



The Spherical ACD Meter

June 2009

An Instrument for Measuring Shade

The Spherical ACD meter allows you to make quick estimates of shade and other canopy density parameters.

HOW TO USE IT

1. After ensuring that magnetic declination is set correctly, point the instrument true south and bring the notch on the lid close to your eye as shown in Figure 1.
2. Hold the base steady while keeping the bubble centred in the bullseye level. The centre of the mirror should appear even with the top edge of the rear sight (the notch) while taking a reading as shown in Figure 2.
3. Estimate the proportion of area occupied by canopy in each segment marked on the mirror.



Figure 1
Correct position for taking a reading.

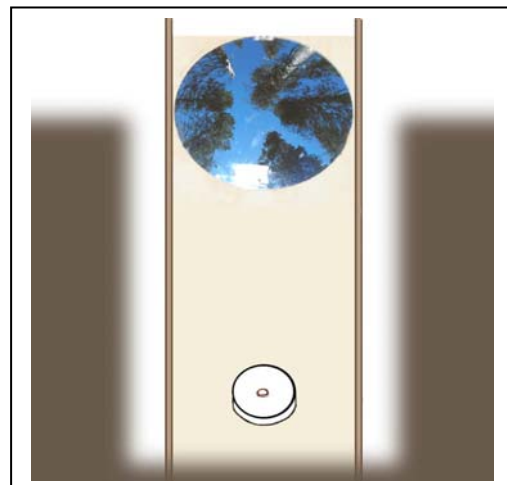


Figure 2
Correct view of mirror through sight

CANOPY DENSITY IN DIFFERENT PARTS OF THE SKY

The main purpose of the Spherical ACD Meter is to estimate canopy density in the area traversed by the sun between 10 AM and 2 PM local solar time in August. This is described under “Angular Canopy Density”. The mirror might also be etched to show other areas of sky as described under “Canopy Around the Zenith”.

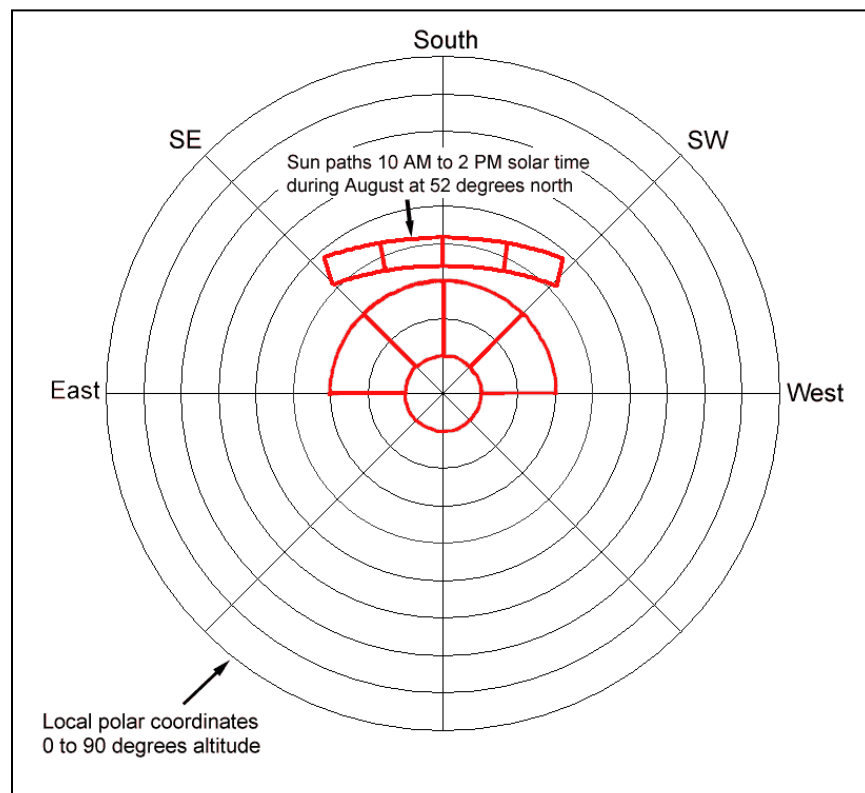


Figure 3

At 52 degrees latitude, August sun paths are always lower than a vertical angle of 60 degrees. This allows room on the mirror for lines at 60 and 80 degrees.

