Name: Faisal Moola

Organization: David Suzuki Foundation

Date: October 11, 2017

Subject: Presentation to Site C Inquiry Panel October 13th 2017: written submission

Dear Sir/Madam

I was scheduled to appear before the BCUC Inquiry Panel on October 13th 2017. I was invited to speak to the Panel about the importance of natural capital to understanding the full economic costs of the Site C dam. Unfortunately, I am unable to address the Panel in person due to a scheduling conflict and thus have arranged with the BCUC staff (Ms. Sarah Walsh) to submit my comments in writing instead. Unfortunately, I am unable to travel from Toronto to Vancouver to address the Panel.

Please find the attached documentation, which expands further on my original submission to the Inquiry Panel dated August 30th 2017.

thank you kindly

Faisal

Dr. Faisal Moola, PhD
Director General
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October 11th 2017

BCUC Site C Inquiry Panel

David Morton, Chair, and Commissioners Karen Keilty, Dennis Cote and Richard Mason

Re: recognizing the impacts of the Site C dam on natural capital and ecosystem services

Dear Members of the Commission Panel:

I am writing to provide you some additional information on the importance of natural capital in the Peace Valley in your review of the economic impacts of the Site C project. This letter is a follow-up to my earlier submission to the BCUC Site C Inquiry Panel, dated August 30th 2017, and specifically the report: *The Peace Dividend: Assessing the Economic Value of Ecosystems in B.C.'S Peace River Watershed. David Suzuki Foundation. 2014.* [1] This report found that the market and non-market ecosystem benefits of natural capital in the Peace Valley and surrounding region are extremely valuable in monetary terms. We conservatively estimated that the ecosystem services provided by farmland and nature in the Peace River Watershed are conservatively worth an estimated $7.9 billion to $8.6 billion a year[2] – through the cumulative contribution of services such as water supply, air filtration, flood and erosion control, habitat for wildlife and agricultural pollinators, carbon storage and other benefits. While the study was done at the watershed scale, the ecosystem services values per ha / yr are significant and are illustrative of the importance of natural capital in the valley. They are summarized in the following two tables from the report:

[1] http://www.davidsuzuki.org/publications/DSF_Peace_natcap_web_July_29%20copy.pdf

[2] the Total Ecosystem Services Value reported is incomplete because it was not possible to quantify and value all of the ES provided by the study area's ecosystems. However, using the ecological and economic data that were available, several values were estimated for key ES.

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TABLE 9: SUMMARY OF THE ECOSYSTEM SERVICES VALUES FOR THE PEACE RIVER WATERSHED STUDY AREA

Ecosystem service	Annual value $/hectare/year (2012 Cdn$)	Total annual value $/year (2012 Cdn$)
Water supply	$32.60	$2,502,441
Air filtration by trees	$3.51	$12,684,230
Forest ecosystem carbon storage (1.14 billion tonnes based on BC VRI forest age/carbon analysis; 948.6 million tonnes using average/ha and AAFC data)	Central value $1,175.69 ($4.48/tC) $460.19 (treed wetland – aboveground biomass only)	Range from $1.56 billion to $8.5 billion; central value $4,425,760,501 to $5,092,465,112
Wetland soil carbon storage (253.9 million tonnes)	$715.24 to $2,453.85	Range from $401 million to $1.89 billion; central value of $1,137,249,649
Other soil carbon storage (261.9 million tonnes)	$921.32 (grassland) $1,073.77 (pasture) $1,552.03 (shrubland) $1,181.55 (cropland)	Range from $413.5 million to $1.95 billion; central value of $1,172,829,309
Carbon sequestration	$138.08 (forest) $33.42 (wetland) $56.20 (shrubland/ grassland/ perennial cover)	Range from $285.5 million to $1.15 billion; central value of $620,855,368
Wetland flood control, water supply, nutrient recycling	$256.67 (wetland)	$133,157,316
Water filtration	$6.23 (forest, treed wetland)	$22,529,524
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Pollination	$43.63 (shrubland/ grassland, perennial cover/pasture)	$39,895,056
Habitat	$379.43 (wetlands) $41 (perennial cover/pasture)	$206,744,044
Recreation	$21.47 (forest, wetland, shrubland, grassland) $215.97 (water)	$119,738,498
Cultural values	$9.38 (farmlands) $0.39 (protection of forest, wetland)	$5,258,881

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TABLE 10: SUMMARY OF THE ECOSYSTEM SERVICES VALUES BY LAND COVER TYPE (2012 $)

Land Cover Type	Annual value (excluding carbon storage values) $/hectare/year	Annual Value (including carbon storage values) $/hectare/year
Forest	$169.34	$1,345
Shrubland	$121.35	$1,673
Grassland	$155.88	$1,077
Treed wetlands	$883.21	$3,455
Shrub wetlands	$745.13	$3,199
Grass/herb wetlands	$745.13	$1,460
Water	$248.57	$249
Annual cropland	$9.38	$1,191
Perennial cropland/pasture	$184.75	$1,259

These values should be taken into consideration when looking at the full economic costs of the Site C dam in terms of the degradation and/or loss of ecosystem services over the lifetime of the project. Replacing the natural services (e.g., flood control) provided by farmland and nature in the Peace Valley with built substitutes would likely cost millions of dollars, likely for a lesser level of service than nature is able to provide for free. And these estimates of replacement costs are only one portion of the true value natural capital in the valley to sustaining the health and wellbeing of local communities. One cannot put a price on some of the services received from nature: like the health, psychological, and cultural services that are critically important to local First Nations and their use of the Peace Valley.

For example, hunting and trapping supports a holistic approach to the overall health and well-being of many Canadians, especially in Indigenous communities. A David Suzuki Foundation study on the importance of caribou hunting to First Nations in the boreal forest found, "harvesting as a practice is not solely a process of obtaining meat for nutrition. With each hunt a deliberate set of relationships and protocols is awakened and reinforced. These include reciprocity, social cohesion, spirituality and the passing on of knowledge to future generations."[3]

Indeed, for First Nations in the region, the land and waters of the Peace Valley are an integral part of their identity, their stories, their songs and their language. The valley is shared among First Nations groups for historic, cultural and subsistence purposes. Communities continue to share their culture with younger generations through trapping, fishing, hunting, the collection of medicinal plants, crafts, ceremonies, canoes and drums.

[3] The Cultural and Ecological Value of Boreal Woodland Caribou Habitat, davidsuzuki.org/publications/downloads/2012/Report-Caribou.pdf

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While some studies have been done to estimate the economic value of wilderness to First Nations, such as a willingness-to-pay study conducted for aboriginal communities in Saskatchewan and a study on food replacement costs from other northern communities in western Canada, our study of the economic value of natural capital in the Peace Region was based on an overview of the cultural and spiritual values of the Peace region to the local First Nations, as described in their own words in a Traditional Land Use Study (TLUS) prepared by the Treaty 8 Tribal Association in 2012.[4] The TLUS identified 796 site-specific use values that were mapped in the Peace River Valley, mostly clustered along the low-lying Peace River flats and adjacent streams. The cultural and spiritual values included:

- Spiritual places
- Burials
- Medicine collection areas
- Teaching areas
- Ceremonial and prayer offering places
- Locations associated with place names and oral histories
- Habitat areas
- Movement corridors
- River crossing areas for ungulates and large carnivores (i.e., grizzly bears)
- Winter fish habitat and spawning areas
- Bear dens
- Moose and ungulate calving areas and winter browse
- Temporary and permanent or regularly used camping/habitation areas
- Gathering places including locations used for generations
- Fish harvesting sites (i.e., bull trout, dolly varden, rainbow trout, grayling, whitefish)
- Preferred harvesting areas for berries, plant foods and wood materials
- Preferred drinking water sources
- Kill sites for moose, deer, black bear, small birds and furbearers
- Transportation values including trails, horse crossings and boat crossings
- Water routes by canoe and motorboat

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[4] Candler, C. 2012. Doig River First Nation, Prophet River First Nation, Halfway River First Nation and West Moberly First Nations Traditional Land Use Study Data and Methodology Report for BC Hydro's Proposed Site C Project. Prepared on behalf of the four participating First Nations (Doig River First Nation, Prophet River First Nation, West Moberly First Nations and Halfway River First Nation). Submitted to Treaty 8 Tribal Association (T8TA).

Key sites identified included Lynx Creek, Peace River Islands, Bear Flats, Cache Creek, Bison Jump, Halfway River, Moberly River and Hudson's Hope.

Lynx Creek was an ancestral gathering place for Dane-zaa families prior to and after the signing of Treaty 8. It includes permanent camping and habitation areas, preferred hunting and fishing areas, important wildlife habitat and associated oral histories.

Peace River Islands provide wildlife habitat and are considered sacred refuge areas for animals, especially moose and deer during calving and rearing. Hunting for subsistence is restricted. The islands also have specific histories associated with spiritual and cultural importance.

Bear Flats and Cache Creek, located along the river valley, were, like Lynx Creek, ancestral gathering places for Dane-zaa families. These locations are still regularly used for camping and habitation, ceremonies, sacred areas, preferred fishing and hunting sites, significant wildlife habitat, freshwater springs, trail and transportation routes, as well as oral histories.

Communities continue to share their culture with younger generations through trapping, fishing, hunting, the collection of medicinal plants, crafts, ceremonies, canoes and drums. It should also be emphasized that these cultural and spiritual values are critical to the meaningful exercise of Treaty and Indigenous Rights by local First Nations in the Peace Valley and surrounding areas.

First Nations Cultural Values

Cultural values are irreplaceable, so it is difficult to place a monetary value on them. Since they are vital to First Nations, they are considered invaluable. However, studies have reported non-use values for aboriginal communities. For example, a Saskatchewan study surveyed aboriginal and non-aboriginal households to assess their willingness to pay (WTP) for the protection of wilderness.[a] The aboriginal households on average were willing to pay $84.62/ hhld/year (1991 $) in terms of an existence or non-use value (i.e., recreational value was reported as a separate value). If we transferred this value to the First Nation populations in our study area, the WTP of $125.13/hhld/year in 2012 dollars would be multiplied by the estimated number of aboriginal households in the Peace River watershed (2,794 hhlds). The cultural non-use value could then be estimated at $349,613 per year.

In addition, the subsistence values such as wood harvesting, hunting, fishing, trapping, food gathering and the use of natural materials for crafts and medicines for First Nations lands have

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also been evaluated in other regions of Canada. For example, in a northern Alberta study, the replacement value of subsistence foods and materials was estimated to range from $6,875 to $15,126 (2012 $) per household for northern communities.[b] The replacement cost depends on the amount of subsistence food and materials collected and used by First Nations and the local prices of purchasing food and materials. If we transferred this value for our study area, based on the estimated number of FN households the potential subsistence values for First Nations ranges from $19.2 million to $42.3 million per year. It would be valuable to undertake a study in the future to document subsistence products and values for the Peace region. The WTP and subsistence values were not included in the overall ES total values, but they are reported here for as illustrative examples.

