.xls models for other temperature-impaired tributaries and riparian restoration was identified as necessary to address tributary DO and pH impaired waters as well, Shade.xls models were developed for Huckleberry Creek, Reichel Creek, Tempo Lake Outlet, Ayer Creek, Lake Lawrence Creek, Adams Creek, and the Unnamed Spring to Deschutes River. Lake Lawrence Creek and Adams Creek were not included on the Clean Water Act Section 303(d) 2012 list as impaired for water temperature; the solar heat TMDLs for these two creeks are anticipated to aid in improvements to DO and pH, respectively.

To capture critical conditions relative to water temperature, the Shade.xls model application was evaluated for the middle of summer when the maximum solar heat load is anticipated to be exerted on the tributaries. The existing Shade.xls models generated by Ecology for Black Lake Ditch and Percival Creek were run for the date of July 24, 2004, and that date was adopted for the new Shade.xls model simulations conducted for the other tributaries.

2.2.1 TTools Application

Inputs for TTools included the following:

- Stream Centerline Shapefile: These were digitized using LiDAR and aerial imagery.
- Stream Wetted Width Shapefile: Water edges on both sides of the stream centerline were digitized using LiDAR and aerial imagery. Where channel banks were not easily determined, general assumptions of channel width were applied to the entire reaches based on available data such as portions of the channel visible in imagery (Table 4).

- Coarse-Resolution Elevation Raster: 30-meter resolution (32.8-ft) statewide elevation grid was used to calculate long-range topographic shade angles.
- Fine-Resolution Elevation Raster: 6-foot resolution bare earth (last-return) LiDAR raster from the Puget Sound LiDAR Consortium was used for sampling ground elevation in the riparian corridor.
- Vegetation Shapefile: Vegetation within 40 meters on either side of each tributary wetted width were digitized into distinct land cover polygons using both aerial imagery and vegetation (first-return) 6-foot resolution LiDAR rasters from the Puget Sound LiDAR Consortium. The land use classes identified for the riparian areas included the following: water, pavement, building, grass, sparse forest, medium forest, and dense forest.

When TTools was run, the stream centerlines were segmented every 10 meters to allow for fine-resolution simulation because some tributaries are relatively short in length (e.g., Tempo Lake Outlet is 268 meters long). The following 10-meter segment-scale outputs from TTools were applied as input parameters in the Shade.xls model and the values from TTools for each tributary are summarized in Table 4:

- Location of the node as a distance from upstream in meters
- Channel elevation in meters
- Solar aspect in degrees
- Wetted width in meters and Distance from the stream centerline to the wetted width
- Near stream disturbance zone width in meters, which was set equal to wetted width
- Channel incision in meters; although not a direct output from TTools, it was estimated by subtracting the channel elevation from the near-stream (zone 0) bare earth elevation
- Topographic shade angles in degrees from the West, South, and East
- Riparian vegetation codes for 9 separate four-meter (approximately 13-foot) zones perpendicular to the stream on both left and right banks
- Riparian ground elevation for 9 separate four-meter (approximately 13-foot) zones perpendicular to the stream on both left and right banks

Table 4. Summary of tributary attribute results from TTools.

Waterbody	2012 303(d) List for Temperature	Tributary Length (m)	Average Channel Elevation (m)	Median Wetted Width (m)	Average Channel Incision (m)	Dominant Riparian Vegetation Class
Huckleberry Creek	Yes	5,706	298	4.0	0.8	Dense Forest
Reichel Creek	Yes	1,936	130	2.0	0.3	Grass
Tempo Lake Outlet	Yes	268	73	4.0	0.8	Dense Forest
Unnamed Spring to Deschutes River	Yes	52	71	2.0	0.1	Medium Forest
Ayer Creek	Yes	1,532	46	4.0	0.1	Grass
Black Lake Ditch[1]	Yes	3,633	38	4.0	0.5	Shrub
Percival Creek[1]	Yes	5,452	31	2.3	0.7	Medium Deciduous
Lake Lawrence Tributary	No	1,279	127	3.0	0.6	Grass
Adams Creek (East)	No	1,910	30	4.0	0.7	Dense Forest

[1]TTools outputs for Black Lake Ditch and Percival Creek are summarized based on previously constructed models by Ecology (Roberts et al., 2012) applied in the approved water temperature TMDLs for these waterbodies (EPA, 2018).

2.2.2 Shade Modeling: Existing Conditions

Shade.xls models for existing conditions were developed for the mainstem Deschutes River, as well as Black Lake Ditch and Percival Creek as part of the technical assessment completed by Ecology (Roberts et al., 2012) for the approved TMDLs. Hemispherical digital photography data observed at nine locations on the mainstem and six locations along Percival Creek informed the development of Shade.xls models for the Deschutes River and Percival Creek. Often, however, hemispherical digital photography data are not available for this purpose; this was the case for Black Lake Ditch and the other tributaries, so the Shade.xls models were constructed using available data, such as LiDAR.

The Shade.xls model requires inputs related to height, density, and overhang for each land use type identified during the TTools riparian sampling. The ArcGIS Zonal Statistics tool was used to estimate the average height of each riparian land use class. A vegetation height raster was generated by subtracting the last-return bare earth LiDAR raster from the first-return vegetation elevation raster. Estimates for density were based on visual assessment of aerial imagery and first-return LiDAR rasters, while estimations of vegetation overhang were derived from height and overhang relationships observed in the Percival Creek, Black Lake Ditch, and Deschutes River mainstem Shade.xls models that were informed by field data (

Table 5).

Table 5. Shade.xls model inputs for existing conditions of riparian land use/cover classes.

Land Use	Height (m)	Canopy Density (%)	Canopy Overhang (m)
Water	0.0	100%	0.0
Pavement	0.0	100%	0.0
Building	4.5	100%	0.0
Grass	1.0	100%	0.1
Sparse Forest	10.0	50%	1.0
Medium Forest	10.0	90%	2.5
Dense Forest	20.0	90%	4.0

The hourly effective shade output from the Shade.xls model is based on topography and vegetation. Effective shade is calculated based on the geometry of the channel, vegetation height, density, and overhang, and solar position based on latitude, time of year, and time of day. The outputs from the Shade.xls model can be used to inform the existing thermal inputs to the stream and include:

- Hourly and daily average solar radiation in watts per square meter that reaches the waterbody surface;
- Hourly and daily average effective shade as a percentage due to topography and vegetation.

For the tributaries covered in this report, these features were evaluated at 10-meter longitudinal intervals along the stream corridor for the critical summer conditions from July 24, 2004. Ecology's TTools and Shade.xls models for Black Lake Ditch and Percival Creek were set up at longer intervals of 100 meters (Roberts et al., 2012).

2.2.3 Shade Modeling: System Potential Vegetation

System potential vegetation (SPV) represents mature riparian ecosystem growth. When SPV is restored along a riparian corridor of a stream, shade is increased, which filters solar radiation, reduces stream temperatures, and limits nuisance phytoplankton and benthic algae. Restoration of SPV can also improve the riparian microclimate, cooling both air and stream temperatures under the canopy, and naturally restore channel characteristics over time, such as narrowing of the channel and increasing sinuosity (National Research Council, 2002).

To quantify the impact of SPV restoration on heat fluxes to the tributaries impaired for temperature, DO and/or pH, the Shade.xls models generated for existing conditions were modified to represent mature riparian vegetation conditions. The mature vegetation scenario allows for the quantification of solar radiation heat load to the water surface due to both topographic and maximum SPV shade influences. Mature vegetation was represented by maximum height, overhang, and densities for vegetation that could grow naturally in the riparian corridors of the impaired tributaries. The SPV characteristics identified in the accepted temperature TMDLs for the Deschutes River, Percival Creek, and Black Lake Ditch (Wagner and Bilhimer, 2015) were applied for the tributaries covered in this report as follows:

- Non-Wetland SPV: 40 meters tall, 90 percent density, 4-meter overhang
- Wetland SPV: 10 meters tall, 75 percent density, 1-meter overhang

Based on Washington Department of Natural Resource soils data, the entire Deschutes River watershed is anticipated to have a SPV species of Douglas Fir, with small pockets of Red Alder. The SPV growth occurring on non-wetland soils is a simulation of Douglas Fir growth in the riparian corridor. Wetland soils are not capable of achieving the same SPV growth as non-wetland areas as the soils remain highly saturated year-round and support different types of mature vegetation.

It is assumed that either wetland or non-wetland SPV can be achieved in the riparian corridor unless the area is currently developed (pavement or building present) or classified as water and will result in attainment of numeric criteria. Wetland SPV is applied for wetlands identified by the National Wetland Inventory spatial dataset. The tributaries with the most extensive riparian wetland soils include Ayer Creek and Lake Lawrence Tributary. The Black Lake Ditch and Percival Creek Shade.xls models developed by Ecology differed slightly in that they allowed for areas identified as water, pavement, or buildings to be revegetated in the SPV scenario, which targeted natural conditions without human influence.

The results of the Shade.xls modeling include both effective shade and associated heat load for both existing and SPV scenarios. The difference in effective shade between these scenarios represents the current shade deficit expressed as a relative percentage. Similarly, the difference in heat load between these scenarios represents the total excess heat load that the stream receives under existing shade conditions relative to SPV conditions.

The average daily effective shade deficit and heat load results are summarized in

Table 6 as an average along the entire stream reach. Effective shade deficits at each segment node (i.e. each 10-meter increment) are shown in Figure 3 to Figure 9. The tabular data associated with existing shade, SPV shade, and the associated shade deficit at each segment node is presented in full in Appendix F-1. An effective shade deficit of 100 percent reflects a condition where existing conditions provide no shade from vegetation and topography. An effective shade deficit of 0 percent reflects a condition where existing conditions are equivalent to SPV conditions. The reach with the largest average shade deficit (48 percent) is Lake Lawrence Creek, which is surrounded by agricultural fields and grassland, although it is not listed as impaired for temperature (based on the 2012 list) and the single available temperature observation from October 2004 was below the 7-DADMax. Lake Lawrence Creek, although not listed as impaired for temperature exhibits the most capacity for improvement. Huckleberry Creek is the reach with the lowest average shade deficit (1 percent), as it is mostly surrounded by dense riparian forest. Implementation should focus on the conservation of existing riparian vegetation for Huckleberry Creek.

Table 6. Longitudinal average daily effective shade deficits and solar heat loads during the critical period.

Waterbody[1]	Average Effective Shade for Existing Vegetation (%)	Average Effective Shade for SPV (%)	Average Effective Shade Deficit (%)	Average Existing Heat Load (W/m^2)	Average SPV Heat Load (W/m^2)	Average Heat Load Deficit (W/m^2)
Huckleberry Creek	96%	97%	1%	12	8	4
Reichel Creek	71%	94%	23%	90	18	71
Tempo Lake Outlet	79%	93%	14%	65	23	42
Unnamed Spring to Deschutes River	99%	99%	<1%	4.8	4.0	0.8
Ayer Creek	34%	79%	45%	207	66	141
Lake Lawrence	46%	94%	48%	169	19	149
Adams Creek (East)	90%	98%	8%	33	8	25

[1]Results for the Black Lake Ditch and Percival Creek Shade.xls models can be found in Ecology's TMDLs (Wagner and Bilhimer, 2015).

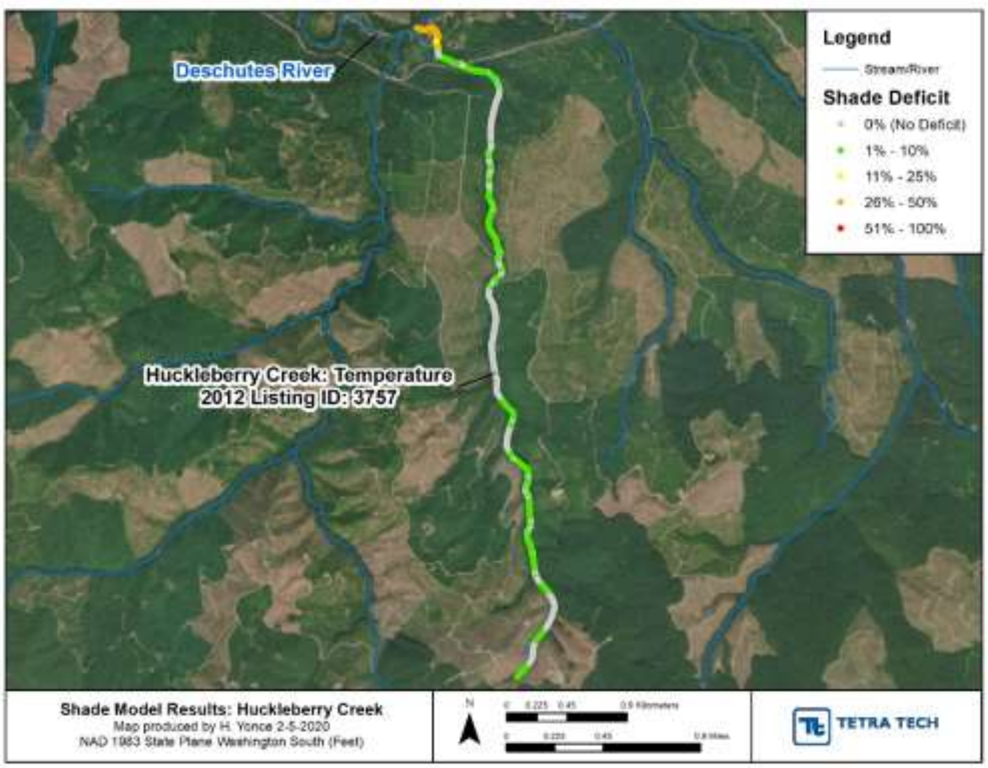


Figure 3. Average daily shade deficit along Huckleberry Creek.

Figure 4. Average daily shade deficit along Tempo Lake Outlet.

Figure 5. Average daily shade deficit along Unnamed Spring to Deschutes River.

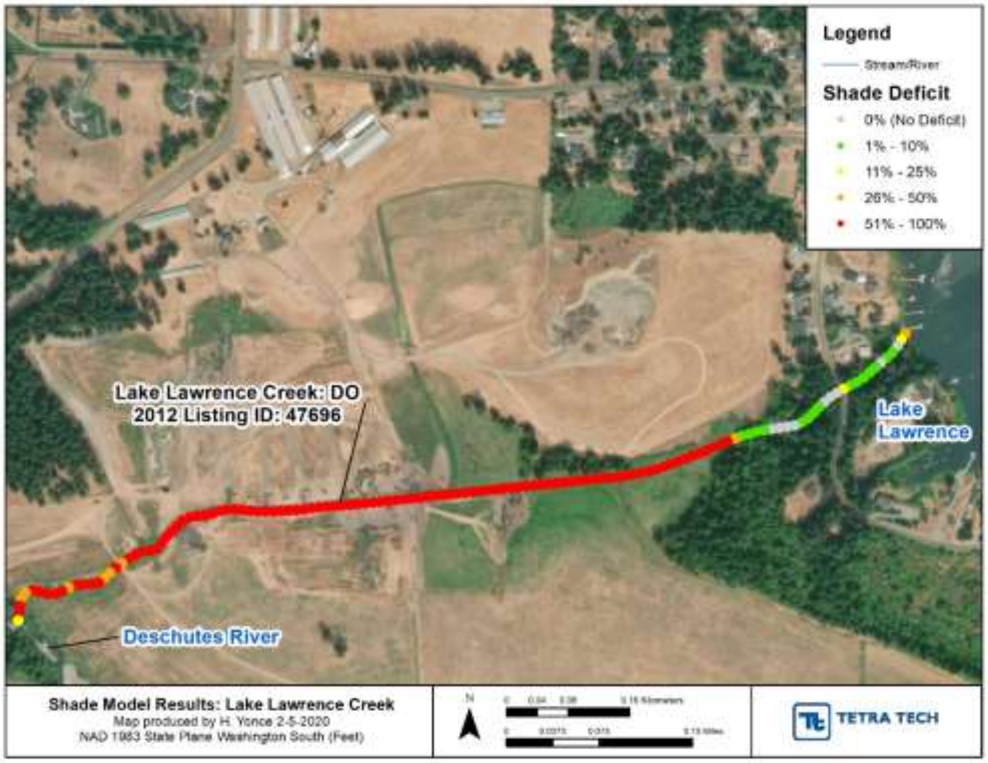


Figure 6. Average daily shade deficit along Lake Lawrence Tributary.

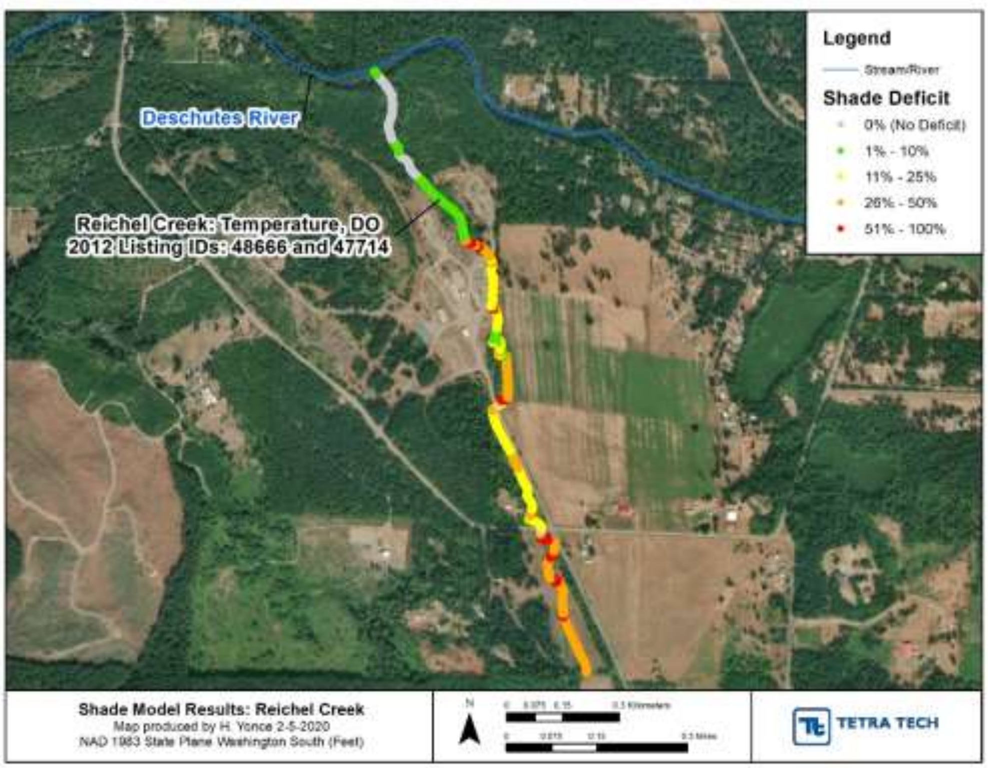


Figure 7. Average daily shade deficit along Reichel Creek.