The figure shows polygons etched on the mirror when the instrument is configured for 52 degrees north latitude.

Angular Canopy Density

Vegetation along the sun's path intercepts direct solar radiation and reduces incoming heat energy on clear days. Solar radiation carries more heat energy when the sun is high in the sky. Therefore, shade between 10 AM and 2 PM (local solar time) is more beneficial for reducing stream heating than is shade before 10AM or after 2PM. The percentage of shade between 10AM and 2PM is referred to as "Angular Canopy Density" or ACD. The portion of the sky in which ACD is measured depends on your latitude and the time of the year in which stream temperature is a concern. This is commonly the month of August in the northern hemisphere.

The mirror of the Spherical ACD Meter can be engraved for any latitude and can be used within several degrees of the design latitude with little error. Examples of variations in sun paths with latitude are shown in Appendix 4.

The four sun path segments in Figure 4 define the area of the sky that is traversed by the sun in one hour increments from 10 AM to 2 PM local solar time. Angular Canopy Density is calculated as the average of canopy density in these four segments. The two curved lines define the season in which ACD is of interest (in this case, the month of August at 52 degrees latitude). The five straight lines indicate sun positions at one-hour increments.

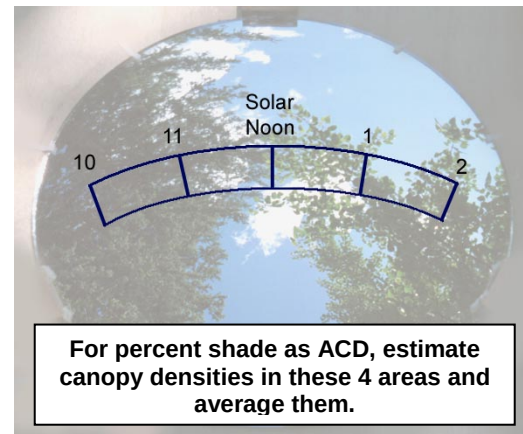


Figure 4
Area in which ACD is measured

Canopy Around the Zenith

While vegetation along the sun's path is important for intercepting direct solar radiation, canopy in other parts of the sky is important for other reasons such as intercepting precipitation and blocking outgoing longwave radiation at night. Depending on the latitude for which the Spherical ACD Meter is configured, it may allow you to also measure canopy density at zenith angles of up to 30 degrees.

If your instrument is engraved with sky segments shown in Figure 5, the central circular area defines a zenith angle of 10 degrees, i.e the area above a vertical angle of 80 degrees. This corresponds closely with the area measured with a "moosehorn" and can be used to estimate "canopy cover" or "mean crown completeness". Canopy density in the 10-degree zenith angle can be estimated while the instrument is pointed in any direction as long as it is held level.

The four segments adjacent to this circular area in Figure 5 define four equal areas of sky between 60 and 80 degrees altitude at horizontal angle intervals of 45 degrees. For example, when the instrument is pointed south, the leftmost segment represents azimuths from east to southeast and the next segment represents azimuths from southeast to south.

By reading canopy density in these four segments with the instrument pointed south and then doing the same with it pointed north, canopy density in all compass directions between zenith angles of 10 to 30 degrees (vertical angles of 60 to 80 degrees) can be obtained.

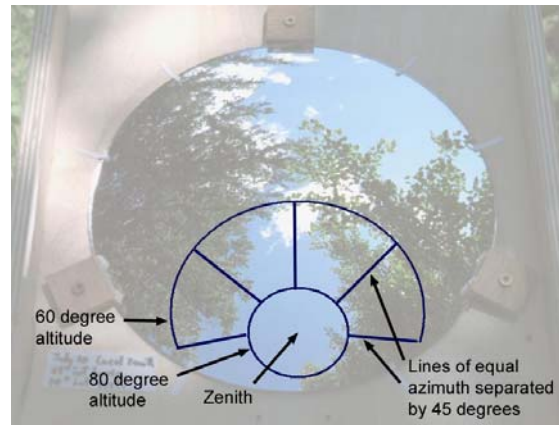


Figure 5
Segments around the zenith

A sample field form for entering data is provided in Appendix 2.

