



DEPARTMENT OF  
**ECOLOGY**  
State of Washington

## **Standard Operating Procedure EAP046, Version 3.0**

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### **Computer Analysis of Hemispherical Digital Images Collected as Part of a TMDL or Forests and Fish Unit Technical Study**

August 2019  
Publication 19-03-224  
Recertified 2019

## Purpose of this Document

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The Washington State Department of Ecology develops Standard Operating Procedures (SOPs) to document agency practices related to sampling, field and laboratory analysis, and other aspects of the agency's technical operations.

## Publication Information

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This SOP is available on the Department of Ecology's website at <https://fortress.wa.gov/ecy/publications/SummaryPages/1903224.html>.

Ecology's Activity Tracker Code for this SOP is 08-514.

### ***Recommended citation:***

Stohr, A. 2019. Standard Operating Procedure EAP046, Version 3.0: Computer Analysis of Hemispherical Digital Images Collected as Part of a TMDL or Forests and Fish Unit Technical Study. Publication No. 19-03-224. Washington State Department of Ecology, Olympia.  
<https://fortress.wa.gov/ecy/publications/SummaryPages/1903224.html>. Recertified 2019.

## Contact Information

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For more information contact:

Publications Coordinator  
Environmental Assessment Program  
P.O. Box 47600, Olympia, WA 98504-7600  
Phone: (360) 407-6764

Washington State Department of Ecology – <https://ecology.wa.gov>

- Headquarters, Olympia 360-407-6000
- Northwest Regional Office, Bellevue 425-649-7000
- Southwest Regional Office, Olympia 360-407-6300
- Central Regional Office, Union Gap 509-575-2490
- Eastern Regional Office, Spokane 509-329-3400

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Environmental Assessment Program  
Standard Operating Procedure EAP046  
Version 3.0

Original Author – A. Stohr  
Date – 5/06/2008

Original Reviewers – James Kardouni, Jack Janisch  
Date – 4/21/2008

Current Editor – Tighe Stuart  
Date – 4/18/2019

Current Reviewer – Nuri Mathieu  
Date – 4/19/2019

QA Approval – Arati Kaza, Ecology Quality Assurance Officer

Approved Date: 4/21/2008  
RECERTIFIED: 04/24/2019  
Signatures on File

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### SOP Revision History

Revision Date	Rev number	Summary of changes	Sections	Reviser(s)
11/3/03	1	First draft of SOP	all	D. Bilhimer
2/26/2007	1.2	Incorporated internal comments	all	D. Bilhimer
4/2/2008	2.0	Extensive changes. Incorporated Forests and Fish unit methods. Added site file management section. Extensively updated technical methods	all	A. Stohr
5/06/2008	2.1	Minor changes. Incorporated Jack and James comments from version 2.0 draft	all	A. Stohr
1/17/2014	2.2	Clarified methods that the TMDL staff use to calculate effective shade from Hemiview software	6.6.2.2	T. Stuart
1/22/2014	2.2	Recertified	all	B. Kammin
4/18/2019	3.0	Extensive changes. Re-wrote image analysis sections to reflect software change from HemiView® to GLA®. Added appendix to document comparability of results from two software packages. Removed some Forests and Fish material that is no longer used. Various other edits and changes to reflect current practice.	all	T. Stuart
8/2/2019	3.0	Accessibility and formatting updates.	All	R. Froese

## **1.0 Purpose and Scope**

- 1.1 The objective of this analysis is to estimate total radiation load, canopy cover, and/or effective shade from photographs taken with a hemispherical fish-eye adapter lens.
- 1.2 Hemispherical digital photographs are taken looking upwards from beneath the plant canopy, using a 180° fish-eye lens and digital camera. Images are generally taken under the riparian canopy or in the middle of a stream channel. The Gap Light Analyzer (GLA<sup>®</sup>) software application is used with these images to determine total solar radiation, canopy cover, and effective shade for a time period selected by the user.
- 1.3 To perform the analysis, GLA<sup>®</sup> converts the full color hemispherical photo to a two-color image where black pixels represent shading vegetation and topography, and white pixels represent sky pixels. Whether a pixel is assigned a shade or sky value is determined by its brightness and color values. The purpose of image processing is to “tune” the hemispherical photo so that shading vegetation that might have a high enough brightness and/or color value to be classified as sky can be diminished and can correctly be classified as shade. In addition, portions of the sky that are blue, in an otherwise cloudy sky may be incorrectly classified as shade, and these can also be corrected.
- 1.4 The best hemispherical photographs are gathered under evenly overcast skies or early in the morning before the sun is present in the picture. Because of uncontrollable weather conditions and many clear sunny days during the summer months (when hemispherical photos are typically taken), there may be poor contrast between the riparian vegetation and the sky, or the solar disk may be present in the photograph. Raw images from the field may need some image corrections before they can be analyzed using the GLA<sup>®</sup> software.
- 1.5 Analysis generally follows this sequence:
  - 1.5.1 Acquire photos and site-specific station data using SOP EAP045 (Stohr and Bilhimer, 2019).
  - 1.5.2 Decide which pictures will be used, and gather key site data for each location.
  - 1.5.3 Review image and decide whether photo editing is needed.
  - 1.5.4 If needed, use Adobe Photoshop (or other photo editing software) to process image. Save edited image to a new file name.
  - 1.5.5 Import image into GLA<sup>®</sup>, register the image, and enter site configuration data.
  - 1.5.6 Classify image to a two-color, shade/sky image using the threshold value.
  - 1.5.7 Run calculations. Export results from GLA<sup>®</sup> to Excel.
  - 1.5.8 Calculate desired outputs such as canopy cover and effective shade.

