# Temperature Modeling of River and Lakes

# Course Project–Spokane River

Due: March 13, 2008

## Project Objectives

1. What is the temperature standard for the Spokane River in Washington?
    a. Document the designated uses, temperature standard criteria and whether natural conditions apply in the application of the standard.
    b. Do the river temperatures exceed the standard? What is the basis for this judgment?
2. Assume the temperature standard is 17.5 $^{o}$C and therefore the 7-day moving average of the daily maximum temperature cannot exceed this temperature. Also assume natural conditions do not apply. Develop management strategies for reducing river temperatures below the standard described in the previous two sentences.
    a. Find management scenarios that meet the temperature standard and demonstrate they meet the standard by showing time series plots at the furthest downstream location comparing the river temperatures to the standard.
    b. Comment on the strategies employed to meet the standard. Are they costly, realistic for the circumstances of the river.
3. Document results in a brief report using MS Word.

## Background

The Spokane River reach between Upper Falls Dam (RM 74.1) and Nine Mile Pool (RM 62.0) is simulated in this workshop problem (Figure 1). The Spokane wastewater treatment plant is located at RM 67.4 (segment 27) and Hangman Creek is located at RM 72.4 (segment 11).

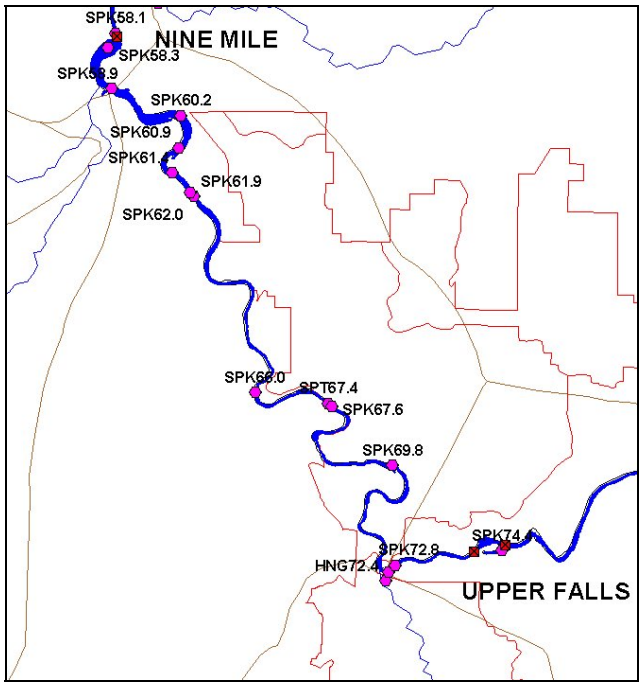



**Figure 1. Spokane River between Upper Falls Dam and Nine Mile Dam.**

## Model Grid

The segments are oriented as shown in Figure 2 below. The side view of the grid is shown in Figure 3.

