Environment and Climate Change Canada / Environnement et Changement climatique Canada

Standard Operating Procedures for Benthic Invertebrate Monitoring in Wadeable Streams of the Athabasca Oil Sands Region; additions to the national CABIN protocol

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Acronyms

CABIN	Canadian Aquatic Biomonitoring Network
CRI	Canadian Rivers Institute
ECCC	Environment and Climate Change Canada
FWQM&SD-AA	Freshwater Quality Monitoring and Surveillance Division – Athabasca Artic Watershed
GIS	Geographic Information System
OS	Oil sands
PAH	Polycyclic Aromatic Hydrocarbons

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1.0 Introduction

1.1 Benthic Invertebrate Monitoring in the Oil Sands

In 2011, Environment and Climate Change Canada's (ECCC) Freshwater Quality Monitoring & Surveillance Division – Arctic and Athabasca Watershed (FWQM&SD-AA) developed a benthic invertebrate monitoring program for tributaries of the Athabasca River in and around the mineable area of the Athabasca oil sands (OS). Detailed information on the objectives and study design can be found in the Integrated Monitoring Plan for the Oil Sands (Environment Canada 2011), as well as in the Joint Canada–-Alberta Implementation Plan for Oil Sands Monitoring (Canada and Government of Alberta 2012). The sampling approach is based on the Canadian Aquatic Biomonitoring Network's (CABIN) standard protocols for wadeable streams, which are centered on the collection of benthic macroinvertebrates from erosional habitats by way of a 3-minute travelling kick. Habitat data are also collected to characterize stream environments, and these include water chemistry, channel measurements, substrate particle size, aquatic and riparian vegetation, and upstream land uses. CABIN field and laboratory protocol manuals can be found here: https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/resources.html. Along with the standard CABIN suite of measurements, several additional biological and habitat data are collected as part of the ECCC OS tributary biomonitoring program. These "CABIN +" methods were established to address study questions that are specific to the OS area, and which are described in detail below. In addition to field-measured habitat data, Geographic Information System (GIS)-derived hydrological, geological, and land-use information is collected to quantify the disturbance area in the upstream catchment for each site, and to develop a reference model based on the CABIN reference condition approach. A list of GIS-derived habitat variables can be found in Section 3.2.1, "GIS-Derived Hydrological, Geological, and Land-Use Information".

1.2 Sampling Design

Assessments of benthic habitats and community structures are carried out in erosional habitats within priority tributaries, which include 1) those with existing OS activities, many of which have been sampled historically (e.g., Steepbank and Muskeg rivers); 2) those with no or minimal OS activities, but which may be slated for future development (e.g., Firebag River); and 3) those that are currently in "reference" condition and are not slated for future development (e.g., tributaries of the Birch River). The sampling design for each of these priority areas follows a longitudinal gradient approach in which the sites are stratified within three OS exposure categories, where applicable:

1. **Reference Type 1:** Upstream of OS development; no known exposure to natural bitumen deposits at the stream's surface;

2. **Reference Type 2:** No or minimal OS activities; confirmed or suspected exposure to natural OS bitumen deposits at the stream's surface; and

3. **Test Site:** Increasing OS activities in the upstream catchment; confirmed or suspected exposure to natural OS bitumen deposits at the stream's surface.

The Steepbank, MacKay, and Ells rivers are the major tributaries in the OS mineable area that include study sites in all three categories. There are currently no surface-mining activities in the Firebag River basin, and thus the study sites in this tributary fall within the Type 1 and Type 2 reference categories. More information on the study design can be found in the Integrated Monitoring Plan for the Oil Sands (Environment Canada 2011), as well as in the Joint Canada–Alberta Implementation Plan for Oil Sands Monitoring (Canada and Government of Alberta 2012).

2.0 General Considerations

Those implementing the CABIN field protocols should be trained by an ECCC-certified CABIN instructor to ensure that they are equipped with the skills and knowledge to 1) successfully conduct CABIN sampling to a nationally acceptable standard; and 2) use online CABIN resources (database, analytical, and reporting tools). ECCC, in partnership with the Canadian Rivers Institute (CRI) at the University of New Brunswick, provides several CABIN training courses each year, whereby users can be certified as Field Assistants, Field Technicians, or Project Managers (Table 1). Registration and online modules are provided by the CRI (http://canadianriversinstitute.com/training/cri-workshop) while the field practicum and certification are provided by ECCC.

Table 1 – CABIN training options

Training Level	Course Requirements	Who Should Take This
Project Manager	All 6 Online Modules Field Certification	Project leaders and people involved in a CABIN study from beginning to end
Field Technician	Modules 1, 2, Data Entry Field Certification	Field technicians who are not involved in study design or data analysis
Field Assistant	Field Certification	Field assistants who are not involved in study design or data analysis and who will not require access to the CABIN database (access to the CABIN database and analytical tools is dependent upon completion of the required online modules)

3.0 Sampling Procedures

3.1 CABIN Wadeable Streams Protocol

The complete CABIN wadeable streams field manual (including an equipment checklist) and laboratory manual can be found at https://www.canada.ca/en.environment-climate-change/services/canadian-aquatic-biomonitoring -network/resources.html. An OS biomonitoring-specific equipment list can be found in Appendix 1.

Following the 3-minute travelling kick to collect benthic invertebrates (Figure 1), the bucket-swirl (elutriation) technique described in the CABIN field manual is used to remove large volumes of inorganic materials that often accumulate in the net. Reducing the volume of sand and gravel helps prevent damage to the organisms collected. Benthic samples are preserved in 95% ethanol and sent to a Society for Freshwater Science-accredited laboratory for lowest-level taxonomic identification. Sample sorting and quality assurance/quality control methods are described in the CABIN laboratory manual, which can be found at https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring -network/resources.html.

Figure 1. Crew member performing the CABIN 3-minute travelling kick to collect benthic invertebrates from a riffle.