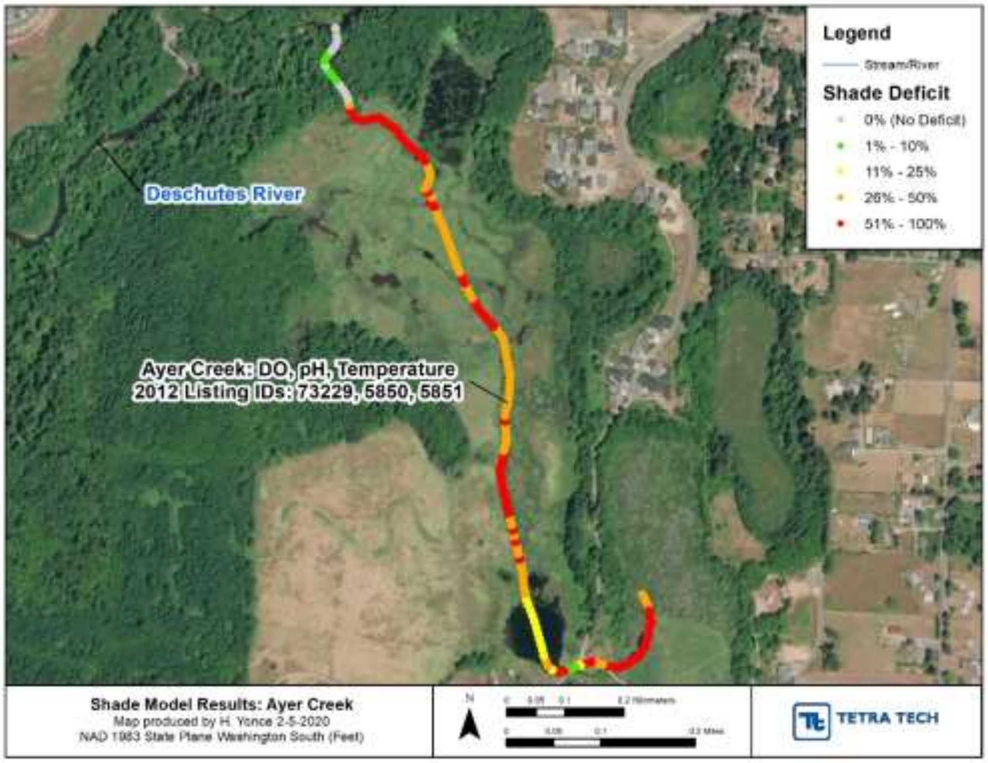


Figure 8. Average daily shade deficit along Ayer Creek.

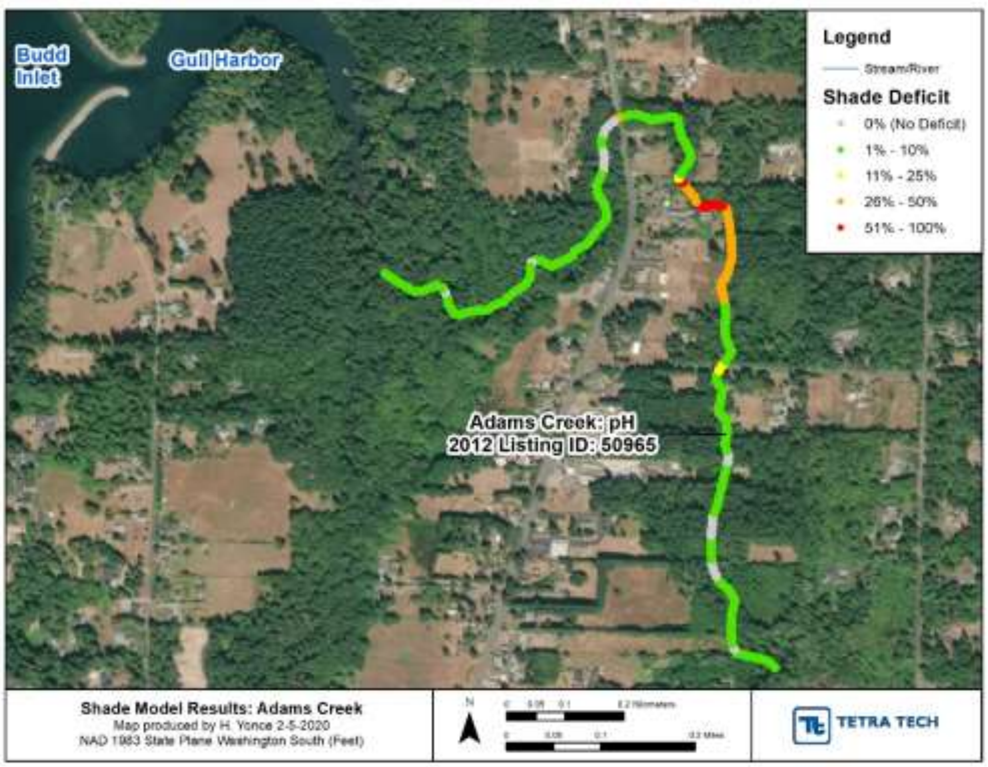


Figure 9. Average daily shade deficit along Adams Creek (East).

2.3 TMDLS: THERMAL HEAT

The TMDL is the highest amount of a pollutant that a waterbody can receive without violating the water quality standard (40 CFR § 130.2(f)). Removing shade deficits by establishing SPV along the riparian corridors will reduce the thermal heat loads to the streams; the resulting microclimate effects are anticipated to reduce near-stream air temperatures, ultimately reducing water temperatures. TMDLs for water temperature are expressed using a surrogate measure, daily solar heat load (averaged over the day), which corresponds with the revegetation of riparian buffers to SPV (Table 7). The solar heat TMDLs are based on the critical summer period (shade simulation on July 24), thus, are the maximum allowable daily loads. The TMDLs were converted from Shade.xls model output units of W/m^2 (

Table 6) to $kWh/m^2/day$ as an average of all segments. The daily TMDL in KWh/day was calculated per segment by multiplying the load from each segment by the 10 m segment length and 72 m total riparian buffer width, and then the segment loads were summed to get the TMDL along the length of the impaired waterbody. Targets for longitudinal increments at a finer resolution are presented in Appendix F-1 because the TMDLs vary along the length of the stream. The SPV effective shade values are typically greater than 95%, except for Ayer Creek due to site-specific limitations relative to type of riparian vegetation (e.g., wetland soil type) and large stream width. The solar heat TMDLs are higher where the achievable SPV results in lower effective shade, such as along Ayer Creek (i.e., due to the presence of wetlands). Lake Lawrence Creek and Adams Creek are not listed as impaired for water temperature; the riparian shade and solar heat TMDLs are established to support attainment of DO and pH criteria in these creeks as well as support water quality improvements in the Deschutes River. Targets established in the approved temperature TMDLs for Black Lake Ditch and Percival Creek are reported in Wagner and Bilhimer (2015).

Table 7. Effective shade targets and daily maximum solar heat TMDLs.

Waterbody	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat ($kWh/m^2/day$)	Daily Heat TMDL (kWh/day)
Huckleberry Creek	96%	97%	1%	0.288	0.192	53,861
Reichel Creek	71%	94%	23%	2.160	0.432	55,602
Tempo Lake Outlet	79%	93%	14%	1.560	0.552	10,908
Unnamed Spring to Deschutes River	99%	99%	<1%	0.115	0.096	413
Ayer Creek	34%	79%	45%	4.968	1.584	175,841
Lake Lawrence Creek[1]	46%	94%	48%	4.056	0.456	43,354
Adams Creek (East)[1]	90%	98%	8%	0.792	0.192	24,848

[1]Lake Lawrence Creek and Adams Creek are not listed as impaired for water temperature; however, riparian shade and heat loading targets are established to support attainment of DO and pH criteria in the creeks as well as support water quality improvements in the Deschutes River.

3.0 NUTRIENTS

This section discusses the basis of using temperature and nutrients as surrogates for the pH and DO impaired tributaries of the Deschutes River. It also provides the technical approach for estimating existing loads and identifying the TMDLs.

3.1 RELATIONSHIP BETWEEN NUTRIENTS, DO, AND PH

3.1.1 Influencing Factors for DO

Instream DO is controlled by multiple factors. Warm waterbodies may exhibit low DO levels because warmer temperatures decrease oxygen solubility (oxygen saturation) in water. Oxygen saturation is the maximum level of dissolved oxygen expected based on the temperature and salinity of the water. The best achievable DO concentration is generally limited to the oxygen saturation level, however, photosynthesis by excess algae during daylight hours can lead to DO concentrations that exceed the DO saturation concentration (supersaturation), which can also be harmful to aquatic life. At nighttime, excess algae can exacerbate low oxygen conditions and cause large diurnal DO fluctuations during respiration.

The addition of oxygen-demanding substances, which may include pollutant loads of dissolved nutrients (nitrogen and phosphorus species), carbonaceous biochemical oxygen demand (CBOD), and organic solids, may also stress oxygen conditions. Oxygen in diffuse groundwater may positively or negatively impact DO conditions in the river. Because physical characteristics like channel bed geometry affect reaeration rates, hydromodifications, such as changes in channel shape or riparian shade resulting from land use activities, for example, can negatively impact reaeration processes. Interactions with the channel bed can act as DO stressors, such as hyporheic exchange with hypoxic pore water and the sediment oxygen demand (SOD) exerted by decaying matter in the sediment.

Periodic stormwater inflows may also act as DO stressors because substances in stormwater runoff delivered to the river accumulate in the water column and sediment over time. Natural processes and anthropogenic activities, such as detrital matter from vegetation on the landscape and fertilizer applied to lawns or cropland, elevate stormwater nutrient loads. As previously discussed, nutrients facilitate the production of algae and contribute to SOD, which can lead to a violation of the DO standard during dry weather conditions.

3.1.2 Influencing Factors for pH

pH deviations are commonly the result of excess floating phytoplankton and attached benthic algae. As discussed above, reduced riparian vegetation limits shade and allows solar radiation to effectively penetrate the water column, enabling an increase in primary productivity, particularly if sufficient nutrients are available. During daylight hours, these autotrophs photosynthesize, producing oxygen (O_2) and removing carbon dioxide (CO_2) as well as bicarbonate ions (HCO_3^-), which increases water column hydroxide (OH^-) and ultimately pH (Chapra, 2014). During nighttime hours, algae respire. Carbon dioxide released through algae respiration forms carbonic acid (H_2CO_3), which dissociates, releases a hydrogen ion, and effectively lowers water column hydroxide and pH. Other potential pH stressor sources include rainwater condition (e.g., acid rain), site geology and lithology, low stream alkalinity (ability to resist changes in pH), inorganic carbon availability, stormwater quality, and point source effluent, where applicable.

3.1.3 Nutrients as a Surrogate for DO and pH

As described above, excess nutrients facilitate the growth of benthic and planktonic algae and submerged plants, which consume oxygen through respiration, lowering DO in the water column, and algal activities impact instream pH responses. Elevated nutrients also enhance decomposition of organic matter in the sediment bed and instigate chemical transformations that deplete water column DO (e.g., nitrification). In addition to this well-established relationship between nutrients and DO and pH levels, nutrients were identified by Ecology in the *2015 Deschutes TMDLs* as the primary cause of the DO and pH water quality concerns in the tributaries (in conjunction with elevated thermal loading). Thus, EPA selected phosphorus and nitrogen as surrogates for DO and pH in the tributaries.

3.2 TECHNICAL APPROACH

Total phosphorus (TP) and total nitrogen (TN) targets were developed as surrogates for waterbodies impaired for DO and/or pH. Elevated water temperatures can also contribute to DO and pH excursions, thus, riparian shade and solar heat loading targets were also established for these segments as described in Section 2.0.

As discussed in Section 3.1.1, biochemical oxygen demand (BOD) is a potential DO stressor. However, the Technical Report (Robert et al. 2012) for the *2015 Deschutes TMDLs* stated BOD is very low throughout the Deschutes River system. While BOD targets are not defined for the DO TMDLs, TN and TP are stoichiometrically related to BOD, and labile organic nitrogen and phosphorus are embedded in BOD, thus, achieving the TN and TP targets will coincide with controlling BOD loading to the receiving waterbodies.

Washington has not adopted numeric nutrient criteria for freshwater streams. However, under the antidegradation policy, human activities that impact water quality are to apply reasonable methods of prevention, control, and treatment of pollutants to restore and maintain surface water quality in Washington (WAC 173-201A-300). Designated uses are to be protected under Tier I of the antidegradation policy, which applies to all surface waters and all sources of pollution, including nutrients although numeric nutrient criteria have not been issued for streams by Washington. In alignment with the antidegradation policy and to protect DO and pH conditions in the tributaries, nutrient targets are established for the TMDLs.

EPA applied a reference site-based approach for developing nutrient targets and TMDLs for the tributaries impaired by pH and/or DO. In the absence of numeric criteria, using reference site data as a basis to translate the narrative criteria into a numeric target for TMDL development is a common approach, as described in EPA's Protocol for Developing Nutrient TMDLs (EPA, 1999). EPA recommends applying the 25^{th} percentile condition from a reference population of streams with varying levels of human influence because it is likely associated with lower levels of disturbance in the catchments (EPA, 2000a; EPA, 2000b). This approach is implemented to determine nutrient concentration targets for the TMDLs.

The technical approach is reasonable for establishing DO and pH TMDLs for the following reasons:

- The scientific literature has established that elevated nutrient loads promote excessive algae, which contribute to instream DO and pH fluctuations that can violate water quality standards;
- Surrogate nutrient targets have been implemented in DO and pH TMDLs in Washington (Moore and Ross, 2010; Snouwaert and Stuart, 2015);
- The approach applies ambient TN and TP values recommended by EPA for establishing targets for TMDLs;
- The target values applied to develop TN and TP TMDLs are based on reference streams within the ecoregion.

3.3 MONITORING DATA

Monitoring data from 2000 to present from EIM and Thurston County were reviewed. DO monitoring records are summarized in Table 8 for waterbodies impaired for DO addressed in this report. The lowest minimum DO record is associated with Ayer Creek (1.1 mg/L) where average DO is also quite low (3.6 mg/L) based on monitoring completed in 2003 and 2004.

Table 8. Observed DO concentration data for waterbodies impaired for DO (mg/L).

Waterbody	Data Source	Period of Record	Water Quality Standard (mg/L)	Sample Count	Mean	Min	Max
Ayer Creek	EIM	7/9/2003 – 12/28/2004	8.0	36	3.6	1.1	8.6

Waterbody	Data Source	Period of Record	Water Quality Standard (mg/L)	Sample Count	Mean	Min	Max
Black Lake Ditch	EIM and Thurston County	7/9/2003 - 9/12/2018	9.5	252	9.4	5.3	16.4
Lake Lawrence Creek	EIM	9/3/2003 – 10/13/2004	9.5	3	2.6	2.4	2.8
Percival Creek	EIM and Thurston County	1/19/2000 – 9/13/2017	9.5	248	10.9	8.4	14.3
Reichel Creek	EIM and Thurston County	7/1/2003 – 9/10/2018	9.5	168	9.1	4.3	13.2

Monitoring shows pH values outside of the water quality standard (

Table 9). Ayer Creek and Adams Creek have exhibited lower pH conditions (6.2 s.u.) whereas high pH excursions have been observed at Black Lake Ditch (9.5 s.u.).

Table 9. Observed pH (s.u.) for waterbodies impaired for pH.

Waterbody	Source	Period of Record	Water Quality Standard (s.u.)	Count	Mean	Min	Max
Adams Creek (East)	EIM	7/1/2003 – 12/28/2004	6.5 - 8.5	55	6.9	6.2	7.8
Ayer Creek	EIM	7/9/2003 – 10/13/2004	6.5 - 8.5	29	6.7	6.2	7.6
Black Lake Ditch	EIM and Thurston County	7/9/2003 – 8/6/2018	6.5 - 8.5	255	7.2	6.4	9.5

Nutrient monitoring data for the DO and pH impaired waterbodies are summarized in Table 10 and Table 11. Maximum TN concentrations exceeded 1 mg/L at Ayer Creek, Adams Creek, Lake Lawrence Creek and Reichel Creek, and the highest TP concentrations are associated with the former two impaired waterbodies.

Table 10. Observed TN for waterbodies impaired for DO and/or pH (mg/L).

Waterbody	Data Source[1]	Period of Record	Count	Mean	Min	Max
Adams Creek (East)	EIM	10/12/2004 – 3/29/2005	10	1.1	0.5	1.5
Ayer Creek	EIM	1/14/2004 – 3/29/2005	20	0.7	0.2	1.5
Black Lake Ditch	EIM	1/13/2004 – 12/28/2004	14	0.4	0.2	0.5
Lake Lawrence Creek	EIM	10/13/2004 (single day)	2	1.7	1.7	1.7
Percival Creek	EIM	7/1/2003 – 3/29/2005	46	0.5	0.3	0.9
Reichel Creek	EIM	1/14/2004 – 12/28/2004	16	0.7	0.1	1.2

[1]Thurston County water quality monitoring did not include TN or all constituents necessary to compute TN.

Table 11. Observed TP for waterbodies impaired for DO and/or pH (mg/L).

Waterbody	Data Source	Period of Record	Count	Mean	Min	Max
Adams Creek (East)	EIM	10/12/2004 – 3/29/2005	8	0.08	0.03	0.23
Ayer Creek	EIM	1/14/2004 – 3/29/2005	18	0.07	0.04	0.16
Black Lake Ditch	EIM and Thurston County	1/13/2004 – 9/12/2018	181	0.03	0.01	0.08
Lake Lawrence Creek	EIM	10/13/2004 (single day)	1	0.05	0.05	0.05
Percival Creek	EIM and Thurston County	1/19/2000 – 9/13/2017	240	0.03	0.01	0.09
Reichel Creek	EIM and Thurston County	1/14/2004 – 9/10/2018	153	0.06	0.02	0.11

3.4 TECHNICAL ANALYSIS

The targets established for these TMDLs correspond to ambient water quality criteria recommendations developed by EPA and aggregated by Level II and Level III ecoregions (EPA, 2000a). The upper portion of the Reichel Creek drainage area is in the Cascades Level III ecoregion; however, the outlet of Reichel Creek is in the

Puget Lowlands Level III ecoregion so the recommended criteria for the Puget Lowlands Level III ecoregion were applied for establishing TN and TP targets for Reichel Creek. The drainage areas of the other pH and DO impaired tributaries are fully within the Puget Lowlands Level III ecoregion. Recommended criteria for TN and TP are included for the Puget Lowlands Level III ecoregion: 0.34 mg/L for TN and 0.0195 mg/L (19.5 µg/L) for TP. These values were used as nutrient targets for DO and pH impaired tributaries.

Mean observed TN and TP concentrations for all the DO and pH impaired waterbodies addressed in this report exceed the defined target. Maximum TN concentrations observed at Adams Creek and Ayer Creek are more than four times higher than the TN target and the maximum TN concentration observed at Reichel Creek is more than three times higher than the target. Observed TP concentrations are also elevated compared to the TP target. Mean TN and TP concentrations for Black Lake Ditch are only slightly higher than the target at 0.4 mg/L and 0.02 mg/L for TN and TP.

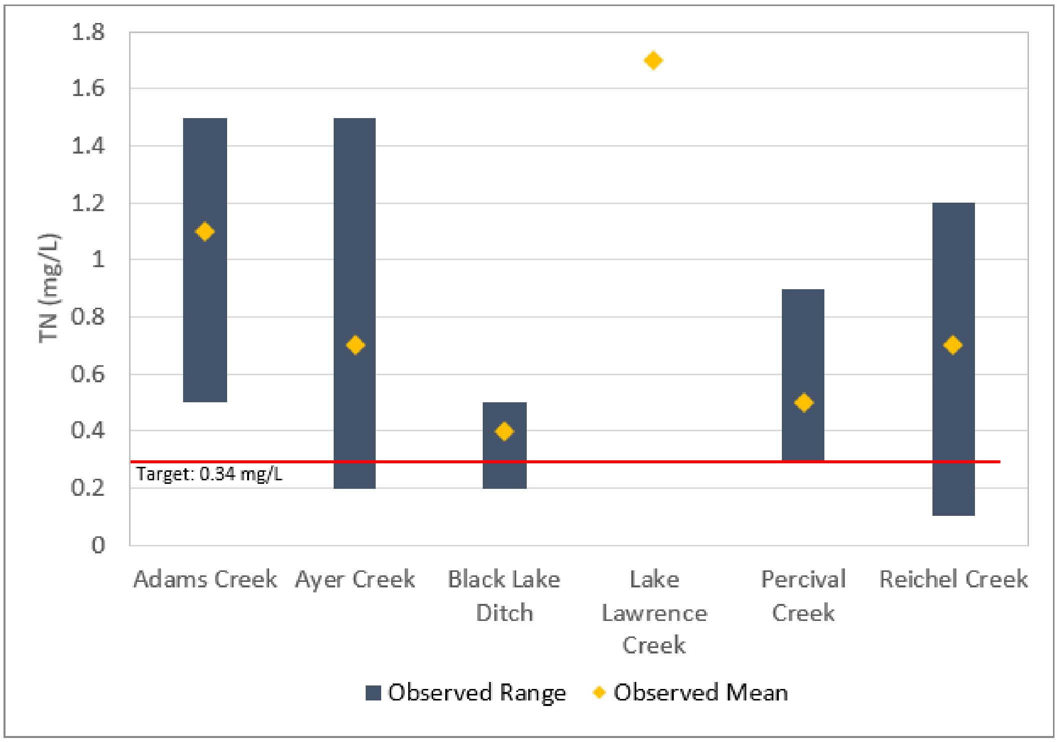


Figure 10. Observed TN concentrations for waterbodies impaired for DO and/or pH and the target ambient TN concentration for the Puget Lowlands Ecoregion (Level III).