MAKING OCULAR ESTIMATES

It is recommended that you estimate canopy density in each segment to the nearest 10 percent unless you feel more confident. For example, if canopy density is very low or very high, more precise estimates are easier. Due to the complexity of canopy structure and inherent sources of error, even with photographic methods, there is little to be gained by making visual estimates of canopy density to within less than 5 percent or to spend more than 5 or 10 seconds making a single estimate.

The accuracy with which different users can estimate ACD with this instrument was documented in Teti and Pike (2005). While they found significant differences between 5 different users, all of them were able to estimate average ACD to within 11 percent of values measured by computer analysis of fisheye images. Operators who received an hour of training were more accurate than an operator who received 15 minutes of training.

Appendix 1 contains sample photographs of forest canopy and the corresponding canopy densities as measured by computer on fisheye photographs. For practice, we suggest that you estimate canopy density in the photos as you would in the field and record your numbers on the enclosed form, then compare your numbers with the computer measurements. You will find that canopy density is most difficult to estimate when the canopy is highly fragmented. The appendix includes a comparison of canopy densities estimated by an experienced user with those made by computer. Because ACD is the average of four separate estimates and canopy above 60 degrees is the average of nine separate estimates, estimates of ACD and canopy density above 60 degrees are more

accurate than estimates of canopy density in individual segments. This is shown in the scattergram.

INTERPRETING CANOPY DENSITY

There are many different canopy density parameters and methods for measuring it. Therefore, when planning your data collection it is important to consider the relevant parameter and measurement method. Likewise, when reporting your data it is useful to describe your purpose and methods.

The term “Angular Canopy Density” was first used by Brazier and Brown (1973). They and other authors (Wooldridge and Stern, 1979; Beschta, et al., 1987) suggested that for purposes of summertime stream heating, shade is most important between 10 AM and 2 PM in mid to late summer and that this should be the reference parameter for the exposure of streams to sunlight. Since canopy density is simply a proportion of area occupied by canopy, data can also be reported as the portion occupied by gaps, which is 1 minus canopy density. Therefore, average ACD on a stream reach is an estimate of the attenuation of solar radiation by shade and $1 - \text{average ACD}$ is a measure of solar radiation transmittance. This was confirmed by Teti (2006) who found that 93 percent of the variability of average solar radiation transmittance on stream reaches (measured by computer analysis of fisheye photos) was explained by ACD (also measured by computer).

If you are specifically interested in the proportion of ground covered by the vertical projections of canopy (sometimes referred to as “canopy cover” or “crown closure” in the literature), or if you want results which correspond with those taken with a “moosehorn”, (e.g. Bunnell and Vales, 1990) you can use canopy density in the 10 degree zenith angle, i.e. canopy density above 80 degrees.

If your objective is to estimate population statistics or make statistical inferences about canopy density, you should be familiar with experimental design and statistics and potential sources of error in ocular estimation. The spatial variability of ground-based canopy density is high and it is important to try to obtain large, unbiased samples.

CARE AND MAINTENANCE

Do not expose the Spherical ACD Meter to temperature above 55 degrees Celsius (130 F). Do not leave on the dashboard of a closed vehicle in summer.

The mirror surface is glass so it can be cleaned with rubbing alcohol and a clean cotton cloth.

Proper calibration of the instrument depends on the precise orientation of the sight, the bubble level, and the mirror. If any of these are moved or damaged, the instrument will

need to be recalibrated. A simple check can be made by viewing something that is precisely at the vertex (i.e. directly above the mirror). The vertex should appear in the central segment of the mirror where the azimuth lines would intersect if extended.

If the instrument is damaged or you suspect it needs recalibration, please return it to me. I will repair defects associated with materials or workmanship at no cost.