1.6 Effective shade values calculated from field-collected hemispherical photos can be compared to values estimated with the computer model, SHADE. During TMDL analysis, the SHADE model is typically used to estimate effective shade resulting from riparian vegetation. The model usually calculates shade at 100-meter intervals along a stream. Effective shade values generated for hemispherical photos taken in the middle of a stream channel give a field-measured value to compare against the model-generated value. The calculated canopy cover estimates can be used as the vegetation density input to the SHADE model.

## 2.0 Applicability

2.1 This procedure applies to all hemispherical photo analysis conducted by EAP. This procedure includes instructions for Hemispherical photos, which are often used in TMDL studies for temperature, dissolved oxygen, and/or pH. They have also been used by Forests and Fish staff who generally take photos in small, steep, headwater stream areas. The procedure is general enough to apply to other situations with only minimal changes to meet a project's unique objectives.

## 3.0 Definitions

3.1 **Effective Shade:** Fraction of total possible solar radiation above the vegetation and topography that is blocked from reaching the surface of the stream and summed over a full day. The effective shade at a particular location (the location of the hemispherical photo) can be calculated, using GLA<sup>®</sup>, for any day or season of the year. Because the solar path across the sky changes each day, the solar exposure a particular location receives will also change each day. Note: To date, studies have covered deciduous “leaf on” portions of the year. For winter analysis, it would not be appropriate to run a winter “leaf off” date with a summer deciduous canopy photo.

3.2 **Canopy Cover:** The percentage of the sky that is blocked by vegetation or topography. Unlike effective shade, this is a largely static quantity (assuming no wind) between full leaf expansion and leaf drop. This value can also be measured by a densiometer.

3.3 **Hemispherical photo:** A hemispherical, or fish-eye, digital picture. A hemispherical photo is a permanent record of canopy condition.

3.4 **Gap Light Analyzer (GLA<sup>®</sup>):** A computer software package for the analysis of hemispherical digital images. The software is available for free download at:

<https://www.caryinstitute.org/science-program/our-scientists/dr-charles-d-canham/gap-light-analyzer-gla>

3.5 **Riparian vegetation:** Vegetation occurring along stream corridors.

3.6 **SHADE:** A computer program used by Ecology to estimate stream center effective shade from riparian vegetation and stream channel maps.

3.7 **Thermistor:** A temperature data logger

3.8 **TMDL:** Total Maximum Daily Load

#### **4.0 Personnel Qualifications/Responsibilities**

4.1 Persons involved in the field data collection and analysis must have experience and training in the natural, environmental or physical sciences. Relevant computer skills needed for this procedure include the following software packages: Gap Light Analyzer<sup>®</sup>, Adobe Photoshop Elements, and Microsoft Excel.

4.2 Natural Resource Scientist 1/2/3, Environmental Engineer 1/2/3, Environmental Specialist 1/2/3/4/5, Hydrogeologist 1/2/3/4, Administrative Intern 1/2/3, Environmental Technician.

#### **5.0 Equipment, Reagents, and Supplies**

5.1 The analyst must have access to the following computer software: Gap Light Analyzer (GLA<sup>®</sup>), an image-processing program such as Adobe Photoshop Elements<sup>®</sup>, and Microsoft Excel. This procedure assumes the hemispherical photos have already been collected under SOP EAP045 for hemispherical digital photography field surveys (Stohr and Bilhimer, 2019). That protocol covers all equipment necessary to acquire the hemispherical photos.

#### **6.0 Summary of Procedure**

6.1 Gather site information prior to beginning photo analysis.

6.1.1 For each site where hemispherical photos were taken, the following data are needed:

- Latitude/Longitude – needed both as decimal degrees (for calculating magnetic declination) and as D:MM:SS (for entry in GLA<sup>®</sup>). For both these uses, degree values need to be positive (e.g., Longitude 117, not -117).
- Elevation (meters)
- Photo date (for purposes of calculating magnetic declination)
- Magnetic Declination – calculated from latitude/longitude and photo date using the web tool at <https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml> or a similar one. Magnetic declination data is necessary if the photo was collected by orienting to magnetic north, which is standard procedure for TMDL staff. If the photo was collected oriented to true north, then this data is not needed.

6.1.2 It is common to have more than one hemispherical photo at each site. For example, TMDL staff often have three photos assigned to each site; C= center of stream, LB = riparian zone on the left bank, RB = riparian zone on the right bank. In this case, each

photo does *not* need to be defined as a separate site; multiple photos taken at one site can share a site information (configuration) file in GLA<sup>®</sup>.

6.2 Initial photo evaluation. This step is to determine whether photo editing in Adobe Photoshop (Step 6.3) is needed for proper pixel classification.