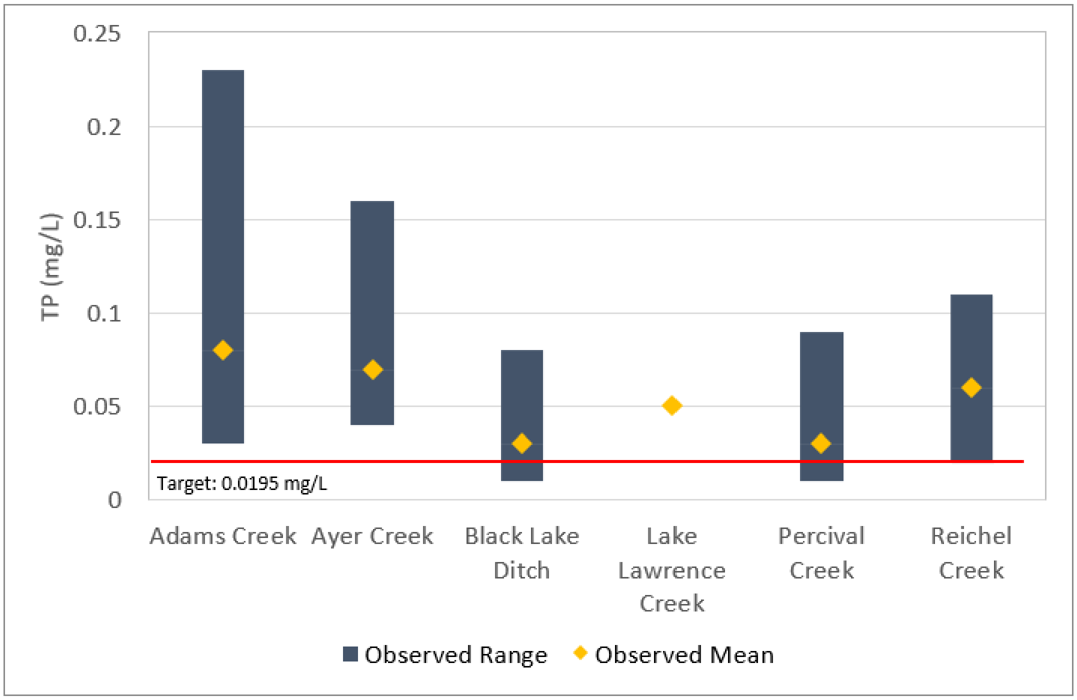


Figure 11. Observed TP concentrations for waterbodies impaired for DO and/or pH and the target ambient TP concentration for the Puget Lowlands Ecoregion (Level III).

3.5 TMDLS: NUTRIENTS

The nutrient TMDLs are expressed as flow-varied loads based on the TN and TP concentration targets (0.34 mg-N/L and 0.0195 mg-P/L):

$$TN\ TMDL = Q \times 0.34 \times 2.45$$

where $TN\ TMDL$ is the total maximum daily TN load in units of kilograms per day, Q is the daily streamflow in units of cubic feet per second, 0.34 is the TN concentration target in units of milligrams per liter, and 2.45 is a multiplicative factor to convert the load to units of kilograms per day.

$$TP\ TMDL = Q \times 0.0195 \times 2.45$$

Where$TP\ TMDL$ is the total maximum daily TP load in units of kilograms per day, Q is the daily streamflow in units of cubic feet per second, 0.0195 is the TP concentration target in units of milligrams per liter, and 2.45 is a multiplicative factor to convert the load to units of kilograms per day.

Because the TMDLs vary with flow, two different TN and TP TMDLs were calculated for each tributary to show the variation in loads between those associated with average flow conditions and 95th percentile flow (met or exceeded 5 percent of the time) (Table 12). Where long-term flow gaging records were not available, flows are based on daily flows observed at the Deschutes River at Tumwater United States Geological Survey (USGS) gage (period of 10/1/1997 to 9/30/2018) scaled based on relative drainage area. Long-term flow gaging records were available for Black Lake Ditch (period of 2/23/1988 to 6/4/1998) and were applied directly. Black Lake Ditch is a tributary to Percival Creek and flows originating from the Black Lake Ditch drainage area were based on gage records. Flows originating from the remainder of the drainage area to Percival Creek were estimated using the Tumwater gage scaling method.

Table 12. TN and TP TMDLs for waterbodies impaired for DO and/or pH.

Waterbody	Average Daily Flow (cfs)	95th Percentile Flow (cfs)	TN Total Maximum Daily Load (kg/day)		TP Total Maximum Daily Load (kg/day)	
			Based on Average Daily Flow	Based on 95th Percentile Flow	Based on Average Daily Flow	Based on 95th Percentile Flow
Adams Creek (East)	2.1	6.4	1.8	5.4	0.10	0.31
Ayer Creek	3.3	10	2.8	8.4	0.16	0.48
Black Lake Ditch	61	202	51	168	2.9	9.6
Lake Lawrence Creek	7.4	22	6.1	19	0.35	1.1
Percival Creek	75	244	62	203	3.6	12
Reichel Creek	19	56	16	47	0.89	2.7

The percent reductions required for nitrogen and phosphorus based on the maximum observed concentrations in the tributaries (from the data summarized in Table 10 and Table 11) are shown in the following figures.

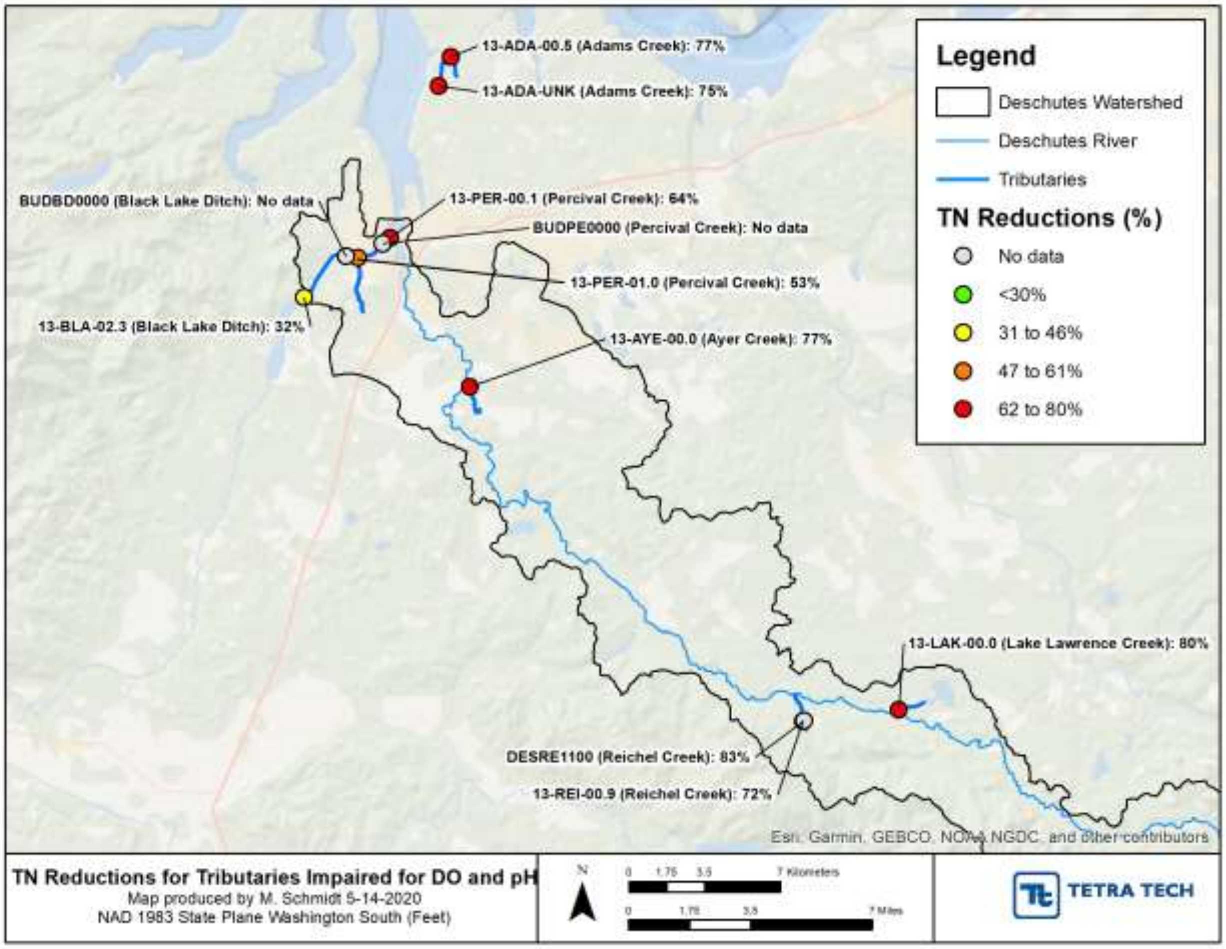


Figure 12. Required nitrogen reductions for tributaries impaired for DO and pH (based on maximum observed concentration and target concentration).

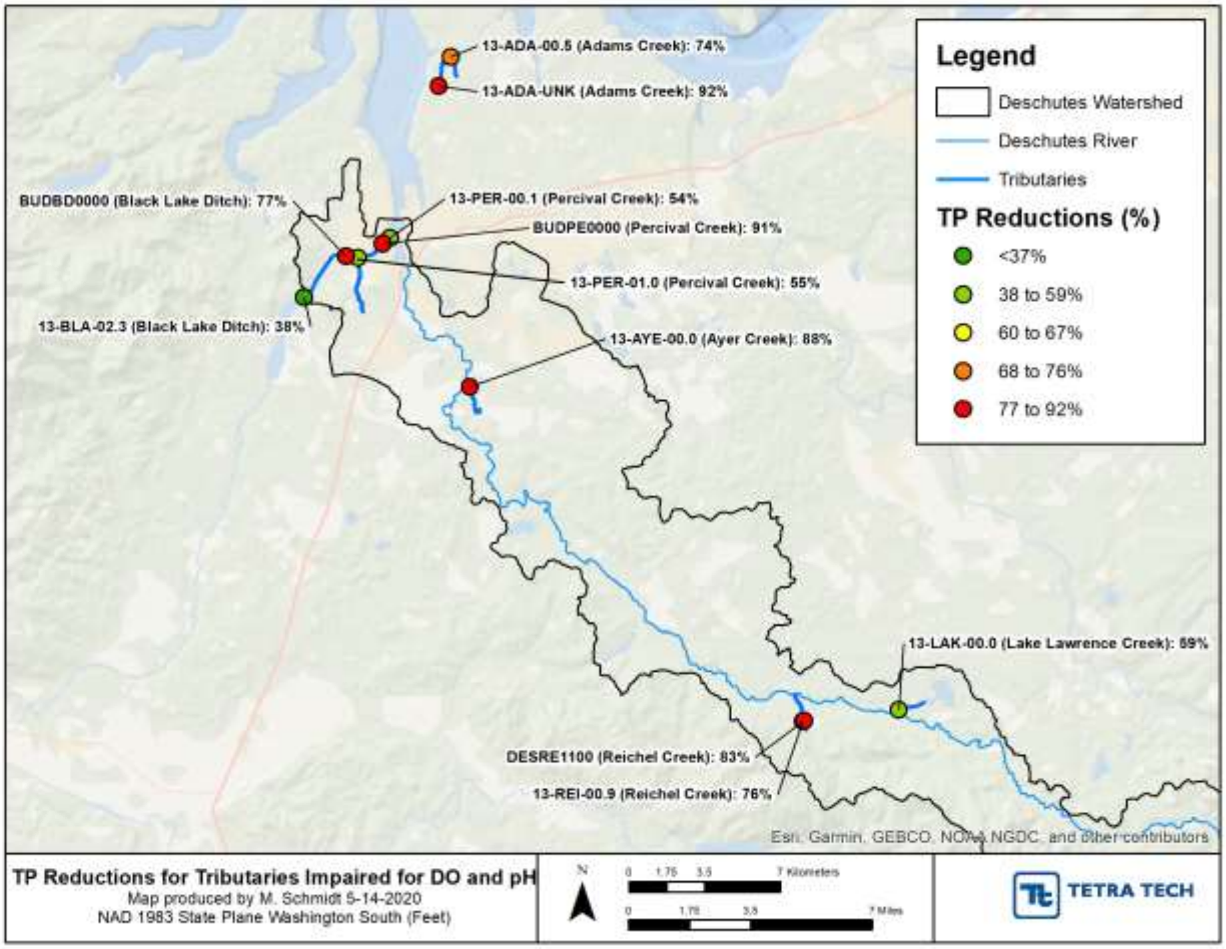


Figure 13. Required phosphorus reductions for tributaries impaired for DO and pH.

4.0 SOURCE ASSESSMENT

This section describes the source assessment for point sources within the watersheds of the tributaries impaired for tributary temperature, DO, and pH. According to a query of Ecology's Water Quality Permitting and Reporting System (PARIS) in April 2020, the USEPA's National Pollutant Discharge Elimination System (NPDES) permitted sources in the watersheds for the impaired tributaries include city and county MS4s as well as facilities covered under the General Permits for Industrial Stormwater and Sand and Gravel (
Table 13). There are also 13 permittees under the Construction Stormwater General Permit. Although construction stormwater is a short-term source, active permits are summarized here, and included in the source assessment in recognition that there will likely be an ongoing level of construction activity in the tributary watersheds with permittees authorized to discharge under that permit. This section includes a summary of each type of permit included in the source assessment and the approach used to estimate currently loading.

Table 13. NPDES permitted stormwater sources.

Permittee	Permit Number	Permit Type	Receiving Water(s)
K and M Quarry (Black Lake Quarry)	WAG501118	Sand and Gravel	Black Lake Ditch
Pepsi Northwest Beverages LLC	WAR009988	Industrial Stormwater	Black Lake Ditch
Pepsi Northwest Beverages LLC	WAR004082	Industrial Stormwater	Black Lake Ditch
Devlin Designing Boat Builders	CNE301457	Industrial Stormwater	Black Lake Ditch
Truss Components of Washington	WAR000758	Industrial Stormwater	Percival Creek
City of Tumwater	WAR045020	MS4	Black Lake Ditch and Percival Creek
Thurston County	WAR045025	MS4	Adams Creek, Ayer Creek, Black Lake Ditch, Percival Creek
City of Olympia	WAR045015	MS4	Black Lake Ditch and Percival Creek
WSDOT	WAR043000A	MS4	Black Lake Ditch and Percival Creek
Keanland Park	WAR301629	Construction Stormwater	Ayer Creek
Woodbury Crossing Multi-Family	WAR304598	Construction Stormwater	Black Lake Ditch and Percival Creek
Fieldstone	WAR305028	Construction Stormwater	Black Lake Ditch and Percival Creek
Capital High School Performing Arts Center	WAR307830	Construction Stormwater	Black Lake Ditch and Percival Creek
Olympia Orthopedic Associates Facility	WAR307941	Construction Stormwater	Black Lake Ditch and Percival Creek
Ernies Trailer	WAR308092	Construction Stormwater	Black Lake Ditch and Percival Creek
Olympia McDonalds Redevelopment	WAR308726	Construction Stormwater	Black Lake Ditch and Percival Creek
The 80 West Apartments	WAR304653	Construction Stormwater	Percival Creek
Forest Park Townhomes	WAR304711	Construction Stormwater	Percival Creek
Tumwater Pointe Apartments	WAR306799	Construction Stormwater	Percival Creek
SPSCC Health and Wellness Center	WAR307331	Construction Stormwater	Percival Creek
Genesis Acres	WAR308019	Construction Stormwater	Percival Creek
Wellington - Lennar	WAR308398	Construction Stormwater	Percival Creek

4.1 SUMMARY OF PERMIT TYPES

This section gives an overview of all the permit types in

Table 13.

Municipal Separate Storm Sewer Systems (MS4s)

Urban areas that collect stormwater runoff and discharge it to surface waters are required to have a NPDES MS4 permit under the Clean Water Act (CWA). Incorporated cities with populations over 100,000 and unincorporated counties with populations over 250,000 are regulated under Phase I permits, and smaller jurisdictions are regulated under Phase II permits. Entities in the study area hold active Western Washington Phase II Municipal Stormwater Permits, including the cities of Olympia and Tumwater, and Thurston County. A Phase I Municipal Stormwater Permit is held by WSDOT and associated land intersecting the catchments is the responsibility of WSDOT (Wagner and Bilhimer, 2015). MS4 permittees are required to use available methods of prevention, control, and treatment to prevent and manage pollution to waters of the state to meet the goals of the CWA.

Sand and Gravel Stormwater Discharges

Sand and gravel process, dewatering, and stormwater discharges covered by NPDES permits are subject to regulations specified in Ecology's *Sand and Gravel General Permit* (effective April 1, 2018). Depending on the type of sand and gravel activity, water quality sampling may be required to be reported regularly in Discharge Monitoring Reports (DMRs). Monitoring constituents vary, but may include: pH, turbidity, total suspended solids, oil sheen, and total dissolved solids. Water temperature is considered for sampling if the receiving waterbody is impaired for temperature. Sampling frequency requirements vary from none required, once per month, twice monthly, quarterly, or daily when runoff occurs. All facilities must have an Erosion and Sediment Control Plan.

Industrial Stormwater Discharges

Ecology's *Industrial Stormwater General Permit* (as modified, effective January 2, 2015) sets requirements for eligible discharges associated with Industrial stormwater. Depending on the type of industrial activity, stormwater discharges have the potential to contain nutrients or other constituents, which can contribute to low oxygen levels or pH excursions in receiving waters. All industrial stormwater general permittees are required to monitor turbidity, pH, total copper, total zinc, and oil sheen at varying frequency, generally shown to be once per year. Industrial stormwater sites only require sampling of BOD_5, nitrate+nitrite, and TP if activities include "chemical and allied products", "air transportation", or "food and kindred products". Additional sampling related to nutrients may be required if the discharge waterbody is impaired for nutrients.

Construction Stormwater Discharges

Construction stormwater discharges covered by NPDES permits are subject to conditions in Ecology's *Construction Stormwater General Permit* (as modified, effective January 1, 2016). The General Permit for Construction Stormwater specifies that permit holders are required to not contribute to violation of surface water and groundwater quality standards and sediment management standards. Facilities covered by the permit must implement all known, available, and reasonable methods of prevention, control, and treatment develop and implement a Stormwater Pollution Prevention Plan and apply stormwater Best Management Practices (BMPs). Active construction stormwater permittees within the tributary catchments are listed in

Table 13.

4.2 TEMPERATURE

The point sources in

Table 13 within the watersheds with temperature TMDLs are a construction stormwater permittee for Ayer Creek and the Thurston County MS4 for Ayer and Adams creeks. The main stressor for water temperature is shade loss and elevated solar heat loading, and other sources (e.g., urban stormwater) are not expected to significantly contribute to the elevated water temperatures in the assessed segments, particularly during the summer when stream temperatures are at their highest. Therefore, thermal loading from stormwater discharges are not included in the source assessment. However, thermal loading associated with the loss of riparian shade within the Thurston County MS4 was estimated.