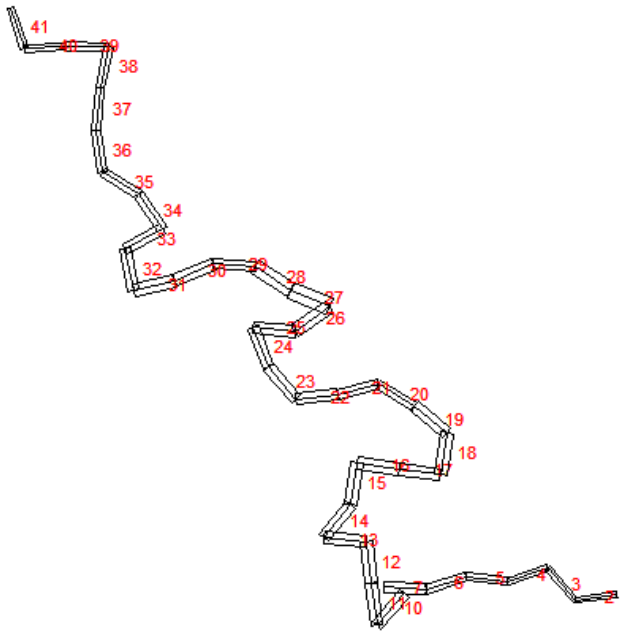



**Figure 2. Model segment layout.**

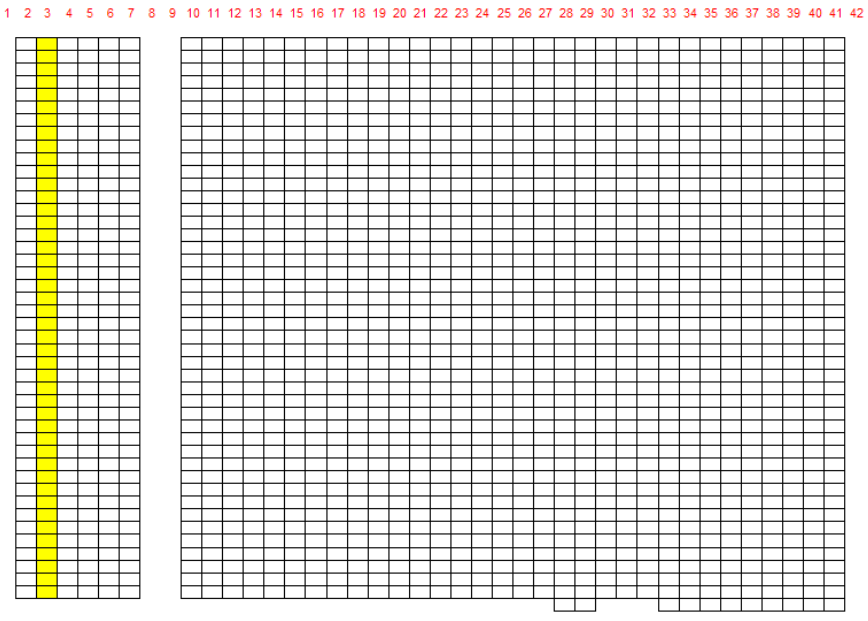



**Figure 3. Model vertical layers for Spokane River model.**

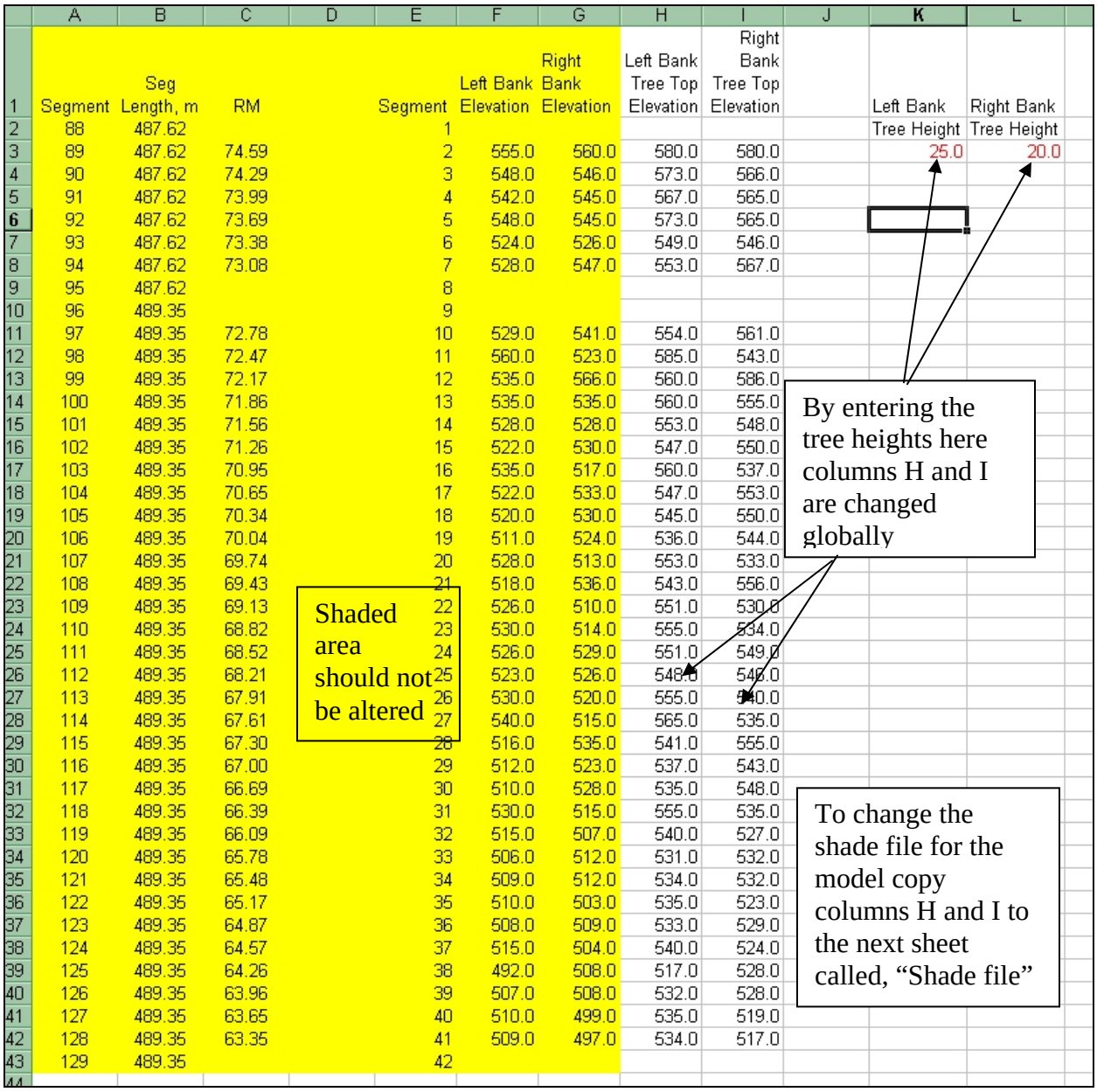
Tributary inputs are located at segments 11 and 27 representing a tributary Hangman Creek and the Spokane WWTP, respectively. You may want to examine the input files for temperature and flow by running the preprocessor and examining the pre.opt file where it gives statistical summaries of flow and

temperature for each tributary (or you can look at the files directly using a text editor or plotting in Excel).