Standard CABIN habitat data collected at each site include:

- **Primary site data:**
  - Surrounding and dominant land use (determined by aerial reconnaissance, GIS information, and/or satellite imaging)
  - Latitude and longitude
  - Elevation
- **Reach data:**
  - Habitat types present (e.g., riffle, pool, or rapids)
  - % Canopy coverage
  - % Macrophyte coverage
  - Streamside vegetation present
  - Dominant streamside vegetation
  - % Periphyton coverage
- **Channel data:**
  - Slope
  - Bankfull width
  - Wetted width
  - Bankfull depth minus wetted depth
  - Flow velocity
- **Substrate data:**
  - 100 pebble count
  - Embeddedness estimates for 10% of the pebbles
  - Size of the interstitial/surrounding material
- **Water chemistry and physicals (measured *in situ*):**
  - Temperature

- pH
- Specific conductance
- Dissolved oxygen

- **Water chemistry and physicals (measured in the laboratory)**
  - Conductivity, turbidity, etc.
  - Nutrients
  - Major ions
  - Metals

Water samples are collected upstream of the kick area and within the riffle (Figure 2). The sampling technique is described in more detail in the CABIN field manual and a complete list of OS parameters for laboratory analysis can be found in Appendix 2.

Figure 1. Crew member collecting a water sample from a riffle (facing upstream, with a bottle lowered to approximately half of the stream's depth).

3.2 CABIN + Protocols

Tributary biomonitoring in the OS area includes the collection of several biological and habitat variables that are additional to the standard CABIN suite of measurements, and include the following:

1. GIS-derived hydrological, geological, and land-use information;

2. The collection of periphyton for biomass estimates and taxonomic identification;

3. The collection of odonates to measure Hg levels;

4. The collection of fine sediment to analyze metals and polycyclic aromatic hydrocarbons (PAHs);

5. Quantitative estimates of canopy cover in the sampling reach;

6. Qualitative estimates of bryophyte coverage in the sampling reach; and

7. The measurement of “spot” velocities within the kick area.

The CABIN + measurements are described in more detail below, and the complete field sheet for the OS tributary biomonitoring program can be found in Appendix 3.

3.2.1 GIS-Derived Hydrological, Geological, and Land-Use Information

GIS data are used to describe the natural landscape and to quantify the extent of human disturbance upstream of each study site. ArcGIS and ArcHydro programs are used to delineate the upstream catchment of each study site, and hydrological, geological, and land-use information is quantified using national and provincial polygon layers (see Tables 2 and 3 for details regarding the source and resolution of data used by ECCC for OS benthic monitoring).

Table 2 – GIS-derived topographical and hydrological information collected for the upstream catchment area for each sampling site

Category	Scale/Resolution	Data/Source
Basin Morphometry	27 m	Area and perimeter calculated from delineated basins
Topography	27 m	Described using 27 m DEM and the Geospatial Modeling Environment v. 0.6.0.0 (Beyer 2012): Min/Max/Mean/SD Catchment Elevation and Slope *www.geobase.ca – Digital Elevation Data*
Hydrology	1:50,000	National Hydro Network intersected with catchment boundaries using the intersect function in ArcGIS *National Hydro Network* *www.geobase.ca*

Table 3 – GIS-derived geological, climat,e and oil sands (OS) land-use information collected for the upstream catchment area for each sampling site

Category	Scale/Resolution	Data Source
Bedrock	1:5,000,000	Geologic Map of Canada intersected with catchment boundaries using the intersect function in ArcGIS *Natural Resources Canada* *www.geoscan.ess.nrcan.gc.ca*
Surface Geology	1:5,000,000	Geologic Map of Canada intersected with catchment boundaries using the intersect function in ArcGIS *Natural Resources Canada* *www.geogratis.ca*
Land Cover	1:2,000,000	Land Cover intersected with catchment boundaries using the intersect function in ArcGIS *www.geobase.ca*
Climate	7.5 km	Summarized using rasterized grids that describe the normal temperatures from 1971–2001, and which provide long-term monthly and annual averages for temperature and precipitation • Mean number of growing degree days • Mean annual mean temperature • Mean annual maximum temperature • Mean annual minimum temperature • Mean annual mean precipitation • Mean maximum temperature by month • Mean minimum temperature by month • Mean precipitation month *Natural Resources Canada* *Dan McKenney – dan.mckenney@nrcan-rncan.gc.ca*
Oil Sands Lease	1:20,000	Lease information intersected with catchment boundaries using the intersect function in ArcGIS *RAMP* *http://www.ramp-alberta.org/data/map/mapdata.aspx*
Land Change Area	1:25,000	Land-change information intersected with catchment boundaries using the intersect function in ArcGIS *RAMP* *http://www.ramp-alberta.org/data/map/mapdata.aspx*

3.2.2 Algal Biomass Estimates

Algal biomass is used as a general indicator of water quality (e.g., nutrient status), primary production, and food availability for scraper invertebrates. Biomass is estimated by measuring the amount of chlorophyll *a* in the periphyton samples collected from a known area using a scalpel and a Falcon tube cap as a template.

Periphyton collected in this manner from five rocks is combined into one composite sample for each site.

- **Equipment needed:**
    - Scalpel wand and blade
    - A 50 mL sample jar
    - 95% ethanol
    - A Falcon tube cap (3.5 cm in diameter)
- **Procedure:** Collect five rocks from within the riffle (kick area), and which have periphyton coverage that is *representative* of the sampling area. For each rock:
    - place the Falcon tube cap on an area of the rock with representative/even periphyton coverage;
    - trace around the cap's circumference with a scalpel (i.e., etch an outline into the periphyton/rock);
    - use the scalpel to remove all the periphyton/debris within the etched circular area (Figure 3) and place it into a 50 mL plastic sample jar labeled with the site name, date, and sample type (i.e., "Chl *a*");
    - preserve the sample with 95% ethanol using safe handling procedures; secure the lid and seal the jar with parafilm; and
    - store the sample jars in a cooler for transport to the laboratory (chlorophyll *a* is measured with a fluorometer).

Figure 2. Periphyton scraped from a known circular area for algal biomass estimation and taxonomic identification.

3.2.3 Algal Taxonomy

Algal taxonomy is assessed for a known surface area, which can be used to produce a density estimate for various algal taxa. Repeat the procedure described above to obtain algal biomass estimates:

- **Equipment needed:**
  - Scalpel wand and blade
  - A 50 mL sample jar
  - 95% ethanol
  - A Falcon tube cap (3.5 cm in diameter)
- **Procedure:** Use the same five rocks collected from within the riffle habitat for algal biomass estimates. For each rock:
  - combine all five scrapings into a separate 50 mL sample jar labeled with the site name, date, and sample type (e.g., “tax”);
  - preserve the sample with 10% buffered formalin using safe handling procedures; secure the lid and seal the jar with parafilm;
  - store sample jars in a cooler for transport to the laboratory; and
  - send samples to a certified taxonomist for identification.