However, this accounting fails to take into account the cultural and spiritual values of subsistence hunting—which often form the fabric of a community's identity. As noted in report *The Cultural and Ecological Value of Boreal Woodland Caribou Habitat*,[c] released in 2013 by the David Suzuki Foundation and the Assembly of First Nations, hunting is often integral to many First Nations as much for its role in strengthening knowledge and relationships, as for providing nutrition and recreation, meaning, health and wellness.

As the report notes: "...[T]he sharing of the harvest is an important source of nutrition and satisfaction for recipients, and a source of respect for generous harvesters.... Economic valuation of this sharing would almost certainly underestimate the true value and motivations for such social institutions."

. [a] Kulshreshtha, S.N., and Loewen, K.G. 1997. "Value of Wilderness Protection in Saskatchewan: A Case Study of Existence Values." In: Sustainable Forests: Global Challenges and Local Solutions. Haworth Press.

. [b] M.K.Haener and W.L.Adamowicz, "Regional Forest Resource Accounting; a northern Alberta case study," Canadian Journal of Forest Research 30 (2000).

. [c] The Cultural and Ecological Value of Boreal Woodland Caribou Habitat, davidsuzuki.org/publications/ downloads/2012/Report-Caribou.pdf

The intent of our natural capital research was to provide a baseline assessment of the ecosystem services provided by the Peace Valley and surrounding region. The values are incomplete, but they do deliver a meaningful estimate of the magnitude of the existing ecosystem values that the

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BCUC Inquiry Panel can use to reflect on the cost of land-use change and ecological fragmentation should the Site C dam be built.

Ideally, detailed site valuations for specific ecosystem functions should be undertaken to provide more precise values of marginal changes due to site-level ecosystem alteration or destruction should the Site C dam proceed. In the absence of this research, one cannot get a full and complete picture of the magnitude of economic impacts of the dam, resulting from the degradation and loss of natural capital in the Peace Valley.

Our analysis is illustrative of how natural capital in British Columbia and Canada is valued — and undervalued – in regulatory decisions. I encourage the BCUC Inquiry Panel to use our natural capital report, and other natural capital valuations, to inform your review of the broader economic costs of the Site C dam.

We believe that the evidence shows that farmland and ecosystems in the Peace Valley have an incredible ability to generate natural wealth if protected from further land use development. It is for this reason that the David Suzuki Foundation believes that the Site C Dam should be cancelled.

Yours truly,

Dr. Faisal Moola, PhD

Director General, Ontario and Northern Canada

David Suzuki Foundation

Adjunct Professor, Faculty of Forestry, University of Toronto

Adjunct Professor, Faculty of Environmental Studies, York University

Cc

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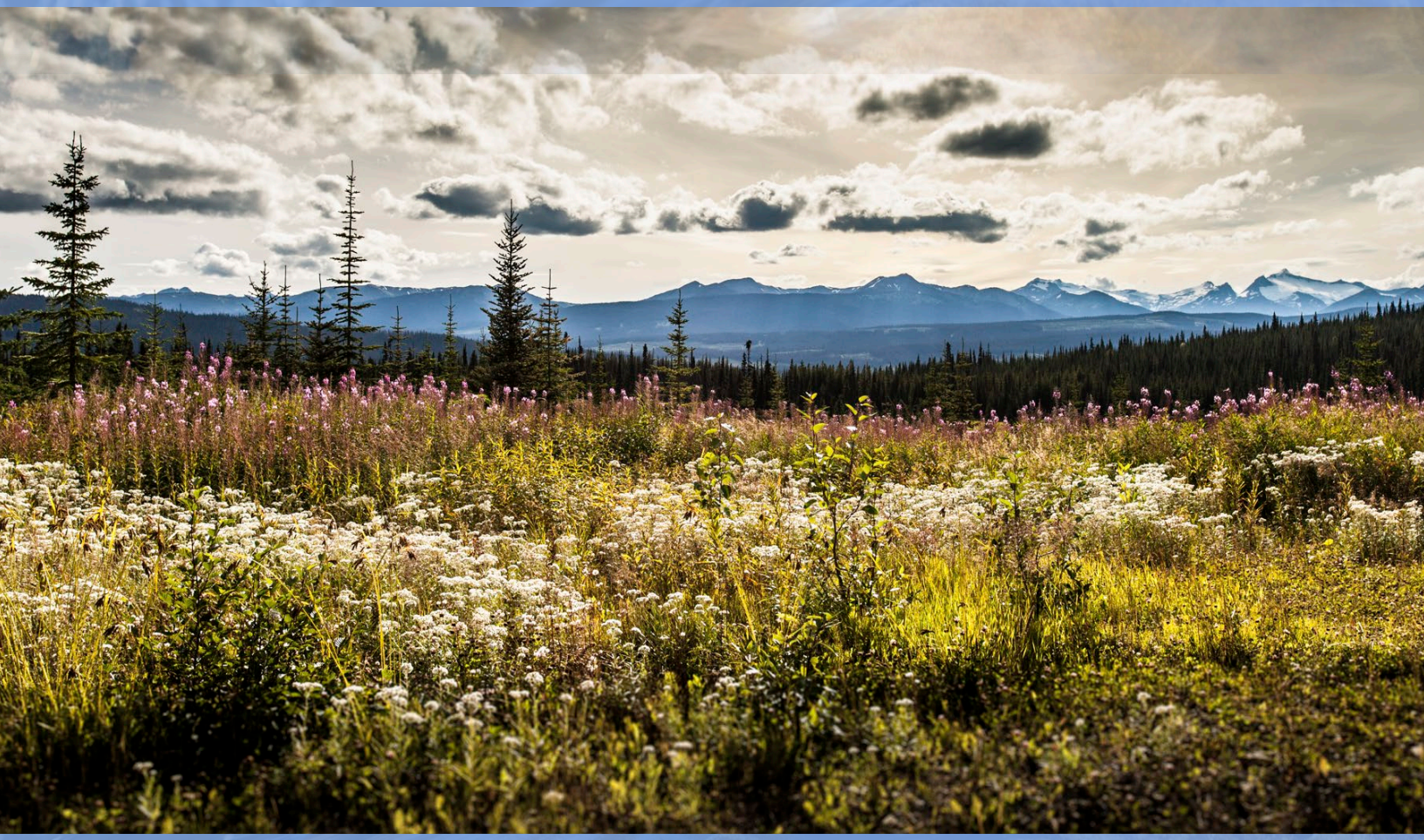
Chiefs Roland Wilson and Lynette Tsakoza, Nun wa dee Stewardship Society
Hon. John Horgan, Premier of British Columbia
Hon. Michelle Mungall, Minister of Minister of Energy, Mines and Petroleum Resources
Hon. Scott Fraser, Minister of Indigenous Relations and Reconciliation

The Peace Dividend

ASSESSING THE ECONOMIC VALUE OF ECOSYSTEMS IN B.C.'s PEACE RIVER WATERSHED



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Suzuki
Foundation

THE PEACE DIVIDEND: ASSESSING THE ECONOMIC VALUE OF ECOSYSTEMS IN B.C.'S PEACE RIVER WATERSHED

2014

by Sara J. Wilson, Natural Capital Research & Consulting

Foreword by Dr. Faisal Moola, Director General of David Suzuki Foundation's Ontario and Northern Canada Department

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Contents

APPENDICES

FIGURES

TABLES

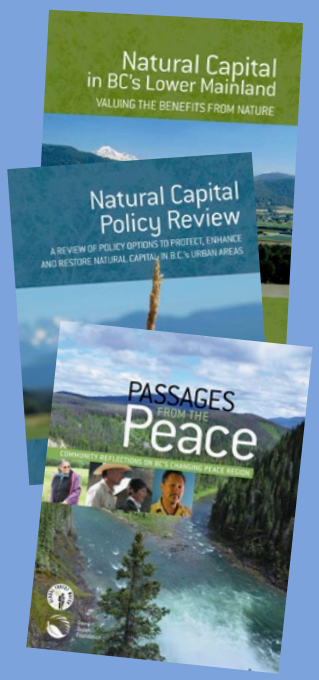
ACKNOWLEDGEMENTS

The author would like to thank the David Suzuki Foundation, West Moberly First Nation, Doig River First Nation, and Treaty 8 Tribal Association for their support and interest in pursuing natural capital and ecosystem services research. In particular, I would like to thank Rachel Plotkin, Amy Hu and Faisal Moola for their commitment, interest in and contributions to the report. Thank you to Mark Anielski, Kai Chan, Brian Churchill, Andrea Morrison, Jillian Ridington, Robin Ridington and Amy Taylor for their time in providing comments on the report. Thanks to Ryan Cheng of Global Forest Watch Canada for the spatial data and mapping undertaken for this project.

DISCLAIMER

This study should be considered a baseline and coarse-scale natural capital account for the B.C. portion of the Peace River Watershed. It is a first step toward a more comprehensive accounting of natural capital assets in the region and the ecosystem services provided by its ecosystems and natural areas. More Canadian research is required to determine a full range of ecosystem service values relevant to Canadian ecoregions and land cover types. This work is intended to encourage others to consider the value of natural capital assets and ecosystem services and to stimulate dialogue on the values of natural capital, ecosystem services, stewardship and conservation.

The content of this study is the responsibility of its author and does not necessarily reflect the views and opinions of those acknowledged above. Every effort has been taken to ensure the accuracy of the information contained in this study. However, it is important to acknowledge that ecosystems have many values that cannot be monetized and that ecosystem service research and valuations are approximations with inherent uncertainty. It is also important to remember that although we can place a monetary value on ecosystems and ecosystem services, we cannot replace the ecosystems provided by the Earth.



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FOREWORD

Over the past 20 years, we at the David Suzuki Foundation have learned a lot about the importance of maintaining healthy ecosystems in order to sustain the health and wellbeing of communities.

PHOTO COURTESY KYLEWITH/ FLICKR CREATIVE COMMONS

ACCORDING TO A STUDY PUBLISHED several years ago in the research journal *Science*, few places on our planet have been untouched by modern humans.

From Arctic tundra to primeval rainforest to arid desert, our natural world has been fragmented by ever-expanding towns and cities, crisscrossed with roads, transmission lines and pipelines, and pockmarked by pump jacks, flare stacks, and other industrial infrastructure used to drill, frack, and strip-mine fossil fuels from the ground.

The need to supply food, fibre, fuels, shelter, freshwater and energy to more than seven billion of us now inhabiting the planet is driving the wholesale conversion of forests, wetlands, grasslands, and other ecosystems, including in sensitive areas such as the Peace Region of northeastern British Columbia.

Earlier research published by the David Suzuki Foundation has revealed that the pace and scale of industrial development in the Peace Region is massive. From the air, this vast area of rich boreal forest and rolling farmland now appears as a fractured landscape of clearcuts, seismic lines, oil and gas wells, roads, pipelines and fragmented fields. If future development proceeds as proposed, including the flooding of the Peace River for the Site C dam project, the result will be even greater cumulative changes in a region of Canada that is already under significant pressure and where little protected habitat has been set aside for wildlife and other ecological values.