## Shade file modification guidance

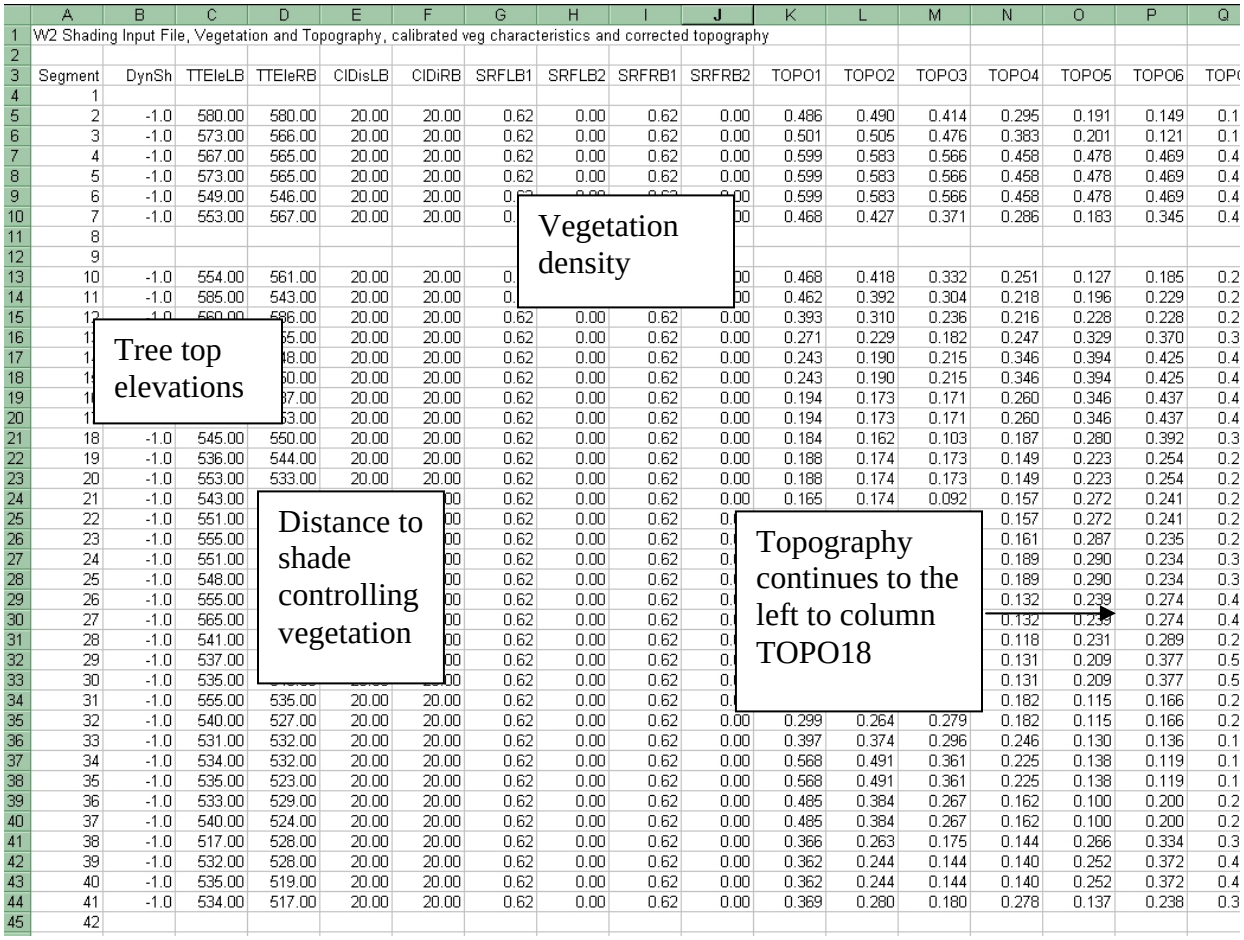
For an explanation of the fields in the shade file and how a shade file might be developed refer to the User Manual, Appendix C. An Excel file, Shade.xls, has been developed for use in modifying the shade file for simulations. The Excel file has the following sheets:

| Sheet name | Description |
|---|---|
| Shadefile_original | Original shade file information |
| Treetop | Tree top spreadsheet for changing tree top elevations globally |
| Shadefile | Shade file to be saved as an input to the model |
| TreeTopElev_LB | Plot of original and modified tree top elevations on the left bank and the left bank surface elevation. |
| TreeTopElev_RB | Plot of original and modified tree top elevations on the right bank and the left bank surface elevation. |
| CLDistance_LB | Plot of original and modified distance from the river centerline to the shade controlling vegetation for the left bank |
| CLDistance_RB | Plot of original and modified distance from the river centerline to the shade controlling vegetation for the right bank |
| Vegetation density_LB | Plot of original and modified vegetation density on the left bank |
| Vegetation density_RB | Plot of original and modified vegetation density on the right bank |