6.2.1 Open an image using any photo viewing software, such as Windows Photo Viewer.

6.2.2 Visually assess the photo by asking the following question: *Do all of the sky portions of the photo appear to be brighter (lighter colored) than all of the vegetation portions?*

6.2.3 The answer to this question is likely to be YES, if:

- The sky was overcast at the time the photo was taken
- The vegetation is entirely dark colored, such as conifer trees

Go to Step 6.4 (GLA analysis).

6.2.4 The answer to this question is likely to be NO, if:

- The sky was partly or entirely clear at the time the photo was taken, with lots of blue visible
- Some of the vegetation is light colored, such as bright green leaves backlit by sunlight, or yellowing reed canary grass.

Go to Step 6.3 (Photoshop).

6.2.5 If unsure, proceed to Step 6.4 (GLA<sup>®</sup> analysis) and work through the procedure until Step 6.4.4 (Threshold selection). If able to find a threshold that appropriately classifies sky as white and vegetation as black, then proceed. If it becomes apparent that any threshold chosen will either classify some sky as vegetation or vice versa, then go back to Step 6.3 (Photoshop).

6.3 **Image Processing in Adobe Photoshop.** The image processing procedure uses Adobe Photoshop elements to correct color and brightness problems with the original image if GLA<sup>®</sup> is not classifying it correctly. Generally, the less editing and fewer decisions we make about classification the better. There are a range of revision tools in Adobe Photoshop Elements so pick one that works without being heavy-handed.

6.3.1 Open your hemispherical photo in Adobe Photoshop Elements. Save your image with a new name or in a new folder location, so as to make sure that an unedited original copy of the photo is preserved.

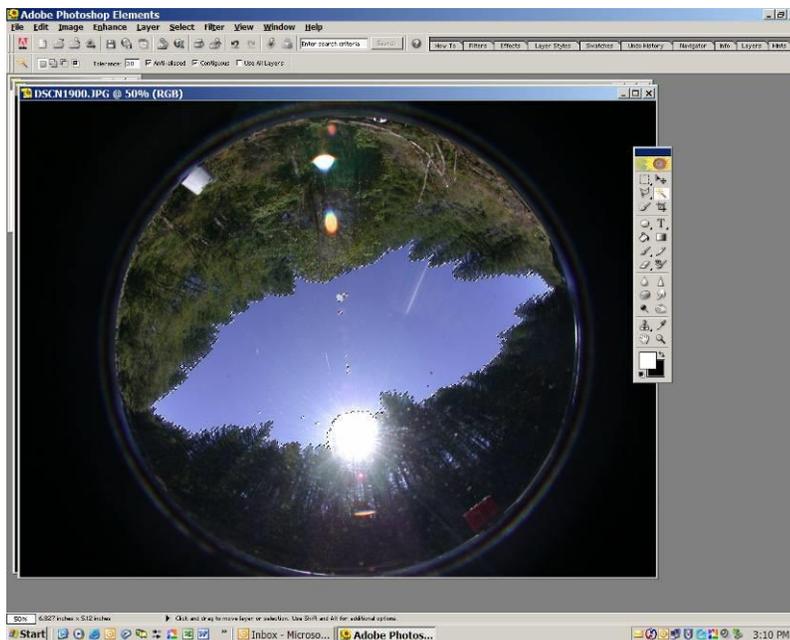
6.3.2 Photo editing suggestions from TMDL staff.

- 6.3.2.1 Select the magic wand tool from the tool bar (Figure 1) and move the wand into the sky portion of the image.



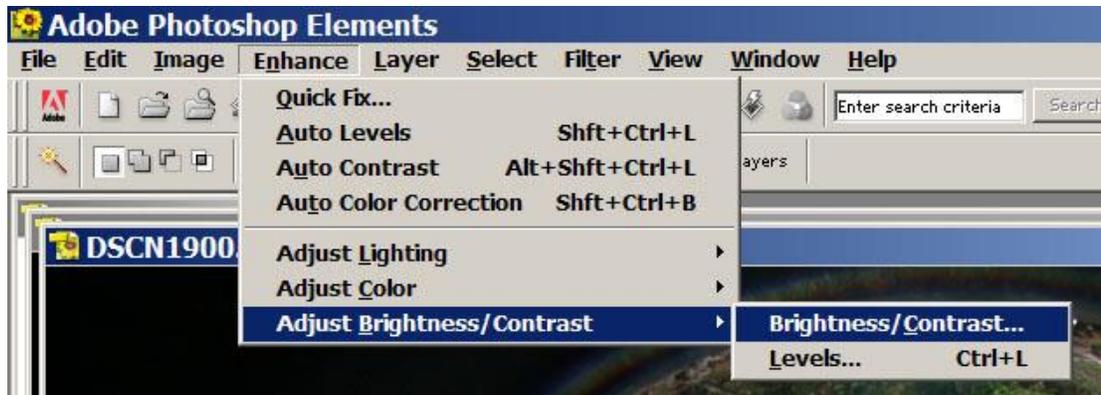
**Figure 1. Magic wand tool in Photoshop Elements.**

- 6.3.2.1.1 The magic wand tool selects pixels of color based on the color values of neighboring pixels. Using this tool allows you to select the sky pixels around the complicated shapes of riparian vegetation. Hold the SHIFT key and click the left mouse button several times while in different parts of the sky to select as much of the sky as you can (Figure 2).