Over the past 20 years, we at the David Suzuki Foundation have learned a lot about the importance of maintaining healthy ecosystems in order to sustain the health and wellbeing of communities. These ecosystems, or "natural capital," form the life-support systems of our planet, providing clean air, clean water, healthy food to eat, and a plethora of other ecological benefits, including contributing to the cultural and traditional ways of First Nations.

For example, ecological economists have conservatively estimated that Canada's massive boreal forest provides a staggering $570 billion a year, an average of $3,400 per hectare, in ecological benefits such as climate regulation, flood protection, water regulation, waste treatment, and pollination. Furthermore, these benefits are worth over 13.5 times more societal economic value than the GDP generated by natural capital extraction industries such as mining, oil and gas development, and forestry.

It is our hope that our natural capital valuation study of the Peace Region will help to cultivate a deeper appreciation among the public and policy-makers of the true value of the region's natural and managed ecosystems and thereby help to ensure this sensitive area of Canada is carefully managed now and well into the future.

— Dr. Faisal Moola, PhD
David Suzuki Foundation Director General,
Ontario and Northern Canada

Executive Summary

THE PEACE RIVER WATERSHED in northeastern British Columbia is a valuable ecological and cultural region. First Nations and their ancestors have lived in the area for more than 10,000 years. The unique warm microclimate and productive farmland soils of the Peace River Valley provide the best growing conditions in northern B.C. The valley also provides key habitat for moose, elk and deer and is an essential corridor for migratory birds, caribou and grizzly bear populations.

The region, however, has experienced widespread change due to industrial development and ecological fragmentation. Logging, mining, oil and gas development, large-scale hydro dams, roads, pipelines and other industrial developments have impacted most of the watershed's ecosystems.[1] Between 1974 and 2010 land-use change and ecological fragmentation had an ecological impact on approximately 67 per cent of the watershed.[2]

Local First Nations and other residents are concerned that the cumulative impacts of ongoing industrial and resource development will cause further decline in wildlife habitat and community well-being. The region has widespread tenure concessions for future exploration and development. In addition, a third major hydroelectric development project (Site C) is proposed for the Peace River Valley. The proposed dam would flood important historical and spiritual First Nations sites, highly productive agricultural lands and wildlife habitat.[3,4]

This report assesses the economic values for the ecosystem services provided by natural capital within the B.C. portion of the Peace River Watershed (approximately 5.6 million hectares).

Our study found that forests were the dominant ecosystem type, covering about 64 per cent of the study area.[5] The other land cover types included wetlands (9%), grasslands (8%), snow cover, rock and exposed

Local First Nations and other residents are concerned that the cumulative impacts of ongoing industrial and resource development will cause further decline in wildlife habitat and community well-being.

PHOTO COURTESY DON HOFFMANN

1 Lee, P., and Hanneman, M. 2012. *Atlas of land cover, industrial land uses and industrial-caused land change in the Peace Region of British Columbia*. Global Forest Watch Canada report #4.

2 Ibid. The physical impact included physical changes on the landscape from industrial development, and infrastructure changes to the study area, such as oil and gas wellsites, clearcuts, mines, roads and pipelines, agricultural clearings and golf courses. The ecological footprint was measured with a 500-metre buffer around all land-use impacts.

3 Fawcett, M. 2010. "The Case Against the Site C Dam." TheTyee.ca http://thetyee.ca/Opinion/2010/04/05/CaseAgainstSiteC/

4 Chillborne Environmental. 2009. *The Living Peace River Valley: An Overview of the Peace River Valley's Natural and Cultural Values*. West Moberly First Nations and Peace Valley Environment Association.

5 The forest cover was predominantly coniferous forest (73%), with smaller areas of broadleaf forest (24%) and mixed-wood forest (3%).

MAP OF THE B.C. PEACE RIVER WATERSHED STUDY AREA

This study was undertaken to provide information for local communities regarding the importance of the area's ecosystems for the well-being of the Peace River Watershed and its people.

lands (5%), perennial croplands and pastures (4%), shrublands (4%), annual croplands (2%), water (1%) and developed land (0.1%). An additional 2% of the study area could not be classified in any land cover type because of technical issues such as cloud cover and shadowing in satellite images.

Ecosystem service (ES) values were developed based on land cover data, forest age class and socio-economic information from the Peace River region and other valuation studies. If local or regional data were not available, values were transferred from other relevant studies. Values were transferred either by assigning an average value from global meta-analysis studies, or by adjusting the transfer value by our study area's population. The approach was documented for each valuation in the results section.

Economic values were developed for water supply, air filtration, carbon storage, carbon sequestration, flood control, water filtration, erosion control, habitat, recreational and cultural services. The greatest values were for carbon storage. Since carbon storage helps regulate the climate, which is a global system, the benefits of stored carbon reach beyond the local population to regional, national and even international beneficiaries.

The total annual value for carbon stored in the Peace River Watershed was estimated at $6.7 billion to $7.4 billion per year (central values); and the total value for the other ecosystem service values was estimated to range from $879.4 million to $1.74 billion per year in economic benefits.[6]

6 The total land cover area used for valuation excludes: unclassified land, snow/ice, rock/rubble, exposed land, developed land and cloud cover area (366,429 hectares).

SUMMARY OF THE ECOSYSTEM SERVICES VALUES FOR THE PEACE RIVER WATERSHED STUDY AREA		
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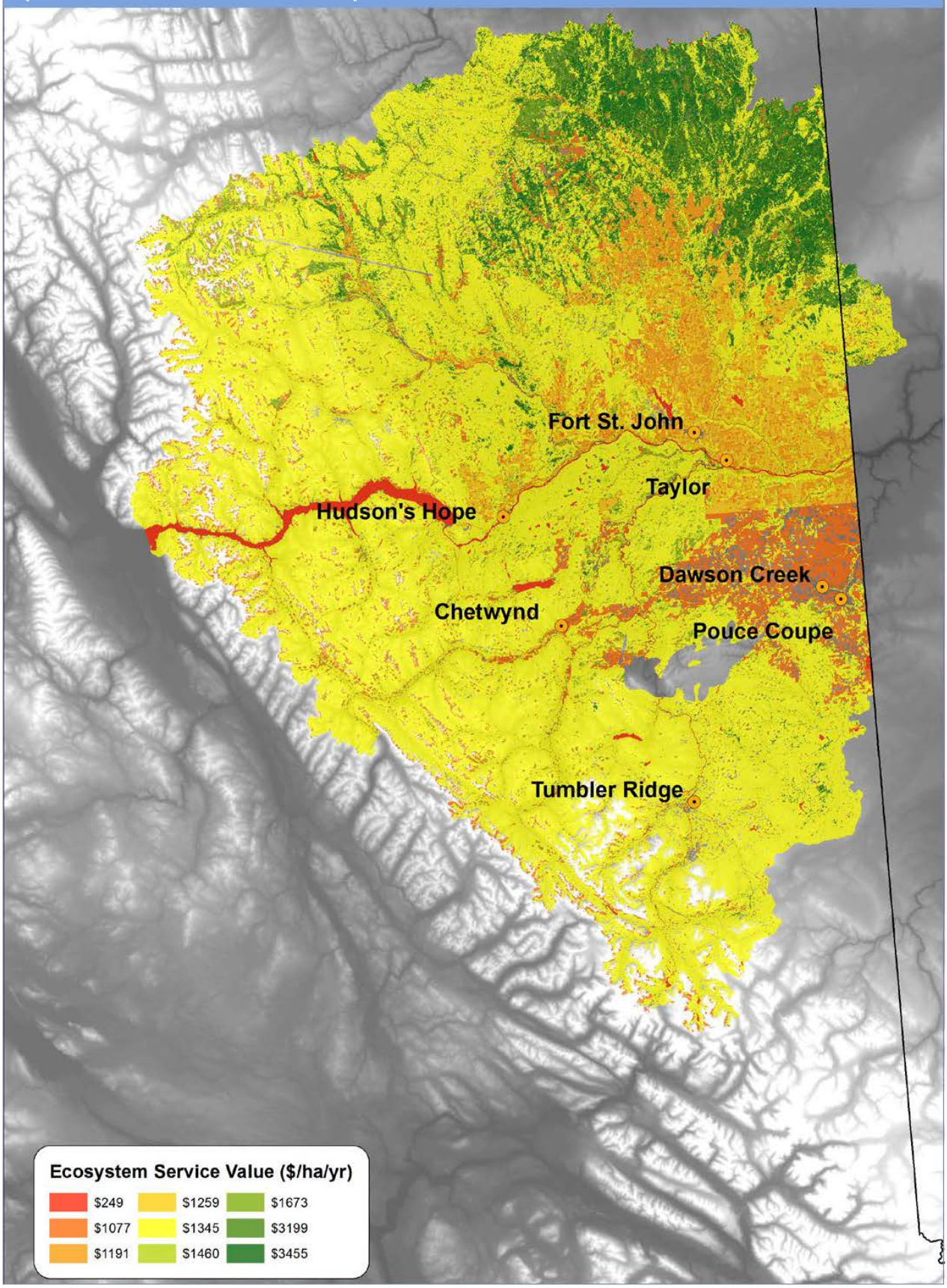
AVERAGE ECOSYSTEM SERVICE VALUES BY LAND COVER TYPE IN THE B.C. PEACE RIVER WATERSHED (INCLUDES FOREST CARBON VALUES)



It is hoped that this report will encourage discussion about how natural capital in B.C. and Canada is valued — and undervalued.

PHOTO COURTESY WAYNE SAWCHUCK/PICTURE BC

Over a 50-year period, the central net present value (NPV) was $204.6 billion (with a range from $83.7 billion to $333.7 billion), including all ES values.[7] Based on the population of the study area, the central NPV per person was estimated at $3.9 million per person (central value at 3 per cent discount rate) (see textbox on discount rates on page 31).

The intent of this report was to provide a baseline assessment for the ecosystem services provided by the Peace River Watershed at the regional scale. The total ES value is a partial estimate because it was not possible to quantify and value all of the ecosystem services provided by the study area's ecosystems. The values are incomplete at this stage but they do deliver a meaningful estimate of the magnitude of the existing ecosystem values for local communities, First Nations and policy decision-makers to reflect on the cost of land-use change and ecological fragmentation in the study area. The values also reflect the economic benefits of protecting and restoring the region's ecosystems, farmlands and cultural heritage. Detailed site valuations for specific ecosystem functions should be undertaken to provide more precise values of marginal changes resulting from site-level ecosystem alteration, destruction or investment.

It is hoped that this report will encourage discussion about how natural capital in British Columbia and Canada is valued – and undervalued. Decision-makers and the public are encouraged to use this report to inform policy, land use planning, and resource management discussions about how best to protect and restore the region's ecological integrity and ensure a sustainable future.

7 A range of NPVs were reported from a low of $162.6 billion to a high of $236.8 billion based on a range of carbon values and discount rates.

