

# Appendix D

## Ecosystem services potential: Boreal forest case study methodology

The boreal forest case study is a proof-of-concept research and development activity conducted by Environment Canada and Natural Resources Canada as part of the MEGS initiative. This issue of *Human Activity and the Environment* includes results for a single ecosystem service—water purification—that was included in a larger study on the potential to provide 10 services across Canadian boreal forest. This study is undergoing further review and validation.

Ecosystem services included in the case study were selected based on their relevance to broad-scale assessment, federal policy, and the study scope, the importance of the service, and the likelihood of success in spatially mapping the indicator.

The ecosystem potential analyses included the identification of the key service-specific biophysical processes and drivers, their relationships with the targeted ecosystem services, and the development of quantitative models to provide coarse estimation of ecosystem potential for each selected service. The models incorporate biophysical data, such as climatic variables, topography, landscape structure and configuration as well as land cover data. This approach complements the human landscape modification analysis in section 3.2, which covers a broader geographic area, but only uses land cover and land use variables to coarsely evaluate overall ecosystem integrity.

For each individual service, the case study sought out the best available model to assess potential from published and peer reviewed literature and expert opinion. The best available model was selected and modified based primarily on the performance of biophysical models, their ecological relevance in the boreal, the availability of reliable spatially explicit data to reflect the key biophysical process represented in the model and the sensitivity to changes in management decisions.

The spatial extent of this case study was watersheds that fall almost entirely within the Canadian boreal forest region. The watershed was used as the unit of analysis. This selection was based on the fact that watershed delineations are ecologically meaningful and relevant for decision-making and that this spatial resolution was suitable for ensuring both data availability and feasibility of data processing.

For the integrated assessment of the overall spatial variability of service delivery, the project used flower diagrams which allow for the representation of the magnitude of delivery of multiple ecosystem services, without masking the individual contribution of each to the overall service potential.

## Water purification: methods, data sources and calculations

The objective of this part of the study was to estimate water purification potential across Canadian boreal forest watersheds based on landscape conditions and related environmental quality indicators.

The methodology selected is consistent with and builds on an analysis conducted across the continental United States by the US Forest Service.<sup>1,2</sup> The extent of analysis corresponds to all watersheds that fall completely within Canada's boreal zone.<sup>3</sup>

1. Weidner, E. and A. Todd, 2011, *From the Forest to the Faucet: Drinking Water and Forests in the US*, Methods Paper, United States Department of Agriculture Forest Service, [www.fs.fed.us/ecosystemservices/pdf/forests2faucets/F2F\\_Methods\\_Final.pdf](http://www.fs.fed.us/ecosystemservices/pdf/forests2faucets/F2F_Methods_Final.pdf) (accessed April 15, 2013).
2. Barnes, M.C., A.H. Todd, R. Whitney Lija and P.K. Barten, 2009, *Forests, Water and People: Drinking water supply and forest lands in the Northeast and Midwest United States*, United States Department of Agriculture Forest Service, [http://na.fs.fed.us/pubs/misc/watersupply/forests\\_water\\_people\\_watersupply.pdf](http://na.fs.fed.us/pubs/misc/watersupply/forests_water_people_watersupply.pdf) (accessed April 15, 2013).
3. Brandt, J.P., 2009, "The extent of the North American boreal zone," *Environmental Reviews*, Vol. 17, pages 101 to161.

The selected predictor variables used to assess the water purification potential index, additional information on the datasets used and associated data sources, as well as the scoring scheme associated with ranges of values within the distribution of observed values by attribute, are provided in Tables 1 and 2 (Appendix D).