**Figure 2. Using the magic wand tool to select the sky pixels. The sky pixel selection follows the outline of the tree canopy with a dashed line.**

- 6.3.2.2 Select the brightness/contrast control menu from the command bar as shown in Figure 3.



**Figure 3. The adjust brightness/contrast menu.**

- 6.3.2.2.1 This will open the tool with slider controls for brightness and contrast. Adjust the sky pixel brightness so that it is a high value. In GLA<sup>®</sup>, the sky pixels need to have the highest brightness values. Adjusted sky pixels should look something like the example in Figure 4. Often the solar disc can also be dealt with by simply copying a section of sky and pasting over it.



**Figure 4. Sky pixels brightened.**

- 6.3.2.3 Besides the magic wand tool, there are other selection tools that are also useful. Here are some common tools that may come in handy (use the help function in Elements to learn more about using each tool):
- 6.3.2.3.1 *Dodge and burn tools*, for brightening or darkening pixels similar to the brightness controls only it functions as a paintbrush style that you can freehand with the mouse.

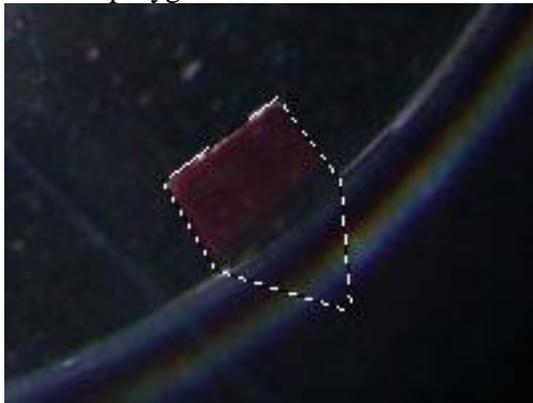
6.3.2.3.2 *Stamp tool*, for cloning other parts of the image using the mouse. This can be useful for covering up anomalies such as sun glare (bright spots with riparian vegetation behind it); basically covering up what GLA<sup>®</sup> would incorrectly interpret as sky and making sure the pixels are classified as shading vegetation. This can also be helpful for removing the little dark “bubbles” that show up sometimes when adjusting the sky brightness using the magic wand tool.

6.3.2.3.3 *Paint brush tool*, useful for removing highlights on tree trunks or sun flares by painting a black color over the part of the image that is definitely vegetation or some other shading feature.

6.3.2.3.4 *Note: Don't create vegetation in the image where there is none now. If sun flares or hotspots have obscured the canopy any touchups should be minimal and an assessment of whether or not to analyze the picture should be considered.*

6.3.2.4 The north/south orientation markers may require editing. The markers are located on the image perimeter, and will almost always be in front of vegetation or topography. Therefore we usually want them to classify as black “vegetation pixels” in GLA<sup>®</sup>. Sometimes these markers, especially the white “south” marker, will mis-classify as sky. If this occurs, modify the markers as follows:

6.3.2.4.1 Use the polygon selector tool to select around each marker (Figure 5).



**Figure 5. North orientation marker selected for brightening/darkening.**

6.3.2.4.2 Use the brightness slider (per step 6.3.2.2) to darken or lighten the markers as appropriate. Make sure you can still tell which one is the red “north” marker, as you will need that for image registration in GLA<sup>®</sup>.

6.3.3 Photo Editing suggestions from Forests and Fish staff

6.3.3.1 When the solar disc is present in the photo, adjusting threshold may not correct the image without substantial loss elsewhere. So, examine the solar disc first. If the program classifies the solar disc correctly as sky, then move on to glare and other corrections. Otherwise, the solar disc can often be masked by darkening the image slightly, then copying and pasting a small section taken from elsewhere in the image.

This reduces the contrast enough to split out vegetation from sky without drastic alteration of other settings. It also preserves image fine structure, often lost when the spray can or other heavy handed editing techniques are used. Generally, the less editing and fewer decisions we make about classification the better. Briefly describe your edits and record them as QA, along with threshold, in the spreadsheet.