There are riparian areas along Adams Creek and Ayer Creek that are designated as MS4 regulated land for Thurston County. For Ayer Creek, the riparian area for the most upstream 200 meters of the creek is within MS4 boundaries, which is highlighted in Appendix F-1, Table F-1 (segments 0 to 200m). From 210 meters to the mouth of Ayer Creek is non-MS4 riparian land. For Adams Creek, the last 700 meters of riparian segments near the mouth are within the MS4 boundary, and they are highlighted in Appendix F-1, Table F-3 (segments 1210 to 1910m). The remaining upstream segments (0 to 1200 meters) are non-MS4 land (Table F-3). The existing and target effective shade values within each MS4 are an average based on the effective shade values in Appendix F-1, and the existing heat load is calculated by summing the load from the segments that fall within the MS4 boundary for each tributary and then converting them from an area-based load to kilowatt-hours per day by multiplying by the segment length and riparian buffer width of 72m (Table 14).

Table 14. Existing heat load and effective shade within the MS4 boundaries.

Waterbody	Existing Daily Heat Load (kWh/day)	Existing Effective Shade	Effective Shade Target
Adams Creek	9,280	97%	97%
Ayer Creek	77,546	32%	90%

4.3 NUTRIENTS

As part of the nutrient source assessment, existing nutrient loads are estimated for sources in the catchments of the tributaries impaired for pH and/or DO, which include Adams Creek, Ayer Creek, Black Lake Ditch, Lake Lawrence Creek, Percival Creek and Reichel Creek.

Municipal Separate Storm Sewer Systems (MS4s)

The dynamics of nutrient loading in urban streams poses a challenge for quantifying MS4 stormwater flows and loads. Factors such as unknown event mean concentrations at stormwater outfalls and uncertain stormwater flow pathways, runoff volumes, and subsurface conveyances contribute to the general uncertainty that makes quantifying urban stormwater flows and loads particularly difficult. These TMDLs use the best information available for predicted stormwater runoff from MS4 regulated areas and urban stormwater quality conditions to approximate nutrient loads for the MS4s that drain to the tributaries impaired for DO and/or, pH. The following segments have contributing catchments with MS4 jurisdictions within their boundaries (Figure 14 and Figure 15):

- Ayer Creek (5850 for pH, 5851 for DO)

- Adams Creek (East; 50965 for pH)
- Black Lake Ditch (50989 for pH and 47761 for DO)
- Percival Creek (48085 for DO)

Land within MS4 boundaries represent MS4 regulated areas. WSDOT has responsible land within the Percival Creek and Black Lake Ditch catchments (Interstate 5 corridor and U.S. 101 corridor). A linear coverage from WSDOT[1] was applied to approximate WSDOT responsible land. Highway ramps and crossroads within interchanges were buffered by 15 feet (30 feet total width across the lane and shoulder) and the four-lane, single direction roads were buffered by 60 feet (about 175 feet total width across the eight lanes, shoulder, and median). The buffered areas were merged and cut out of the overlapping MS4s. MS4 regulated land applied in the analysis included all areas (both developed and undeveloped) within the MS4 boundaries. The percent of catchment attributed to MS4s and non-MS4 areas for the waterbodies is shown in Figure 15. Waterbodies impaired for DO, pH, and/or water temperature with catchments fully attributed to non-MS4 areas are not shown, including Lake Lawrence Creek, Reichel Creek, Huckleberry Creek, Tempo Lake Outlet and the Unnamed Spring.

Table 15. Permitted MS4s in catchments of waterbodies impaired for temperature, DO, and/or pH.

Jurisdiction	Permit Type	Permit Number
City of Olympia	Western Washington Phase II Municipal Stormwater Permit	WAR045015
City of Tumwater	Western Washington Phase II Municipal Stormwater Permit	WAR045020
Thurston County	Western Washington Phase II Municipal Stormwater Permit	WAR045025
WSDOT	WSDOT Phase I Municipal Stormwater Permit	WAR043000A

[1] NatHwySysState.shp, obtained from https://www.wsdot.wa.gov/mapsdata/geodatacatalog/default.htm.

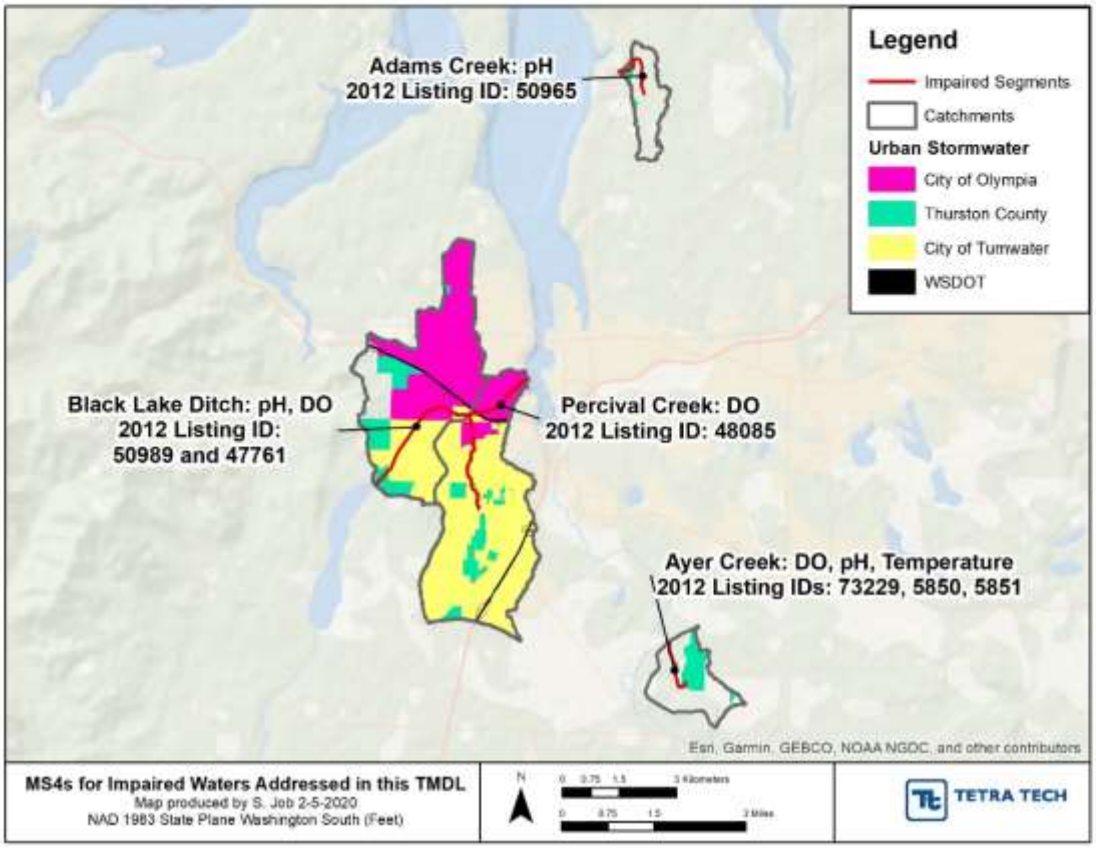
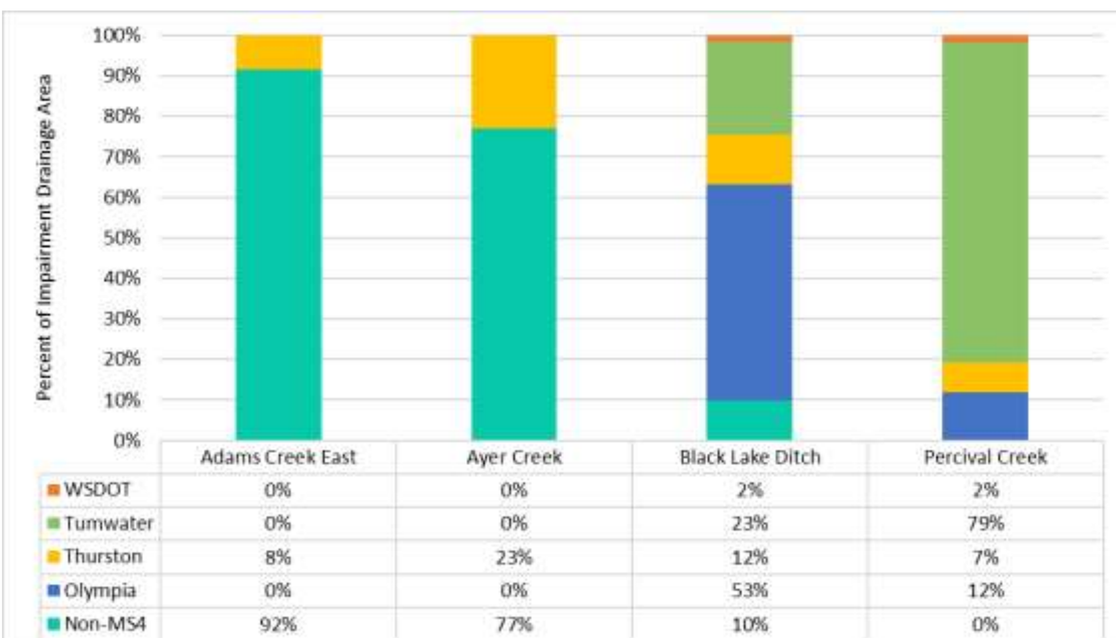


Figure 14. MS4 boundaries within catchments for waterbodies impaired for temperature, DO and/or pH.



	Adams Creek East	Ayer Creek	Black Lake Ditch	Percival Creek
WSDOT	0%	0%	2%	2%
Tumwater	0%	0%	23%	79%
Thurston	8%	23%	12%	7%
Olympia	0%	0%	53%	12%
Non-MS4	92%	77%	10%	0%

Figure 15. Percent of tributary catchment attributed to MS4s and non-MS4 areas for waterbodies.

Existing nutrient loads from MS4s were calculated as the product of estimated annual runoff for the area and regional Event Mean Concentrations (EMCs) for urban and undeveloped land. The Simple Method (Schueler, 1987) was applied to estimate annual runoff within MS4 boundaries. The Simple Method was originally developed as an efficient, yet reasonably accurate, method to estimate stormwater runoff and associated nutrient loads for urban lands. The Simple Method is an empirical formulation based on data from several dozen sites spanning the range of possible percent imperviousness. It has been adopted and adapted by numerous municipalities and agencies since its publication for various purposes, chiefly in relation to compliance with stormwater management criteria. The form of the equation is as follows:

$$R = 0.9 * P * (0.05 + 0.9\, I_a)$$

where *R* is the runoff depth (inches), *P* is the annual precipitation depth (inches), and I_a is the impervious area fraction (0 to 1). The method does not consider variations in infiltration potential of the pervious areas. However, in practice, most developed urban soils have lost much of their infiltration potential following site disturbance and compaction.

The average annual precipitation depth between 2000 – 2018 at the Olympia Airport Global Historical Climatology Network Daily (GHCND: USW00024227) was about 50.14 inches, and this value was universally applied in the computation of runoff depth, *P*. Runoff volume calculations were performed separately for the developed and undeveloped portions of each combination of catchment and MS4 permittee. This approach was used because different representative stormwater concentrations were applied for developed and undeveloped areas (discussed more below), and because the distribution of imperviousness varies across the watershed. The area of each land use category (e.g., forest) within each combination of catchment and responsible entity (e.g., Thurston County portion of the Adams Creek drainage area) was tabulated from the National Land Cover Dataset (NLCD 2011 at a 30-meter resolution). The land use categories were then reclassified into either “developed” or “undeveloped” categories. NLCD classes included in the “developed” umbrella category were “Developed, Open Space”, “Developed, Low Intensity”, “Developed, Medium Intensity”, and “Developed, High Intensity”. All other land use categories were considered “undeveloped”. For each developed portion of an MS4 within a catchment, the average percent impervious area was approximated using the NLCD 2011 imperviousness grid (see Table 16 - Table 19). For undeveloped areas, the impervious area was assumed to equal zero, resulting in a uniform undeveloped runoff depth of 2.3 inches per year. The product of *R* and the contributing area yields the annual runoff volume.

Table 16. Runoff approximation summary for Adams Creek (East).

Jurisdiction	Developed Percent Imperviousness	Developed Runoff Depth (in/yr)	Developed Runoff Volume (ac ft/yr)	Undeveloped Runoff Volume (ac ft/yr)
Thurston	23%	11.7	18.6	1.7

Table 17. Runoff approximation summary for Ayer Creek.

Jurisdiction	Developed Percent Imperviousness	Developed Runoff Depth (in/yr)	Developed Runoff Volume (ac ft/yr)	Undeveloped Runoff Volume (ac ft/yr)
Thurston	16%	8.6	72.8	16.2

Table 18. Runoff approximation summary for Black Lake Ditch.

Jurisdiction	Developed Percent Imperviousness	Developed Runoff Depth (in/yr)	Developed Runoff Volume (ac ft/yr)	Undeveloped Runoff Volume (ac ft/yr)
Olympia	47%	21.4	2,365	65.2
Tumwater	47%	21.2	816	48.1
Thurston Co.	23%	11.6	128	46.9
WSDOT	65%	28.7	121	<0.1

Table 19. Runoff approximation summary for Percival Creek[1].

Jurisdiction	Developed Percent Imperviousness	Developed Runoff Depth (in/yr)	Developed Runoff Volume (ac ft/yr)	Undeveloped Runoff Volume (ac ft/yr)
Olympia	47%	21.4	2,888	85.9
Tumwater	40%	18.7	3,929	163
Thurston Co.	24%	12.1	301	62.8
WSDOT	68%	29.7	283	<0.1

[1]Includes sources in the upstream Black Lake Ditch catchment.

Stormwater monitoring data collected by NPDES Phase I MS4s in western Washington (Hobbs et al., 2015) were used to characterize representative urban EMCs. The median reported TP EMC for western Washington permittees (110 µg/L; Hobbs et al., 2015) was applied as the representative concentration for establishing MS4 TP loads for developed lands. The median concentration was applied because it is less affected by outliers and small sample sizes compared to the average concentration. Similarly, the median reported EMCs for total Kjeldahl nitrogen (TKN) and nitrite+nitrate (863 µg/L and 245 µg/L, respectively) were summed to obtain the TN EMC for western Washington permittees (1,108 µg/L).

The undeveloped land EMCs were more difficult to specify, since a regional study or data source for undeveloped monitoring could not be located. The manual for the pollutant load application tool (PLOAD) (EPA, 2001), a GIS-based application used to calculate nonpoint sources of pollution, provides summaries of nutrient monitoring data for both developed and undeveloped uses. (Note undeveloped uses in the catchments are defined as all non-developed NLCD classes, such as forest, pasture, herbaceous, shrub/scrub, and wetlands). The undeveloped TP EMC, 50.8 µg/L, was approximated from the ratio of undeveloped to developed TP EMCs listed in the PLOAD manual for the nation (0.46). The ratios of undeveloped to developed TKN and nitrite+nitrate EMCs in the PLOAD manual for the nation (0.75 and 0.97, respectively) were used to approximate an undeveloped TN EMC of 885 µg/L. The representative developed and undeveloped EMCs were combined with predicted runoff volumes to compute existing average daily loads (annual load / 365.25 days per year) for the MS4s (

Table 20 and Table 21).

Table 20. Approximate existing stormwater TP loads (kg/day) from MS4s.

Jurisdiction	Adams Creek	Ayer Creek	Black Lake Ditch	Percival Creek[1]
Olympia	NA	NA	0.890	1.09
Tumwater	NA	NA	0.311	1.49
Thurston	0.008	0.030	0.056	0.123
WSDOT	NA	NA	0.045	0.105

[1]Percival Creek loads include sources in the upstream Black Lake Ditch catchment.

Table 21. Approximate existing urban stormwater TN loads (kg/day) from MS4s.

Jurisdiction	Adams Creek	Ayer Creek	Black Lake Ditch	Percival Creek[1]
Olympia	NA	NA	9.05	11.1
Tumwater	NA	NA	3.20	15.2
Thurston	0.08	0.32	0.62	1.31
WSDOT	NA	NA	0.45	1.06

[1]Percival Creek loads include sources in the upstream Black Lake Ditch catchment.

Sand and Gravel Stormwater Discharges

The only two facilities authorized to discharge under the Sand and Gravel General Permit that are located within tributary drainages addressed in this report are both in the Black Lake Ditch drainage. Concrete Recyclers (WAG501507) discharges to groundwater and to an infiltration basin at Black Lake Quarry, which is the other permitted facility (K and M Quarry; WAG501118). Therefore, EPA does not consider Concrete Recyclers a direct discharge to Black Lake Ditch (which would require a WLA) and it is not explicitly included in the source assessment. Black Lake Quarry is permitted to discharge site stormwater and mine dewatering water to Black Lake Ditch, which is impaired for pH, DO, and temperature. The facility has a turbidity limit for its stormwater of 50 NTU and a pH range of 6.5-8.5. The facility conducts routine stormwater quality sampling including monitoring of oil and grease, turbidity, and pH (reported pH values range from 7.7 to 8 s.u.), but it does not have nutrient or temperature monitoring requirements. DMRs for this facility do not report relevant parameters.

The dewatering discharge is not considered a source of nutrient loading, but the stormwater runoff could potentially be a source (A. Caroll-Perkins, personal communication, 4/10/2020). Since there is no nutrient monitoring requirement, and thus no discharge monitoring data to quantify existing nutrient loads from Black Lake Quarry, regional stormwater EMCs were also used to estimate nutrient loads associated with discharges covered under the Sand and Gravel General Permit. Therefore, representative concentrations for industrial land reported for NPDES Phase I Stormwater permittees in western Washington (Hobbs et al., 2015) are applied – TN: 1,095 µg/L and TP: 171 µg/L. Runoff depth is estimated using the Simple Method (described in the MS4 section above) and it is combined with the facility footprint area provided by Ecology (L. Weiss, personal communication, 9/27/2019) to estimate runoff volume. The site footprint, which is 102 acres, is conservatively assumed to be fully impervious, thus resulting in a runoff depth of R = 42.9 inches or 3.58 feet that is combined with the footprint area to estimate the runoff volume. The site area and approximated existing daily average stormwater loads for Black Lake Quarry are presented in

Table 22.

Table 22. Approximate existing stormwater TN and TP loads for Black Lake Quarry.

Facility	Site Area (acres)	Waterbody	TN Load (kg/day)	TP Load (kg/day)
Black Lake Quarry (K and M Quarry; WAG501118)	102	Black Lake Ditch	1.347	0.210

Industrial Stormwater Discharges

There are currently four facilities authorized to discharge under the Industrial Stormwater General Permit that are located within two tributary drainages addressed in this report. Pepsi Northwest Beverages LLC (WAR009988 and WAR004082) and Devlin Designing Boat Builders (CNE301457) are permitted to discharge industrial stormwater within the drainage area of Black Lake Ditch. CNE301457 is not included in the source assessment because it is self-certified as a no-exposure facility, meaning the stormwater has no exposure to any industrial products and they do not have industrial stormwater discharge. Truss Components of Washington, INC (WAR000758) is permitted to discharge industrial stormwater within the drainage area of Percival Creek.

Based on EPA's review of the current permits, Truss Components has a Carbonaceous Oxygen Demand limit, and the Pepsi Northwest facilities process "food and kindred products", which requires a limit corresponding to the pH water quality standard (6.5-8.5), and benchmark values for TP and nitrate. The DMRs for the Pepsi Northwest facilities did not contain any nutrient results, so representative concentrations for industrial urban land reported for NPDES Phase I Stormwater permittees in western Washington (Hobbs et al., 2015) were used to estimate existing loads for all permitted facilities – TN: 1,095 µg/L and TP: 171 µg/L. Runoff depth is estimated using the Simple Method (described in the MS4 section above) and it is combined with the facility footprint area provided by Ecology (L. Weiss, personal communication, 9/27/2019) to estimate runoff volume. Site footprints are conservatively assumed to be fully impervious, thus, resulting in a runoff depth of R = 42.9 inches or 3.58 feet that is combined with the footprint area to estimate the runoff volume. Site areas and approximated existing daily average stormwater loads for industrial facilities are listed in Table 23.