3.2.4 Collection of Odonate Nymphs for Mercury Estimates

After the standard 3-minute travelling kick has been performed at a site, a second, untimed kick is undertaken in the riffle to collect odonate nymphs. Odonate nymphs are targeted for mercury analysis because they are generally predatory feeders and have the potential to bioaccumulate mercury. Care is taken to ensure that the sample is collected from a riffle area that was not disturbed in the first kick (typically upstream of the primary riffle, depending on the size of the stream and the available riffle habitat).

- **Equipment needed:**
  - Standard CABIN benthic collection equipment (kick net, sieve, etc.)
  - Whirl Pak bags
  - Teflon-coated tweezers
  - Nitrile gloves (CertiClean Class 10)

- **Procedure:** Once the kick is complete, the sample is placed into a sieve and sorted on site for odonate collection:
    - Teflon-coated tweezers are used to pick out 20 of the largest-bodied nymphs from the sample debris; place the samples into a Whirl Pak bag;
    - A body size of 1.5–2.5 cm (Figure 4) is optimal to ensure adequate mass for mercury analysis, and since this size class generally represents the oldest nymphal stage, it has the most potential for mercury bioaccumulation; and
    - The samples must be kept frozen until analyzed.

Figure 4. Appropriate odonate size class to be collected for mercury analysis.

3.2.5 Collection of Fine Sediment for the Analysis of Metals, Mercury, and PAHs

The sediment samples are collected in depositional areas to assess the concentration of substrate-bound metals and PAHs.

- **Equipment needed:**
    - A stainless-steel ladle
    - 2 × 250 mL amber glass jars (per site) – these should be certified metal-free
- **Procedure:**
    - Find a depositional area within the sampling reach, where the flow is as close to nil as possible and contains fine sediment (i.e., sand/silt/clay – with grain sizes smaller than 1 mm).
    - Use the stainless-steel ladle to scoop the fine sediment into both amber glass jars, draining away as much water as possible from the ladle before filling the jars.

- ○ The jars should be filled approximately three-quarters of the way to the top.
- ○ Wipe away any sediment on the cross-threads of the jar with a gloved finger, so that the lids will thread and close properly.
- ○ Make sure not to touch the inside of the jar or lid.
- ○ Label the jar with the site name, date, and sample type ("PAH" for jar # 1 and "metals" for jar # 2).
- ○ Keep the sediment samples cool or frozen during shipping/storage, per laboratory instructions.

3.2.6 Quantitative Estimate of the Canopy Cover

Quantitative estimates of the canopy (riparian vegetation) cover are taken with a convex spherical densiometer (Figure 5) at three locations within the sampling reach: 1) upstream, 2) within, and 3) downstream of the kick area. A densiometer is an instrument typically used in forestry science to measure overstory density. Instructions on how to use a convex spherical densiometer can be found in Appendix 4.

- **Procedure:** At each of the three locations within the sampling reach:
  - ○ wade as close to the centre of the stream as possible (while considering safe wading procedures); and
  - ○ record the % canopy cover measured in four directions – facing upstream, facing downstream, facing left bank, and facing right bank.

Figure 5. Spherical convex densiometer (www.forestry-suppliers.com).

3.2.7 Qualitative Estimate of Bryophyte Coverage

Bryophytes are a group of non-vascular plants that include mosses; they are commonly found in Northern Alberta streams (Figure 6). The percent of bryophyte coverage is estimated within the reach, just as qualitative estimates of periphyton and macrophytes are made in the standard CABIN protocol. Bryophyte coverage within the defined reach should be assessed and discussed by/with all crew members so there is consensus as to the percent coverage that is representative of the reach.

Figure 6. Stream rocks covered in bryophytes (photo taken in the Firebag River).

3.2.8 Measurement of Spot Velocities within the Kick Area

In addition to the standard CABIN cross-sectional velocity measurements, five approximately equidistant velocity measurements are taken along the benthic kick path (with the standard CABIN head rod method or with a digital velocity metre). The kick path (disturbed area) may be seen visually; if not, the sampler should confirm the path direction/area with the crew member who performed the kick.

4.0 References

Environment Canada. 2011. *Integrated Monitoring Plan for the Oil Sands: Expanded Geographic Extent for Water Quality and Quantity, Aquatic Biodiversity and Effects, and Acid Sensitive Lake Component*. En14-49/2011E-PDF. ISBN 978-1-100-18939-0. Environment Canada, Gatineau, QC, Canada.

Environment Canada. 2012. Canadian Aquatic Biomonitoring Network field and laboratory manuals: https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/resources.html

Environment Canada and Government of Alberta. 2012. *Joint Canada–Alberta Implementation Plan for Oil Sands Monitoring*.

APPENDIX 1 – Equipment List for OS Tributary Biomonitoring

Benthic Kick		**Channel Measurements**	
2	Kick Net with 400 µm Mesh	1	Survey Rod
1	Tray	2	Hand Level
1	Swirl Bucket	1	Tape Measure
2	Squirt Bottle	2	Range Finders
1	Spoon	1	Clipboard
1	Ladle	1	SonTek FlowTracker
1	Stopwatch	**Substrate Data**	
1	Sieve (400 µm)	4	Ruler (30 cm)
2	1 L Plastic Jar*	**Canopy Cover**	
8L	95% Ethanol	2	Densiometer
8L	Ethanol-proof Marker	**Water Chemistry**	
1	Label on Waterproof Paper*	1	YSI Mutlimeter
3	Pencil	1	2 L Plastic Bottle*
Algae		2	500 mL Plastic Bottle*
2	Scalpel Wand	1	100 mL Plastic Bottle*
1	Box of Scalpel Blades	1	Bottle of HCl (500 mL)
1	Sharps Container	1	Plastic Pipette*
3	Falcon Tube Caps	1	Pair of Nitrile Gloves
1	50 mL Vial*	1	Cooler with Ice Packs (transport)
2	Ethanol-proof Marker	**Mercury Analysis**	
4L	95% Ethanol (Chl-a)	2	Teflon-coated Tweezers
2L	10% Buffered Formalin	2	Whirl Pak Bags*
3	10 mL Syringe	1	Pair of Mercury Gloves*
2	Safety Glasses	**Miscellaneous**	
1	Box of Nitrile Gloves	1	Field Sheet*
1	Box of Parafilm	1	Waterproof Camera
Sediment Contaminants		1	GPS Unit
2	250 mL Amber Glass Jar	1	Safety Kit**
1	Stainless-steel Ladle	1	Survival Kit***