REFERENCES

Bunnell, Fred L. and David J. Vales. 1990. Comparison of methods for estimating forest overstory cover: differences among techniques. Can. J. For. Res. 20:101-107

Beschta, Robert L., Robert E. Bilby, George W. Brown, L. Blair Holtby, and Terry D. Hofstra. 1987. Stream temperature and aquatic habitat: fisheries and forestry interactions. pp. 191-232 in Cundy, Terrance W. and Ernest O. Salo (eds.). Streamside Management: Forestry and Fishery Interactions. Proceedings of Conference at Univ. of Wash. Feb. 1986. Institute of Forest Resources, Contribution no. 57, 471p.

Brazier, Jon R. and George W. Brown. 1973. Buffer strips for stream temperature control. Research Paper 15, School of Forestry, Oregon State Univ., Corvallis, OR. 8 p.

Teti, P. 2001. A new instrument for measuring shade provided by overhead vegetation. Extension Note #34. Cariboo Forest Region. B.C. Ministry of Forests. 8p. URL: www.for.gov.bc.ca/rsi/research/cextnotes/extnot34.pdf

Teti, P. 2006. Stream Shade as a Function of Channel Width and Riparian Vegetation in the BC Southern Interior. Streamline Watershed Management Bulletin. 9(2):10-15
URL www.forrex.org/streamline/streamline.asp

Teti, P.A. and R.G. Pike. 2005. Selecting and testing an instrument for surveying stream shade. BC Journal of Ecosystems and Management 6(2):1-16. URL: www.forrex.org/publications/jem/jem.asp

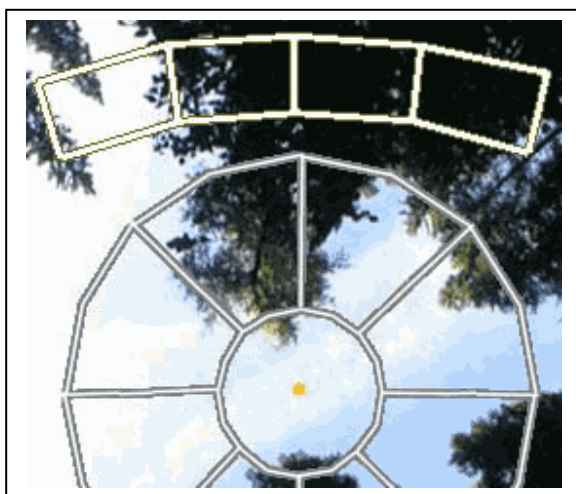
Wooldridge, David D. and Douglas Stern. 1979. Relationships of Silvicultural Activities and Thermally Sensitive Forest Streams. Report DOE 79-5a-5, College of Forest Resources, University of Washington, 90 pp.

Contact

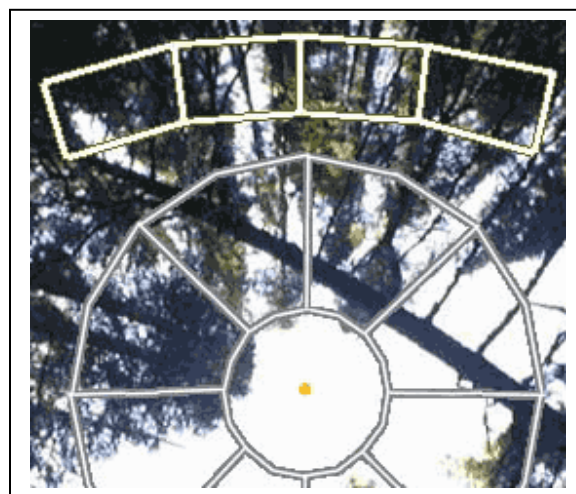
Pat Teti
1427 Kallyn Rd.
Williams Lake, B.C. V2G 4Y1
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APPENDIX 1