| | A | B | C | D | E | F | G | H | I | J | K | L |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Segment | Seg Length, m | RM | | Segment | Left Bank Elevation | Right Bank Elevation | Left Bank Tree Top Elevation | Right Bank Tree Top Elevation | | Left Bank Tree Height | Right Bank Tree Height |
| 2 | 88 | 487.62 | | | 1 | | | | | | | |
| 3 | 89 | 487.62 | 74.59 | | 2 | 555.0 | 560.0 | 580.0 | 580.0 | | 25.0 | 20.0 |
| 4 | 90 | 487.62 | 74.29 | | 3 | 548.0 | 546.0 | 573.0 | 566.0 | | | |
| 5 | 91 | 487.62 | 73.99 | | 4 | 542.0 | 545.0 | 567.0 | 565.0 | | | |
| 6 | 92 | 487.62 | 73.69 | | 5 | 548.0 | 545.0 | 573.0 | 565.0 | | | |
| 7 | 93 | 487.62 | 73.38 | | 6 | 524.0 | 526.0 | 549.0 | 546.0 | | | |
| 8 | 94 | 487.62 | 73.08 | | 7 | 528.0 | 547.0 | 553.0 | 567.0 | | | |
| 9 | 95 | 487.62 | | | 8 | | | | | | | |
| 10 | 96 | 489.35 | | | 9 | | | | | | | |
| 11 | 97 | 489.35 | 72.78 | | 10 | 529.0 | 541.0 | 554.0 | 561.0 | | | |
| 12 | 98 | 489.35 | 72.47 | | 11 | 560.0 | 523.0 | 585.0 | 543.0 | | | |
| 13 | 99 | 489.35 | 72.17 | | 12 | 535.0 | 566.0 | 560.0 | 586.0 | | | |
| 14 | 100 | 489.35 | 71.86 | | 13 | 535.0 | 535.0 | 560.0 | 555.0 | | | |
| 15 | 101 | 489.35 | 71.56 | | 14 | 528.0 | 528.0 | 553.0 | 548.0 | | | |
| 16 | 102 | 489.35 | 71.26 | | 15 | 522.0 | 530.0 | 547.0 | 550.0 | | | |
| 17 | 103 | 489.35 | 70.95 | | 16 | 535.0 | 517.0 | 560.0 | 537.0 | | | |
| 18 | 104 | 489.35 | 70.65 | | 17 | 522.0 | 533.0 | 547.0 | 553.0 | | | |
| 19 | 105 | 489.35 | 70.34 | | 18 | 520.0 | 530.0 | 545.0 | 550.0 | | | |
| 20 | 106 | 489.35 | 70.04 | | 19 | 511.0 | 524.0 | 536.0 | 544.0 | | | |
| 21 | 107 | 489.35 | 69.74 | | 20 | 528.0 | 513.0 | 553.0 | 533.0 | | | |
| 22 | 108 | 489.35 | 69.43 | | 21 | 518.0 | 536.0 | 543.0 | 556.0 | | | |
| 23 | 109 | 489.35 | 69.13 | | 22 | 526.0 | 510.0 | 551.0 | 530.0 | | | |
| 24 | 110 | 489.35 | 68.82 | | 23 | 530.0 | 514.0 | 555.0 | 534.0 | | | |
| 25 | 111 | 489.35 | 68.52 | | 24 | 526.0 | 529.0 | 551.0 | 549.0 | | | |
| 26 | 112 | 489.35 | 68.21 | | 25 | 523.0 | 526.0 | 548.0 | 546.0 | | | |
| 27 | 113 | 489.35 | 67.91 | | 26 | 530.0 | 520.0 | 555.0 | 540.0 | | | |
| 28 | 114 | 489.35 | 67.61 | | 27 | 540.0 | 515.0 | 565.0 | 535.0 | | | |
| 29 | 115 | 489.35 | 67.30 | | 28 | 516.0 | 535.0 | 541.0 | 555.0 | | | |
| 30 | 116 | 489.35 | 67.00 | | 29 | 512.0 | 523.0 | 537.0 | 543.0 | | | |
| 31 | 117 | 489.35 | 66.69 | | 30 | 510.0 | 528.0 | 535.0 | 548.0 | | | |
| 32 | 118 | 489.35 | 66.39 | | 31 | 530.0 | 515.0 | 555.0 | 535.0 | | | |
| 33 | 119 | 489.35 | 66.09 | | 32 | 515.0 | 507.0 | 540.0 | 527.0 | | | |
| 34 | 120 | 489.35 | 65.78 | | 33 | 506.0 | 512.0 | 531.0 | 532.0 | | | |
| 35 | 121 | 489.35 | 65.48 | | 34 | 509.0 | 512.0 | 534.0 | 532.0 | | | |
| 36 | 122 | 489.35 | 65.17 | | 35 | 510.0 | 503.0 | 535.0 | 523.0 | | | |
| 37 | 123 | 489.35 | 64.87 | | 36 | 508.0 | 509.0 | 533.0 | 529.0 | | | |
| 38 | 124 | 489.35 | 64.57 | | 37 | 515.0 | 504.0 | 540.0 | 524.0 | | | |
| 39 | 125 | 489.35 | 64.26 | | 38 | 492.0 | 508.0 | 517.0 | 528.0 | | | |
| 40 | 126 | 489.35 | 63.96 | | 39 | 507.0 | 508.0 | 532.0 | 528.0 | | | |
| 41 | 127 | 489.35 | 63.65 | | 40 | 510.0 | 499.0 | 535.0 | 519.0 | | | |
| 42 | 128 | 489.35 | 63.35 | | 41 | 509.0 | 497.0 | 534.0 | 517.0 | | | |
| 43 | 129 | 489.35 | | | 42 | | | | | | | |