* Per site
** Includes: Satellite phone, SPOT device, first-aid kit, throw bags, bear spray, air horns, flagging tape, carabiners
*** Includes: Tent, sleeping bags, dehydrated meals, stove and fuel, pots, bush saw, matches, kindling, candles, lighters, headlamps, emergency blanket, whistle, water tablets, scissors, knife, sunscreen

APPENDIX 2 – Water Chemistry Parameters for Laboratory Analysis

METALS

ALUMINUM DISSOLVED
ALUMINUM TOTAL
ANTIMONY DISSOLVED
ANTIMONY TOTAL
ARSENIC DISSOLVED
ARSENIC TOTAL
BARIUM DISSOLVED
BARIUM TOTAL
BERYLLIUM DISSOLVED
BERYLLIUM TOTAL
BISMUTH DISSOLVED
BISMUTH TOTAL
BORON DISSOLVED
BORON TOTAL
CADMIUM DISSOLVED
CADMIUM TOTAL
CALCIUM DISSOLVED
CALCIUM TOTAL
CERIUM DISSOLVED
CERIUM TOTAL
CESIUM DISSOLVED
CESIUM TOTAL
CHROMIUM DISSOLVED
CHROMIUM TOTAL
COBALT DISSOLVED
COBALT TOTAL
COPPER DISSOLVED
COPPER TOTAL
GALLIUM DISSOLVED
GALLIUM TOTAL
GERMANIUM DISSOLVED
GERMANIUM TOTAL
INDIUM DISSOLVED
INDIUM TOTAL
IRON DISSOLVED
IRON TOTAL
LANTHANUM DISSOLVED
LANTHANUM TOTAL
LEAD DISSOLVED
LEAD TOTAL
LITHIUM DISSOLVED
LITHIUM TOTAL
MAGNESIUM DISSOLVED
MAGNESIUM TOTAL
MANGANESE DISSOLVED
MANGANESE TOTAL
MERCURY TOTAL
METHYL MERCURY
MOLYBDENUM DISSOLVED
MOLYBDENUM TOTAL
NICKEL DISSOLVED
NICKEL TOTAL
NIOBIUM DISSOLVED
NIOBIUM TOTAL
PALLADIUM DISSOLVED
PALLADIUM TOTAL
PLATINUM DISSOLVED
PLATINUM TOTAL
POTASSIUM DISSOLVED
POTASSIUM TOTAL
RUBIDIUM DISSOLVED
RUBIDIUM TOTAL
SCANDIUM DISSOLVED
SCANDIUM TOTAL
SELENIUM DISSOLVED
SELENIUM TOTAL
SILVER DISSOLVED
SILVER TOTAL
SODIUM DISSOLVED
SODIUM TOTAL
STRONTIUM DISSOLVED
STRONTIUM TOTAL
TELLURIUM DISSOLVED
TELLURIUM TOTAL
THALLIUM DISSOLVED
THALLIUM TOTAL
TIN DISSOLVED
TIN TOTAL
TITANIUM DISSOLVED
TITANIUM TOTAL
TUNGSTEN DISSOLVED
TUNGSTEN TOTAL
URANIUM DISSOLVED
URANIUM TOTAL
VANADIUM DISSOLVED
VANADIUM TOTAL
YTTRIUM- DISSOLVED
YTTRIUM TOTAL
ZINC DISSOLVED
ZINC TOTAL
ZIRCONIUM DISSOLVED
ZIRCONIUM TOTAL

ORGANICS

1,2,3,4-TETRAHYDRONAPHTHALENE	C3-4-PROPYLDIBENZOTHIOPHENE
1-METHYLNAPHTHALENE	C3-CHRYSENE
2-CHLORONAPHTHALENE	C3-N-PROPYLFLUORENE
2-METHYLNAPHTHALENE	C3-PHENANTHRENE
3-METHYLCHLORANTHRENE	C3-TRIMETHYLNAPHTHALENE
9-ETHYLFLUORENE	C4-CHRYSENE
9-METHYLFLUORENE	C4-FLUORENES
ACENAPHTHENE	C4-PHENANTHRENE
ACENAPHTHYLENE	C4-TETRAMETHYLNAPHTHALENE
ANTHRACENE	CHRYSENE
BENZO(A)ANTHRACENE	D - PERYLENE
BENZO(A)PYRENE	DIBENZ(A,H)ANTHRACENE
BENZO(B)FLUORANTHENE	DIBENZO(A,H) ANTHRAC
BENZO(E)PYRENE	DIBENZOTHIOPHENE
BENZO(G,H,I)PERYLENE	FLUORANTHENE
BENZO(K)FLUORANTHENE	FLUORANTHENE D10
BIPHENYL	FLUORENE
C1-CHRYSENE	FLUORENE-D10 (SURROGATE)
C1-METHYLDIBENZOTHIOPHENE (3PKS)	INDENE
C1-METHYLFLUORANTHENE (2PKS)	INDENO(1,2,3-C,D)PYRENE
C1-METHYLFLUORENE (3PKS)	NAPHTHALENE
C1-NAPHTHALENES	NAPHTHALENE-D8 (SURROGATE)
C1-PHENANTHRENE	PERYLENE
C2-1,6-DIMETHYLNAPHTHALENE (5PKS)	PERYLENE-D12 (SURROGATE)
C2-1,9-DIMETHYLFLUORENE	PHENANTHRENE
C2-3-ETHYLFLUORANTHENE	PYRENE
C2-CHRYSENE	PYRENE-D10 (SURROGATE)
C2-DIMETHYLDIBENZOTHIOPHENE	RETENE
C2-PHENANTHRENE	
C3-2,4,7-TRIMETHYLDIBENZOTHIOPHENE	
C3-2-ISOPROPYLNAPHTHALENE	