Table 23. Approximate existing stormwater TN and TP loads for industrial facilities.

Facility	Site Area (acres)	Waterbody	TN Load (kg/day)	TP Load (kg/day)
Pepsi Northwest Beverages LLC (WAR009988)	4.0	Black Lake Ditch	0.053	0.008
Pepsi Northwest Beverages LLC (WAR004082)	24.2	Black Lake Ditch	0.320	0.050
Truss Components of Washington (WAR000758)	2.0	Percival Creek	0.026	0.004

Construction Stormwater Discharges

All active construction stormwater permittees in the catchments of the tributaries impaired for water temperature, DO and/or pH are within MS4 boundaries, excluding Keanland Park in the Ayer Creek catchment. Therefore, current loading from active construction sites is inexplicitly aggregated with MS4 existing loads (except for Keanland Park that is aggregated with nonpoint sources in the Ayer Creek catchment). Nevertheless, potential loading from construction stormwater sites was estimated to be conservative and develop a basis for WLAs that is separate from the MS4 loads and allocations. Footprints for permitted active sites are used to approximate aggregated construction stormwater nutrient loads to the tributaries impaired for DO and/or pH. Representative concentrations for industrial urban land reported for NPDES Phase I Stormwater permittees in western Washington (Hobbs et al., 2015) are applied – TN: 1,095 µg/L and TP: 171 µg/L because construction activities are temporary and related stormwater discharges are not expected to significantly elevate loading to waterbodies, as the permit conditions primarily focus on limiting discharges off-site. Runoff depth is estimated using the Simple Method (described in the MS4 section above) and it is combined with the aggregated facility footprint (disturbed acres) area provided by Ecology (L. Weiss, personal communication, 2/19/2020) to estimate runoff volume. Site footprints are conservatively assumed to be fully impervious, thus, resulting in a runoff depth of R = 42.9 inches or 3.58 feet that is combined with the aggregated disturbed area to estimate the runoff volume and nutrient loads (Table 24).

Table 24. Active NPDES permitted construction stormwater permits.

Waterbodies	Disturbed Area (acres)	TN Load (kg/day)	TP Load (kg/day)
Ayer Creek	43.0	0.568	0.089
Black Lake Ditch (applicable to downstream Percival Creek)	28.5	0.376	0.059
Percival Creek (excluding sites in the upstream Black Lake Ditch drainage area)	25.5	0.336	0.053

4.4 SOURCE ASSESSMENT SUMMARY

A table that summarizes the nitrogen and phosphorus loads estimated for the DO and pH TMDLs is provided in Table 25.

Table 25. Nitrogen and phosphorus loads (kg/day) for estimated average daily stormwater flow (cfs).

Source[1]	Adams Creek			Ayer Creek			Black Lake Ditch			Percival Creek			Lake Lawrence Creek			Reichel Creek		
	Flow	TN	TP	Flow	TN	TP	Flow	TN	TP	Flow	TN	TP	Flow	TN	TP	Flow	TN	TP
City of Olympia (MS4)	-	-	-	-	-	-	3.35	9.05	0.890	4.11	11.06	1.088	-	-	-	-	-	-
City of Tumwater (MS4)	-	-	-	-	-	-	1.19	3.20	0.311	5.65	15.19	1.488	-	-	-	-	-	-
Thurston County (MS4)	0.03	0.08	0.008	0.12	0.32	0.030	0.24	0.62	0.056	0.50	1.31	0.123	-	-	-	-	-	-
WSDOT (MS4)	-	-	-	-	-	-	0.17	0.45	0.045	0.39	1.06	0.105	-	-	-	-	-	-
Industrial Stormwater	-	-	-	-	-	-	0.14	0.37	0.058	0.15	0.40	0.062	-	-	-	-	-	-
Sand and Gravel Stormwater	-	-	-	-	-	-	0.50	1.35	0.210	0.50	1.35	0.210	-	-	-	-	-	-
Construction Stormwater	-	-	-	0.21	0.57	0.089	0.14	0.38	0.059	0.27	0.71	0.111	-	-	-	-	-	-

[1]Point sources not relevant to the waterbody catchment are listed as “-“

4.5 WASTELOAD ALLOCATIONS

Table 26 shows the percent reductions required for each permitted source.

Table 26. Reductions required from existing loads to meet the WLAs.

Source[1]	Adams Creek			Ayer Creek			Black Lake Ditch		Percival Creek	
	TN	TP	Temperature	TN	TP	Temperature	TN	TP	TN	TP
City of Olympia (MS4)	-	-	-	-	-	-	69%	82%	69%	82%
City of Tumwater (MS4)	-	-	-	-	-	-	69%	82%	69%	82%
Thurston County (MS4)	71%	83%	33%	68%	80%	85%	68%	79%	68%	80%
WSDOT (MS4)	-	-	-	-	-	-	69%	82%	69%	82%
Industrial, Sand and Gravel, and Construction Stormwater	-	-	-	69%	89%	-	69%	89%	69%	89%

[1]Point sources not relevant to the waterbody catchment are listed as “-“

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6.0 APPENDIX F 1: TABULAR SHADE DEFICIT AND THERMAL TMDL RESULTS

Existing shade deficits were calculated at 10-meter increments along the length of each waterbody, as discussed and summarized in Section 2.0, and presented in the following tables. Effective shade targets and heat TMDLs are also provided in the following tables.

Table F-1. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Ayer Creek.

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
0	50%	90%	39%	3.740	0.777	2.963
10	49%	89%	40%	3.789	0.792	2.997
20	49%	89%	40%	3.809	0.840	2.969
30	45%	98%	52%	4.095	0.166	3.929
40	40%	98%	58%	4.497	0.156	4.341
50	39%	98%	59%	4.584	0.146	4.438
60	39%	99%	60%	4.590	0.102	4.487
70	38%	99%	61%	4.690	0.107	4.583
80	37%	99%	62%	4.752	0.107	4.645
90	38%	99%	60%	4.623	0.110	4.513
100	39%	99%	59%	4.544	0.110	4.434
110	34%	99%	64%	4.946	0.112	4.834
120	34%	99%	65%	4.957	0.069	4.888
130	31%	99%	68%	5.164	0.069	5.096
140	27%	99%	72%	5.505	0.068	5.438
150	22%	99%	77%	5.868	0.057	5.811
160	20%	99%	78%	5.967	0.108	5.858
170	4%	57%	53%	7.241	3.255	3.986
180	11%	60%	49%	6.675	3.027	3.648
190	9%	58%	49%	6.834	3.136	3.697
200	9%	67%	58%	6.833	2.459	4.374
210	5%	55%	50%	7.129	3.340	3.789
220	0%	12%	12%	7.484	6.620	0.863
230	2%	11%	9%	7.366	6.666	0.699
240	3%	11%	8%	7.253	6.643	0.610
250	8%	86%	78%	6.875	1.044	5.831

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
260	3%	66%	63%	7.251	2.535	4.716
270	1%	24%	23%	7.393	5.674	1.719
280	4%	36%	32%	7.201	4.806	2.395
290	3%	30%	26%	7.253	5.273	1.980
300	2%	19%	17%	7.340	6.064	1.276
310	2%	18%	16%	7.350	6.151	1.199
320	2%	17%	15%	7.354	6.201	1.152
330	2%	16%	14%	7.371	6.289	1.082
340	1%	15%	14%	7.399	6.378	1.021
350	1%	16%	14%	7.397	6.325	1.072
360	2%	17%	15%	7.390	6.262	1.129
370	2%	18%	16%	7.380	6.150	1.230
380	2%	21%	19%	7.360	5.910	1.450
390	2%	26%	24%	7.335	5.546	1.789
400	4%	25%	21%	7.226	5.636	1.590
410	6%	32%	25%	7.025	5.127	1.898
420	16%	55%	39%	6.276	3.365	2.912
430	28%	75%	47%	5.408	1.887	3.520
440	28%	76%	48%	5.433	1.832	3.601
450	27%	77%	50%	5.452	1.732	3.720
460	27%	77%	50%	5.458	1.727	3.731
470	26%	77%	50%	5.519	1.735	3.785
480	29%	78%	49%	5.347	1.663	3.683
490	28%	78%	49%	5.375	1.686	3.689
500	34%	88%	53%	4.922	0.918	4.003
510	40%	89%	49%	4.531	0.859	3.673
520	38%	89%	51%	4.652	0.820	3.832
530	41%	89%	48%	4.420	0.793	3.626
540	43%	90%	48%	4.301	0.716	3.585
550	40%	92%	52%	4.513	0.585	3.928
560	39%	98%	59%	4.612	0.158	4.454
570	38%	98%	60%	4.666	0.160	4.506
580	37%	98%	60%	4.696	0.159	4.537

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
590	36%	98%	61%	4.777	0.164	4.614
600	38%	98%	59%	4.625	0.162	4.463
610	38%	98%	60%	4.656	0.162	4.495
620	38%	98%	59%	4.624	0.170	4.454
630	41%	98%	57%	4.449	0.160	4.289
640	37%	90%	52%	4.690	0.778	3.912
650	37%	88%	51%	4.709	0.882	3.828
660	28%	77%	49%	5.422	1.715	3.707
670	27%	76%	49%	5.447	1.784	3.662
680	28%	76%	48%	5.411	1.783	3.628
690	37%	87%	50%	4.696	0.946	3.750
700	38%	87%	49%	4.649	0.938	3.710
710	36%	87%	50%	4.794	1.013	3.781
720	37%	87%	50%	4.745	1.000	3.745
730	37%	86%	49%	4.757	1.048	3.708
740	36%	84%	49%	4.805	1.164	3.641
750	38%	86%	49%	4.675	1.025	3.650
760	40%	87%	47%	4.513	1.000	3.513
770	38%	87%	48%	4.634	1.012	3.621
780	38%	87%	48%	4.620	1.009	3.612
790	40%	88%	47%	4.465	0.901	3.564
800	38%	88%	49%	4.617	0.923	3.694
810	38%	87%	50%	4.674	0.939	3.735
820	38%	87%	50%	4.683	0.943	3.741
830	37%	87%	50%	4.694	0.949	3.745
840	37%	87%	50%	4.700	0.954	3.746
850	39%	88%	49%	4.566	0.905	3.661
860	40%	89%	49%	4.466	0.813	3.653
870	40%	90%	49%	4.472	0.766	3.706
880	39%	90%	51%	4.557	0.768	3.790
890	25%	75%	51%	5.660	1.866	3.794
900	24%	75%	51%	5.716	1.852	3.864
910	23%	75%	52%	5.787	1.883	3.904

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
920	25%	75%	50%	5.651	1.866	3.785
930	25%	75%	50%	5.625	1.851	3.774
940	26%	75%	49%	5.546	1.861	3.686
950	26%	75%	50%	5.572	1.850	3.721
960	28%	76%	48%	5.413	1.778	3.635
970	25%	75%	50%	5.651	1.871	3.780
980	25%	75%	50%	5.622	1.870	3.752
990	27%	76%	48%	5.460	1.835	3.624
1000	30%	76%	46%	5.269	1.810	3.459
1010	29%	76%	47%	5.353	1.836	3.517
1020	28%	76%	47%	5.374	1.824	3.551
1030	30%	76%	46%	5.272	1.819	3.453
1040	31%	76%	45%	5.181	1.804	3.378
1050	28%	75%	48%	5.435	1.842	3.593
1060	27%	75%	48%	5.469	1.843	3.625
1070	35%	76%	41%	4.850	1.764	3.087
1080	31%	76%	45%	5.209	1.799	3.410
1090	27%	75%	48%	5.472	1.846	3.625
1100	26%	75%	49%	5.539	1.853	3.685
1110	24%	75%	51%	5.684	1.854	3.830
1120	22%	73%	51%	5.859	2.010	3.849
1130	19%	63%	44%	6.069	2.768	3.301
1140	24%	75%	51%	5.676	1.865	3.811
1150	26%	76%	49%	5.518	1.810	3.708
1160	28%	77%	48%	5.386	1.756	3.630
1170	32%	79%	47%	5.114	1.604	3.510
1180	38%	80%	42%	4.678	1.522	3.156
1190	35%	82%	47%	4.857	1.353	3.504
1200	30%	89%	59%	5.272	0.823	4.449
1210	23%	98%	76%	5.789	0.121	5.669
1220	23%	98%	75%	5.758	0.116	5.643
1230	26%	99%	73%	5.581	0.092	5.489
1240	21%	99%	77%	5.892	0.087	5.805

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
1250	26%	99%	73%	5.568	0.083	5.484
1260	27%	98%	71%	5.468	0.129	5.339
1270	23%	99%	76%	5.805	0.072	5.733
1280	29%	99%	70%	5.362	0.073	5.289
1290	28%	99%	71%	5.418	0.072	5.346
1300	28%	99%	71%	5.383	0.078	5.305
1310	25%	99%	74%	5.630	0.076	5.554
1320	22%	99%	77%	5.865	0.059	5.806
1330	24%	99%	75%	5.687	0.052	5.634
1340	25%	99%	74%	5.616	0.053	5.563
1350	30%	99%	69%	5.227	0.059	5.168
1360	37%	99%	62%	4.698	0.079	4.619
1370	36%	98%	62%	4.779	0.114	4.665
1380	68%	99%	30%	2.396	0.107	2.289
1390	99%	99%	0%	0.094	0.079	0.015
1400	99%	99%	0%	0.094	0.074	0.020
1410	99%	99%	0%	0.097	0.080	0.017
1420	99%	99%	0%	0.103	0.084	0.019
1430	99%	99%	0%	0.100	0.078	0.022
1440	99%	99%	0%	0.101	0.076	0.025
1450	99%	99%	0%	0.098	0.070	0.028
1460	99%	99%	0%	0.095	0.085	0.010
1470	99%	99%	0%	0.098	0.071	0.027
1480	99%	99%	0%	0.097	0.070	0.027
1490	99%	99%	0%	0.104	0.084	0.020
1500	99%	99%	0%	0.105	0.086	0.019
1510	99%	99%	0%	0.098	0.098	0.000
1520	98%	98%	0%	0.115	0.115	0.000
1530	17%	23%	6%	6.258	5.780	0.477

[1]Shaded cells from 0m to 200m are within the Thurston County MS4

Table F-2. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Huckleberry Creek.

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
0	98%	99%	1%	0.117	0.058	0.058
10	98%	99%	1%	0.117	0.058	0.058
20	99%	99%	0%	0.109	0.074	0.034
30	99%	99%	0%	0.097	0.074	0.023
40	99%	99%	0%	0.097	0.074	0.023
50	99%	99%	0%	0.097	0.074	0.023
60	99%	99%	0%	0.097	0.074	0.023
70	99%	99%	0%	0.099	0.070	0.029
80	99%	99%	0%	0.099	0.070	0.029
90	99%	99%	0%	0.099	0.070	0.029
100	99%	99%	0%	0.099	0.070	0.029
110	99%	99%	0%	0.099	0.070	0.029
120	99%	99%	0%	0.099	0.070	0.029
130	99%	99%	0%	0.099	0.070	0.029
140	99%	99%	0%	0.098	0.085	0.013
150	99%	99%	0%	0.098	0.085	0.013
160	99%	99%	0%	0.098	0.085	0.013
170	99%	99%	0%	0.098	0.085	0.013
180	99%	99%	0%	0.099	0.099	0.000
190	99%	99%	0%	0.099	0.099	0.000
200	99%	99%	0%	0.099	0.099	0.000
210	99%	99%	0%	0.099	0.099	0.000
220	99%	99%	0%	0.100	0.100	0.000
230	99%	99%	0%	0.100	0.100	0.000
240	99%	99%	0%	0.100	0.100	0.000
250	99%	99%	0%	0.100	0.100	0.000
260	99%	99%	0%	0.100	0.100	0.000
270	99%	99%	0%	0.100	0.100	0.000
280	99%	99%	0%	0.099	0.098	0.000
290	99%	99%	0%	0.098	0.081	0.017
300	99%	99%	0%	0.098	0.081	0.017
310	99%	99%	0%	0.098	0.081	0.017
320	99%	99%	0%	0.097	0.076	0.022

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
330	99%	99%	0%	0.097	0.076	0.022
340	99%	99%	0%	0.097	0.076	0.022
350	99%	99%	0%	0.097	0.076	0.022
360	99%	99%	0%	0.097	0.076	0.022
370	99%	99%	0%	0.096	0.067	0.029
380	99%	99%	0%	0.096	0.067	0.029
390	99%	99%	0%	0.097	0.074	0.023
400	99%	99%	0%	0.097	0.074	0.023
410	99%	99%	0%	0.097	0.074	0.023
420	99%	99%	0%	0.097	0.074	0.023
430	99%	99%	0%	0.097	0.074	0.023
440	99%	99%	0%	0.098	0.092	0.007
450	99%	99%	0%	0.098	0.092	0.007
460	99%	99%	0%	0.098	0.092	0.007
470	99%	99%	0%	0.098	0.092	0.007
480	99%	99%	0%	0.098	0.092	0.007
490	99%	99%	0%	0.098	0.092	0.007
500	99%	99%	0%	0.098	0.092	0.007
510	99%	99%	0%	0.098	0.092	0.007
520	99%	99%	0%	0.096	0.091	0.005
530	99%	99%	0%	0.096	0.091	0.005
540	99%	99%	0%	0.096	0.091	0.005
550	99%	99%	0%	0.096	0.091	0.005
560	99%	99%	0%	0.096	0.096	0.000
570	99%	99%	0%	0.096	0.096	0.000
580	99%	99%	0%	0.096	0.096	0.000
590	99%	99%	0%	0.096	0.096	0.000
600	99%	99%	0%	0.096	0.096	0.000
610	99%	99%	0%	0.096	0.096	0.000
620	99%	99%	0%	0.096	0.096	0.000
630	99%	99%	0%	0.095	0.093	0.002
640	99%	99%	0%	0.095	0.093	0.002
650	99%	99%	0%	0.095	0.093	0.002

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
660	99%	99%	0%	0.095	0.093	0.002
670	99%	99%	0%	0.096	0.077	0.019
680	99%	99%	0%	0.096	0.077	0.019
690	99%	99%	0%	0.096	0.077	0.019
700	99%	99%	0%	0.096	0.077	0.019
710	99%	99%	0%	0.096	0.077	0.019
720	99%	99%	0%	0.097	0.077	0.020
730	99%	99%	0%	0.097	0.077	0.020
740	98%	99%	1%	0.125	0.077	0.048
750	98%	99%	1%	0.125	0.077	0.048
760	98%	99%	1%	0.124	0.062	0.061
770	98%	99%	1%	0.124	0.062	0.061
780	98%	99%	1%	0.124	0.062	0.061
790	98%	99%	1%	0.124	0.062	0.061
800	98%	99%	1%	0.124	0.062	0.061
810	98%	99%	1%	0.124	0.062	0.061
820	96%	99%	3%	0.283	0.062	0.221
830	97%	99%	2%	0.242	0.062	0.180
840	99%	99%	0%	0.095	0.085	0.010
850	99%	99%	0%	0.106	0.094	0.013
860	99%	99%	0%	0.096	0.088	0.007
870	99%	99%	0%	0.098	0.083	0.015
880	99%	99%	0%	0.099	0.092	0.008
890	99%	99%	0%	0.100	0.084	0.015
900	99%	99%	0%	0.097	0.071	0.026
910	99%	99%	0%	0.093	0.078	0.015
920	99%	99%	0%	0.098	0.083	0.015
930	99%	99%	0%	0.104	0.093	0.011
940	99%	99%	0%	0.090	0.062	0.029
950	99%	99%	0%	0.074	0.042	0.032
960	99%	99%	0%	0.082	0.048	0.034
970	99%	99%	0%	0.077	0.043	0.034
980	99%	99%	0%	0.085	0.049	0.036