**Figure 4. Tree top elevation calculation sheet**




| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | W2 Shading Input File, Vegetation and Topography, calibrated veg characteristics and corrected topography | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | |
| 3 | Segment | DynSh | TTEleLB | TTEleRB | CIDisLB | CIDiRB | SRFLB1 | SRFLB2 | SRFRB1 | SRFRB2 | TOPO1 | TOPO2 | TOPO3 | TOPO4 | TOPO5 | TOPO6 | TOPO |
| 4 | 1 | | | | | | | | | | | | | | | | |
| 5 | 2 | -1.0 | 580.00 | 580.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.486 | 0.490 | 0.414 | 0.295 | 0.191 | 0.149 | 0.1 |
| 6 | 3 | -1.0 | 573.00 | 566.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.501 | 0.505 | 0.476 | 0.383 | 0.201 | 0.121 | 0.1 |
| 7 | 4 | -1.0 | 567.00 | 565.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.599 | 0.583 | 0.566 | 0.458 | 0.478 | 0.469 | 0.4 |
| 8 | 5 | -1.0 | 573.00 | 565.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.599 | 0.583 | 0.566 | 0.458 | 0.478 | 0.469 | 0.4 |
| 9 | 6 | -1.0 | 549.00 | 546.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.599 | 0.583 | 0.566 | 0.458 | 0.478 | 0.469 | 0.4 |
| 10 | 7 | -1.0 | 553.00 | 567.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.468 | 0.427 | 0.371 | 0.286 | 0.183 | 0.345 | 0.4 |
| 11 | 8 | | | | | | | | | | | | | | | | |
| 12 | 9 | | | | | | | | | | | | | | | | |
| 13 | 10 | -1.0 | 554.00 | 561.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.468 | 0.418 | 0.332 | 0.251 | 0.127 | 0.185 | 0.2 |
| 14 | 11 | -1.0 | 585.00 | 543.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.462 | 0.392 | 0.304 | 0.218 | 0.196 | 0.229 | 0.2 |
| 15 | 12 | -1.0 | 560.00 | 586.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.393 | 0.310 | 0.236 | 0.216 | 0.228 | 0.228 | 0.2 |
| 16 | 13 | -1.0 | 555.00 | 565.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.271 | 0.229 | 0.182 | 0.247 | 0.329 | 0.370 | 0.3 |
| 17 | 14 | -1.0 | 555.00 | 548.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.243 | 0.190 | 0.215 | 0.346 | 0.394 | 0.425 | 0.4 |
| 18 | 15 | -1.0 | 555.00 | 560.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.243 | 0.190 | 0.215 | 0.346 | 0.394 | 0.425 | 0.4 |
| 19 | 16 | -1.0 | 555.00 | 537.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.194 | 0.173 | 0.171 | 0.260 | 0.346 | 0.437 | 0.4 |
| 20 | 17 | -1.0 | 555.00 | 553.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.194 | 0.173 | 0.171 | 0.260 | 0.346 | 0.437 | 0.4 |
| 21 | 18 | -1.0 | 545.00 | 550.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.184 | 0.162 | 0.103 | 0.187 | 0.280 | 0.392 | 0.3 |
| 22 | 19 | -1.0 | 536.00 | 544.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.188 | 0.174 | 0.173 | 0.149 | 0.223 | 0.254 | 0.2 |
| 23 | 20 | -1.0 | 553.00 | 533.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.188 | 0.174 | 0.173 | 0.149 | 0.223 | 0.254 | 0.2 |
| 24 | 21 | -1.0 | 543.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.157 | 0.272 | 0.241 | 0.2 |
| 25 | 22 | -1.0 | 551.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.157 | 0.272 | 0.241 | 0.2 |
| 26 | 23 | -1.0 | 555.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.161 | 0.287 | 0.235 | 0.2 |
| 27 | 24 | -1.0 | 551.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.189 | 0.290 | 0.234 | 0.3 |
| 28 | 25 | -1.0 | 548.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.189 | 0.290 | 0.234 | 0.3 |
| 29 | 26 | -1.0 | 555.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.132 | 0.239 | 0.274 | 0.4 |
| 30 | 27 | -1.0 | 565.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.132 | 0.239 | 0.274 | 0.4 |
| 31 | 28 | -1.0 | 541.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.118 | 0.231 | 0.289 | 0.2 |
| 32 | 29 | -1.0 | 537.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.131 | 0.209 | 0.377 | 0.5 |
| 33 | 30 | -1.0 | 535.00 | 555.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.131 | 0.209 | 0.377 | 0.5 |
| 34 | 31 | -1.0 | 555.00 | 535.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.165 | 0.174 | 0.092 | 0.182 | 0.115 | 0.166 | 0.2 |
| 35 | 32 | -1.0 | 540.00 | 527.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.299 | 0.264 | 0.279 | 0.182 | 0.115 | 0.166 | 0.2 |
| 36 | 33 | -1.0 | 531.00 | 532.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.397 | 0.374 | 0.296 | 0.246 | 0.130 | 0.136 | 0.1 |
| 37 | 34 | -1.0 | 534.00 | 532.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.568 | 0.491 | 0.361 | 0.225 | 0.138 | 0.119 | 0.1 |
| 38 | 35 | -1.0 | 535.00 | 523.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.568 | 0.491 | 0.361 | 0.225 | 0.138 | 0.119 | 0.1 |
| 39 | 36 | -1.0 | 533.00 | 529.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.485 | 0.384 | 0.267 | 0.162 | 0.100 | 0.200 | 0.2 |
| 40 | 37 | -1.0 | 540.00 | 524.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.485 | 0.384 | 0.267 | 0.162 | 0.100 | 0.200 | 0.2 |
| 41 | 38 | -1.0 | 517.00 | 528.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.366 | 0.263 | 0.175 | 0.144 | 0.266 | 0.334 | 0.3 |
| 42 | 39 | -1.0 | 532.00 | 528.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.362 | 0.244 | 0.144 | 0.140 | 0.252 | 0.372 | 0.4 |
| 43 | 40 | -1.0 | 535.00 | 519.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.362 | 0.244 | 0.144 | 0.140 | 0.252 | 0.372 | 0.4 |
| 44 | 41 | -1.0 | 534.00 | 517.00 | 20.00 | 20.00 | 0.62 | 0.00 | 0.62 | 0.00 | 0.369 | 0.280 | 0.180 | 0.278 | 0.137 | 0.238 | 0.3 |
| 45 | 42 | | | | | | | | | | | | | | | | |

**Figure 5. Shade file**

Column width and cell formatting should not be changed.

To save the information on this Excel sheet as a shade input file for CE-QUAL-W2:

1. Save the excel file so all of your information is saved.
2. Go to “File”, “Save as” and then change the “save as type:” from an excel file to a “Formatted Text (Space delimited) (*.prn)” and then change the file name from Shade.prn to “Shade.npt”, including the quotes
3. Click on the Save button. If you are prompted with any message boxes just say yes
4. Close the file. If you are asked if you want to save any changes, say No.