PHYSICALS	MAJOR IONS
ALKALINITY GRAN CACO3	CALCIUM DISSOLVED/FILTERED
ALKALINITY PHENOLPHTHALEIN CACO3	CALCIUM DISSOLVED/FILTERED
ALKALINITY TOTAL CACO3	CHLORIDE DISSOLVED
BICARBONATE (CALCD.)	FLUORIDE DISSOLVED
CARBONATE (CALCD.)	MAGNESIUM DISSOLVED/FILTERED
COLOUR TRUE	MAGNESIUM DISSOLVED/FILTERED
FREE CO_2 (CALCD.)	POTASSIUM DISSOLVED/FILTERED
HARDNESS NON-CARB. (CALCD.)	POTASSIUM DISSOLVED/FILTERED
HARDNESS TOTAL (CALCD.) CACO3	SIO_2
HYDROXIDE (CALCD.)	SIO_2
OXYGEN DISSOLVED	SODIUM DISSOLVED/FILTERED
PH	SODIUM DISSOLVED/FILTERED
RESIDUE FIXED NONFILTRABLE	SULPHATE DISSOLVED
RESIDUE NONFILTRABLE	SODIUM ADSORPTION RATIO (CALCD.)
SATURATION INDEX (CALCD.)	SODIUM PERCENTAGE (CALCD.)
SPECIFIC CONDUCTANCE	
STABILITY INDEX (CALCD.)	
TOTAL DISSOLVED SOLIDS (CALCD.)	
TURBIDITY	

NUTRIENTS
AMMONIA DISSOLVED
AMMONIA UN-IONIZED (CALCD.)
CARBON DISSOLVED ORGANIC
CARBON PARTICULATE ORGANIC
CARBON TOTAL ORGANIC (CALCD.)
NITROGEN DISSOLVED NO_3 AND NO_2
NITROGEN PARTICULATE
NITROGEN TOTAL (CALCD.)
NITROGEN TOTAL DISSOLVED
PHOSPHOROUS PARTICULATE (CALCD.)
PHOSPHOROUS TOTAL
PHOSPHOROUS TOTAL DISSOLVED

APPENDIX 3 – Modified CABIN Field Sheet for OS Tributary Biomonitoring

Field Crew________________________________ Sampling Date (D/M/Y) ____________

Site Name ________________________________ Site Code:______________________

QAQC site ☐Yes ☐No PN WQ # ____________________

OHS: Site Inspection Sheet Completed ☐

Primary Site Data

CABIN Study Name: ___PN TRIBS___________

Local Basin name:__________________________ Ecoregion___________________________

River/Stream Name:_________________________ Stream Order (map scale 1:50,000):_________

Select one: Test Site ☐ Potential Reference Site ☐ Confirmed ☐ How?____________________

Geographical description/notes:

Land Use Potentially Influencing Stream (0-50 m)

Land Use: (check those present) information source: ______________

☐ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ____________

Dominant Land Use: (check one) information source: ______________

☐ Forest ☐ Field/Pasture ☐ Agriculture ☐ Residential/Urban

☐ Logging ☐ Mining ☐ Commercial/Industrial ☐ Other ____________

Location Data

Latitude:___________N Longitude: - ___________W (deg/min/sec *or* decimal deg)

Elevation:_______(fasl *or* masl) GPS Datum: GRS80 (NAD83/WGS84) ☐ Other ________ ☐

Site Location Map Drawing

Field Crew________________________________ Sampling Date (D/M/Y) ____________

Site Name ________________________________ Site Code:________________________

QAQC site ☐Yes ☐No PN WQ # ________________________

Photos

field sheet ☐ upstream ☐ downstream ☐ across site ☐ aerial view ☐
substrate (exposed bar) ☐ substrate (aquatic) ☐ miscellaneous ____________ ☐

Reach Data *(representative reach = 6x bankfull width)*

1. Habitat types present in reach *(check those present):*
   ☐ riffle ☐ rapids ☐ straight run ☐ pool/back eddy

2. Canopy Coverage *(hint: stand in middle of stream review entire reach - check one)*
   ☐ 0% ☐ 1-25% ☐ 26-50% ☐ 51-75% ☐ 76-100%

3. Macrophyte Coverage *(i.e. not algae; check one):*
   ☐ 0% ☐ 1-25% ☐ 26-50% ☐ 51-75% ☐ 76-100%

4. Bryophyte Coverage *(i.e. not algae; check one):*
   ☐ 0% ☐ 1-25% ☐ 26-50% ☐ 51-75% ☐ 76-100%

5. Streamside Vegetation (*check those present):*
   ☐ ferns/grasses ☐ shrubs ☐ deciduous trees ☐ coniferous trees

6. Dominant Streamside Vegetation (*check one*):
   ☐ ferns/grasses ☐ shrubs ☐ deciduous trees ☐ coniferous trees

6. Dominant Periphyton Coverage on Substrate *(benthic algae; check one*)
   ☐ **1** - Rocks not slippery, no obvious colour (thin layer < 0.5 mm thick)
   ☐ **2** - Rocks slightly slippery, yellow-brown to light green colour (0.5-1 mm thick)
   ☐ **3** - Rocks have a noticeable slippery feel (footing is slippery), with patches of thicker green to brown algae (1-5 mm thick)
   ☐ **4** - Rocks are very slippery (algae can be removed with thumbnail), numerous large clumps of green to dark brown algae (5 mm -20 mm thick)
   ☐ **5** - Rocks mostly obscured by algal mat, extensive green, brown to black algal mass may have long strands (> 20 mm thick)

Chlorophyll Scraping: 5 Blue caps ☐Taxonomy ☐ Chlorophyll ☐ SI

Benthic Invertebrate Samples

Habitat (s) sampled (*check one*): ☐ riffle ☐ rapids ☐ straight run ☐ pool/back eddy

Samples completed for - ☐ 400 ☐ 250 ☐ SI ☐ Hg

Sampled reduced using “Bucket Swirling Method”: YES ☐ NO ☐ If YES, debris collected for QAQC ☐

Kick samples	Kick1	Kick2	Kick3
Mesh Size 250 or 400 um			
Person Sampling			
Sampling Time (i.e. 3 min)			
No. of Sample Jars			
Typical Depth (in kick area)			

Preservative used:

____

Notes:

____

____

____

Field Crew________________________________ Sampling Date (D/M/Y) _____________

Site Name ________________________________ Site Code:________________________

QAQC site ☐Yes ☐No PN WQ # ________________________

SUBSTRATUM ASSESSMENTS

1) Visual Estimates of Substrate Composition and Surrounding/Interstitial Material

Indicate the substrate class for the following

A- DOMINANT SUBSTRATE
B- 2ND MOST DOMINANT SUBSTRATE
C- SURROUNDING MATERIAL

SUBSTRATE SIZE CLASS	CATEGORY	INDICATE A,B,C
organic cover	0	
<0.1 cm silt	1	
0.1-0.2 cm sand	2	
0.2-1.6 cm gravel	3	
1.6-3.2 cm	4	
3.2-6.4 cm	5	
6.4-12.8 cm	6	
12.8-25.6 cm	7	
>25.6 cm	8	
bedrock	9	