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
990	99%	99%	0%	0.088	0.058	0.031
1000	99%	99%	0%	0.089	0.065	0.025
1010	99%	99%	0%	0.067	0.041	0.025
1020	99%	99%	0%	0.063	0.040	0.023
1030	99%	99%	0%	0.073	0.043	0.030
1040	99%	99%	0%	0.073	0.043	0.030
1050	99%	99%	0%	0.074	0.043	0.031
1060	99%	99%	0%	0.083	0.055	0.028
1070	99%	99%	0%	0.078	0.060	0.019
1080	99%	99%	0%	0.081	0.051	0.030
1090	99%	99%	0%	0.081	0.048	0.033
1100	99%	99%	0%	0.082	0.048	0.033
1110	99%	99%	0%	0.099	0.073	0.025
1120	99%	99%	0%	0.096	0.065	0.030
1130	99%	99%	0%	0.088	0.056	0.032
1140	99%	99%	0%	0.086	0.053	0.033
1150	99%	99%	0%	0.083	0.051	0.032
1160	99%	99%	0%	0.094	0.067	0.027
1170	99%	99%	0%	0.096	0.071	0.026
1180	99%	99%	0%	0.096	0.070	0.026
1190	99%	99%	0%	0.097	0.070	0.026
1200	99%	99%	0%	0.083	0.053	0.030
1210	99%	99%	0%	0.085	0.054	0.031
1220	99%	99%	0%	0.088	0.060	0.028
1230	99%	99%	0%	0.090	0.071	0.019
1240	99%	99%	0%	0.089	0.064	0.025
1250	99%	99%	0%	0.080	0.055	0.024
1260	99%	99%	0%	0.085	0.066	0.019
1270	99%	99%	0%	0.082	0.068	0.015
1280	99%	99%	0%	0.081	0.070	0.011
1290	99%	99%	0%	0.085	0.064	0.021
1300	99%	99%	0%	0.085	0.056	0.029
1310	99%	99%	0%	0.087	0.070	0.017

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
1320	99%	99%	0%	0.092	0.076	0.016
1330	99%	99%	0%	0.092	0.074	0.019
1340	99%	99%	0%	0.088	0.056	0.032
1350	99%	99%	0%	0.082	0.053	0.028
1360	99%	99%	0%	0.083	0.050	0.033
1370	99%	99%	0%	0.086	0.050	0.036
1380	99%	99%	0%	0.090	0.057	0.033
1390	99%	99%	0%	0.095	0.071	0.025
1400	99%	99%	0%	0.097	0.074	0.022
1410	99%	99%	0%	0.093	0.062	0.030
1420	99%	99%	0%	0.095	0.067	0.027
1430	99%	99%	0%	0.095	0.067	0.028
1440	99%	99%	0%	0.084	0.051	0.033
1450	99%	99%	0%	0.085	0.054	0.031
1460	99%	99%	0%	0.094	0.064	0.030
1470	99%	99%	0%	0.095	0.067	0.028
1480	99%	99%	0%	0.091	0.065	0.026
1490	99%	99%	0%	0.090	0.063	0.027
1500	99%	99%	0%	0.102	0.085	0.018
1510	99%	99%	0%	0.098	0.077	0.020
1520	99%	99%	0%	0.098	0.077	0.022
1530	99%	99%	0%	0.094	0.072	0.021
1540	99%	99%	0%	0.092	0.078	0.014
1550	99%	99%	0%	0.100	0.079	0.021
1560	99%	99%	0%	0.099	0.080	0.020
1570	99%	99%	0%	0.101	0.078	0.023
1580	99%	99%	0%	0.099	0.072	0.027
1590	99%	99%	0%	0.100	0.080	0.020
1600	99%	99%	0%	0.098	0.076	0.023
1610	99%	99%	0%	0.090	0.065	0.025
1620	99%	99%	0%	0.093	0.062	0.031
1630	99%	99%	0%	0.093	0.062	0.031
1640	99%	99%	0%	0.084	0.051	0.033

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
1650	99%	99%	0%	0.075	0.043	0.032
1660	99%	99%	0%	0.082	0.066	0.017
1670	99%	99%	0%	0.087	0.076	0.011
1680	99%	99%	0%	0.094	0.066	0.028
1690	99%	99%	0%	0.101	0.076	0.025
1700	99%	99%	0%	0.091	0.058	0.033
1710	99%	99%	1%	0.099	0.057	0.042
1720	99%	99%	1%	0.085	0.043	0.042
1730	99%	99%	1%	0.089	0.044	0.045
1740	99%	99%	1%	0.088	0.043	0.044
1750	99%	99%	1%	0.090	0.044	0.046
1760	99%	99%	0%	0.099	0.065	0.034
1770	99%	99%	1%	0.096	0.058	0.038
1780	99%	99%	1%	0.096	0.057	0.038
1790	99%	99%	1%	0.092	0.047	0.045
1800	99%	99%	1%	0.084	0.044	0.040
1810	99%	99%	0%	0.086	0.051	0.035
1820	99%	99%	1%	0.091	0.052	0.039
1830	99%	99%	1%	0.086	0.042	0.043
1840	99%	99%	0%	0.100	0.081	0.019
1850	99%	99%	0%	0.103	0.088	0.015
1860	99%	99%	0%	0.098	0.073	0.025
1870	99%	99%	1%	0.094	0.049	0.045
1880	99%	99%	0%	0.098	0.073	0.025
1890	99%	99%	0%	0.093	0.069	0.023
1900	99%	99%	0%	0.094	0.070	0.023
1910	99%	99%	0%	0.095	0.074	0.022
1920	99%	99%	0%	0.097	0.080	0.017
1930	99%	99%	0%	0.102	0.092	0.010
1940	99%	99%	0%	0.097	0.085	0.012
1950	99%	99%	0%	0.107	0.106	0.001
1960	99%	99%	0%	0.104	0.096	0.008
1970	99%	99%	0%	0.099	0.099	0.000

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
1980	99%	99%	0%	0.096	0.083	0.013
1990	99%	99%	0%	0.097	0.085	0.011
2000	99%	99%	0%	0.098	0.094	0.004
2010	99%	99%	0%	0.096	0.087	0.009
2020	99%	99%	0%	0.098	0.084	0.014
2030	99%	99%	0%	0.099	0.087	0.013
2040	99%	99%	0%	0.104	0.088	0.016
2050	99%	99%	0%	0.109	0.102	0.006
2060	99%	99%	0%	0.108	0.100	0.009
2070	99%	99%	0%	0.108	0.100	0.008
2080	99%	99%	0%	0.103	0.092	0.011
2090	99%	99%	0%	0.108	0.101	0.007
2100	99%	99%	0%	0.099	0.079	0.019
2110	99%	99%	0%	0.095	0.070	0.025
2120	99%	99%	0%	0.095	0.070	0.026
2130	99%	99%	0%	0.090	0.062	0.028
2140	99%	99%	0%	0.089	0.060	0.029
2150	99%	99%	0%	0.096	0.078	0.018
2160	99%	99%	0%	0.099	0.087	0.012
2170	99%	99%	0%	0.090	0.059	0.031
2180	99%	99%	0%	0.092	0.064	0.028
2190	99%	99%	0%	0.101	0.076	0.025
2200	99%	99%	0%	0.100	0.073	0.027
2210	99%	99%	0%	0.095	0.064	0.032
2220	99%	99%	1%	0.087	0.048	0.039
2230	99%	99%	0%	0.090	0.053	0.036
2240	99%	99%	0%	0.090	0.054	0.036
2250	99%	99%	1%	0.093	0.055	0.038
2260	99%	99%	0%	0.102	0.070	0.033
2270	99%	99%	0%	0.102	0.070	0.032
2280	99%	99%	0%	0.104	0.072	0.032
2290	99%	99%	0%	0.099	0.066	0.034
2300	99%	99%	0%	0.100	0.066	0.034

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
2310	99%	99%	0%	0.098	0.064	0.035
2320	99%	99%	0%	0.102	0.072	0.031
2330	99%	99%	0%	0.100	0.068	0.032
2340	99%	99%	0%	0.098	0.065	0.033
2350	99%	99%	0%	0.098	0.065	0.033
2360	99%	99%	0%	0.106	0.089	0.017
2370	99%	99%	0%	0.105	0.091	0.014
2380	99%	99%	0%	0.106	0.090	0.015
2390	99%	99%	0%	0.103	0.083	0.020
2400	99%	99%	0%	0.098	0.088	0.010
2410	99%	99%	0%	0.100	0.084	0.016
2420	99%	99%	0%	0.104	0.094	0.010
2430	99%	99%	0%	0.098	0.087	0.011
2440	99%	99%	0%	0.100	0.089	0.011
2450	99%	99%	0%	0.099	0.092	0.007
2460	99%	99%	0%	0.100	0.092	0.008
2470	99%	99%	0%	0.100	0.090	0.010
2480	99%	99%	0%	0.100	0.099	0.001
2490	99%	99%	0%	0.098	0.080	0.018
2500	99%	99%	0%	0.099	0.082	0.017
2510	99%	99%	0%	0.102	0.088	0.014
2520	99%	99%	0%	0.105	0.094	0.012
2530	99%	99%	0%	0.110	0.110	0.000
2540	99%	99%	0%	0.110	0.110	0.000
2550	99%	99%	0%	0.109	0.103	0.006
2560	99%	99%	0%	0.109	0.107	0.002
2570	99%	99%	0%	0.110	0.110	0.000
2580	99%	99%	0%	0.110	0.110	0.000
2590	99%	99%	0%	0.109	0.109	0.000
2600	99%	99%	0%	0.108	0.108	0.000
2610	99%	99%	0%	0.107	0.104	0.004
2620	99%	99%	0%	0.110	0.110	0.000
2630	99%	99%	0%	0.109	0.109	0.000

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
2640	99%	99%	0%	0.107	0.107	0.000
2650	99%	99%	0%	0.107	0.107	0.000
2660	99%	99%	0%	0.109	0.109	0.000
2670	99%	99%	0%	0.108	0.108	0.000
2680	99%	99%	0%	0.109	0.109	0.000
2690	99%	99%	0%	0.107	0.107	0.000
2700	99%	99%	0%	0.107	0.107	0.000
2710	99%	99%	0%	0.109	0.109	0.000
2720	99%	99%	0%	0.107	0.107	0.000
2730	99%	99%	0%	0.107	0.107	0.000
2740	99%	99%	0%	0.105	0.105	0.000
2750	99%	99%	0%	0.106	0.106	0.000
2760	99%	99%	0%	0.111	0.111	0.000
2770	99%	99%	0%	0.111	0.111	0.000
2780	99%	99%	0%	0.109	0.109	0.000
2790	99%	99%	0%	0.111	0.111	0.000
2800	99%	99%	0%	0.111	0.111	0.000
2810	99%	99%	0%	0.110	0.110	0.000
2820	99%	99%	0%	0.110	0.110	0.000
2830	99%	99%	0%	0.110	0.110	0.000
2840	99%	99%	0%	0.110	0.110	0.000
2850	99%	99%	0%	0.099	0.099	0.000
2860	99%	99%	0%	0.099	0.099	0.000
2870	99%	99%	0%	0.096	0.096	0.000
2880	99%	99%	0%	0.097	0.097	0.000
2890	99%	99%	0%	0.099	0.099	0.000
2900	99%	99%	0%	0.095	0.095	0.000
2910	99%	99%	0%	0.100	0.100	0.000
2920	99%	99%	0%	0.099	0.099	0.000
2930	99%	99%	0%	0.096	0.096	0.000
2940	99%	99%	0%	0.095	0.095	0.000
2950	99%	99%	0%	0.095	0.095	0.000
2960	99%	99%	0%	0.100	0.100	0.000

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
2970	99%	99%	0%	0.103	0.103	0.000
2980	99%	99%	0%	0.098	0.098	0.000
2990	99%	99%	0%	0.099	0.099	0.000
3000	99%	99%	0%	0.102	0.102	0.000
3010	99%	99%	0%	0.101	0.101	0.000
3020	99%	99%	0%	0.101	0.101	0.000
3030	99%	99%	0%	0.100	0.100	0.000
3040	99%	99%	0%	0.099	0.099	0.000
3050	99%	99%	0%	0.097	0.097	0.000
3060	99%	99%	0%	0.100	0.100	0.000
3070	99%	99%	0%	0.104	0.104	0.000
3080	99%	99%	0%	0.105	0.105	0.000
3090	99%	99%	0%	0.102	0.102	0.000
3100	99%	99%	0%	0.104	0.104	0.000
3110	99%	99%	0%	0.106	0.106	0.000
3120	99%	99%	0%	0.105	0.105	0.000
3130	98%	98%	0%	0.120	0.120	0.000
3140	99%	99%	0%	0.099	0.099	0.000
3150	99%	99%	0%	0.097	0.097	0.000
3160	99%	99%	0%	0.094	0.094	0.000
3170	99%	99%	0%	0.090	0.089	0.001
3180	99%	99%	0%	0.089	0.089	0.000
3190	99%	99%	0%	0.093	0.093	0.000
3200	99%	99%	0%	0.098	0.086	0.012
3210	99%	99%	0%	0.103	0.080	0.022
3220	99%	99%	0%	0.103	0.079	0.023
3230	99%	99%	0%	0.098	0.073	0.025
3240	29%	29%	0%	5.326	5.309	0.016
3250	73%	74%	1%	2.003	1.941	0.062
3260	98%	98%	0%	0.120	0.120	0.000
3270	99%	99%	0%	0.108	0.108	0.000
3280	99%	99%	0%	0.096	0.066	0.029
3290	99%	99%	1%	0.094	0.055	0.039

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
3300	99%	99%	1%	0.090	0.052	0.038
3310	99%	99%	1%	0.091	0.050	0.041
3320	99%	99%	1%	0.087	0.049	0.039
3330	99%	99%	0%	0.098	0.075	0.023
3340	99%	99%	0%	0.100	0.097	0.003
3350	99%	99%	0%	0.099	0.091	0.008
3360	99%	99%	0%	0.098	0.091	0.007
3370	99%	99%	0%	0.102	0.083	0.019
3380	99%	99%	0%	0.098	0.068	0.030
3390	99%	99%	0%	0.100	0.070	0.029
3400	99%	99%	0%	0.100	0.070	0.030
3410	99%	99%	0%	0.101	0.093	0.008
3420	99%	99%	0%	0.096	0.086	0.010
3430	99%	99%	0%	0.094	0.082	0.012
3440	99%	99%	0%	0.095	0.077	0.018
3450	99%	99%	0%	0.088	0.066	0.022
3460	99%	99%	0%	0.088	0.078	0.009
3470	99%	99%	0%	0.094	0.062	0.032
3480	99%	99%	0%	0.089	0.058	0.031
3490	99%	99%	0%	0.092	0.062	0.030
3500	99%	99%	0%	0.098	0.082	0.015
3510	49%	58%	10%	3.853	3.126	0.726
3520	99%	99%	0%	0.074	0.040	0.034
3530	99%	99%	0%	0.077	0.041	0.036
3540	95%	97%	2%	0.372	0.246	0.126
3550	99%	99%	0%	0.085	0.072	0.014
3560	99%	99%	0%	0.090	0.069	0.021
3570	99%	99%	0%	0.086	0.053	0.034
3580	99%	99%	0%	0.085	0.050	0.035
3590	99%	99%	0%	0.085	0.050	0.034
3600	99%	99%	0%	0.084	0.048	0.036
3610	99%	99%	0%	0.090	0.068	0.022
3620	99%	99%	0%	0.090	0.066	0.024

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
3630	99%	99%	0%	0.093	0.071	0.022
3640	99%	99%	0%	0.091	0.066	0.025
3650	99%	99%	0%	0.092	0.066	0.027
3660	99%	99%	0%	0.094	0.069	0.024
3670	99%	99%	0%	0.096	0.069	0.027
3680	99%	99%	0%	0.089	0.058	0.030
3690	99%	99%	0%	0.080	0.053	0.028
3700	99%	99%	0%	0.081	0.053	0.028
3710	99%	99%	0%	0.069	0.041	0.029
3720	99%	99%	0%	0.068	0.040	0.028
3730	99%	99%	0%	0.077	0.044	0.033
3740	99%	99%	0%	0.076	0.043	0.033
3750	99%	99%	0%	0.085	0.062	0.024
3760	99%	99%	0%	0.082	0.049	0.033
3770	99%	99%	0%	0.089	0.059	0.030
3780	99%	99%	0%	0.085	0.050	0.035
3790	99%	99%	0%	0.083	0.047	0.036
3800	99%	99%	0%	0.081	0.046	0.035
3810	99%	99%	0%	0.073	0.042	0.030
3820	99%	99%	0%	0.080	0.052	0.028
3830	99%	99%	0%	0.079	0.057	0.023
3840	99%	99%	0%	0.079	0.055	0.024
3850	99%	99%	0%	0.076	0.051	0.025
3860	99%	99%	0%	0.078	0.047	0.031
3870	99%	99%	0%	0.075	0.049	0.026
3880	99%	99%	0%	0.086	0.066	0.020
3890	99%	99%	0%	0.090	0.068	0.022
3900	99%	99%	0%	0.091	0.061	0.030
3910	99%	99%	0%	0.082	0.050	0.032
3920	99%	99%	0%	0.074	0.044	0.031
3930	99%	99%	0%	0.079	0.060	0.020
3940	99%	99%	0%	0.080	0.054	0.026
3950	99%	99%	0%	0.082	0.049	0.032

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
3960	99%	99%	0%	0.089	0.056	0.033
3970	99%	99%	0%	0.088	0.053	0.035
3980	99%	99%	0%	0.090	0.058	0.032
3990	99%	99%	0%	0.089	0.054	0.034
4000	99%	99%	0%	0.087	0.051	0.036
4010	99%	99%	0%	0.096	0.071	0.025
4020	99%	99%	0%	0.092	0.062	0.030
4030	99%	99%	0%	0.091	0.061	0.030
4040	99%	99%	0%	0.090	0.058	0.032
4050	99%	99%	0%	0.095	0.076	0.019
4060	99%	99%	0%	0.089	0.081	0.009
4070	99%	99%	0%	0.092	0.072	0.020
4080	99%	99%	0%	0.090	0.077	0.013
4090	99%	99%	0%	0.091	0.072	0.018
4100	99%	99%	0%	0.085	0.057	0.028
4110	99%	99%	0%	0.084	0.055	0.029
4120	99%	99%	0%	0.102	0.070	0.032
4130	99%	99%	0%	0.088	0.056	0.032
4140	99%	99%	0%	0.093	0.063	0.030
4150	99%	99%	0%	0.096	0.082	0.014
4160	99%	99%	0%	0.093	0.069	0.024
4170	99%	99%	0%	0.090	0.081	0.010
4180	99%	99%	0%	0.091	0.082	0.009
4190	99%	99%	0%	0.088	0.070	0.017
4200	99%	99%	0%	0.091	0.069	0.022
4210	99%	99%	0%	0.089	0.055	0.034
4220	99%	99%	0%	0.091	0.060	0.031
4230	99%	99%	0%	0.083	0.046	0.037
4240	99%	99%	0%	0.085	0.067	0.018
4250	99%	99%	0%	0.087	0.070	0.017
4260	99%	99%	0%	0.090	0.077	0.013
4270	99%	99%	0%	0.087	0.070	0.017
4280	99%	99%	0%	0.088	0.057	0.031