PART 1

Introduction

There are concerns among local First Nations and other residents that additional industrial development will cause further ecological degradation, resulting in a decline in community well-being and unique wildlife habitat.

PHOTO COURTESY ANDREW TYLOSKY/PICTURE BC

BRITISH COLUMBIA'S PEACE REGION, located in the northeast corner of the province, has experienced widespread change due to industrial development and ecological fragmentation. Most of the Peace River Watershed's ecosystems have felt the impacts of logging, mining, oil and gas development, large-scale hydro dams, roads, pipelines and other industrial developments.[8] According to a recent satellite-based analysis, land-use change occurred across 20 per cent of the Peace River Watershed, but had an ecological impact, in terms of ecosystem fragmentation and habitat degradation, on approximately 67 per cent of the watershed.[9]

There are concerns among local First Nations and other residents that additional industrial development will cause further ecological degradation, resulting in a decline in community well-being and unique wildlife habitat. The region features widespread tenure concessions for future mineral exploration and development, logging and oil and gas development, as well as a proposed third major hydroelectric development project (Site C) along the Peace River Valley. Local First Nations, farmers, environmentalists and other residents have voiced their opposition to Site C.[10] Treaty 8 First Nations in the region have presented a joint declaration to the British Columbia government, requesting that further research on the cumulative impacts of industrial development in the region be undertaken before any further development takes place.[11]

This report gives an assessment of the ecosystem services provided by natural capital within the B.C. portion of the Peace River Watershed (PRW). It identifies the ecosystem services supplied by the study area's ecosystems based on the PRW's land cover and land use. This study was undertaken to provide information for local communities regarding the importance of the area's ecosystems for the well-being of the Peace River Watershed and its people. Another objective was to provide information to support decision-making at the policy level in hopes of maintaining the study area's environmental assets. The management of landscapes for the provision of ecosystem services requires information about the amount and location of

8 Lee and Hanneman, supra note 1.

9 Ibid. The physical impact included physical changes on the landscape from industrial development, and infrastructure changes to the study area, such as oil and gas wellsites, clearcuts, mines, roads and pipelines, agricultural clearings and golf courses. The ecological footprint was measured with a 500-metre buffer around all land-use impacts.

10 Fawcett, supra note 3.

11 *Treaty 8 First Nations Declaration on the Site C Dam Proposal*. Sept. 17, 2010. http://fathertheo.wordpress.com/2011/03/09/treaty-8-first-nations-declaration-on-the-site-c-dam-proposal/

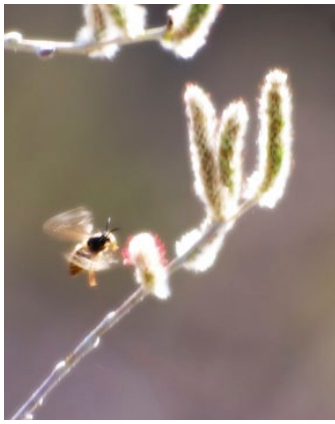
natural capital so that the impacts of land-use change, on both natural capital and the ecosystem services provided, can be assessed.

1.1 Natural Capital and Ecosystem Services

Natural capital refers to the Earth's land, water, atmosphere and resources. Organized and bundled within the Earth's natural ecosystems, this capital provides resources and flows of services to support all life. Natural capital is critical to the economic and social well-being of Canadians. Our landscapes consist of forests, wetlands, grasslands, lakes, rivers, estuaries and marine environments that provide ecosystem services for local communities and industries, regional and global processes, as well as biodiversity and habitat.

Among the numerous services ecosystems provide are storage of floodwaters, water capture and filtration, absorption and treatment of pollution from water and air, and climate regulation resulting from carbon storage in trees, plants, soils, sediments and marine habitats. However, since populations do not pay directly for these services, they are undervalued in our market economy.

Communities and governments are beginning to recognize the essential ecosystem services supplied by their natural capital, a trend emerging at the global, national and regional levels. For example, a 1997 study estimated that the total value of the world's ecosystems goods and services was between US$18 trillion and $61 trillion (2000 $),[12] an amount similar to the size of the global economy. A follow-up study estimated that global habitat loss costs about $250 billion each year (2002 $).[13] In 2005, the United Nations Millennium Ecosystem Assessment (MA) reported on the condition of the world's ecosystems and their ability to provide services. The MA found that over the past 50 years, humans have changed the Earth's ecosystems more rapidly and extensively than in any other period in human history. The assessment concluded that 60 per cent of the world's ecosystem services are being degraded or used unsustainably (e.g., provision of freshwater, purification of air and water, and regulation of regional and local climate).[14]



Communities and governments are beginning to recognize the essential ecosystem services supplied by their natural capital, a trend emerging at the global, national and regional levels.

PHOTO COURTESY BRUCE MCKAY/FLICKR CREATIVE COMMONS

1.2 Why is it Important to Measure and Value Natural Capital and Ecosystem Services?

Human life depends on the continuing ability of the natural environment to function and provide its many benefits. Yet economic growth generally focuses on the development of land and the extraction of resources for human use. In order to recognize the value of natural capital, it is essential that governments begin to identify, measure and monitor the state of our natural capital and the changes in quantity and quality of these assets. Without comprehensive values for ecosystems and the services they provide, these essential assets will continue to be undervalued and even disregarded in land-use and natural-resource policies.

The loss of ecosystems such as forests and wetlands results in a decreased stock of natural capital and a reduction in the flow of ecosystem services for human communities. This loss can lead to costs such as reduced water quality and the resulting effects on human health, the need to replace or restore water resources, and damages caused by an increase in flooding and an unstable climate.

12 Costanza, R. et al. 1997. "The value of the world's ecosystem services and natural capital." *Nature*. 387:253-259.

13 Balmford, A. et al. 2002. "Economic Reasons for Conserving Wild Nature." *Science*. 297: 950-953.

14 Millennium Ecosystem Assessment. 2005. "Ecosystems and Human Well-being: Synthesis." Island Press. Washington, D.C.

However, in general, the full costs of losses in natural capital are not paid for when land-use change occurs. Natural capital and ecosystem services are mostly viewed as public goods, so their values are not counted as internal costs by companies and governments.[15]

Communities are now facing cumulative environmental problems resulting from human impacts on ecosystems. These problems include: a destabilized climate due to increased concentrations of carbon dioxide in the atmosphere; a decline in clean and reliable water supplies due to pollution and the overuse of water; and degraded land cover resulting in increased flooding. Further declines in natural capital have been predicted if businesses and communities continue along the same path of economic growth without reducing their impacts on the environment. If companies were required to pay for the full cost of the effects of their activities on the environment, they would likely change their practices to minimize the loss of ecosystem services.

For example, the environmental cost of all global human activity was estimated at US$6.6 trillion in 2008, equivalent to 11 per cent of global gross domestic product (GDP).[16] The largest single cost was due to greenhouse gas emissions, which accounted for more than half of the total. Other major costs included the effects on health of air pollution particulates, and the damage caused by the overuse and degradation of freshwater. The world's largest 3,000 companies caused US$2.15 trillion of these total costs. These environmental costs are predicted to increase to an estimated US$28.6 trillion by 2050 (18 per cent of GDP) if "business as usual" continues.[17]

Natural capital and ecosystem services are mostly viewed as public goods, so their values are not counted as internal costs by companies and governments.

PHOTO COURTESY TUCHODI/ FLICKR CREATIVE COMMONS

15 UK National Ecosystem Assessment. 2011. *The UK National Ecosystem Assessment: Synthesis of the Key Findings*. UNEP-WCMC. Cambridge, U.K.

16 Garfunkel, A. (ed.). 2011. *Universal Ownership: Why Environmental Externalities Matter to Institutional Investors*. Trucost Plc, PRI Association and UNEP Finance Initiative. www.unepfi.org/fileadmin/documents/universal_ownership_full.pdf

17 Ibid.

PART 2

Overview of the Study Area

2.1 Location and Description of the Study Area

The study area comprises the B.C. portion of the Peace River Watershed in the northeast corner of the province (approximately 5,611,799 hectares). The study boundary was defined using the Water Survey of Canada's drainage basins (i.e., watersheds), and the British Columbia-Alberta border (Figure 1). It includes five drainage basins that contribute to the Peace River within British Columbia: Upper Peace-Halfway, Upper Peace-Kiskatinaw, Pine, Beatton and eastern Williston Lake.

The study area comprises the B.C. portion of the Peace River Watershed in the northeast corner of the province (approximately 5.6 million hectares)

GOOGLE EARTH SATELLITE MAGE

2.2 Ecology of the Study Area

The Peace region is recognized as an important ecological and cultural region in Canada. The topography of the area varies from Rocky Mountains in the west to prairies in the east. The landscape includes coniferous forests, deciduous forests, grasslands, shrublands, rivers, streams and wetlands that provide critical habitat for wildlife. The Peace River Valley and its uplands support more than 300 wildlife species and 400 plant species. The area also provides a major wildlife corridor that is critical to maintaining the biodiversity of the valley and its surrounding regions.

The Peace River, the main river within the study area, flows east from the Rocky Mountains through much of northern Alberta into Lake Athabasca, and eventually into the Arctic Ocean. The Peace River was originally called "Wonchiigli" or "Chu Nachii" in the First Nation Beaver language.[18]

18 According to the report *The Living Peace River Valley: An Overview of the Peace River Valley's Natural and Cultural Values* (supra note 4), the Peace River was originally called "Wpchiigli," meaning big river. However, J. Ridington and R. Ridington report that the Peace River was called "Wonchiigli," which does not translate to English, as well as "Chu Nachii," which means "big river" in the Beaver language (pers. comm.).

FIGURE 1: MAP OF THE B.C. PEACE RIVER WATERSHED STUDY AREA

The Peace River Watershed supports 188 sensitive species such as grizzly bears, wolverine, bighorn sheep, woodland caribou, short-eared owl and bull trout.[19] The region provides critical wintering habitat for a diverse range of animals including moose, elk and deer. Important moose calving grounds are located along the riverbanks and on small islands throughout the river. The Peace River Valley also provides a corridor for migrating birds, as well as for wide-ranging species such as caribou, wolverine, lynx and grizzly bear.

The valley hillsides are covered in grasslands and montane shrublands that provide important wintering habitat and food sources for ungulates such as moose, elk, mule deer and white-tailed deer. The river's riparian habitats are also critical to ungulates and provide prime migratory waterfowl breeding grounds in spring and fall. Bald eagles, raptors and migratory neotropical songbirds nest within the broadleaf forests along the river.

Mountain and boreal woodland caribou populations in the Peace region have declined over the past several decades and are now listed in the region as threatened with extinction.[20] The primary cause of their decline is habitat loss and degradation, primarily due to industrial resource extraction and the ensuing shift in predator/prey dynamics.[21]

19 Pearson, M., and Healey, M.C. 2012. Species at Risk and Local Government: a Primer for B.C. Stewardship Centre for British Columbia, Courtenay B.C. www.speciesatrisk.bc.ca/advancedsearch?district=PRRD

20 Species at Risk Public Registry. Schedule 1: List of Wildlife Species at Risk. Species at Risk Act. Government of Canada. http://www.registrelep.gc.ca/species/schedules_e.cfm?id=1 (accessed March 2014).