**Table 1**  
**Selected attributes, datasets, calculations and sources**

ID	Attribute	Datasets	Calculations	Sources
1	Percent forested land by watershed (F)	Canada 250m Land Cover Time Series 2000-2011	Total area of forest classes was calculated by watershed using these four NRCan CCRS classes: 'needleleaf_temperate,' 'needleleaf_taiga,' 'broadleaf,' and 'mixed_forest'.	Natural Resources Canada, 2012, <i>Canada 250m Land Cover Time Series 2000-2011</i> , Earth Sciences Sector, Canada Centre for Remote Sensing (CCRS).
2	Percent agricultural land by watershed (A)	Canada 250m Land Cover Time Series 2000-2011	Total area was calculated by watershed using the NRCan CCRS 'cropland' land cover class.	Natural Resources Canada, 2012, <i>Canada 250m Land Cover Time Series 2000-2011</i> , Earth Sciences Sector, Canada Centre for Remote Sensing.
3	Weighted percent riparian forest cover (R)	Canada 250m Land Cover Time Series 2000-2011; Waterbody Edge Density	Calculated as the ratio between the total area of forest classes within a 250 m buffer along water bodies in a watershed and the total edge of waterbodies.	Natural Resources Canada, 2012, <i>Canada 250m Land Cover Time Series 2000-2011</i> , Earth Sciences Sector, Canada Centre for Remote Sensing. Natural Resources Canada, 2007, <i>National Hydro Network, Canada</i> , Earth Sciences Sector, Mapping Information Branch, Centre for Topographic Information, <a href="http://geobase.ca/geobase/en/data/nhn/index.html">http://geobase.ca/geobase/en/data/nhn/index.html</a> (accessed March 1, 2013).
4	Percent wetlands (W)	CanVec	Estimated as the total wetlands area summed by watershed.	Natural Resources Canada, 2013, <i>CanVec</i> , Earth Sciences Sector, Mapping Information Branch, Centre for Topographic Information, <a href="http://www.geogratis.gc.ca">www.geogratis.gc.ca</a> (accessed September 12, 2013).
5	Percent total anthropogenic disturbance (TD)	EC Boreal disturbance dataset 2010	Estimated as the total area disturbed by polygonal (Cutblock; Mine; Reservoir; Settlement; Well site; Agriculture; Oil and Gas; Unknown) and buffered linear (road; powerline; railway; seismic line; pipeline; dam; airstrip; unknown) anthropogenic features. This attribute could only be estimated for 2010 due to data availability.	Pasher, J., E. Seed, and J. Duffe, 2013, "Development of boreal ecosystem anthropogenic disturbance layers for Canada based on 2008 to 2010 Landsat imagery," <i>Canadian Journal of Remote Sensing</i> , Vol. 39, no. 1, pages 42 to 58.
6	Weighted percent burn area (B)	Canadian National Fire Database; Homogeneous Fire Regimes	Estimated by associating each watershed with the Homogeneous Fire Regime zones (HFR) in which the largest proportion of the watershed was located. For example, if 30%, 60%, and 30% of a watershed was located in HFR 1, 24, 21 respectively, then HFR 24 was the de facto HFR for that watershed. For each HFR zone, natural range of variability in decadal burn extent was assessed using data from 1940 to 2010. The post-fire regeneration time for vegetation to resume its hydrologic functions was set at 10 years. For example, total area burn for the year 2000 was estimated by including fires reported between 1990 to 1999 inclusively. <sup>1</sup>	Natural Resources Canada, 2010, <i>Canadian National Fire Database, Agency Fire Data</i> , Canadian Forest Service, Northern Forestry Centre, <a href="http://cwfis.cfs.nrcan.gc.ca/en_CA/nfdb/poly">http://cwfis.cfs.nrcan.gc.ca/en_CA/nfdb/poly</a> (accessed September 12, 2013). Boulanger, Y., S. Gauthier, P.J. Burton, and M.-A. Vaillancourt, 2012, "An alternative fire regime zonation for Canada," <i>International Journal of Wildland Fire</i> , Vol. 21, no. 8, pages 1052 to 1064.
7	Edge density (ED)	EC Boreal disturbance dataset 2010	Estimated as the total edge from linear features (road, powerline, railway, seismic line, pipeline, dam, airstrip, unknown) divided by total watershed area. This attribute could only be estimated for 2010 due to data availability.	Pasher, J., E. Seed, and J. Duffe, 2013, "Development of boreal ecosystem anthropogenic disturbance layers for Canada based on 2008 to 2010 Landsat imagery," <i>Canadian Journal of Remote Sensing</i> , Vol. 39, no. 1, pages 42 to 58.

See notes at the end of the table.