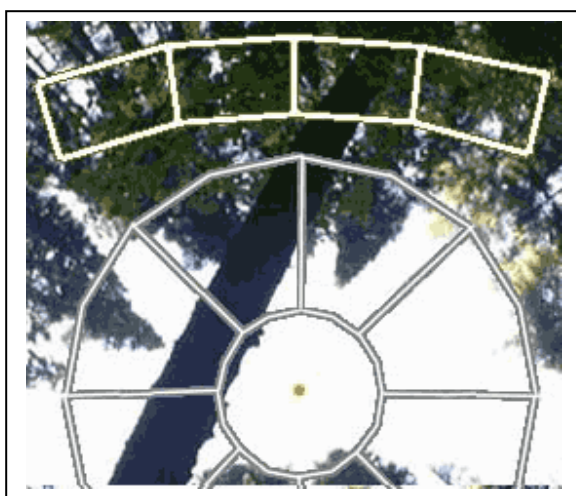
SAMPLE IMAGES WITH COMPUTER CALCULATED CANOPY DENSITIES AND COMPARISON OF COMPUTER WITH OCULAR ESTIMATES



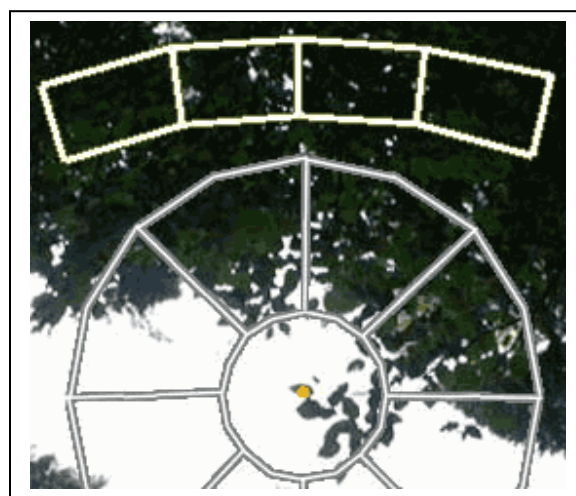
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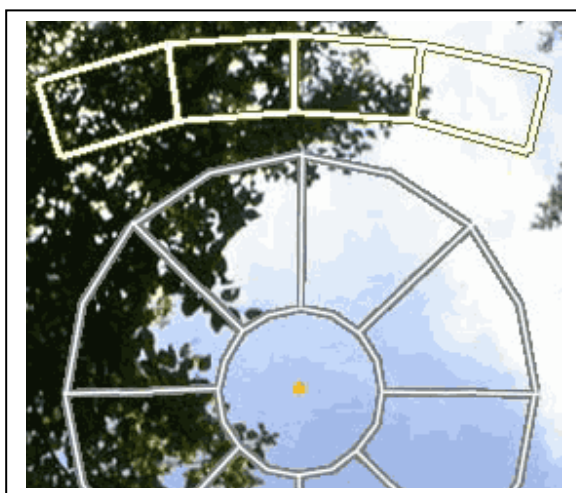
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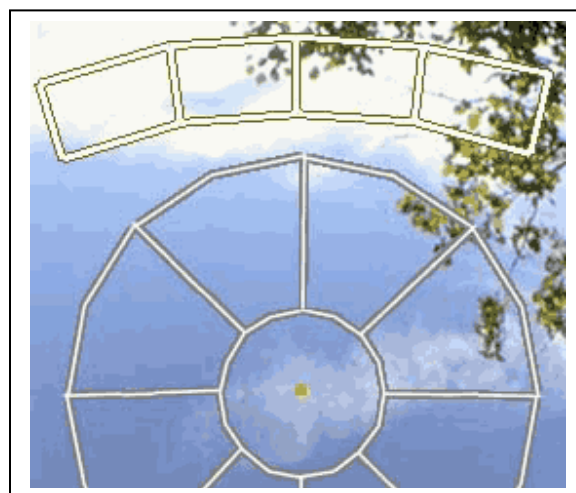
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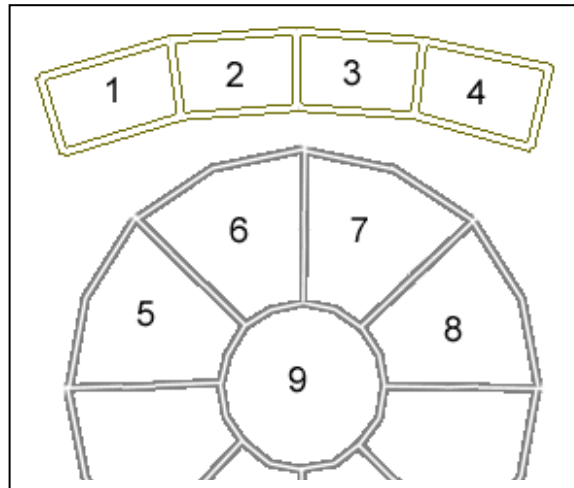
852