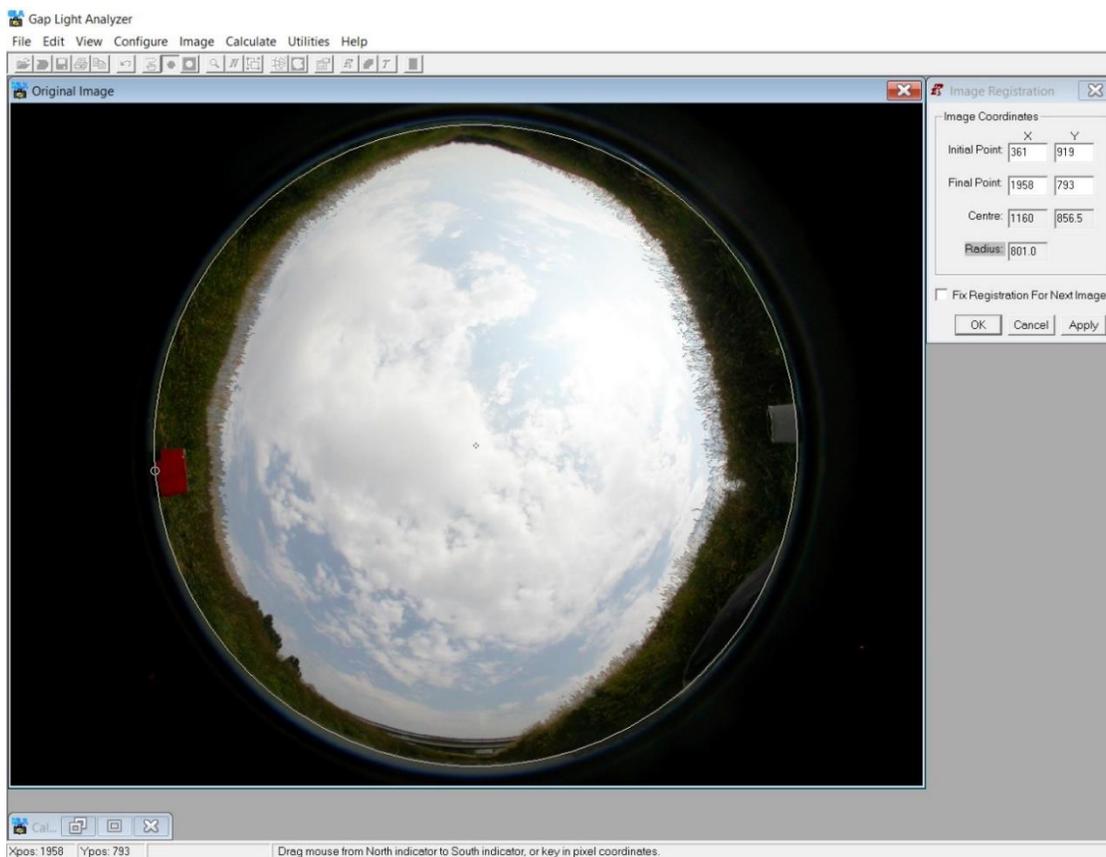
6.3.3.2 Now examine the image for glare. For example, on sunny days, glare on tree trunks will be classified as sky. As with the solar disc, small sections of the image can be copied elsewhere to preserve the general stand structure. Sometimes odd reflections also show up in the image, so approach them the same way.

6.3.3.3 Then move on to foliage. If the threshold is too low, light flecks will show up as vegetation. If too high, foliage edges will wash out and be classified as sky. Focus on conifer foliage in the mid taurus of the image because the distortion is generally higher at the photo perimeter and foliage may be washed out at zenith. Then adjust the sky/vegetation threshold to a value between full opacity and full transparency of the conifer foliage, toggling between the actual image and classified image. Zoom in and out as needed. Try to balance over-estimation of direct overhead canopy gaps and under-estimation of perimeter canopy gaps overall.

#### 6.4 **Gap Light Analyzer (GLA)<sup>©</sup> Image Analysis.**

6.4.1 Launch GLA<sup>©</sup>. Go to File>Open Image and select the image to be analyzed. The image will appear in the “Original Image” window.

6.4.2 Image registration. “Registration” in GLA<sup>©</sup> refers to the process of defining the extent of the circular hemispherical image for analysis. Go to Configure > Register Image. Click at the base of the red (north) orientation marker and drag to the base of the white (south) orientation marker to define the image extent (Figure 6).



**Figure 6. Image registration in GLA®.**

After clicking OK, the image will now appear in two side-by-side windows: “Registered Image” and “Working Image.”

6.4.3 Enter site data.

6.4.3.1 If you have already created a site configuration file (.scn) for the site pertaining to your image (for example, if you previously processed a different photo from the same site), then you can re-use that file. Go to **Configure > Load Configuration...** and select the appropriate .scn file.

6.4.3.2 If you do not have a .scn file, then go to **Configure > Edit Configuration...**

6.4.3.3 Go to the “Image” tab of the “Configuration Settings” dialogue box.

6.4.3.3.1 Set “Initial Cursor Point” to North.

6.4.3.3.2 If the photo was collected by orienting to true north (i.e., magnetic declination was accounted for in the field), then select “Geographic North.”

- 6.4.3.3.3 If the photo was collected by orienting to magnetic north (standard procedure for TMDL staff), then select “Magnetic North” and enter the appropriate magnetic correction/declination (see Step 6.1.1).
- 6.4.3.3.4 Set Projection Distortion to “Polar.” This is the only option that corresponds to a hemispherical/fisheye lens. The other options correspond to other lens types (for example, the Lambert Equal Area projection might be used for a fully spherical (360°) lens).
- 6.4.3.4 Proceed to the “Site” tab of the “Configuration Settings” dialogue box.
  - 6.4.3.4.1 Enter the Latitude, Longitude, and Elevation for the photo site.
  - 6.4.3.4.2 Select “Horizontal” Orientation, for most applications. If the particular desired application involves photos taken at an incline, it is possible to enter an angle and azimuth here to specify the incline.
  - 6.4.3.4.3 Make sure the “Use Topographic Mask Data” box is unchecked.
- 6.4.3.5 Proceed to the “Resolution” tab of the “Configuration Settings” dialogue box.
  - 6.4.3.5.1 Choose optimal solar time step depending on model run period. If you are only running the GLA<sup>®</sup> analysis for a one-day period, then you can choose a time step of 2 minutes and still have a reasonable calculation runtime. If you are running a longer seasonal analysis, you will need a larger time step to avoid excessive runtime.
  - 6.4.3.5.2 Choose start and end date. For TMDL analysis for temperature, dissolved oxygen, and/or pH, we are often interested in the critical period at the hottest part of the summer, which we will represent as a single day, usually August 1. Depending on the needs of the analysis, it is possible to enter any day of the year, or any seasonal period. It is important that the period or date chosen corresponds with the vegetative conditions shown in the image; for example, it would not be appropriate to analyze a date during the winter leaf-off period using a photo taken during summer leaf-on period.
  - 6.4.3.5.3 Keep default sky regions (36 Azimuth Regions, 9 Zenith Regions)
- 6.4.3.6 Proceed to the “Radiation” tab of the “Configuration Settings” dialogue box.
  - 6.4.3.6.1 Select “Modelled” data source.
  - 6.4.3.6.2 Specify the parameters for the solar radiation model. These are important for realistically defining the incoming (above canopy) radiation. The default values will likely not be appropriate. Table 1 provides some guidelines for the parameter values. Unless otherwise indicated, these values are taken from the GLA<sup>®</sup> Users Manual, Chapter 8, which provides further explanation and guidance.