Table 1 – continued

## Selected attributes, datasets, calculations and sources

ID	Attribute	Datasets	Calculations	Sources
8	Linear Density (LD)	Roads; Powerlines; Pipelines; Railways	Estimated as the total edge from linear features (power corridors, roads, railways). However, the attribute was estimated for 2001 and 2010 to allow change analysis.	Statistics Canada, 2002, <i>Road Network File, 2001</i> , Catalogue no. 92F0157X. Statistics Canada, 2006, <i>Road Network File, 2006</i> , Catalogue no. 92-500-X. Natural Resources Canada, 2013, <i>CanVec</i> , Earth Sciences Sector, Mapping Information Branch, Centre for Topographic Information, <a href="http://www.geogratis.gc.ca">www.geogratis.gc.ca</a> (accessed September 12, 2013). Natural Resources Canada, 2012, <i>National Railway Network (NRWN)</i> , <a href="http://www.geobase.ca/geobase/en/data/nrwn/description.html">www.geobase.ca/geobase/en/data/nrwn/description.html</a> (accessed February 1, 2013).
9	Human Footprint (HF)	Roads; Powerlines; Pipelines; Railways; Settlements; Agriculture	Estimated as the total area disturbed by settlements and linear anthropogenic features (power corridors, roads, railways) within a 1 km buffer.	Statistics Canada, 2002, <i>Road Network File, 2001</i> , Catalogue no. 92F0157X. Statistics Canada, 2006, <i>Road Network File, 2006</i> , Catalogue no. 92-500-X. Natural Resources Canada, 2013, <i>CanVec</i> , Earth Sciences Sector, Mapping Information Branch, Centre for Topographic Information, <a href="http://www.geogratis.gc.ca">www.geogratis.gc.ca</a> (accessed September 12, 2013). Natural Resources Canada, 2012, <i>National Railway Network (NRWN)</i> , <a href="http://www.geobase.ca/geobase/en/data/nrwn/description.html">www.geobase.ca/geobase/en/data/nrwn/description.html</a> (accessed February 2013). Statistics Canada, 2002, <i>Population Ecumene Census Division Boundary File (Geography Products: Spatial Information Products, 2001 Census)</i> , Catalogue no. 92F0159X. Statistics Canada, 2007, <i>Population Ecumene Census Division Cartographic Boundary File, Census year 2006</i> , Catalogue no. 92-159-X. Natural Resources Canada, 2012, <i>Canada 250m Land Cover Time Series 2000-2011</i> , Earth Sciences Sector, Canada Centre for Remote Sensing.
10	Slope (S)	Canadian Digital Elevation Data (CDED, 1:50,000)	Derived from a digital elevation model (1:250,000) using the bilinear interpolation method of re-sampling and averaged over the watershed.	Natural Resources Canada, 2000, <i>Canadian Digital Elevation Data</i> , Earth Sciences Sector, Centre for Topographic Information, <a href="http://www.geobase.ca/geobase/en/data/cded/index.html">www.geobase.ca/geobase/en/data/cded/index.html</a> (accessed September 12, 2013).
11	N and S exceedance level (NS)	Aurams model from EC (data for 2000)	Assigned for regions where current atmospheric deposition of N and S is greater than the critical loads ('exceeded'). Critical loads are defined as "a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge." <sup>2</sup>	Environment Canada, 2013, Critical load exceedance data.

1. Boulanger, Y., S. Gauthier, P.J. Burton and M.-A. Vaillancourt, 2012, "An alternative fire regime zonation for Canada," *International Journal of Wildland Fire*, Vol. 21, no. 8, pages 1052 to 1064.

2. Nilsson, J. and P. Grennfelt (eds.), 1988, *Critical Loads for Sulphur and Nitrogen*, Miljörapport 1988:15, Nordic Council of Ministers, Copenhagen.

**Source(s):** Environment Canada and Natural Resources Canada, 2013.

**Table 2**  
**Scoring scheme associated with ranges of values within the distribution of observed values by attribute**