870



896

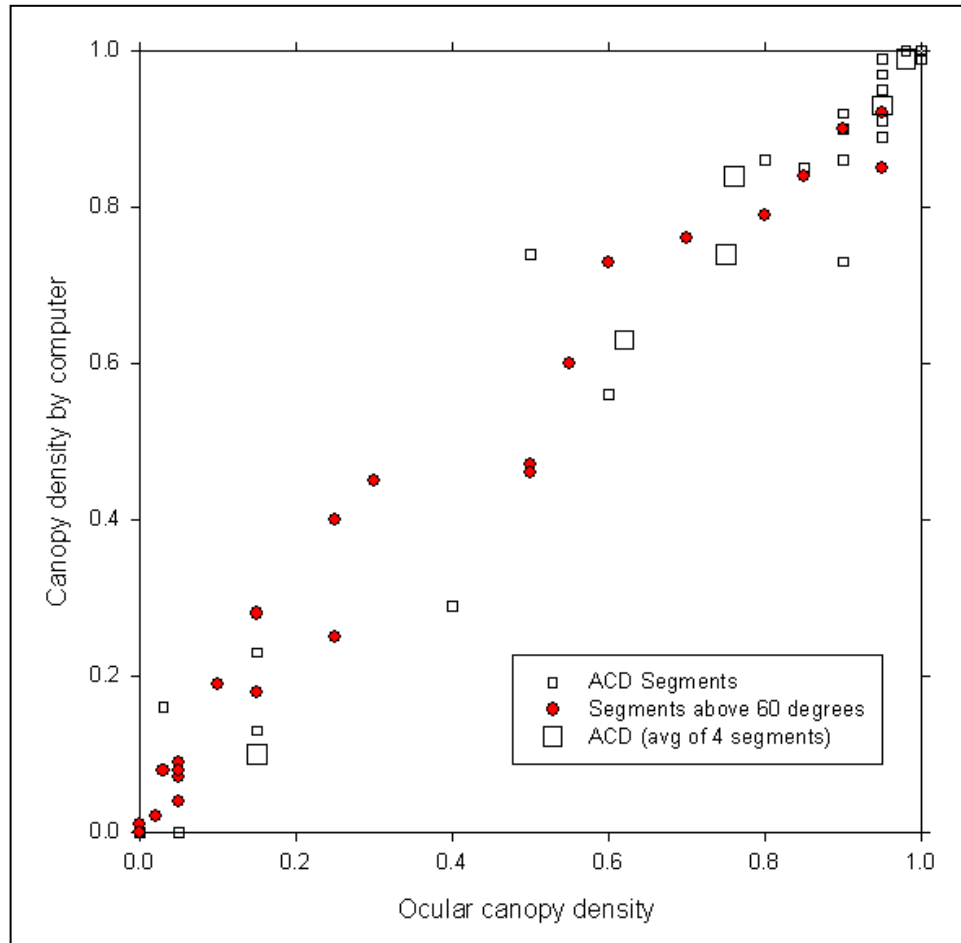


Reference numbers for segments

	Numbered segments on mirror								
	1	2	3	4	5	6	7	8	9
					60 to 80 degrees elevation				above 80
Photo	ACD 1	ACD 2	ACD 3	ACD 4	SE-E	S-SE	SW-S	W-SW	
842	0.23	0.73	0.99	1.00	0.02	0.79	0.40	0.18	0.08
843	0.85	0.74	0.86	0.92	0.85	0.73	0.60	0.28	0.08
844	0.86	0.95	0.99	0.91	0.45	0.84	0.46	0.01	0.08
852	1.00	0.99	0.97	1.00	0.25	0.90	0.92	0.92	0.19
863	0.00	0.37	0.93	0.19	0.00	0.18	0.19	0.00	0.00
868	0.72	0.52	0.16	0.96	0.67	0.43	0.65	0.85	0.70
870	0.89	0.90	0.56	0.16	0.76	0.47	0.02	0.00	0.04
896	0.00	0.00	0.13	0.29	0.00	0.00	0.09	0.07	0.00

Computer canopy density measurements

(Note that even computer measurements are subject to some error)



Computer versus ocular canopy density estimates on sample photos

APPENDIX 2

SAMPLE FIELD FORM

Field Form for Shade Surveys

Stream Name:		Date						2003			
Field crew initials:	Photo										
ACD user		Sky		Overcast		Scattered		Partly		Clear	