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
4290	99%	99%	0%	0.089	0.061	0.029
4300	99%	99%	0%	0.099	0.076	0.023
4310	99%	99%	0%	0.101	0.081	0.020
4320	99%	99%	0%	0.086	0.051	0.035
4330	99%	99%	0%	0.082	0.052	0.029
4340	99%	99%	0%	0.079	0.050	0.029
4350	99%	99%	0%	0.087	0.073	0.014
4360	99%	99%	0%	0.090	0.070	0.020
4370	99%	99%	0%	0.098	0.098	0.000
4380	99%	99%	0%	0.085	0.066	0.018
4390	99%	99%	0%	0.085	0.068	0.017
4400	99%	99%	0%	0.083	0.063	0.020
4410	99%	99%	0%	0.086	0.059	0.026
4420	99%	99%	0%	0.097	0.084	0.013
4430	99%	99%	0%	0.099	0.084	0.016
4440	99%	99%	0%	0.101	0.085	0.015
4450	99%	99%	0%	0.100	0.083	0.017
4460	99%	99%	0%	0.106	0.096	0.010
4470	99%	99%	0%	0.100	0.083	0.017
4480	99%	99%	0%	0.098	0.080	0.018
4490	99%	99%	0%	0.100	0.082	0.017
4500	99%	99%	0%	0.101	0.086	0.015
4510	99%	99%	0%	0.107	0.101	0.006
4520	99%	99%	0%	0.103	0.097	0.006
4530	99%	99%	0%	0.103	0.100	0.003
4540	99%	99%	0%	0.103	0.100	0.003
4550	99%	99%	0%	0.103	0.100	0.003
4560	99%	99%	0%	0.103	0.097	0.006
4570	99%	99%	0%	0.103	0.097	0.006
4580	99%	99%	0%	0.098	0.081	0.018
4590	99%	99%	0%	0.096	0.079	0.017
4600	99%	99%	0%	0.090	0.079	0.011
4610	99%	99%	0%	0.089	0.074	0.015

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
4620	99%	99%	0%	0.089	0.076	0.013
4630	99%	99%	0%	0.090	0.070	0.021
4640	99%	99%	0%	0.097	0.091	0.006
4650	99%	99%	0%	0.097	0.083	0.014
4660	99%	99%	0%	0.099	0.088	0.011
4670	99%	99%	0%	0.099	0.087	0.012
4680	99%	99%	0%	0.098	0.092	0.006
4690	99%	99%	0%	0.098	0.087	0.011
4700	99%	99%	0%	0.103	0.089	0.014
4710	99%	99%	0%	0.101	0.082	0.019
4720	99%	99%	0%	0.100	0.084	0.017
4730	99%	99%	0%	0.102	0.087	0.015
4740	99%	99%	0%	0.103	0.089	0.013
4750	99%	99%	0%	0.102	0.084	0.019
4760	99%	99%	0%	0.101	0.091	0.009
4770	99%	99%	0%	0.100	0.093	0.007
4780	99%	99%	0%	0.100	0.098	0.002
4790	99%	99%	0%	0.093	0.074	0.020
4800	99%	99%	0%	0.092	0.074	0.018
4810	99%	99%	0%	0.100	0.079	0.021
4820	99%	99%	0%	0.104	0.086	0.018
4830	99%	99%	0%	0.101	0.079	0.022
4840	99%	99%	0%	0.103	0.084	0.019
4850	99%	99%	0%	0.099	0.074	0.024
4860	99%	99%	0%	0.098	0.073	0.024
4870	99%	99%	0%	0.097	0.078	0.019
4880	99%	99%	0%	0.091	0.056	0.035
4890	99%	99%	0%	0.092	0.058	0.034
4900	99%	99%	0%	0.092	0.059	0.033
4910	99%	99%	0%	0.098	0.066	0.032
4920	99%	99%	0%	0.097	0.064	0.033
4930	99%	99%	0%	0.094	0.064	0.030
4940	99%	99%	0%	0.097	0.064	0.033

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
4950	99%	99%	0%	0.094	0.061	0.033
4960	99%	99%	0%	0.078	0.058	0.020
4970	99%	99%	0%	0.080	0.058	0.022
4980	99%	99%	0%	0.081	0.055	0.026
4990	99%	99%	0%	0.082	0.055	0.027
5000	99%	99%	0%	0.081	0.047	0.034
5010	99%	99%	1%	0.082	0.043	0.039
5020	99%	99%	0%	0.080	0.046	0.034
5030	99%	99%	0%	0.079	0.047	0.032
5040	99%	99%	0%	0.079	0.043	0.036
5050	99%	99%	0%	0.079	0.043	0.036
5060	99%	99%	0%	0.089	0.053	0.036
5070	99%	99%	0%	0.089	0.056	0.033
5080	99%	99%	0%	0.089	0.060	0.029
5090	99%	99%	0%	0.089	0.060	0.029
5100	99%	99%	0%	0.088	0.057	0.031
5110	99%	99%	0%	0.084	0.051	0.032
5120	99%	99%	0%	0.083	0.050	0.033
5130	99%	99%	0%	0.083	0.050	0.033
5140	99%	99%	0%	0.087	0.057	0.030
5150	41%	46%	5%	4.402	4.052	0.350
5160	27%	38%	12%	5.494	4.630	0.864
5170	99%	99%	0%	0.111	0.111	0.000
5180	99%	99%	0%	0.073	0.073	0.000
5190	99%	99%	0%	0.073	0.068	0.005
5200	99%	99%	0%	0.073	0.047	0.026
5210	99%	99%	0%	0.074	0.047	0.026
5220	99%	99%	0%	0.075	0.050	0.026
5230	99%	99%	0%	0.077	0.042	0.035
5240	99%	99%	1%	0.099	0.055	0.044
5250	99%	99%	1%	0.098	0.057	0.041
5260	99%	99%	0%	0.097	0.061	0.036
5270	99%	99%	0%	0.074	0.051	0.023

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
5280	99%	99%	0%	0.072	0.049	0.023
5290	99%	99%	0%	0.097	0.067	0.030
5300	99%	99%	0%	0.102	0.071	0.031
5310	99%	99%	0%	0.101	0.071	0.029
5320	99%	99%	0%	0.083	0.056	0.027
5330	99%	99%	0%	0.086	0.058	0.028
5340	99%	99%	0%	0.085	0.057	0.028
5350	56%	62%	6%	3.311	2.847	0.463
5360	99%	99%	0%	0.106	0.100	0.006
5370	99%	99%	0%	0.106	0.106	0.000
5380	99%	99%	0%	0.100	0.080	0.020
5390	99%	99%	0%	0.102	0.089	0.012
5400	99%	99%	0%	0.106	0.106	0.000
5410	99%	99%	0%	0.107	0.107	0.000
5420	75%	76%	2%	1.910	1.781	0.129
5430	75%	98%	23%	1.869	0.118	1.752
5440	69%	98%	28%	2.290	0.168	2.122
5450	70%	98%	28%	2.239	0.160	2.079
5460	71%	98%	27%	2.196	0.139	2.057
5470	76%	99%	22%	1.799	0.113	1.686
5480	76%	99%	22%	1.782	0.106	1.676
5490	76%	99%	22%	1.776	0.105	1.671
5500	80%	99%	18%	1.482	0.094	1.387
5510	70%	99%	28%	2.243	0.105	2.138
5520	70%	99%	29%	2.264	0.105	2.158
5530	64%	99%	34%	2.669	0.087	2.582
5540	64%	98%	34%	2.716	0.173	2.543
5550	71%	98%	28%	2.192	0.126	2.066
5560	69%	98%	29%	2.318	0.128	2.190
5570	60%	99%	39%	2.982	0.093	2.890
5580	24%	60%	36%	5.667	2.968	2.700
5590	54%	98%	44%	3.475	0.154	3.321
5600	54%	98%	44%	3.468	0.132	3.336

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
5610	54%	99%	45%	3.443	0.069	3.374
5620	59%	99%	39%	3.049	0.090	2.959
5630	58%	99%	41%	3.145	0.075	3.070
5640	54%	99%	46%	3.475	0.056	3.420
5650	55%	99%	44%	3.344	0.055	3.288
5660	57%	99%	42%	3.216	0.052	3.164
5670	54%	99%	45%	3.455	0.055	3.400
5680	55%	99%	44%	3.376	0.052	3.324
5690	58%	99%	41%	3.154	0.069	3.085
5700	42%	83%	41%	4.336	1.295	3.041
5710	13%	51%	38%	6.528	3.686	2.842

Table F-3. Effective shade targets, deficits, and daily maximum solar heat daily TMDLs for Adams Creek.

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
0	99%	99%	0%	0.106	0.077	0.029
10	99%	99%	0%	0.108	0.080	0.028
20	99%	99%	0%	0.084	0.059	0.025
30	99%	99%	0%	0.083	0.058	0.025
40	99%	99%	0%	0.083	0.057	0.027
50	99%	99%	0%	0.085	0.058	0.027
60	99%	99%	0%	0.086	0.058	0.028
70	99%	99%	0%	0.086	0.057	0.029
80	98%	99%	0%	0.113	0.111	0.002
90	96%	99%	3%	0.300	0.112	0.188
100	94%	99%	5%	0.475	0.105	0.370
110	94%	99%	5%	0.485	0.110	0.375
120	94%	99%	5%	0.486	0.111	0.375
130	94%	99%	5%	0.481	0.111	0.371

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
140	94%	99%	5%	0.477	0.106	0.371
150	96%	99%	3%	0.286	0.091	0.194
160	96%	99%	3%	0.299	0.101	0.198
170	96%	99%	2%	0.263	0.086	0.177
180	96%	99%	2%	0.271	0.086	0.185
190	97%	99%	3%	0.258	0.068	0.189
200	97%	99%	2%	0.245	0.068	0.177
210	96%	99%	3%	0.288	0.097	0.190
220	99%	99%	0%	0.101	0.092	0.009
230	99%	99%	0%	0.101	0.093	0.008
240	99%	99%	0%	0.100	0.098	0.002
250	96%	99%	2%	0.275	0.103	0.172
260	96%	99%	2%	0.283	0.106	0.176
270	96%	99%	2%	0.284	0.105	0.180
280	96%	98%	3%	0.309	0.120	0.188
290	98%	98%	0%	0.114	0.114	0.000
300	99%	99%	0%	0.112	0.112	0.000
310	98%	98%	0%	0.113	0.113	0.000
320	99%	99%	0%	0.112	0.112	0.000
330	99%	99%	0%	0.111	0.088	0.022
340	97%	99%	2%	0.263	0.094	0.169
350	96%	99%	2%	0.263	0.091	0.172
360	96%	99%	2%	0.268	0.096	0.172
370	96%	99%	2%	0.264	0.105	0.159
380	96%	99%	2%	0.269	0.101	0.168
390	96%	99%	3%	0.314	0.098	0.217
400	96%	99%	3%	0.309	0.104	0.205
410	96%	99%	3%	0.303	0.096	0.207
420	99%	99%	0%	0.100	0.094	0.007
430	99%	99%	0%	0.100	0.088	0.012
440	96%	99%	2%	0.271	0.085	0.187
450	96%	99%	3%	0.297	0.095	0.203
460	96%	99%	3%	0.294	0.101	0.192

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
470	94%	99%	5%	0.459	0.103	0.357
480	94%	99%	5%	0.471	0.102	0.369
490	92%	99%	6%	0.581	0.098	0.482
500	94%	99%	5%	0.463	0.082	0.381
510	94%	99%	5%	0.466	0.082	0.384
520	94%	99%	5%	0.455	0.105	0.349
530	94%	99%	5%	0.451	0.090	0.361
540	94%	99%	5%	0.452	0.098	0.353
550	94%	99%	5%	0.465	0.082	0.382
560	94%	99%	5%	0.465	0.082	0.383
570	94%	99%	5%	0.472	0.092	0.380
580	94%	98%	5%	0.468	0.115	0.353
590	61%	71%	10%	2.917	2.151	0.766
600	44%	61%	17%	4.234	2.937	1.297
610	94%	98%	4%	0.447	0.151	0.296
620	94%	99%	5%	0.460	0.089	0.371
630	94%	99%	5%	0.463	0.101	0.361
640	94%	99%	5%	0.450	0.103	0.347
650	94%	99%	5%	0.459	0.105	0.354
660	94%	99%	5%	0.456	0.104	0.351
670	94%	98%	5%	0.461	0.122	0.340
680	94%	98%	5%	0.466	0.121	0.345
690	94%	98%	5%	0.456	0.117	0.339
700	94%	99%	5%	0.469	0.101	0.367
710	94%	99%	5%	0.484	0.098	0.386
720	61%	98%	37%	2.891	0.117	2.774
730	58%	98%	40%	3.141	0.115	3.026
740	59%	98%	39%	3.047	0.115	2.932
750	70%	99%	28%	2.230	0.096	2.133
760	70%	99%	29%	2.236	0.096	2.140
770	66%	99%	33%	2.546	0.094	2.452
780	66%	99%	33%	2.555	0.094	2.461
790	67%	99%	32%	2.469	0.101	2.368

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
800	61%	99%	37%	2.900	0.101	2.799
810	50%	77%	27%	3.757	1.722	2.035
820	66%	99%	33%	2.562	0.108	2.455
830	63%	99%	36%	2.807	0.105	2.702
840	60%	99%	38%	2.965	0.106	2.859
850	61%	99%	38%	2.956	0.103	2.853
860	61%	99%	38%	2.932	0.103	2.829
870	60%	99%	38%	2.984	0.101	2.883
880	61%	98%	37%	2.928	0.128	2.799
890	32%	99%	67%	5.073	0.051	5.022
900	30%	99%	69%	5.243	0.051	5.192
910	37%	99%	63%	4.755	0.058	4.698
920	36%	97%	61%	4.798	0.190	4.608
930	45%	97%	52%	4.121	0.191	3.930
940	55%	98%	43%	3.361	0.127	3.234
950	55%	99%	44%	3.414	0.106	3.308
960	49%	99%	50%	3.804	0.080	3.724
970	50%	99%	49%	3.747	0.081	3.666
980	24%	74%	51%	5.719	1.918	3.801
990	34%	58%	25%	4.988	3.114	1.874
1000	94%	98%	4%	0.434	0.138	0.296
1010	95%	99%	4%	0.410	0.104	0.307
1020	78%	86%	8%	1.667	1.076	0.592
1030	75%	82%	7%	1.871	1.363	0.508
1040	95%	99%	4%	0.369	0.058	0.310
1050	95%	99%	4%	0.362	0.055	0.307
1060	95%	99%	4%	0.348	0.051	0.297
1070	74%	83%	9%	1.957	1.283	0.675
1080	96%	99%	4%	0.326	0.047	0.278
1090	95%	99%	4%	0.340	0.052	0.288
1100	95%	99%	4%	0.350	0.064	0.286
1110	96%	99%	3%	0.275	0.047	0.228
1120	96%	99%	3%	0.269	0.043	0.226

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
1130	97%	99%	3%	0.260	0.042	0.218
1140	97%	100%	3%	0.250	0.034	0.216
1150	96%	99%	4%	0.324	0.047	0.277
1160	96%	99%	4%	0.311	0.046	0.265
1170	96%	100%	3%	0.289	0.037	0.252
1180	95%	99%	4%	0.339	0.038	0.301
1190	96%	100%	3%	0.282	0.036	0.247
1200	96%	99%	3%	0.292	0.048	0.243
1210	13%	39%	26%	6.548	4.596	1.952
1220	98%	98%	0%	0.147	0.147	0.000
1230	99%	99%	0%	0.082	0.067	0.015
1240	99%	99%	0%	0.088	0.074	0.014
1250	99%	99%	0%	0.090	0.071	0.018
1260	99%	99%	0%	0.089	0.063	0.026
1270	99%	99%	0%	0.092	0.064	0.028
1280	99%	99%	0%	0.099	0.085	0.014
1290	99%	99%	0%	0.088	0.071	0.017
1300	99%	99%	0%	0.090	0.074	0.017
1310	99%	99%	0%	0.089	0.072	0.017
1320	99%	99%	0%	0.088	0.055	0.033
1330	99%	99%	0%	0.087	0.054	0.033
1340	99%	99%	0%	0.086	0.056	0.030
1350	99%	99%	0%	0.086	0.055	0.030
1360	99%	99%	0%	0.090	0.058	0.032
1370	99%	99%	0%	0.100	0.067	0.033
1380	99%	99%	0%	0.105	0.084	0.021
1390	99%	99%	0%	0.090	0.069	0.022
1400	99%	99%	0%	0.103	0.070	0.033
1410	99%	99%	0%	0.096	0.064	0.032
1420	99%	99%	0%	0.092	0.061	0.031
1430	99%	99%	0%	0.090	0.052	0.037
1440	99%	99%	0%	0.089	0.052	0.037
1450	99%	99%	0%	0.091	0.059	0.032

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
1460	99%	99%	0%	0.078	0.043	0.035
1470	99%	99%	0%	0.082	0.048	0.035
1480	99%	99%	0%	0.085	0.049	0.037
1490	99%	99%	0%	0.087	0.056	0.031
1500	99%	99%	0%	0.075	0.041	0.033
1510	99%	99%	1%	0.081	0.042	0.039
1520	99%	99%	1%	0.086	0.042	0.044
1530	98%	99%	1%	0.170	0.088	0.082
1540	99%	99%	1%	0.089	0.047	0.042
1550	99%	99%	0%	0.087	0.059	0.028
1560	99%	99%	0%	0.075	0.044	0.031
1570	99%	99%	0%	0.093	0.079	0.014
1580	99%	99%	0%	0.087	0.056	0.031
1590	99%	99%	0%	0.093	0.062	0.031
1600	99%	99%	0%	0.099	0.066	0.034
1610	99%	99%	1%	0.095	0.057	0.038
1620	99%	99%	1%	0.086	0.048	0.039
1630	99%	99%	1%	0.089	0.049	0.040
1640	99%	99%	1%	0.089	0.048	0.041
1650	99%	99%	0%	0.103	0.076	0.027
1660	98%	99%	0%	0.114	0.083	0.031
1670	99%	99%	1%	0.080	0.041	0.038
1680	99%	99%	1%	0.086	0.044	0.043
1690	99%	99%	1%	0.097	0.051	0.046
1700	99%	99%	1%	0.077	0.038	0.039
1710	99%	100%	0%	0.072	0.036	0.036
1720	99%	99%	0%	0.085	0.047	0.037
1730	99%	99%	1%	0.088	0.048	0.041
1740	99%	99%	1%	0.082	0.039	0.043
1750	99%	99%	0%	0.081	0.044	0.036
1760	99%	99%	0%	0.096	0.067	0.029
1770	99%	99%	0%	0.094	0.063	0.031
1780	99%	99%	0%	0.086	0.057	0.028

Longitudinal Distance from Headwaters (m)[1]	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
1790	99%	99%	0%	0.101	0.084	0.017
1800	99%	99%	1%	0.097	0.052	0.044
1810	99%	99%	1%	0.080	0.042	0.038
1820	99%	100%	1%	0.079	0.037	0.042
1830	99%	99%	1%	0.088	0.044	0.044
1840	99%	100%	0%	0.068	0.033	0.035
1850	99%	100%	1%	0.071	0.033	0.038
1860	99%	99%	1%	0.089	0.047	0.042
1870	99%	99%	0%	0.086	0.049	0.037
1880	99%	99%	1%	0.095	0.052	0.044
1890	99%	99%	1%	0.087	0.043	0.044
1900	99%	99%	1%	0.092	0.051	0.042
1910	99%	99%	0%	0.094	0.061	0.033

[1]Shaded cells from 1210m to 1910m are within the Thurston County MS4

Table F-4. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Tempo Lake Outlet.

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
0	27%	77%	50%	5.445	1.710	3.734
10	65%	99%	34%	2.644	0.070	2.574
20	62%	98%	36%	2.826	0.151	2.676
30	61%	99%	38%	2.895	0.046	2.849
40	65%	99%	35%	2.637	0.045	2.592
50	71%	99%	28%	2.147	0.081	2.066
60	77%	99%	22%	1.746	0.068	1.678
70	79%	99%	20%	1.573	0.093	1.480
80	83%	83%	0%	1.259	1.244	0.015
90	99%	99%	0%	0.077	0.045	0.032
100	99%	99%	0%	0.078	0.047	0.031
110	99%	99%	0%	0.091	0.071	0.020
120	99%	99%	0%	0.102	0.082	0.019

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
130	99%	99%	0%	0.110	0.099	0.011
140	98%	98%	0%	0.118	0.118	0.000
150	74%	98%	25%	1.963	0.113	1.849
160	56%	99%	43%	3.325	0.083	3.242
170	36%	81%	45%	4.818	1.430	3.388
180	73%	73%	0%	2.003	2.003	0.000
190	98%	98%	0%	0.122	0.122	0.000
200	99%	99%	0%	0.077	0.047	0.030
210	99%	99%	0%	0.080	0.049	0.031
220	99%	99%	0%	0.095	0.059	0.036
230	99%	99%	0%	0.103	0.074	0.028
240	99%	99%	0%	0.105	0.092	0.013
250	99%	99%	0%	0.093	0.072	0.021
260	99%	99%	0%	0.109	0.109	0.000
270	6%	8%	2%	7.076	6.927	0.150

Table F-5. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Unnamed Spring to Deschutes River.