ID	Attribute	Scoring for watershed average			
		Low (1 point)	Moderate (2 points)	High (3 points)	Very high (4 points)
1	Percent forested land by watershed (F)	0 to 24	25 to 49	50 to 75	> 75
2	Percent agricultural land by watershed (A)	> 30	21 to 30	10 to 20	< 10
3	Percent riparian forest cover (R)	0 to 29	30 to 50	51 to 70	> 70
4	Percent wetlands (W)	0 to 2.68	2.68 to 7.47	7.47 to 21.37	> 21.37
5	Percent total anthropogenic disturbance (D)	> 5	0 to 5	...	0
6	Percent burn area (B), by Homogeneous Fire Regime:				
a)	1	> 2.84	0.47 to 2.84	0.006 to 0.47	0 to 0.006
b)	2	> 0.83	...	0 to 0.83	0
c)	3	> 6.22	1.99 to 6.22	0.70 to 1.99	0 to 0.70
d)	4	> 0.18	...	0 to 0.18	0
e)	5	> 0	...	...	0
f)	6	> 1.89	...	0 to 1.89	0
g)	7	> 1.27	...	0 to 1.27	0
h)	8	> 0	...	...	0
i)	9	> 0	...	...	0
j)	10	> 0.03	...	0 to 0.03	0
k)	11	> 0	...	...	0
l)	12	> 0	...	...	0
m)	13	> 0.06	...	0 to 0.06	0
n)	14	> 1.60	...	0.01 to 1.60	0
o)	15	> 0	...	...	0
p)	16	> 8.80	0.58 to 8.80	0.08 to 0.58	0 to 0.08
q)	17	> 6.20	0.99 to 6.20	0.44 to 0.99	0 to 0.44
r)	18	> 0.10	0.02 to 0.10	0 to 0.02	0
s)	19	> 0.62	...	0 to 0.62	0
t)	20	> 0.29	...	0 to 0.29	0
u)	21	> 4.68	0.84 to 4.68	0.22 to 0.84	0 to 0.22
v)	22	> 0	...	...	0
w)	23	> 0	...	...	0
x)	24	> 4.45	1.36 to 4.45	0.55 to 1.36	0 to 1.36
y)	25	> 0.014	...	0 to 0.014	0
z)	26	> 4.51	1.08 to 4.51	0 to 1.08	0
aa)	27	> 1.73	0.24 to 1.73	0 to 0.24	0
ab)	28	> 4.49	0.32 to 4.49	0.03 to 0.32	0 to 0.03
ac)	29	> 3.92	0.16 to 3.92	0 to 0.16	0
ad)	30	> 0.69	...	0 to 0.69	0
ae)	31	> 4.95	0.99 to 4.95	0.05 to 0.99	0
af)	32	> 5.68	2.05 to 5.68	0.39 to 2.05	0 to 0.39
ag)	33	> 1.68	0.97 to 1.68	0.14 to 0.97	0 to 0.14
7	Edge density (ED)	> 0.27	0.5 to 0.27	0.005 to 0.5	0 to 0.005
8	Linear Density (LD)	> 0.05	> 0.016 to 0.05	0.012 to 0.016	0 to 0.012
9	Human Footprint (HF) 2000	> 7.71	2 to 7.71	0.18 to 2	0 to 0.18
9	Human Footprint (HF) 2010	> 7.27	2.33 to 7.27	0.24 to 2.33	0 to 0.24
10	Slope (S)	> 0.97	0.45 to 0.97	0.22 to 0.45	0 to 0.22
11	N and S exceedance level (NS)	> 0	-74.305 to 0	-161.536 to -74.305	< -161.536

**Source(s):** Environment Canada and Natural Resources Canada, 2013.

Various partitioning techniques were used to identify the score associated with each potential value of an attribute. When there was sufficient knowledge to support the identification of an ecological threshold for a given attribute as it related to water purification, then such information was used to identify relative weighting scores for the observed range of variability. However, for many ecological phenomena, no clear threshold of response to a selected predictive variable has been observed or reported. The other technique used was to break the distribution in observed values into its respective quartiles.

The Water Purification Potential Index (WaPPI) was calculated for 2000 and 2010 using the above predictor variables as follows:

$$\text{WaPPI} = F + A + R + W + B + \text{LD} + \text{HF} + S + \text{NS}$$

where F equals percent forested land by watershed; A equals percent agricultural land by watershed; R equals weighted percent riparian forest cover; W equals percent wetlands; B equals weighted percent burn area; LD equals linear density; HF equals human footprint; S equals slope; and NS equals nitrogen and sulphur exceedance level.

For comparison purposes, WaPPI was also assessed using a different national dataset for total disturbance (TD) and edge density (ED).