2) 100 Substratum Composition Assessments

For 100 random substrate locations, measure the intermediate axis or record the class (silt, sand, gravel, bedrock) & for 10 rocks indicate the depth (embeddedness) the substrate is buried in the surrounding material as

E: 1=completely embedded, 2=3/4 embedded, 3=1/2 embedded, 4=1/4 embedded, 5=unembedded

	Diameter (cm)	E		Diameter (cm)	E		Diameter (cm)	E		Diameter (cm)	E
1			26			51			76		
2			27			52			77		
3			28			53			78		
4			29			54			79		
5			30			55			80		
6			31			56			81		
7			32			57			82		
8			33			58			83		
9			34			59			84		
10			35			60			85		
11			36			61			86		
12			37			62			87		
13			38			63			88		
14			39			64			89		
15			40			65			90		
16			41			66			91		
17			42			67			92		
18			43			68			93		
19			44			69			94		
20			45			70			95		
21			46			71			96		
22			47			72			97		
23			48			73			98		
24			49			74			99		
25			50			75			100		

Note: *Dominant size category & subdominant size category based on substrate size class table will be determined in CABIN. Wolman D_{50} (median diameter), Wolman Dg (geometric mean diameter) and the % composition of the substrate classes are also automatically calculated with the 100 pebble measurements entered into CABIN. Median embeddenss score will also be calculated based on data entered into CABIN*

Field Crew________________________________ Sampling Date (D/M/Y) ____________

Site Name ________________________________ Site Code:______________________

QAQC site ☐Yes ☐No PN WQ # ________________________

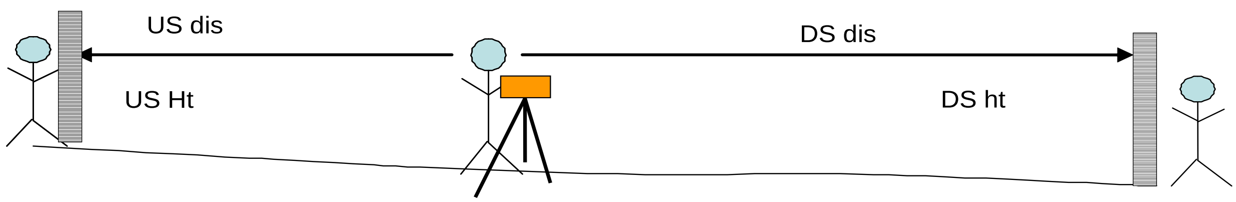
Channel Data

Slope (*indicate how slope was measured)*

☐ 1. **Calculated from map/GIS**:__________ (notes:______________________________)

☐ 2. **Measured in field** (*circle device and fill out table according to device used: a or b*)
b. survey rod, hand level or clinometer & measuring tape

Measurements	Upstream (US)	Downstream (DS)	Calculation
Height of rod (ht) – Water Depth (if applicable)			
Distance (dis)			$US_{dis}+DS_{dis}$=
Change in height (Δht)			$DS_{ht}-US_{ht}$=
Slope (Δht/total dis)			

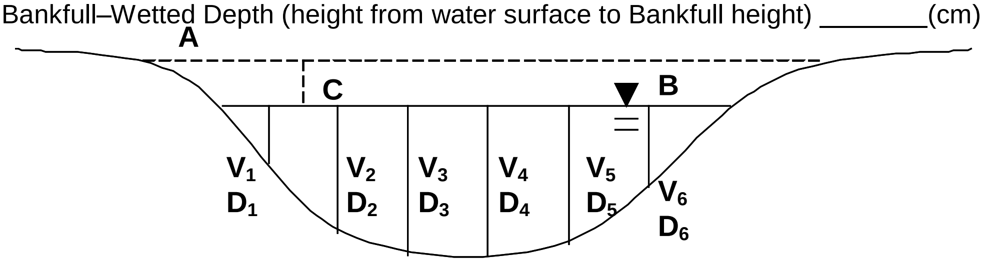


Widths and Depth

Location at site ________________________*(note where in sample site i.e. d/s of kick area)*

A. Bankfull Width __________(m) B. Wetted Stream Width: __________(m)

C. Bankfull–Wetted Depth (height from water surface to Bankfull height) ______(cm)



For wetted widths > 5m, measure a minimum of 5-6 equidistant locations;
For wetted widths < 5m, measure 3-4 equidistant locations

Field Crew________________________________ Sampling Date (D/M/Y) ____________

Site Name ________________________________ Site Code:______________________

QAQC site ☐Yes ☐No PN WQ # ______________________

Velocity and Depth (*Check appropriate measuring device and fill out appropriate chart below*):

☐ **1. Velocity Head Rod (or ruler)**: *Equation* - velocity (m/s) = $\sqrt{[2(\Delta D/100) * 9.81]}$

☐ **2. Direct velocity measurements**: ☐Marsh-McBirney ☐Sontek or ☐Other________________

A) Representative Transect in Reach (6x bankfull width)

1. Velocity Head Rod (ruler)	1	2	3	4	5	6	**AVG**	**Max**	**DIS. Q**
Distance from shore (m)									
Flowing water Depth (**D_1**) (cm)									
Depth of Stagnation (**D_2**) (cm)									
Change in depth (**$\Delta D=D_2-D_1$**) (cm)									
Velocity (cm?/s)									
2. Direct Measurement (Sontek/Other)	1	2	3	4	5	6	**AVG**	**Max**	**DIS. Q**
Distance from shore (m)									
Flowing water Depth (**D_1**) (cm)									
Velocity (m/s)									

B) Within Benthic Habitat Sampled

1. Velocity Head Rod (ruler)	1	2	3	4	5	**AVG**	**Max**
Flowing water Depth (**D_1**) (cm)							
Depth of Stagnation (**D_2**) (cm)							
Change in depth (**$\Delta D=D_2-D_1$**) (cm)							
Velocity (cm?/s)							
2. Direct Measurement (Sontek/Other)	1	2	3	4	5	**AVG**	**Max**
Flowing water Depth (**D_1**) (cm)							
Velocity (m/s)							

Field Crew________________________________ Sampling Date (D/M/Y) ____________

Site Name ________________________________ Site Code:______________________

QAQC site ☐Yes ☐No PN WQ # ______________________

Canopy Cover Densiometer

- **measured from the center of the stream at 3 locations**

Transect	Counts covered or uncovered (C or unC)	Position (facing)			
		Upstream	Downstream	Left	Right
Lower Reach					
Mid Reach					
Upper Reach					