Note taker		Air Temp.		5 10		15 20		25 30		35 40	
Description of first cross section in a reach or local changes within reach											

Location of this section relative to first section (e.g. 0+20m downstream)

At US and DS ends of each reach

UTM East

UTM North

	Start Time	Gradient (percent)	Thalweg azimuth
	Waypoint number		

Record bankfull width and show relative loc. of wetted channel ---->

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Sketch cross section of wetted channel facing downstream -->

Left Bank

Right Bank

ACD Estimates

1

2

3

4

Canopy 80 to 90 degrees

Canopy 60-80 deg facing South

Canopy 60-80 deg facing North

Conifers

Deciduous

Herbaceous

Earth/Rock

Woody Debris

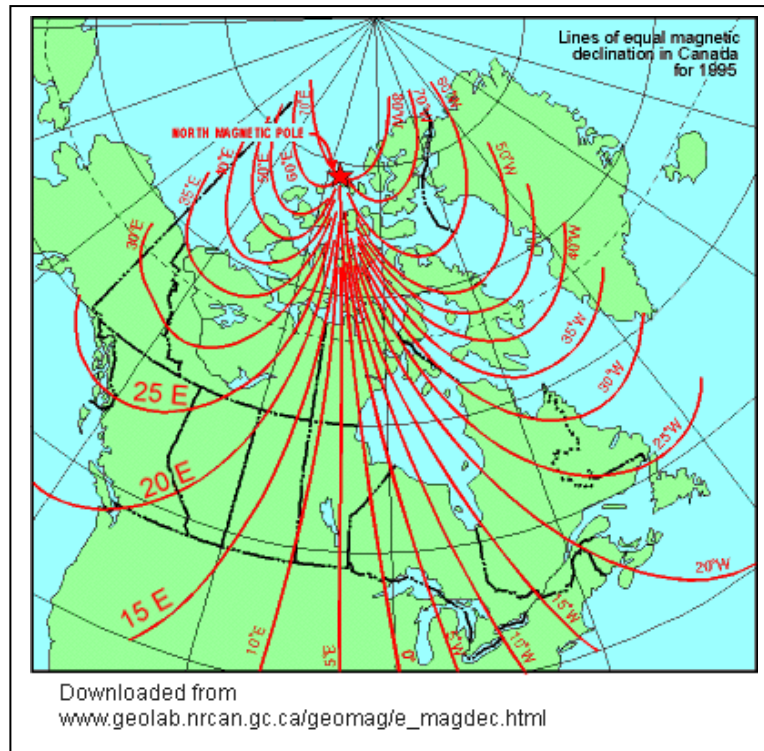
0 to 1 m.

1 to 5 m.

5 m. and higher

APPENDIX 3

Magnetic Declinations



Magnetic declination calculator:

http://www.geolab.nrcan.gc.ca/geomag/mirp_e.shtml

APPENDIX 4

Examples of the effects of latitude and time of year on sun paths