21 COSEWIC Assessment — Woodland Caribou. Species at Risk Public Registry. Government of Canada. www.sararegistry.gc.ca/document/default_e.cfm?documentID=228

2.3 Economy of the Study Area

Among the main economic drivers within the study area are agriculture, tourism, manufacturing, petroleum exploration and development, hydroelectric power generation, forestry and mining. The Peace Region produces 90 per cent of B.C.'s grain, 38 per cent of its hydroelectric power, has more than 10,000 wells drilled, employs about 2,300 workers in forestry jobs and hosts more than 320,000 tourists each year. The Peace region, along with most northern areas of the western provinces, is part of the Western Canada Sedimentary Basin, which holds one of the largest reserves of petroleum and natural gas in the world. In the southern part of the Peace region, 99 oil and gas companies operate within an area that holds between 77 and 176 trillion cubic feet of marketable gas.[22] The Peace Forest District covers more than 4 million hectares of land across the Peace River Regional District. The district includes two Timber Supply Areas (TSA): the Fort St. John TSA and the Dawson Creek TSA. At the Peace River coal fields (west and south of Tumbler Ridge), there are 10 coal mining projects either in operation or proposed. According to the South Peace Economic Development Commission, coal mining contributes about $2 billion of the Peace Region's $6.6 billion in GDP.

The warm microclimate, fertile soils and longer daylight hours during the growing season provide the region, especially the Peace River Valley, with some of the best growing conditions in the province. The study area, which is located within the Peace River Regional District (PRRD), has 121,759 hectares of annual croplands and 241,471 hectares of perennial croplands and pasture. Many of these lands are classified as part of the B.C. Agricultural Land Reserve (ALR).[23]

The agricultural capability of the Peace River Valley is considered high, according to the Canada Land Inventory, meaning it is among the best in all of Canada for agriculture.[24] The Peace River Valley boasts a unique microclimate that is warmer than the surrounding upland areas. This climate and the rich valley soils provide prime agricultural terrain. In the Canada Land Inventory, lands are grouped into seven classes depending on their potential and limitations for agricultural use. The basic criteria for this classification are the inherent soil, climate and landform characteristics. Approximately 10 per cent of the Peace River Valley is classified as Class 1 land (2,464 hectares), and 50 per cent is classified as Class 2 land (12,502 hectares).[25] Class 1 land is described as having optimum potential, and is capable of producing a full range of crops. Soil and climate conditions are ideal, resulting in easy management. Class 2 land is capable of producing a wide range of crops, with some minor restrictions of soil or climate that may reduce capability but pose no major difficulties in management. For example, in the Peace River Valley, many Class 2 lands are limited because of lower moisture levels, which can be supplemented by using irrigation.

Seven main field crops are grown in the region: wheat, oats, barley, alfalfa, other tame hay and fodder crops, canola and forage seed. Alfalfa, tame hay and fodder are the predominant crops grown, and the most common livestock include cattle, poultry, sheep, horses, bison and bees.

The Peace Region produces 90 per cent of B.C.'s grain, 38 per cent of its hydroelectric power, has more than 10,000 wells drilled, employs about 2,300 workers in forestry jobs and hosts more than 320,000 tourists each year.

PHOTO COURTESY KYLEWITH / FLICKR CREATIVE COMMONS

22 South Peace Economic Development Commission. "Energy – Oil and Gas Industry." www.southpeacebc.ca/industries/energy/oil_and_gas.php

23 There are 1.28 million hectares of land within the PRRD that are classified as part of the Agricultural Land Reserve (ALR), comprising 27 per cent of the province's total ALR lands. The ALR is a provincial land zoning that recognizes agriculture as the priority land use and controls non-agricultural uses of these lands. 2004. State of the Agricultural Land Reserve. Smart Growth BC. www.smartgrowth.bc.ca

24 Harris, R. 1982. *Vegetable Production in the Peace Valley: Submission by Dr. R.E. Harris to the B.C. Utilities Commission on behalf of the B.C. Institute of Agrologists regarding the B.C. Hydro and Power Authority Site C Energy Project*. Hearing No. 95. Exhibit 349B. Vancouver, B.C: British Columbia Utilities Commission. Cited in: Feinstein, A. 2010. *B.C.'s Peace River Valley and Climate Change: The Role of the Valley's Forests and Agricultural Land in Climate Change Mitigation and Adaptation*. Chillborne Environmental.

25 Lions Gate Consulting Inc. 2002. Site C Lands: Economic Opportunities Assessment Impact Assessment. Prepared for the BC Hydro Site C Impact Assessment. www.bchydro.com/content/dam/hydro/medialib/internet/documents/policies/pdf/sitec_05_lions_gate_consulting_site_c_impact_assessment.pdf

First Nation peoples and their ancestors have lived in the area for more than 10,000 years.

PHOTO: THREE GENERATIONS OF BEAVER WOMEN AT MOBERLY LAKE, BC, COURTESY GLENBOW MUSEUM

Elders report that traditional land use in the area included hunting, fishing, gathering, habitation and travelling (e.g., by boat and foot). Traditional territories of the local First Nations were used as travel corridors to access riparian areas along the tributaries of the Peace River. Traplines were worked along these tributaries during the fall and winter months, and in the summer months First Nations hunted, fished, and gathered berries and medicines.[26]

2.4 History of Settlement

First Nation peoples and their ancestors have lived in the area for more than 10,000 years. First Nations traditionally roamed throughout the region from the Rocky Mountains to the plains of Alberta following animal migrations and the availability of other foods. Algonquin Cree migrated from further east at the beginning of the fur trade. Sekani, Dane-zaa and Cree settled along the valley and the rivers that flow into the Peace River, setting up more permanent camps as fur traders and homesteaders moved into the area.

The first European settlement, Rocky Mountain Fort, was established near present-day Fort St. John in 1794, one year after Sir Alexander Mackenzie of the North West Company travelled through the Peace River Pass to reach the Pacific Coast.[27] This led to the establishment of fur trading posts in the Peace River Region, including Fort St. John, which was established in 1805. Charles Horetzky first documented the agricultural potential of the area in 1873, during a survey for the Canadian Pacific Railway.[28]

The Canadian government negotiated a series of treaties with indigenous peoples across Canada, geared to allow settlers' rights to natural resources and lands to build a national railway.[29] In 1899, the eighth treaty between First Nations and the Canadian government was signed. Treaty 8, as it was called, allowed for the sharing of lands and resources in northeastern B.C., northern Alberta and northwestern Saskatchewan.

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26 Ridington, A. 2013. *Heritage Values Summary: McLeod Lake Indian Band Traditional Land Use Study for BC Hydro's Proposed "Site C Clean Energy Project" on the Peace River, BC*. Site C Joint Review Panel Presentation (Dec. 18, 2013). www.ceaa-acee.gc.ca/050/documents/p63919/97206E.pdf

27 Chillborne Environmental, supra note 4.

28 Don Cameron Associates. 2013. *Regional Agricultural Plan Draft Background Report: Peace River Regional District*. B.C. Ministry of Agriculture.

29 Chillborne Environmental, supra note 4.

The federal government opened up the "Peace River Block" to homesteaders between 1907 and 1912, during which farmers came to the region to settle on agricultural lands.[30] These farmers cultivated grains, vegetables and forage for cattle and horses. An influx of settlers moved to the region after the Second World War as a result of easier access to the northeast via the newly built Alaska Highway, and land grants provided to returning veterans.

Most of the study area's population now resides in the municipalities of Fort St. John, Dawson Creek, Tumbler Ridge, Chetwynd, Hudson's Hope, Taylor and Pouce Coupe. In addition, there are eight Treaty 8 First Nation Reserves within the study area including East Moberly Lake 169, West Moberly Lake 168A, Beaton River No. 204 (North Parcel), Beaton River 204 (South Parcel), Halfway River 168, Blueberry River No. 205, Doig River 206 and Finlay Bay Indian Reserve No. 21.[31]

2.5 Human Impacts on Natural Capital in the Watershed

The Peace River region has experienced widespread changes due to industrial and human development. Many of the area's natural landscapes have been impacted by activities such as logging, mining, oil and gas development, water withdrawals and stream crossings, large-scale hydro development and agricultural conversion.[32] Cumulative changes were mapped and analyzed in an earlier study that examined human impacts on ecosystems in the Peace River watershed within B.C. from 1974 to 2010. Impacts on the PRW lands included 16,267 oil and gas wellsites (each averaging one hectare in size), 8,517 petroleum and natural gas facilities, 284 km^2 of oil and gas pipeline rights-of-way, 28,587 km of pipelines, 2,296 river/stream crossings due to oil and gas development, 3,868 km^2 of coal tenures, 243 km^2 of mineral tenures, 4 coal mines, 45,293 km of roads, and 1,163 km of transmission lines. The physical footprint of the total land change was approximately 1.1 million hectares (20.2 per cent of the study area), including roads, pipelines, reservoirs, clearcuts, mines, urban development and agricultural conversion. The ecological impact of the cumulative changes was estimated using a 500-metre buffer that demonstrated that about 66.9 per cent of the watershed had been disturbed by human activities.[33]

The Peace River region has experienced widespread changes due to industrial and human development.

PHOTO COURTESY BC MINISTRY OF TRANSPORTATION/FLICKR CREATIVE COMMONS

The upper reaches of the Peace River have been developed for hydropower, including the W.A.C. Bennett and Peace Canyon hydroelectric dams, which produce more than 30 per cent of British Columbia's hydroelectric power.[34] A third large-scale dam called Site C is currently under review. The proposed Site C dam faces significant opposition because it would flood important historical and spiritual First Nations sites, highly productive agricultural lands and wildlife habitat including breeding, calving, migration and wintering sites.[35] For example, the Dane-zaa are concerned about the impact that the Site C dam will have on their traditional territory. The proposed dam will flood hundreds of acres of their territory near Attachie and Bear Flats, including islands that provide important wildlife birthing habitat, traditional habitation and hunting areas, and traditional grave sites. The proposed dam will affect the rights of First Nations under Treaty 8, which states that First Nations have the right to continue with their way of life without interference.[36]

In addition, there are local concerns over the growing number of development projects in the oil and gas industry and the increase in forestry operations, which have contributed to widespread ecological fragmentation.

30 Don Cameron Associates, supra note 28.
31 Lee and Hanneman, supra note 1.
32 Ibid.
33 Ibid.
34 BC Ministry of Environment. "Peace River." www.env.gov.bc.ca/bcparks/heritage_rivers_program/bc_rivers/peace_river.html
35 Chillborne Environmental, supra note 4.
36 Ridington, R., and Ridington, J. 2013. *Where Happiness Dwells: A history of the Dane-Zaa First Nations in collaboration with Elders of the Dane-Zaa First Nations*. UBC Press. Vancouver, B.C.