Water Chemistry & Physicals

Time: ________ (24hr clock) **Time zone**: ____________PN WQ #________________________

Cloud Cover % ___________ Wind ____________ Precipitation _______________

Air Temp (ºC) ________Water Temp (ºC)____________pH ___________Water Depth_________

Specific Conductance (µs/cm) ________DO (mg/L) __________Turbidity (NTU) _____________

Check if samples collected:

☐Nutrients & NFR (TSS) ☐Major Ions ☐Other_______________________________________

Site Safety Inspection

Site Inspected by: _______________________________________

☐ Itinerary left with contact person (incl. contact numbers);

☐ SPOT tracking activated

Vehicle Safety

☐ Safety equipment present (first aid, fire extinguisher, blanket, emergency kit in vehicle)

☐ Equipment and chemicals safely secured for transport

☐ Vehicle parked in safe location; pylons, hazard light, reflective vests if necessary

Site Hazards and Wading Safety

☐ General Sites Hazards identified & listed

____

☐ Instream hazards identified (i.e. log jams, deep pools, slippery rocks) & listed

____

☐ PFDs worn ; ☐ Appropriate footwear, waders, wading belt; ☐ Belay used

☐ Wader boots sterilized if traveling between watersheds

Notes:

APPENDIX 4 – Instructions for Measuring the Canopy Cover with a Convex Spherical Densiometer

Instructions

▲ Keep this sheet for your records.

Forestry Suppliers, Inc.
www.forestry-suppliers.com

Using Forest Densiometers

No. 43887
Spherical Convex Densiometer

No. 43888
Spherical Concave Densiometer

Originally developed and published by Dr. Paul E. Lemmon, the Spherical Densiometer is designed for rugged field use while remaining compact and lightweight for ease of transport. This instrument has been extensively tested by numerous foresters and forestry technicians on stands of ponderosa pine, lodgepole pine and Douglas fir.

History

The pioneering work was done mainly in the Pacific Northwest; however, subsequently the instrument has been used for measuring overstory density throughout the U.S. and internationally. The original methodology was developed to characterize and quantify canopy density for representative forest sites where numerous parameters such as tree size (height, girth, age and growth rates), tree spacing, soil type, slope and slope orientation, elevation and others were determined.

Reading Canopy Areas

The spherical densiometer consists of either a concave or a convex mirror with twenty-four ¼″ squares engraved on the surface. The design is such that the operator views the same degree of arc overhead regardless if the user is in a low lying canopy area or a mature stand of high canopy timber.

Each square of the grid is then equally subdivided mentally into 4 smaller squares (⅛″ x ⅛″) and represented by an imaginary dot in the center of each of the smaller squares. Thus a total of 96 dots representing smaller square areas can then be counted within the grid. Once the representative forest site has been selected for measurement, the user holds the instrument level and far enough away from his/her body such that the operator's head is just outside the grid. The operator can then count the number of dots, representing the smaller (⅛″ x ⅛″) square areas of canopy openings, up to a total of 96. The number determined is then multiplied by 1.04 to obtain the percent of overhead area *not* occupied by canopy. The difference between this percentage and 100% is the estimated overstory density in percent.

Four readings are taken about a reference tree in each site area and averaged. The operator should be positioned with his/her back toward the reference tree, and moving about the reference tree facing North, East, South and West.

"The reference tree in each site represents a typical dominant or co-dominant species in the stand. The points selected around each reference tree should be far enough away (from the reference tree) so that the crown of the reference tree is just outside the overstory area being estimated" (Lemmon, 1956).

The statistical accuracy and repeatability of the instrument is based on taking four readings, using up to 96 dots representing the smaller (⅛″ x ⅛″) squares for up to a total of 384 smaller squares per site (96 x 4), and then averaging all four readings at the different orientations about the reference tree. Obviously, in a forest environment, you will be counting considerably less than 9 dots representing the smaller squares, so the exercise is a lot less laborious than it might first appear. The denser the overstory canopy, the fewer dots you will have to count since you are counting the ⅛″ x ⅛″ areas in which you can see sky in the major portion of each of the smaller squares. With a little practice, you will find that the data can be gathered quickly and with repeatability using the same or different operators.

In open forest where more than half of the canopy area is open to the sky, you can reverse the process and count just the smaller square areas (⅛″ x ⅛″) that are covered by the canopy and multiply by 1.04 to obtain the estimated overstory density percentage.

Reference: Lemmon, Paul E., 1956, A Spherical Densiometer for Estimating Forest Overstory Density; Forest Science 2(4)314-320.
Lemmon, Paul E., 1957, A New Instrument for Measuring Forest Overstory Density; Journal of Forestry 55(9)667-668. 236501.LET

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A New Instrument for Measuring Forest Overstory Density[1]

A new instrument called a "spherical densiometer" has been described for estimating forest overstory density.[2] This pocket-type instrument employs a mirror with spherical curvature which makes possible the reflection of a large overhead area. A grid is used to estimate percentage of this overhead area covered with forest canopy. Estimation is usually from a point near the forest floor. Adequate sampling gives the average canopy of a forest area.

Two models, A and B (Figures 1 and 2), have been adopted as standard. Each employs a highly polished chrome mirror 2½ inches in diameter and having the curvature of a 6 inch sphere. The convex side of the mirror is used in MODEL A and the concave side in MODEL B. Each has some advantages over the other.

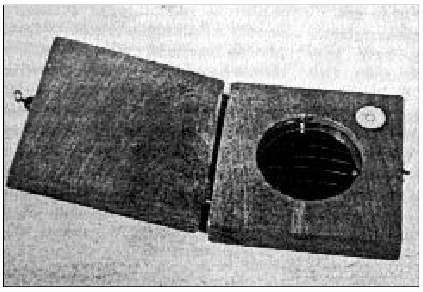

Figure 1
Spherical densiometer, Model A, with estimating grid scratched on the surface of the convex mirror

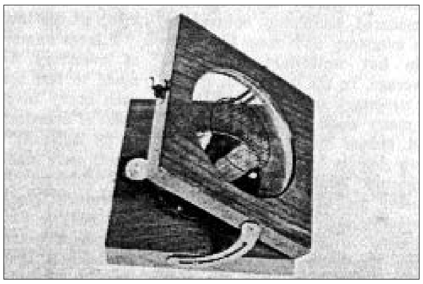

Figure 2
Spherical densiometer, Model B, with estimating grid superimposed between the eye and surface of the concave mirror.