**Table 1. Recommended parameter values for solar radiation model in GLA.**

Parameter	Recommended values
Solar Constant (W/m <sup>2</sup> )	Global value: 1367 (units are W/m <sup>2</sup> )
Units	If interested in total shortwave: MJ m-2 d-1 (use for TMDLs) <sup>a</sup> If interested in PAR: Mols m-2 d-1
Cloudiness Index (kt)	SW BC Winter avg: 0.25-0.35 SW BC Summer avg: 0.55-0.65 SW BC Clear day max: 0.8 Eastern WA, May-Oct clear days: 0.7 <sup>b</sup>
Beam Fraction	Clear sky: 0.85-0.9 Heavy cloud cover: 0
Spectral Fraction	If interested in total shortwave: 1.0 (use for TMDLs) <sup>a</sup> If interested in PAR: Worldwide typical values: 0.44-0.47 Worldwide cloudy day values: 0.483-0.69 SW BC typical – moderately cloudy to clear days: 0.45 SW BC very cloudy days: up to 0.72

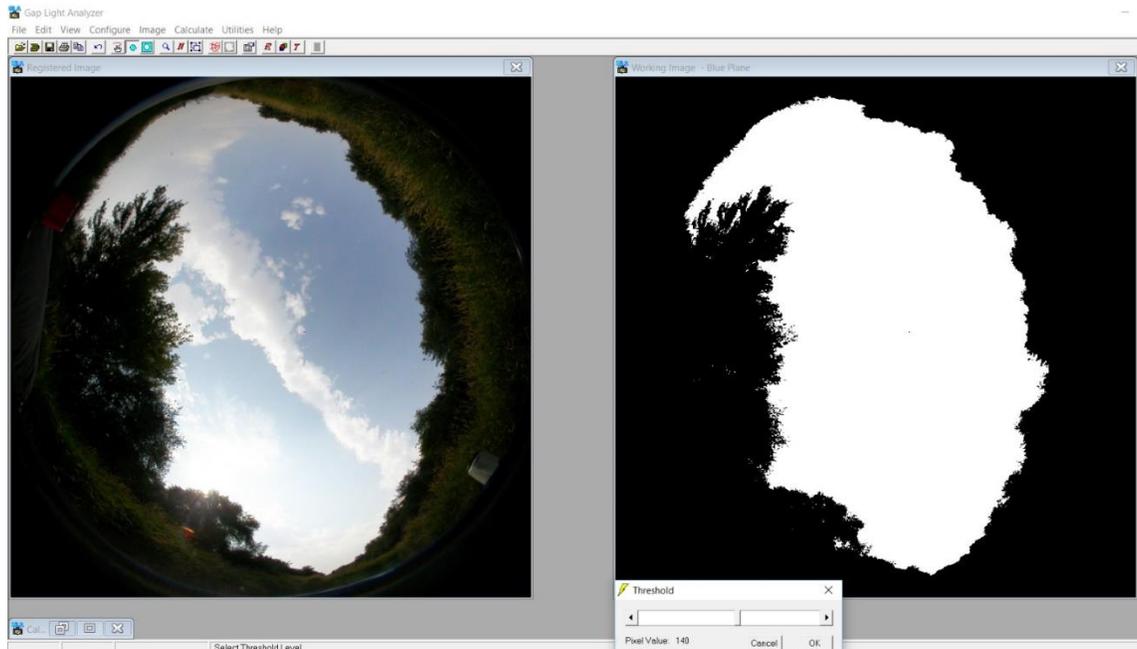
<sup>a</sup> It has been demonstrated that GLA<sup>®</sup> produces identical results for effective shade and canopy cover regardless of which units and what spectral fraction value are used. Although the calculated amount of incoming radiation will differ, the % transmitted through the canopy will remain the same. If effective shade and canopy cover are the only desired outputs, then the units and spectral fraction input do not matter.

<sup>b</sup> Estimated from solar radiation data collected by Ecology during 2007 near Lacrosse, WA.