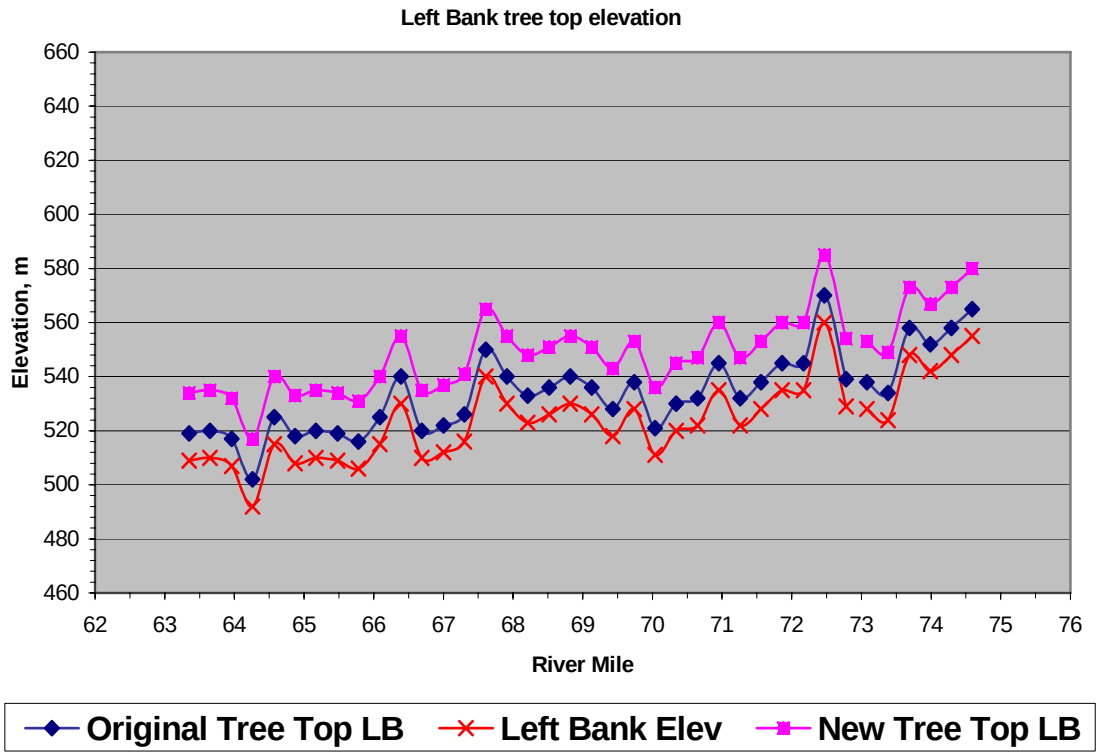



**Figure 6. Tree top elevation, left bank**

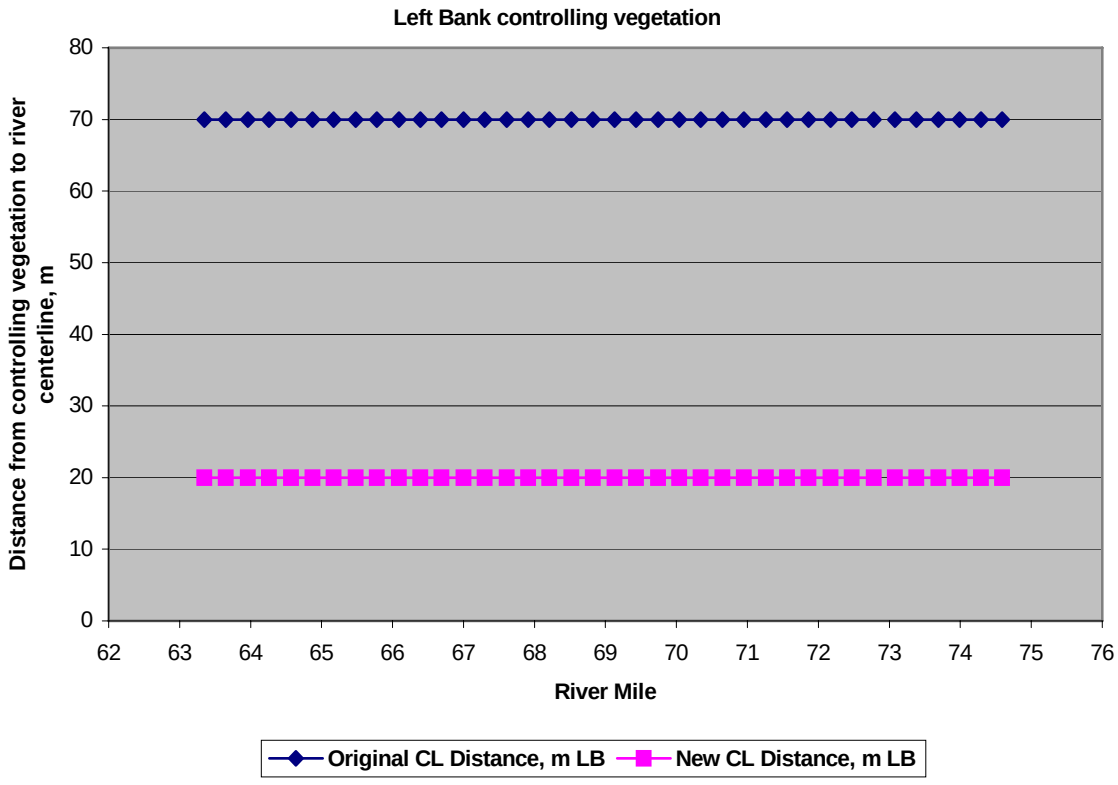



**Figure 7. Distance from the river centerline to the shade controlling vegetation, left bank**

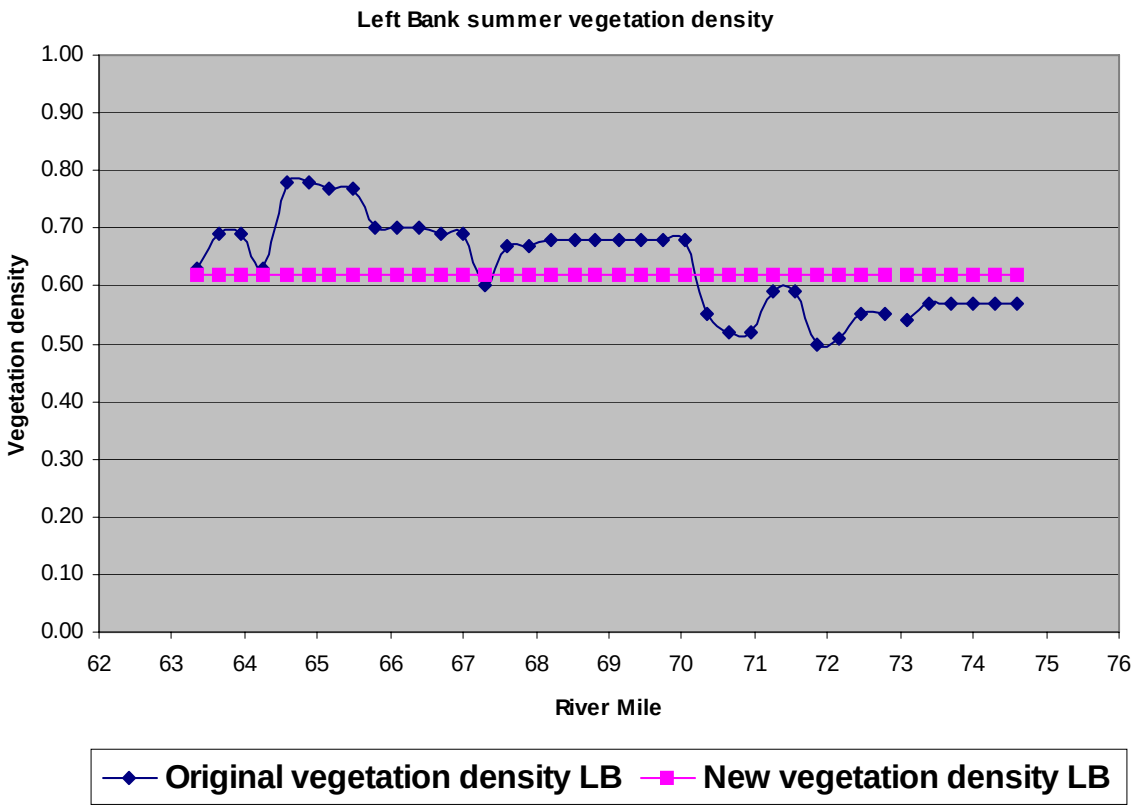



**Figure 8. Vegetation density, left bank**

## Running the River Section Workshop Problem

### Running the model

1. Run the preprocessor (double click on **pre.exe**)
2. Execute the W2 model (double click on **w2.exe**)

### Post-processing

3. Run the post processing code: DMaxTemp.exe. This program reads in the file TempSites.txt which lists the model segments for output. The program then ones the matching temperature output files (two_##.opt), calculates the daily maximum temperature and the 7-day moving average of the daily maximum temperature.

**River Section Workshop Problem File Descriptions**

**Table 1. Model files**

| File Type | File Name | Description |
|---|---|---|
| control file | w2_con.npt | Model control file |
| bathymetry file | bth4.npt | Segment lengths, initial water surface elevation, segment orientation, layer thickness and cell widths |
| meteorological file | met00jr4.npt | Time series file containing temperature, dew point temperature, wind speed, wind direction and cloud cover data (based on solar radiation) |
| Array Viewer file | graph.npt | File used for turning on constituents for viewing while the model is running |
| Wind sheltering file | wsc.npt | Wind sheltering coefficient for each segment and variable over time |