The mirrors are mounted in small wooden recessed boxes with hinged lids similar to compass boxes. The overall dimensions are about 3½ x 3½ x 1⅛ inches. A circular spirit level is mounted (recessed) beside the mirrors. Positive slide fasteners are provided in MODEL B which allow the lid to open to an angle of about 45 degrees.

Cross-shaped and circular grids with squares and dots are used to estimate overstory coverage by tree crowns. Grids are of two kinds: (1) those scratched upon the surface of the mirror (MODEL A), and (2) those superimposed between the mirror and the eye (MODEL B).

The cross-shaped grid scratched upon the convex surface of the mirror in MODEL A has 24 quarter-inch squares (Figure 3A). Instructions for using the densiometer and cumulative values for the squares on the grid are shown on a chart that is attached to the inside of the box lid (Figure 3B). It is easier and faster to estimate the relative amount of overstory coverage with this instrument by assuming the presence of four equi-spaced dots in each square and by counting dots representing openings in the canopy. The percentage of overstory density is then assumed to be the complement of this number. Each assumed dot is assigned a value of one percent in this case. A slight discrepancy exists between estimations using the squares and estimations by counting assumed dots, because there are only 96 dots in the entire grid area. Cumulative values of the squares shown in the chart add up to 100 percent for the entire area within the grid. If desired, one may calculate the exact percentage values for each assumed dot and thereby make the two methods of use exactly comparable.

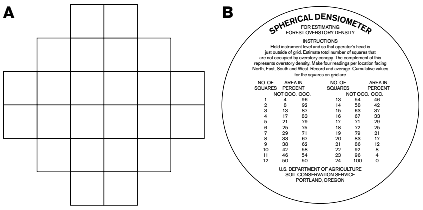

Figure 3
(A) Cross-shaped grid scratched on the convex surface of the mirror in Model A. Each square is 1/4 inch on a side. (B) Instructions for using Model A. This is fastened to the inside of the lid of the mounting box.

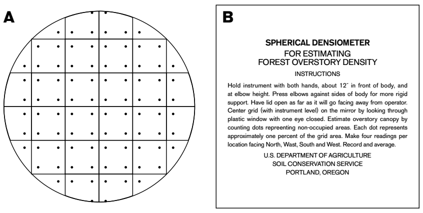

Figure 4
(A) Circular grid superimposed between the eye and the concave mirror in Model B. Each square is 1/4 inch on a side. (B) Instructions for using Model B. This is fastened to the bottom of the mounting box.

MODEL B has a circular grid. The circle is 1½ inches in diameter superimposed over quarter-inch squares. Each square has four equispaced dots (Figure 4A). This grid is made from a positive print of a photographic film mounted between thin sheets of plexiglass and fitted into the window of the box lid. Instructions for operating MODEL B are given on a chart mounted on the bottom of the instrument box (Figure 4B). The operator estimates overstory density by counting the dots representing overstory openings and assuming this to represent the percentage of non covered overstory area. Here again a slight discrepancy exists because there are only 96 dots included within the area of the circular grid. Exact percentage values for each dot may be calculated to estimate the entire circular area as 100 percent. This refinement is not considered necessary for ordinary use of the instrument.

Instruments can be developed with different kinds, sizes, and shapes of grids and with mirrors of different curvatures. However, standardization of these properties is necessary to provide comparable information that can be duplicated. The instruments described have been thoroughly tested and have given satisfactory results with most western conifers. We believe the spherical densiometer described (either MODEL A or B) will serve the needs of practicing forester, range conservationist, and plant ecologist or those of most scientists doing highly technical work.

Operators need a little training to become consistent in the use of the instrument. Judgment and experience is needed to differentiate between overstory areas that are considered completely covered by the overstory and those that have thin but uniformly distributed coverage. In the latter case it may be necessary to estimate the area of many small irregular openings and reduce the percentage overstory density by the sum of these. Training and experience are needed for each different forest species or type because of the differences in overstory characteristics. The season of the year is important when making measurements in forests containing deciduous species.

Experience has shown that sufficient accuracy can be attained with the spherical densiometer by holding it as nearly level as possible in the hand. This is made possible by installing a circular spirit level in the mounting box. No mechanical support, such as a tripod, is needed. This adds to the practicability of the instrument in use.

A large number of measurements of overstory density have been made to test the instrument. One such study involved the measurement of overstory density at points in 28 different forests. Measurements were made at each point by four different operators each using instrument MODEL A and MODEL B. The results were subjected to an analysis of variance to determine consistency of measurements. There were no significant differences among measurements made by different operators or with different instruments and none of the interactions were significant. The differences due to forests, however, were highly significant-above the 99 percent level of probability. Under similar conditions one can expect variations in overstory density measurements to be within ±1.3 percent, ±2.4 percent, and ±3.1 percent at probability levels of 70, 95, and 99 percent respectively. These variations amount to about 2, 3, and 4 percent when the standard deviation is expressed in terms of the overstory at the point of measurement (coefficient of variation).

Another study involved placement of 416 different forest overstory measurements into 5 percent overstory density classes. Variation around the mean within each class was calculated and the standard deviations and coefficients of variation plotted against the overstory density classes. It was found that variation among measurements increased as the overstory being measured decreased only slightly when overstory density decreased from 100 down to about 60 percent but rapidly thereafter. When placing overstory density into 5 percent classes with the spherical densiometer, reliability in the order of about 5 percent can be expected so long as one is measuring forests that have more than about 50 percent overhead canopy. Since one naturally estimates percentage of overstory area not covered in dense forests and overstory area covered in open forests, estimations of overstory density when placed in classes will seldom vary more than ±5 percent.

Loss in reliability of overstory density measurements results from placing forests in overstory density classes based on measurements with the spherical densiometer as contrasted with using the actual measurements. For instance, reliability of about ±1.3 percent can be attained when actual measurements are used whereas the reliability is reduced to about 5 percent when classes are used.

PAUL E. LEMMON
Soil Conservation Service
U. S. Department of Agriculture
Washington, D.C.

[1] Editor's note: At the request of the author the reader's attention is called to the commercial availability of this instrument.

[2] Lemon, Paul E. 1956. A Spherical Densiometer For Estimating Forest Overstory Density. Forest Sci. 2:314-320.

Additional information can be obtained at:

Environment and Climate Change Canada
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