PART 3

Land Cover in the Peace River Watershed

To develop an inventory of the ecosystems and land use across the study area, several sources of geographically referenced data were reviewed.

PHOTO COURTESY TUCHODI/ FLICKR CREATIVE COMMONS

LAND COVER IS THE OBSERVED BIOPHYSICAL COVER on the earth's surface, such as the observed data from Landsat satellite imagery. Thematic land cover maps are commonly produced through the classification of such earth observation data, using remote sensing image processing techniques called geographic information systems (GIS). These maps can include land cover classes or land cover types such as water, forests, urban lands and wetlands. To develop an inventory of the ecosystems and land use across the study area, several sources of geographically referenced data were reviewed.

Land cover data for the study area were identified and classified based on data clipped from Agriculture and Agri-Food Canada's (AAFC)'s Land Cover for Agricultural Regions of Canada GIS dataset.[37] This dataset was produced from Landsat satellite imagery compiled by AAFC to provide land cover mapping that can be used to support a range of land-use programs and activities, such as land-use decision-making and impacts on ecosystem services. Land cover types were tabulated in spreadsheets by area in hectares for each land cover class within the boundary of the study area. The land cover types in hectares and per cent cover for the total PRW study area, along with the PRW area used for ecosystem valuation, are provided in Table 1.

The land cover analysis indicates that forests are the dominant ecosystem type, covering about 64.4 per cent of the study area.[38] The other land cover types include wetlands (9.2%), grasslands (7.8%), snow cover, rock and exposed lands (4.6%), perennial croplands and pastures (4.3%), shrublands (4.2%), annual croplands (2.2%), water (1.4%) and developed land (0.1%). Another 101,711 hectares of land is unclassified (2%) because of technical issues such as cloud cover and shadowing. The area used for ecosystem valuation excludes snow/rock/exposed lands, developed lands and unclassified lands. Therefore, the total PRW area used in the ecosystem valuation analysis is 5,245,371 hectares.

37 Land Cover for Agricultural Regions of Canada, circa 2000 (Version 1.2, 2013 revision). Agri-Geomatics Service. Agriculture and Agri-Food Canada. Government of Canada. A 30-metre resolution raster format land cover classification produced from Landsat satellite imagery. AAFC compiled land cover mapping for agricultural regions across Canada. http://geodiscover.cgdi.ca/wes/CSWSearchClient/OWSResults/DisplayFullMetadata.jsp;jsessionid=F7A2013ABF77FBE857F4660F2335A17E.gdp2?id=F1E6A665-C15B-F64B-FC6D-4472BBA89F55&recordLocale=en_US#top

38 The forest cover is predominantly made up of coniferous forest (72.9%), with smaller areas of broadleaf forest (23.9%) and mixedwood forest (3.2%).

The land cover analysis indicates that forests are the dominant ecosystem type, covering about 64.4 per cent of the study area.

TABLE 1: LAND COVER BY AREA, B.C. PEACE RIVER WATERSHED STUDY AREA

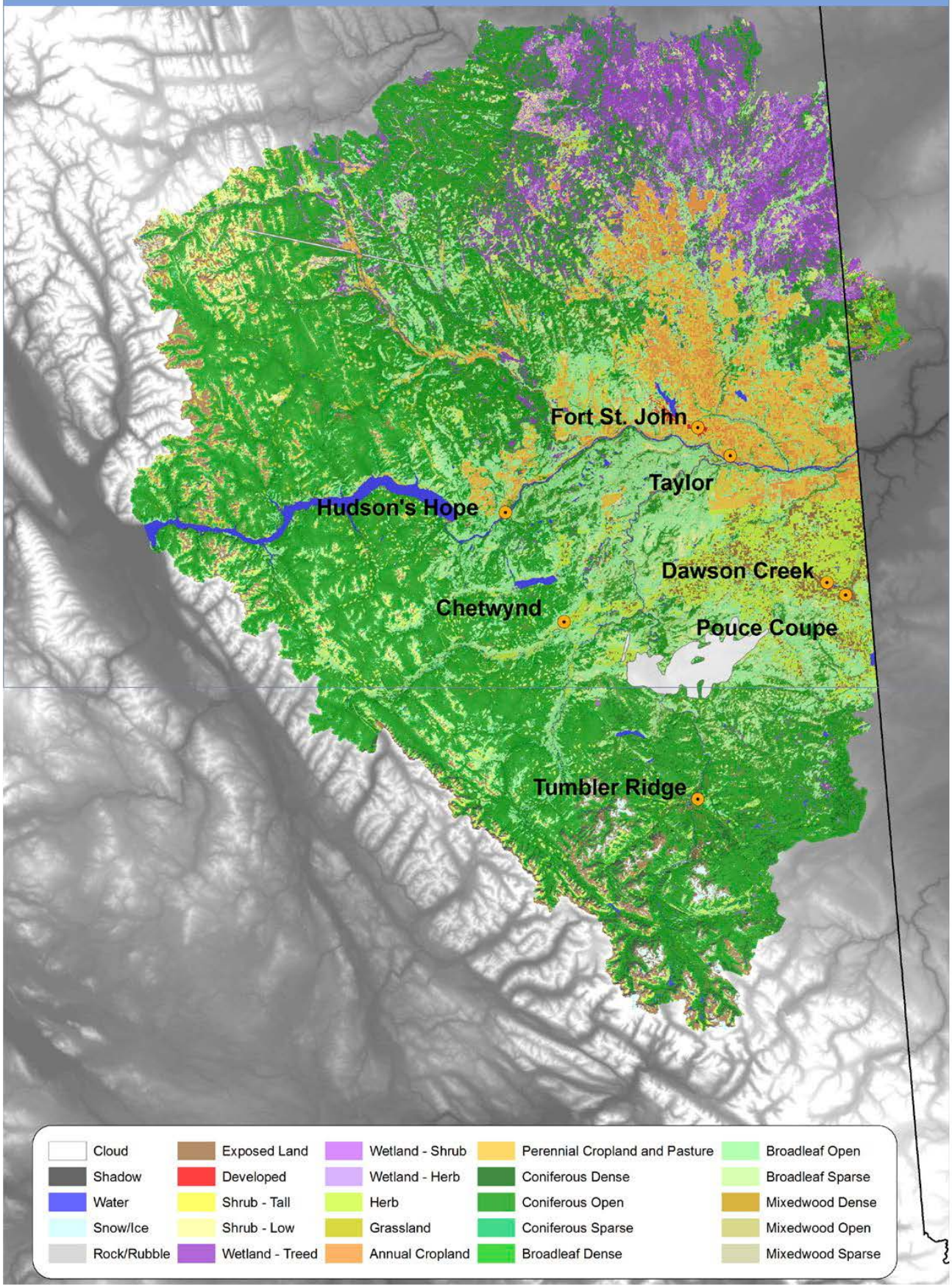
Land cover type	Total area (ha)	% of total land cover	Area for ecosystem valuation[a]
Forest	3,613,741	64.4%	3,613,741
Wetland	518,788	9.2 %	518,788
Grassland	435,414	7.8%	435,414
Snow/Rock/ Exposed land	259,954	4.6%	(not included)
Perennial cropland/ Pasture	241,471	4.3%	241,471
Shrubland	237,447	4.2%	237,447
Annual cropland	121,759	2.2%	121,759
Water	76,751	1.4%	76,751
Developed lands	4,764	0.1%	(not included)
Unclassified lands	101,711	1.8 %	(not included)
Total	5,611,799	100%	5,245,371

Note: [a]The Peace River Watershed study area excluded snow/rock/exposed lands, developed lands and unclassified lands from the ecosystem valuation.

Source: Land Cover for Agricultural Regions of Canada, circa 2000 (Version 1.2). Agriculture and Agri-Food Canada. Government of Canada.

The distribution of land cover types across the study area is illustrated in Figure 2 on page 22. The land cover map shows a large concentration of predominantly treed wetlands in the northeastern portion of the study area (in purple); a large expanse of agricultural croplands and pasture fanning out along the Peace River lowlands (in orange); and coniferous forest covering the western portion of the study area.

FIGURE 2: LAND COVER MAP FOR THE B.C. PEACE RIVER WATERSHED STUDY AREA



PART 4

Methodological Approach for Identification and Valuation

4.1 Identification of Spatial Land Cover and the Quantification of Ecosystem Types

The spatial land cover data presented in Section 3 were used to identify land cover ecosystem types and land use for the study area. Ecosystem types and land use were then used to identify the ecosystem services (ES) provided by the area's natural capital. Figure 3 below outlines the steps undertaken from identifying the study area's land cover data to the valuation of ecosystem services.

The spatial land cover data presented in Section 3 were used to identify land cover ecosystem types and land use for the study area.

PHOTO COURTESY DON HOFFMANN

FIGURE 3: STEPS TAKEN TO IDENTIFY ECOSYSTEM SERVICES

4.2 Classification of Ecosystem Services

Ecosystem services have been defined as the benefits provided by ecosystems. ES are dependent on ecosystem functions, which include the ecological processes and attributes that maintain ecosystems. ES include provisioning services (e.g., food, water), regulating services (e.g., water purification, climate regulation), habitat services and cultural services (e.g., recreation).[39] The Economics of Ecosystems and Biodiversity (TEEB) initiative has classified 22 ES according to these four categories. Table 2 provides a list of TEEB's classification of ecosystem services, including an example for each ES.

39 TEEB (2012). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Pushpam Kumar. Routledge, Abingdon and New York.

TABLE 2: CLASSIFICATION OF ECOSYSTEM SERVICES	
Provisioning Services	
Food	Food, fish and meat for human consumption.
Water supply	Water for human consumption, irrigation and industrial use.
Raw materials	Timber, fuelwood, etc.
Genetic resources	Plant genetic diversity for crop improvement and medicinal purposes
Medicinal resources	Providing drugs, pharmaceuticals, tests, tools and assay organisms.
Ornamental resources	Resources for fashion, jewelry, handicraft, worship and decoration.
Regulating Services	
Gas regulation	Providing clean, breathable air, disease prevention and planet habitability.
Climate regulation	Providing a stable climate and preventing increased climatic variability, glacial and permafrost melt, increased storm frequency and force, and global sea rise.
Disturbance prevention	Preventing and mitigating natural hazards such as floods, storm surges, hurricanes, fires and droughts.
Soil retention	Retaining arable land, slope stability and coastal integrity.
Water regulation	Providing water supply for natural irrigation, drainage, groundwater recharge, river flows and navigation.
Biological control	Providing pest and disease control.
Waste treatment	Absorption of organic waste, natural water filtration and pollution reduction.
Soil formation	Creating soils for agricultural and ecosystems integrity.
Pollination	Providing pollination of wild and domestic plant species.
Nutrient regulation	Promoting healthy soils, and gas, climate and water regulating services.
Habitat Services	
Habitat and biodiversity	Maintaining habitat for genetic and biological diversity, the basis for most other functions.
Nursery	Providing habitat for spawning and nesting for reproduction.
Cultural and Amenity Services	
Esthetic	Enjoying and appreciating the scenery, sounds and smells of nature.
Recreation and tourism	Experiencing outdoor activities in natural ecosystems.
Science and education	Learning and research activities in natural ecosystems.
Cultural and artistic	Experiencing nature through art, film, folklore, books, cultural symbols, architecture, religion, spiritual activities and media.