| Shade file | shade.npt | Shade file for characterizing vegetative and topographic shade or static shade values |
| branch inflow files | qin_br8.npt | Flow rate file for branch 1 inflow |
| | tin_br8.npt | Temperature file for branch 1 inflow |
| | cin_br8.npt | Concentration file for branch 1 inflow |
| tributary files | Hangq00.npt<br>SPKwwtpq00.npt | Flow rate file for tributary 1 (Hangman Creek)<br>Flow rate file for tributary 2 (Spokane wtp) |
| | hangT00.npt<br>SPKwwtpt00.npt | Temperature file for tributary 1<br>Temperature file for tributary 2 |
| | hangC00.npt<br>SPKwwtpc00.npt | Concentration file for tributary 1<br>Concentration file for tributary 1 |
| distributed tributary files | qdt_br8.npt<br>tdt_br9.npt | Flow rate file for distributed tributary 1<br>Flow rate file for distributed tributary 2 |
| | tdt_br8.npt<br>tdt_br9.npt | Temperature file for distributed tributary 1<br>Temperature file for distributed tributary 2 |
| | cdt_br8.npt<br>cdt_br9.npt | Concentration file for distributed tributary 1<br>Concentration file for distributed tributary 2 |
| model output files | snp1.opt | Snapshot file |
| | tsr_1.opt to tsr_7.opt | Time series files |
| | Cpl1.opt | Contour file |

## Appendix A–Shade File Format shade.npt

The shade file consists of 4 types of vegetation information for each bank of the river and then topographic information as well as specifying the time for leaf-out and for trees to lose their leaves if they are deciduous. The column headings are described in the following table:

| Column Heading | Description |
|---|---|
| Segment | Segment number in the model. Only active segment numbers are accepted. |
| DYNSH | If between 0 and 1 this is a non-dynamic constant shade reduction similar to that used in Version 3.0. If this number is negative, this means that the rest of the columns to the right will be read and dynamic shading will be implemented. |
| TTEleLB | Tree top elevation on the left bank (m). The elevation of the left bank plus the height of the tree/vegetation are used to provide the tree top elevation. This is the elevation according to the local datum and is not the elevation above the stream bank. |
| TTEleRB | Tree top elevation on the right bank (m). |
| ClDisLB | Distance from the centerline of the river segment to the shade controlling line of vegetation on the left bank (m). |
| ClDisRB | Distance from the centerline of the river segment to the shade controlling line of vegetation on the right bank (m). |
| SRFLB1 | Shade reduction factor, left bank. This applies from SRFJD1 to SRFJD2 (and over multiple years for the same time period of the simulation goes over 360 days). Based on the extent of vegetation along the length of the segment and the density of the vegetation (0 to 1). |
| SRFLB2 | Shade reduction factor, left bank (0 to 1). This applies from SRFJD2 to SRFJD1 (and over multiple years for the same time period of the simulation goes over 360 days). Based on the extent of vegetation along the length of the segment and the density of the vegetation (0 to 1). |
| SRFRB1 | Shade reduction factor, right bank. This applies from SRFJD1 to SRFJD2 (and over multiple years for the same time period of the simulation goes over 360 days). Based on the extent of vegetation along the length of the segment and the density of the vegetation (0 to 1). |
| SRFRB2 | Shade reduction factor, right bank (0 to 1). ). This applies from SRFJD2 to SRFJD1 (and over multiple years for the same time period of the simulation goes over 360 days). Based on the extent of vegetation along the length of the segment and the density of the vegetation (0 to 1). |
| TOPO1 to TOPO18 | Topographic inclination angle (radians) for every $20^o$ around a segment starting with TOPO1 at $0^o$ North and moving clockwise. |
| SRFJD1 | Shading reduction factor Julian day for which SRF #1 starts to apply. This is typically thought as “leaf-out” conditions for deciduous trees. |
| SRFJD2 | Shading reduction factor Julian day for which SRF #2 starts to apply. This is typically thought as when deciduous trees lose their leaves. |

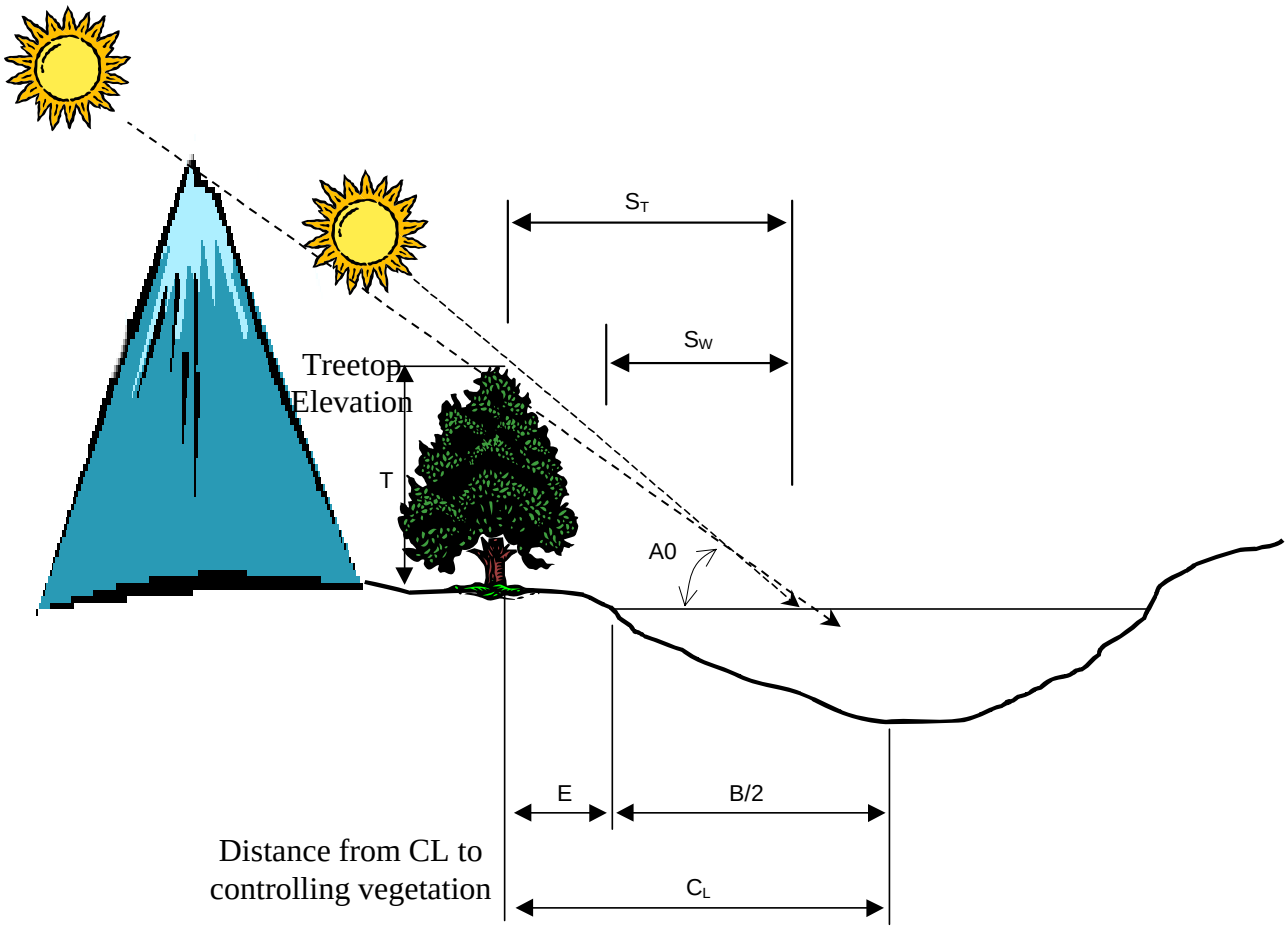



**Figure 9. Topographic and Vegetative shading, solar altitude (A0) and vegetation height (T) affect the shadow length.**