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
0	98%	98%	<1%	0.126	0.122	0.004
10	98%	99%	<1%	0.124	0.101	0.023
20	99%	99%	<1%	0.100	0.086	0.014
30	99%	99%	<1%	0.098	0.085	0.013
40	98%	99%	<1%	0.122	0.066	0.056
50	99%	99%	<1%	0.098	0.085	0.013

Table F-6. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Reichel Creek.

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
0	55%	99%	44%	3.384	0.064	3.321
10	61%	99%	38%	2.937	0.080	2.857
20	57%	99%	42%	3.245	0.075	3.170
30	58%	99%	41%	3.185	0.080	3.105
40	56%	99%	44%	3.335	0.051	3.284
50	53%	99%	46%	3.520	0.073	3.447
60	53%	99%	46%	3.516	0.077	3.439
70	51%	99%	48%	3.673	0.062	3.611
80	52%	99%	47%	3.567	0.060	3.506
90	52%	99%	47%	3.628	0.066	3.562
100	52%	99%	47%	3.602	0.065	3.537
110	54%	99%	45%	3.455	0.087	3.368
120	52%	99%	47%	3.615	0.076	3.539
130	51%	99%	48%	3.688	0.074	3.614
140	51%	99%	48%	3.664	0.076	3.588
150	53%	99%	46%	3.549	0.067	3.482
160	49%	99%	50%	3.840	0.078	3.762
170	55%	99%	44%	3.384	0.084	3.300
180	52%	99%	47%	3.609	0.079	3.530
190	52%	99%	47%	3.628	0.072	3.557
200	60%	99%	39%	3.013	0.070	2.943
210	60%	99%	39%	3.013	0.075	2.937
220	61%	99%	38%	2.900	0.072	2.828
230	60%	99%	39%	2.965	0.074	2.890
240	58%	99%	41%	3.124	0.059	3.065
250	58%	99%	41%	3.145	0.049	3.096
260	49%	99%	50%	3.797	0.043	3.754
270	48%	99%	52%	3.935	0.040	3.895
280	53%	99%	46%	3.513	0.059	3.455
290	58%	99%	41%	3.144	0.084	3.060
300	54%	99%	45%	3.469	0.085	3.384
310	55%	99%	44%	3.389	0.098	3.291

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
320	56%	99%	42%	3.281	0.095	3.186
330	55%	99%	44%	3.376	0.069	3.307
340	43%	99%	56%	4.282	0.049	4.233
350	48%	99%	51%	3.879	0.047	3.832
360	57%	98%	41%	3.223	0.122	3.101
370	68%	99%	30%	2.384	0.097	2.286
380	62%	99%	37%	2.853	0.080	2.773
390	56%	99%	43%	3.295	0.039	3.256
400	46%	99%	54%	4.088	0.040	4.048
410	39%	100%	60%	4.552	0.035	4.517
420	47%	99%	52%	3.968	0.044	3.924
430	58%	98%	40%	3.125	0.157	2.969
440	0%	0%	0%	7.496	7.496	0.000
450	79%	99%	20%	1.575	0.076	1.500
460	87%	99%	12%	1.005	0.112	0.893
470	88%	99%	11%	0.931	0.078	0.852
480	89%	99%	10%	0.812	0.059	0.754
490	81%	99%	19%	1.446	0.057	1.388
500	71%	99%	28%	2.200	0.079	2.122
510	73%	99%	26%	1.994	0.068	1.926
520	75%	99%	24%	1.869	0.056	1.814
530	83%	99%	16%	1.292	0.066	1.226
540	85%	99%	14%	1.125	0.054	1.071
550	83%	99%	16%	1.308	0.072	1.237
560	78%	99%	21%	1.659	0.090	1.570
570	77%	99%	22%	1.721	0.105	1.616
580	84%	99%	15%	1.190	0.055	1.136
590	85%	99%	15%	1.159	0.050	1.109
600	84%	99%	15%	1.206	0.048	1.158
610	83%	99%	16%	1.255	0.055	1.199
620	85%	99%	14%	1.131	0.073	1.057
630	82%	99%	17%	1.328	0.072	1.256
640	61%	99%	38%	2.949	0.084	2.865

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
650	59%	99%	40%	3.083	0.071	3.011
660	61%	99%	38%	2.953	0.070	2.883
670	58%	99%	41%	3.181	0.074	3.107
680	56%	99%	43%	3.316	0.075	3.241
690	83%	99%	16%	1.270	0.077	1.192
700	81%	99%	18%	1.408	0.071	1.337
710	83%	99%	17%	1.312	0.066	1.246
720	81%	99%	18%	1.399	0.070	1.329
730	83%	99%	17%	1.305	0.065	1.240
740	79%	99%	20%	1.562	0.090	1.473
750	79%	99%	20%	1.574	0.102	1.472
760	81%	99%	18%	1.418	0.076	1.342
770	77%	99%	22%	1.716	0.097	1.619
780	77%	98%	22%	1.762	0.115	1.647
790	79%	99%	19%	1.541	0.086	1.455
800	82%	99%	17%	1.351	0.102	1.250
810	63%	98%	36%	2.812	0.145	2.667
820	56%	98%	42%	3.278	0.126	3.152
830	1%	1%	0%	7.420	7.420	0.000
840	74%	98%	24%	1.941	0.160	1.781
850	40%	99%	60%	4.525	0.039	4.486
860	10%	87%	77%	6.729	0.982	5.747
870	8%	50%	41%	6.889	3.784	3.105
880	12%	50%	37%	6.571	3.774	2.797
890	15%	54%	39%	6.395	3.456	2.939
900	26%	74%	48%	5.563	1.924	3.638
910	26%	74%	48%	5.557	1.954	3.603
920	26%	73%	47%	5.562	2.045	3.517
930	24%	72%	47%	5.673	2.136	3.537
940	25%	71%	47%	5.663	2.151	3.512
950	24%	70%	46%	5.729	2.271	3.459
960	23%	69%	46%	5.743	2.313	3.430
970	26%	74%	48%	5.537	1.932	3.605

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
980	14%	56%	42%	6.466	3.316	3.149
990	1%	10%	9%	7.423	6.756	0.667
1000	87%	99%	12%	0.958	0.045	0.913
1010	72%	98%	25%	2.097	0.184	1.913
1020	81%	99%	18%	1.424	0.106	1.318
1030	75%	99%	24%	1.853	0.087	1.766
1040	75%	98%	23%	1.884	0.134	1.750
1050	98%	99%	1%	0.120	0.069	0.051
1060	85%	96%	12%	1.158	0.270	0.888
1070	98%	99%	0%	0.127	0.100	0.027
1080	98%	99%	1%	0.127	0.082	0.045
1090	98%	99%	1%	0.161	0.090	0.071
1100	77%	99%	22%	1.701	0.067	1.635
1110	79%	99%	20%	1.549	0.055	1.494
1120	78%	99%	22%	1.682	0.063	1.619
1130	77%	99%	22%	1.698	0.052	1.646
1140	77%	99%	22%	1.753	0.077	1.677
1150	69%	99%	30%	2.315	0.074	2.241
1160	47%	100%	52%	3.949	0.027	3.921
1170	80%	99%	19%	1.496	0.084	1.412
1180	77%	99%	22%	1.724	0.081	1.643
1190	75%	99%	24%	1.873	0.068	1.805
1200	78%	99%	21%	1.675	0.074	1.601
1210	78%	99%	21%	1.623	0.082	1.541
1220	81%	99%	18%	1.444	0.074	1.370
1230	76%	99%	23%	1.780	0.083	1.698
1240	77%	99%	23%	1.755	0.061	1.694
1250	78%	99%	21%	1.651	0.058	1.593
1260	76%	99%	22%	1.773	0.092	1.681
1270	80%	99%	19%	1.486	0.064	1.422
1280	81%	99%	18%	1.411	0.048	1.363
1290	73%	99%	26%	2.003	0.074	1.928
1300	78%	99%	21%	1.668	0.085	1.583

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
1310	63%	99%	36%	2.744	0.055	2.689
1320	54%	99%	45%	3.452	0.057	3.395
1330	53%	99%	46%	3.492	0.056	3.436
1340	50%	99%	49%	3.720	0.046	3.674
1350	44%	99%	55%	4.170	0.044	4.126
1360	54%	99%	46%	3.483	0.040	3.443
1370	49%	100%	51%	3.860	0.037	3.823
1380	42%	100%	57%	4.338	0.028	4.310
1390	72%	99%	27%	2.105	0.061	2.044
1400	98%	99%	0%	0.122	0.086	0.036
1410	98%	99%	0%	0.121	0.085	0.036
1420	98%	99%	1%	0.118	0.057	0.060
1430	98%	99%	0%	0.127	0.090	0.037
1440	98%	99%	1%	0.125	0.076	0.049
1450	98%	99%	1%	0.124	0.072	0.052
1460	99%	99%	1%	0.112	0.041	0.071
1470	98%	99%	1%	0.114	0.041	0.073
1480	98%	99%	1%	0.121	0.044	0.077
1490	98%	99%	1%	0.119	0.040	0.080
1500	98%	99%	1%	0.114	0.039	0.075
1510	99%	100%	1%	0.112	0.036	0.076
1520	99%	99%	1%	0.111	0.038	0.073
1530	98%	99%	1%	0.125	0.045	0.080
1540	98%	99%	1%	0.119	0.045	0.074
1550	98%	99%	1%	0.127	0.047	0.080
1560	98%	99%	1%	0.123	0.049	0.073
1570	98%	99%	1%	0.118	0.050	0.068
1580	99%	99%	1%	0.090	0.046	0.043
1590	99%	99%	1%	0.087	0.040	0.047
1600	99%	99%	1%	0.093	0.041	0.052
1610	99%	99%	0%	0.063	0.041	0.023
1620	99%	99%	0%	0.060	0.041	0.019
1630	99%	99%	0%	0.061	0.042	0.019

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
1640	99%	99%	0%	0.061	0.061	0.000
1650	99%	99%	0%	0.062	0.062	0.000
1660	99%	99%	0%	0.059	0.050	0.009
1670	99%	100%	0%	0.050	0.032	0.018
1680	99%	100%	0%	0.051	0.032	0.019
1690	99%	99%	0%	0.059	0.046	0.013
1700	99%	100%	0%	0.053	0.031	0.022
1710	99%	100%	0%	0.057	0.034	0.024
1720	99%	100%	0%	0.053	0.029	0.024
1730	99%	100%	0%	0.050	0.028	0.021
1740	99%	99%	0%	0.056	0.039	0.016
1750	99%	99%	0%	0.060	0.053	0.007
1760	99%	99%	0%	0.059	0.049	0.009
1770	99%	99%	0%	0.062	0.062	0.000
1780	99%	99%	0%	0.064	0.064	0.000
1790	99%	99%	0%	0.064	0.064	0.000
1800	99%	99%	0%	0.064	0.064	0.000
1810	99%	99%	0%	0.062	0.062	0.000
1820	99%	99%	0%	0.062	0.062	0.000
1830	99%	99%	0%	0.063	0.063	0.000
1840	99%	99%	0%	0.061	0.061	0.000
1850	99%	99%	0%	0.062	0.062	0.000
1860	99%	99%	0%	0.061	0.061	0.000
1870	99%	99%	0%	0.069	0.069	0.000
1880	99%	99%	0%	0.069	0.069	0.000
1890	99%	99%	0%	0.065	0.065	0.000
1900	99%	99%	0%	0.068	0.068	0.000
1910	99%	99%	0%	0.065	0.065	0.000
1920	99%	99%	0%	0.069	0.069	0.000
1930	15%	21%	6%	6.401	5.943	0.458
1940	27%	28%	1%	5.489	5.419	0.070

Table F-7. Effective shade targets, deficits, and daily maximum solar heat TMDLs for Lake Lawrence Creek.

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load ($kWh/m^2/day$)	Daily Heat TMDL ($kWh/m^2/day$)	Excess Heat Load ($kWh/m^2/day$)
0	49%	87%	38%	3.864	1.002	2.862
10	66%	90%	25%	2.588	0.748	1.841
20	99%	99%	0%	0.090	0.074	0.016
30	99%	99%	0%	0.080	0.046	0.033
40	99%	99%	0%	0.077	0.048	0.029
50	99%	99%	0%	0.078	0.059	0.019
60	99%	99%	0%	0.086	0.055	0.030
70	99%	99%	0%	0.088	0.058	0.031
80	99%	99%	0%	0.085	0.053	0.033
90	99%	99%	0%	0.084	0.048	0.036
100	99%	99%	0%	0.075	0.053	0.023
110	28%	42%	14%	5.368	4.332	1.036
120	99%	99%	0%	0.074	0.074	0.000
130	99%	99%	0%	0.067	0.054	0.013
140	99%	99%	0%	0.067	0.048	0.019
150	99%	99%	0%	0.073	0.043	0.031
160	99%	99%	0%	0.075	0.043	0.032
170	99%	99%	0%	0.078	0.045	0.032
180	99%	99%	0%	0.074	0.046	0.029
190	99%	99%	0%	0.055	0.038	0.017
200	99%	99%	0%	0.057	0.039	0.017
210	99%	99%	0%	0.058	0.040	0.017
220	99%	99%	0%	0.057	0.038	0.019
230	99%	100%	0%	0.056	0.032	0.024
240	99%	99%	0%	0.069	0.044	0.025
250	99%	99%	0%	0.066	0.040	0.025
260	99%	99%	0%	0.067	0.041	0.026
270	64%	92%	28%	2.712	0.623	2.089
280	35%	88%	54%	4.888	0.869	4.019
290	35%	88%	53%	4.872	0.932	3.940
300	32%	90%	58%	5.086	0.736	4.349
310	36%	91%	55%	4.784	0.644	4.139
320	34%	90%	57%	4.987	0.723	4.264

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
330	28%	89%	61%	5.430	0.838	4.592
340	30%	89%	59%	5.251	0.832	4.419
350	30%	89%	59%	5.264	0.824	4.440
360	32%	89%	57%	5.138	0.836	4.302
370	31%	90%	59%	5.175	0.759	4.415
380	34%	90%	57%	4.962	0.713	4.249
390	33%	91%	59%	5.060	0.660	4.400
400	32%	91%	60%	5.137	0.672	4.465
410	31%	91%	59%	5.150	0.695	4.455
420	34%	98%	64%	4.942	0.159	4.783
430	32%	98%	66%	5.085	0.135	4.949
440	37%	98%	62%	4.744	0.125	4.619
450	40%	99%	59%	4.510	0.084	4.426
460	36%	99%	62%	4.766	0.088	4.678
470	33%	99%	66%	5.051	0.092	4.959
480	35%	99%	65%	4.905	0.058	4.847
490	29%	99%	69%	5.292	0.100	5.192
500	33%	99%	66%	5.012	0.063	4.949
510	29%	99%	70%	5.299	0.063	5.235
520	35%	99%	64%	4.882	0.057	4.825
530	34%	99%	65%	4.944	0.039	4.905
540	36%	99%	63%	4.795	0.038	4.757
550	26%	99%	73%	5.583	0.098	5.485
560	27%	91%	64%	5.465	0.699	4.766
570	26%	88%	62%	5.556	0.911	4.645
580	23%	87%	63%	5.759	1.009	4.750
590	25%	87%	63%	5.663	0.950	4.713
600	24%	87%	63%	5.705	0.991	4.714
610	26%	87%	61%	5.525	0.966	4.559
620	27%	87%	60%	5.447	0.957	4.490
630	23%	87%	64%	5.759	0.984	4.775
640	26%	87%	61%	5.550	0.975	4.576
650	27%	87%	61%	5.512	0.938	4.574

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m^2/day)	Daily Heat TMDL (kWh/m^2/day)	Excess Heat Load (kWh/m^2/day)
660	27%	88%	60%	5.456	0.925	4.530
670	27%	88%	60%	5.462	0.933	4.529
680	26%	87%	61%	5.517	0.961	4.556
690	23%	86%	63%	5.774	1.015	4.759
700	26%	87%	61%	5.587	0.984	4.602
710	24%	87%	63%	5.685	0.955	4.730
720	26%	88%	62%	5.560	0.910	4.650
730	26%	88%	62%	5.536	0.906	4.630
740	27%	89%	61%	5.444	0.850	4.595
750	27%	88%	61%	5.491	0.928	4.563
760	26%	88%	62%	5.583	0.929	4.654
770	28%	88%	60%	5.401	0.913	4.488
780	27%	88%	61%	5.447	0.875	4.572
790	27%	88%	61%	5.491	0.901	4.590
800	26%	88%	63%	5.582	0.884	4.698
810	26%	88%	61%	5.518	0.928	4.590
820	27%	88%	62%	5.494	0.867	4.627
830	29%	89%	60%	5.325	0.860	4.465
840	29%	89%	59%	5.303	0.851	4.453
850	29%	89%	59%	5.299	0.846	4.453
860	29%	89%	60%	5.341	0.829	4.512
870	27%	89%	62%	5.481	0.848	4.632
880	31%	89%	58%	5.163	0.790	4.373
890	27%	89%	62%	5.501	0.837	4.665
900	29%	89%	61%	5.340	0.796	4.544
910	32%	91%	58%	5.089	0.713	4.377
920	31%	97%	66%	5.197	0.217	4.980
930	31%	100%	69%	5.179	0.036	5.143
940	32%	100%	68%	5.115	0.036	5.079
950	32%	99%	67%	5.066	0.041	5.025
960	39%	99%	61%	4.611	0.043	4.569
970	27%	99%	72%	5.447	0.044	5.403
980	34%	99%	65%	4.957	0.045	4.912

Longitudinal Distance from Headwaters (m)	Current Effective Shade (%)	Effective Shade Target (%)	Effective Shade Deficit (%)	Existing Daily Heat Load (kWh/m²/day)	Daily Heat TMDL (kWh/m²/day)	Excess Heat Load (kWh/m²/day)
990	29%	99%	70%	5.333	0.043	5.290
1000	37%	99%	63%	4.754	0.052	4.702
1010	40%	99%	59%	4.498	0.055	4.442
1020	39%	99%	61%	4.605	0.053	4.551
1030	42%	99%	57%	4.331	0.056	4.276
1040	45%	99%	55%	4.151	0.056	4.095
1050	44%	99%	55%	4.199	0.053	4.146
1060	30%	100%	69%	5.238	0.037	5.201
1070	34%	99%	65%	4.916	0.047	4.869
1080	43%	99%	56%	4.249	0.047	4.202
1090	40%	99%	60%	4.518	0.045	4.473
1100	58%	99%	42%	3.165	0.047	3.119
1110	42%	99%	57%	4.345	0.044	4.302
1120	53%	99%	46%	3.526	0.044	3.481
1130	52%	99%	47%	3.587	0.044	3.543
1140	49%	99%	51%	3.839	0.046	3.793
1150	39%	100%	61%	4.589	0.034	4.555
1160	39%	100%	60%	4.563	0.033	4.529
1170	39%	100%	61%	4.605	0.034	4.571
1180	50%	99%	49%	3.751	0.040	3.711
1190	44%	99%	55%	4.196	0.041	4.154
1200	38%	99%	62%	4.668	0.050	4.618
1210	40%	99%	59%	4.483	0.040	4.442
1220	39%	99%	60%	4.559	0.040	4.519
1230	39%	100%	61%	4.594	0.037	4.556
1240	53%	99%	46%	3.500	0.057	3.443
1250	61%	99%	39%	2.944	0.047	2.897
1260	47%	99%	52%	3.947	0.069	3.878
1270	46%	98%	52%	4.059	0.135	3.924
1280	1%	18%	18%	7.442	6.118	1.324