Source: TEEB (2012). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Pushpam Kumar. Routledge, Abingdon and New York.

Ecosystem services are often referred to as ecosystem goods and services or ecological goods and services (EG&S), however, this study focused on the non-market ecosystem services, so the term ecosystem services will be used throughout the report. For example, timber market values were not assessed.

4.3 Identification of Ecosystem Services by Land Cover Type

To identify the ES provided by the Peace River Watershed, the ES were categorized by ecosystem types based on the typical ES associated with each land cover type as reported by TEEB.[40] The potential ES provided by each ecosystem type were then compiled based on TEEB's classification, and a review of the study area's ecosystems and socio-economic information. The result was a list of ES provided by the ecosystems and land cover types across the study area (Appendix 3).

4.4 Ecosystem Service Valuation Approach

The study's ecosystem service valuation approach was based on the Total Economic Value (TEV) framework. TEV is the sum of ES values provided by natural capital in a specific region. The TEV framework includes use and non-use values. This framework includes direct use values such as food and water, indirect use values such as climate regulation, and non-use values such as existence values (i.e., protection of biodiversity; see Appendix 4). The ES values reported in this study are mostly direct and indirect-use values (see Table 4, Section 5).

ES values can be estimated from: 1) market-based methods; 2) indirect or surrogate market-based methods (i.e., revealed preference methods); and 3) non-market, survey-based methods (i.e., stated preference methods).[41] Table 3 provides examples for each of these valuation methods.

TABLE 3: TYPICAL ECOSYSTEM SERVICE VALUATION METHODS BY VALUE TYPE

Valuation Approach	Methods	Examples of Value Type
Market-based Valuation: Price-based	Market prices	Food Recreation
Market-based Valuation: Cost-based	Avoided cost Replacement cost Mitigation/Restoration cost	Climate regulation Habitat
Revealed preference	Travel cost method Hedonic pricing	Recreation Urban green space
Stated preference	Contingent valuation Choice modelling Contingent ranking Deliberative group valuation	Biodiversity Protection of cultural value

Adapted from: TEEB (2012). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Pushpam Kumar. Routledge, Abingdon and New York.

40 Ibid.
41 Ibid.

The ES values reported in this study were developed based on land cover data, forest age class data, socio-economic information available for the Peace River region and other ecosystem service valuation studies. The specific approach for each ES valuation is described in the valuation results section. Sources for local or regional socio-economic data and descriptive information were researched and used for valuations where possible. If local or regional data were not available, values were transferred from other relevant ES valuation studies. This was done either by adopting average values from meta-analysis studies (i.e., an average based on values compiled for a specific ecosystem service from an overview of all existing studies in the literature), or from a site-specific study, adjusted by population size, that was a best match for the study area, based on its relevance to the region's ecosystem, location, demographics and/or habitat types.

Several of the ES valuations were based on the avoided cost or replacement cost because they provided values comparable to real market prices that were not dependent on survey respondents' perceptions (i.e., survey-based methods) and were more easily replicable in other contexts.[42] Moreover, avoided costs may be useful for local administrators who must use public funds to repair ecosystem damages resulting from development.

All values are reported in 2012 Canadian dollars. Values reported as U.S. dollars were converted to Canadian dollars using an average annual exchange rate from the Bank of Canada currency converter.[43] Values were inflated to 2012 dollars using the Bank of Canada inflation calculator.[44] The values reported in the text are rounded figures.

PHOTO COURTESY TUCHODI/FLICKR CREATIVE COMMONS

42 de Groot, R.S., et al. 2002, "A typology for the classification, description and valuation of ecosystem functions, goods and services." *Ecological Economics*. 41: 393-408. Farber, S. et al. 2006. "Linking ecology and economics for ecosystem management." *Bioscience*. 56:121-133.

43 Bank of Canada. "10-Year Currency Converter." www.bankofcanada.ca/rates/exchange/10-year-converter/

44 Bank of Canada. "Inflation Calculator." www.bankofcanada.ca/rates/related/inflation-calculator/

PART 5

Ecosystem Service Valuations

The following results provide a first estimate for the average economic values of ecosystem services provided by natural capital within B.C.'s Peace River Watershed. The ES valued in this study are listed in Table 4. The study provides a baseline for the region's ecosystem services values. Given the lack of current land cover data and the lack of local socio-economic information regarding ES, the results do not provide a comprehensive valuation because not all the ecosystem services for each land cover type have been valued in this study.

While water is a provisioning service itself, it also contributes to the production of food, regulating services such as nutrient cycling and cultural services such as recreation.

PHOTO COURTESY PROVINCE OF BC/FLICKR CREATIVE COMMONS

5.1 Provisioning Services

5.1.1 DRINKING WATER SUPPLY

Water is fundamental to the survival of humans, farm animals and wildlife. While water is a provisioning service itself, it also contributes to the production of food, regulating services such as nutrient cycling and cultural services such as recreation. In addition, water is important as an input for many industries including food processing, energy production and forestry.

The Peace River Watershed includes the Upper Peace-Halfway, Upper Peace-Kiskatinaw, Pine, Beatton and eastern Williston Lake watersheds. Watersheds provide critical natural "green" infrastructure that collect, capture, filter and deliver water to communities. Forests, wetlands, grasslands, lakes, rivers and streams play important roles in the supply of water by providing water filtration, detoxification and nutrient retention services, as well as water supply storage and transportation.

The total water cover in the Peace River Watershed is 76,751 hectares according to the land cover spatial data used in this study. The value of the drinking water provided by the PRW's rivers and streams was estimated using a willingness to pay (WTP) for residential water quality improvements, which was transferred from a study undertaken in the Grand River watershed in southern Ontario. There were no similar studies undertaken in western Canada. The average WTP per household ranged from $4.56/household/month to $9.42/household/month (1994 $). These values were converted to 2012 dollars, and multiplied by 12 to estimate an annual value. The average value, therefore, was $119.54/hhld/year (2012 $). This value was then multiplied by the

TABLE 4: ECOSYSTEM SERVICES VALUED FOR THE B.C. PEACE RIVER WATERSHED

Ecosystem services assigned value	Valuation approach	Type of value	Valuation method used
Water supply	Average global value	Direct use	Transfer value per hectare from global average study (38 original studies)
Air filtration (gas regulation)	Avoided cost value	Indirect use	Transfer value from Lower Mainland study adjusted by population (original analysis based on average removal rates of pollutants by tree canopy cover and avoided costs)
Carbon storage (climate regulation)	Avoided cost value	Indirect use	Quantified carbon storage using forest age/carbon analysis; annualized social carbon cost value based on average of U.S. and Canadian government social cost of carbon (SCC) (marginal SCC values from climate models)
Carbon sequestration (climate regulation)	Avoided cost value	Indirect use	Quantified forest carbon sequestration based on forest age/carbon analysis. Social carbon cost value based on average of U.S. and Canadian government SCC (marginal SCC values from climate models)
Flood control/water regulation (disturbance prevention: wetlands)	Meta regression analysis value for Canada	Indirect use	Average value for Canada: from study that evaluated the value of wetlands in agricultural landscapes using a meta regression analysis reported by country
Erosion control (soil retention: perennial cropland/pasture)	Avoided cost value	Indirect use	Value based on avoided water treatment costs to remove sediment provided by conservation of natural cover or conversion of annual cropland to permanent cropland/pasture cover
Waste treatment	Replacement cost value	Indirect use	Average removal rates of excess nutrients per wetland hectare from academic literature and average excess runoff from agricultural statistics and cropland area; average value based on cost to treat/remove excess nutrients from water system
Water filtration (forests)	Avoided cost value	Direct use	Avoided cost of water treatment costs based on current forest cover in PRW and local cost of water treatment in PRW.
Pollination	Market-based value	Indirect use	Estimated as 30 per cent of reported pollinator value for B.C. crops
Habitat and biodiversity	Market-based value/average meta-analysis value	Indirect use / non-use	Estimated net value for increased wildlife viewing on conserved land or cropland restored to natural cover (grassland/pasture); average habitat value from wetland values meta-analysis
Recreation	Survey-based value/travel cost	Direct use	Estimated economic value of outdoor recreation from several recreational surveys
Cultural/ aesthetic	Survey-based	Indirect use/ non-use	1) Willingness to pay to maintain rural scenic views 2) Willingness to pay to protect wilderness/biodiversity

estimated number of households in the study area (25,845.6 hhlds) to estimate the total value of $3.1 million per year.[45] The total value was then divided by the total water cover in the study area, resulting in an estimate for the value of water of $40.25/ha/year. This provides a proxy value for the supply of good quality water, so although a survey could not be undertaken to determine whether households in the study area would be willing to pay the same amount, we can estimate that it represents a conservative value for the benefits Canadians place on having a good water quality supply[46]

Therefore, the average value of $40.25/ha/year (2012 $) from the above study was used to estimate a value for water supply in the study area. The PRW provides water for approximately 64,614 people within B.C., including the populations of Fort St. John, Dawson Creek, Chetwynd, Hudson's Hope, Pouce Coupe, Taylor and Tumbler Ridge.[47] Several additional communities benefit from the supply of water downstream from the B.C. border.

5.2 Regulating Services

5.2.1 AIR QUALITY REGULATION — FORESTS

Trees are essential for good air quality because they produce oxygen. Trees also provide improvements to air quality by capturing air pollutants and retaining or absorbing them with their leaves. By absorbing and filtering out nitrogen dioxide (NO_2), sulfur dioxide (SO_2), ozone (O_3), carbon monoxide (CO) and particulate matter (PM_{10}), trees perform a vital air cleaning service that directly affects the well-being of humans. For example, studies have shown that trees can remove eight to 12 grams of air pollutants per square metre of tree canopy.[48]

An analysis in the B.C. Lower Mainland used CITYgreen software to assess the amount of air pollutants removed from the air by the tree canopy cover. The analysis used average rates from several U.S. studies to estimate the amount of carbon monoxide, nitrogen dioxide, particulate matter and sulphur dioxide that trees absorb. The value of air filtration provided by trees in the B.C. Lower Mainland watersheds was $408.9 million, an average of $495 per hectare of forest cover. In order to transfer the value for this study, the total value for the Lower Mainland was adjusted by its population (2,194,377 people) to estimate the value per person ($186.36 per person). The value per person was then multiplied by the population within the study area (64,614 people) resulting in an estimate of the total value for the PRW of $12 million. This adjusted value was applied to the forest cover area within the PRW, which resulted in a per hectare value estimate of $3.51/ha/year (2012 $).