- 6.4.3.6.3 Select “UOC Model” for Sky-Region Brightness, and set Clear-Sky Transmission Coefficient to default value of 0.65.
- 6.4.3.7 Click “Save As” to save the Configuration Settings as a .scn file. Then click “OK.”
- 6.4.4 Classify image.
- 6.4.4.1 (Optional Step) Go to Image > Choose a Color Plane. Then select “Blue” and click OK. This selects the blue color channel of the image, which brightens the blue areas (typically sky) and darkens other areas (typically vegetation and topography). This is often helpful for correctly classifying pixels.

#### 6.4.4.2

Go to Image > Threshold. The right-hand “Working Image” window will turn to black-and-white. The left-hand “Registered Image” remains in color to provide side-by-side comparison. Adjust the threshold slider until the pixels representing vegetation and topography are black, and the pixels representing sky are white (Figure 7). If it is not possible to find a threshold that correctly classifies nearly all pixels, then the image needs further processing in Photoshop; return to Step 6.3.



**Figure 7. A classified hemispherical photo with an appropriate threshold setting.**

#### 6.4.4.3

Once a suitable threshold has been found, note the threshold (pixel) value. Click OK. Most of the items in the Image menu will be grayed out; if you need to get back to the threshold slider, you must select Undo first.

#### 6.4.4.4

If parts of the image are “compromised,” i.e., have areas that don’t classify correctly due to challenging color patterns (light vegetation against dark sky), have sun glare, human structures, etc., it can be useful to see if the compromised areas fall along the sunpath. Go to Utilities > Plot Sunpath... and click “Calculate.” Compromised areas away from the sunpath will introduce a small amount of error into canopy cover and diffuse transmission estimates, but this may be acceptable (Figure 8). Compromised areas on the sunpath can introduce significant error into the direct transmission (and therefore effective shade) calculations.



**Figure 8. Sunpath plot. The bridge in the upper-left corner of this image is away from the sunpath and will not contribute significant error to the calculations.**

- 6.4.5 Run calculations.
- 6.4.5.1 Go to Calculate > Run Calculations...
- 6.4.5.2 Choose “Canopy Structure and Transmitted Gap Light”. If you want detailed model output data for each time step, then check the box for “Log Details to File...” If you are only interested in overall outputs, then leave this box unchecked. Click “Calculate.”
- 6.4.5.3 When calculation is complete, the “Calculation Summary Results” window will appear. Review results to make sure they seem reasonable. In User Field 1, enter the unique identifier for the photo. For TMDL studies, this is often something like “39NAN-11.3 C”. In User Field 2, it is recommended to record the threshold pixel value used. Click “Append.” This will add a row to the “Calculation Output Summary Data” window.
- 6.4.5.4 Open the “Calculation Output Summary Data” window, which normally sits minimized in the lower left corner of the GLA<sup>®</sup> interface. Check that there is a new line representing the data just appended. Check that lines representing all previous images are intact.
- 6.4.6 Close the “Working Image” and “Registered Image” windows in preparation for running the next image. If desired, these can each be saved, which will allow for exact re-tracing of steps if needed. This is probably not strictly necessary; if you have the

saved .scn file and record of threshold pixel value, it will be possible to very quickly repeat the process with nearly identical results. Very slight differences may result from small mouse-dragging differences during image registration. Do *not* close GLA<sup>®</sup> until all images have been processed.

6.4.7 Repeat process starting at Step 6.2 for each image.

6.4.8 Once all images have been processed, open the “Calculation Output Summary Data” and click “Save As...” to export the results. This creates a semicolon-delimited file that can be opened in Notepad, copied to Excel, and imported using Excel’s “Text to Columns” function.

## 6.5 Output Calculations

6.5.1 The “Calculation Output Summary Data” sheet imported from GLA<sup>®</sup> to Excel contains the information needed to calculate canopy cover and effective shade, which are the two most commonly desired outputs from hemispherical photography analysis.

6.5.1.1 [Canopy Cover] = 100% – [% Cnpy Open]

6.5.1.2 [Effective Shade] = 100% – [% Trans Tot]

6.5.1.3 If output total shortwave radiation values (Abv Dir, Abv Dif, Abv Tot, Trans Dir, Trans Dif, Trans Tot) are needed for modeling purposes, the desired units are often W/m<sup>2</sup>. Values can be converted as follows:

$$1 \text{ MJ/m}^2/\text{d} = 11.574 \text{ W/m}^2$$

## 7.0 Records Management

7.1 All original hemispherical photos should be maintained in their raw electronic form in one data folder (e.g., named hemi\_initial). Copies should be used for the image processing and GLA<sup>®</sup> analysis steps and should be kept in a separate data folder (e.g., named hemi\_final). Both folders should be kept with the other project files.

7.2 Site configuration files (.scn) should be retained. This makes it easier to “retrace your steps” if necessary, and if for some reason the images need to be re-analyzed, it will save a great deal of time. Working image and registered image files can be retained as well if desired. However, GLA<sup>®</sup> saves these two files as bitmaps, so the file size may be large.

## 8.0 Quality Control and Quality Assurance Section

8.1 Image processing should not include substantial changes to the image (adding or subtracting vegetation not in the original image would be entirely improper). Any changes made should be consistent with the vegetation in the original image.

- 8.2 The final spreadsheet output should be reviewed before finalizing to ensure that:
  - 8.2.1 All images were processed.
  - 8.2.2 Shade and canopy cover results make sense given image (“straight face” check).
  - 8.2.3 Units are correct.

## **9.0 Safety**

- 9.1 This procedure involves working at a computer in an office setting, and no special safety procedures are necessary other than normal office guidelines. Give your eyes a break occasionally from staring at these images.

## 10.0 References

- 10.1 Stohr, A. and D. Bilhimer. 2019. Standard Operating Procedure EAP045, Version 3.0: Hemispherical Digital Photography Field Surveys. Publication No. 19-03-201. Environmental Assessment Program, Washington State Department of Ecology, Olympia.  
<https://fortress.wa.gov/ecy/publications/SummaryPages/1903201.html>
- 10.2 Frazer, G., C. Canham, and K. Lertzman. 1999. Gap Light Analyzer (GLA): Imaging software to extract canopy structure and gap light transmission indices from true-colour fisheye photographs, users manual and program documentation. Copyright © 1999: Simon Fraser University, Burnaby, British Columbia, and the Institute of Ecosystem Studies, Millbrook, New York.

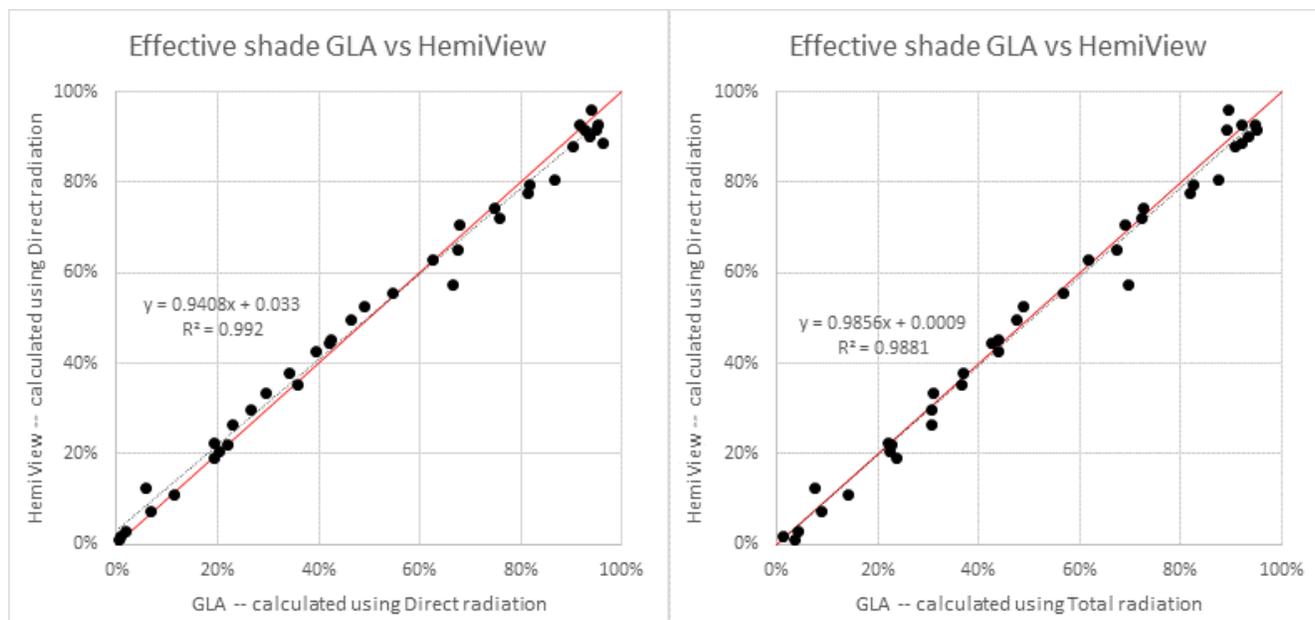
## Appendix A: Comparison of HemiView<sup>®</sup> and GLA<sup>®</sup> effective shade results

Prior to 2017, EAP used the HemiView<sup>®</sup> software package for hemispherical image processing. This software was not supported by Microsoft Windows 10. All previous versions of this SOP up through version 2.2 were written for HemiView<sup>®</sup>.

In 2017, EAP switched to using GLA<sup>®</sup> for image processing. This free software is supported by Windows 10. It has some additional advantages, such as:

1. The ability to use the blue color channel to increase contrast between vegetation and sky.
2. A data output format that simplifies and improves calculation of key parameters such as effective shade.

The comparability of effective shade calculations from the two software packages was tested using 38 hemispherical photos taken for the Upper Yakima Tributaries Temperature TMDL. These photos had previously been analyzed using HemiView<sup>®</sup>. The images were re-processed using GLA<sup>®</sup>, and the results were compared (Figure A-1). This comparison demonstrates that effective shade calculations from the two software packages are very similar. There is little if any bias between the two methods, especially if using GLA<sup>®</sup> total radiation (%Trans Tot) output for the calculation, which is the most scientifically valid method anyway. This is the method used in this SOP (step 6.5.1.2).



**Figure A-1. Comparison of effective shade results from HemiView<sup>®</sup> and GLA<sup>®</sup>. The red line indicates the ideal 1-to-1 relationship.**