Ecosystems regulate the Earth's climate by adding and removing greenhouse gases, such as carbon dioxide, from the atmosphere.

PHOTO COURTESY DON HOFFMANN

5.2.2 CLIMATE REGULATION

Ecosystems regulate the Earth's climate by adding and removing greenhouse gases (GHG), such as carbon dioxide (CO_2), from the atmosphere. Forests, grasslands, wetlands and other land-based ecosystems store more carbon than is in the air. Carbon dioxide is stored in trees, plant biomass, debris and soils, thereby keeping it out of the atmosphere. Ecosystems accumulate carbon in their plants and soils over time, adding or "sequestering" additional carbon each year. As a result, the management of ecosystems has a direct impact on climate regulation.

45 The number of households was estimated based on the assumption that there are approximately 2.5 persons on average per household. The total population in the study area was 64,614, which divided by 2.5 equals 25,845.6 households.

46 Brox, J.A., Kumar, R.C., Stollery, K.R. 2003. "Estimating Willingness to Pay for Improved Water Quality in the Presence of Item Non Response Bias." *American Journal of Agricultural Economics*. 85:414-428.

47 The population does not include rural unincorporated areas, and several First Nations communities.

48 Nowak, D.J., Wang, J., and Endreny, T. 2007. "Environmental and Economic Benefits of Preserving Forests within Urban Areas: Air and Water Quality." In: *The Economic Benefits of Land Conservation*. The Trust for Public Land. San Francisco, Calif.

Economic Value of Stored Carbon

The economic analysis for stored carbon (C) focused on its social value in terms of the avoided costs of higher levels of carbon dioxide in the atmosphere. In general, policy makers determine a social cost of carbon (SCC) to assess the economic benefits of mitigating climate change. The SCC is based on climate change models that provide outputs based on different climate change scenarios.[49] The social cost of carbon was used because it measures the marginal benefit of avoiding the release of each additional tonne of carbon into the atmosphere. Carbon prices were used for comparison purposes because they are determined by government policies, regulations and subsidies, rather than the true value of the service to society.[50]

Because ecosystems hold an annual value for each year that the carbon is not released into the atmosphere, this was reported as an annual value.

PHOTO COURTESY BC MINISTRY OF TRANSPORTATION/FLICKR CREATIVE COMMONS

An average SCC value was calculated for the study's purposes based on two sources: 1) the U.S. government SCC estimates based on three climate change models, which were developed for cost-benefit analysis; and 2) Environment Canada's SCC estimates. The U.S. marginal values ranged from $11 to $52 as the cost for each incremental metric tonne of carbon dioxide equivalent (CO_2e) released into the atmosphere (2013 update; 2007 US dollars).[51] The range of estimates varied depending on the assumptions across the climate change models and the discount rate used (e.g., 2.5%, 3% and 5%, respectively). (See textbox on discount rates on page 31).The central value was $33 per metric tonne of carbon dioxide, based on a three per cent discount rate. This amount was converted to US dollars per tonne of carbon ($121.11/tC),[52] and then converted to 2012 Canadian dollars ($134.97/tC).[53] The second value was from Environment Canada's SCC central estimate of $25 per tonne of CO_2e (2010 $), which is equal to $95.50 per tonne of carbon (2012 $).[54]

Based on the American and Canadian SCC central values, an average value of $115.23/tC was used as the study's central SCC value, equivalent to $31.40/t$CO_2$ (2012 $). The average central value was similar to the 2012 B.C. carbon tax rate of $30 per tonne of CO_2, or $110.10 per tonne of carbon (2012 $).[55]

In order to report a range of values for sensitivity analysis, the low and high SCC values from the U.S. government estimates were used ($11 and $52 per tonne of CO_2, respectively). These values were used to provide a range to account for the uncertainties associated with predicting climate change impacts. The values were converted from dollars per tonne of CO_2 to dollars per tonne of carbon. Therefore, a low value of $40.63 per tonne of carbon and a high value of $192.06 per tonne of carbon (2012 C$) were used in the carbon valuations.

The amount of carbon stored in an ecosystem is gauged at a fixed point in time, rather than an annual accumulation. However, because ecosystems hold an annual value for each year that the carbon is not released into the atmosphere, this was reported as an annual value. In order to estimate an annual value for our reporting purposes, the central SCC value was converted to a carbon annuity, based on the carbon annuity

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49 Price, R., Thornton, S., and Nelson, S. 2007. *The Social Cost of Carbon and the Shadow Price of Carbon: What they are, and how to use them in economic appraisal in the UK*. Department for Environment, Food and Rural Affairs (U.K.).

50 Murray, B., Sohngen, B., and Ross, M. 2007. "Economic consequences of consideration of permanence, leakage and additionality for soil carbon sequestration projects." *Climatic Change*. 80:127-143. Other carbon valuation methods that have been used include: 1) the replacement cost to replace the stored carbon; or 2) the market price set by carbon markets.

51 Interagency Working Group on the Social Cost of Carbon. 2013. *Technical Support Document: Technical Update of the Social Cost of Carbon For Regulatory Impact Analysis*. Executive Order 12866. United States Government. www.whitehouse.gov/sites/default/files/omb/inforeg/social_cost_of_carbon_for_ria_2013_update.pdf

52 $33/t$CO_2$ * 3.67= $121.11/tC; 1 tonne of carbon (C) equals 3.67 tonnes of carbon dioxide (CO_2).

53 The value per tonne of CO_2 was converted to U.S. dollars per tonne of carbon (1 tC = 3.67 tCO_2e), then inflated to 2012 U.S. dollars (www.usinflationcalculator.com), and then converted to Canadian dollars using the average of the low and high exchange rate from the Bank of Canada (www.bankofcanada.ca/rates/exchange/10-year-converter).

54 Regulatory Impact Analysis Statement. Feb. 26, 2011. Sensitivity values ranging from $10 to $100 per tonne of CO_2e, equal to $36.70 to $367 per tonne of carbon. www.gazette.gc.ca/rp-pr/p1/2011/2011-02-26/html/reg3-eng.html. This value was converted to dollars per tonne of carbon (1 tC = 3.67 tCO_2), then inflated to 2012 Canadian dollars per tonne of carbon (using Bank of Canada online inflation calculator) www.bankofcanada.ca/rates/related/inflation-calculator/

55 B.C. Ministry of Finance, "How the Carbon Tax Works," www.fin.gov.bc.ca/tbs/tp/climate/A4.htm. This value was converted to dollars per tonne of carbon (1 tC = 3.67 tCO_2).

PHOTO COURTESY ZACK EMBREE, *FRACTURED LAND* DOCUMENTARY

DISCOUNT RATE

Discount rates are commonly used to assess the economic benefits of investment for decision-making. Benefits are discounted over time to reflect that people generally value immediate benefits over benefits in the future; and that manufactured capital depreciates over time resulting in lower values in the future.

The use of discount rates for natural capital has been widely debated because ecosystems do not depreciate over time. In fact they often appreciate over time, and natural capital will be worth more in the future because as the population grows, the earth's remaining ecosystems will become more valuable. In the case of a service that increases in value in the future, a negative discount rate would be used to capture the net present value. However, there is there is considerable controversy around the use of negative discount rates, so a range of positive social discount rates to estimate the NPV was used.

The NPV for the BC PRW ecosystem services value was calculated over a 50-year period using three different discount rates. A zero per cent discount rate was used to reflect the fact that natural capital does not depreciate over time; a 3 per cent discount rate was used because it is commonly used in socio-economic studies; and a 5 per cent discount rate was used as the high rate because it is a more conventional rate.

account (CAA) concept.[56] The annual carbon annuity value was calculated based on three per cent earnings over 50 years to estimate the annual value for carbon stored by ecosystems. Therefore, the annual values used were: a central value of $4.48/tC/year ($1.22/tCO_2/year); a low-end value of $1.58/tC/year ($0.43/tCO_2/year); and a high-end value of $7.46/tC/year ($2.03/tCO_2/year).[57]

Carbon Stored in Forests

More than half of the carbon stored in land-based ecosystems is currently stored in forests — in tree and root biomass, forest floor debris and soils. Trees remove carbon dioxide from the atmosphere through photosynthesis and convert it into organic carbon such as cellulose and lignin — the main components of wood. About half of each kilogram of wood is carbon, and every kilogram of carbon that is in a tree represents about 3.7 kilograms of carbon dioxide removed from the atmosphere. So forests have the ability to store enormous amounts of carbon, thereby reducing the buildup of carbon dioxide in the atmosphere that is contributing to global climate change.[58]

Forests have the ability to store enormous amounts of carbon, reducing the buildup of carbon dioxide in the atmosphere that is contributing to global climate change.

PHOTO COURTESY TUCHODI/ FLICKR CREATIVE COMMONS

Carbon storage refers to the carbon held in forest biomass and soils. As a result, carbon storage is reported as a weight, such as tonnes of carbon per hectare. B.C.'s forests store significant amounts of carbon, with coastal forests storing up to 1,300 tonnes of carbon per hectare.[59] Forests cover approximately 60 million hectares of the province, with 54 per cent of B.C.'s forests found in the Montane Cordillera ecozone, and smaller forest areas in the Pacific Maritime, Boreal Cordillera, Taiga Plains and Boreal Plains ecozones.[60]

The forest cover in the study area falls within the Montane Cordillera ecozone and the Boreal Plains ecozone. A national study reported that, on average, Boreal Plains ecozone forests store 220 tonnes of carbon per hectare, and Montane Cordillera forests store 255 tonnes of carbon per hectare (an average of 238 tC/ha).[61] In order to estimate stored carbon for each forest age class, a range of carbon estimates from several site-based studies were used. For example, a field study in north-central B.C., near the study area, found that old-growth forests (greater than 140 years old) store an average of 325 to 423 tonnes of carbon (tC) per hectare (fine and coarse soil sites, respectively), and that second-growth forests under 20 years old store about 200 tC per hectare.[62] In another north-central B.C. study, forest carbon content estimates ranged from 174 tC per hectare (under 20 years old) to 292 tC per hectare (175 years and older). Based on the three references cited above, this study used carbon content estimates for each forest age class ranging from 174 tC/ha for forest cover under 20 years old to a high of 423 tC/ha for forest cover more than 250 years old (Table 5 on page 33).

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56 A CAA (carbon annuity account) is an account where the full carbon value is placed directly into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account. Swingland, I. (ed). 2003. *Capturing Carbon and Conserving Biodiversity: The Market Approach*. Earthscan Publications. London, U.K. http://books.google.ca/books?id=oPz8P6cZKUQC&printsec=frontcover#v=onepage&q&f=false; Feng, H. et al. 2002. "The Time Path and Implementation of Carbon Sequestration." *American Journal of Agricultural Economics*. 84:134-149.

57 Calculations: ($115.23/tC * 0.03887; $40.63 * 0.03887; $192.06 * 0.03887). The 3% rate over 50 years was used because a 3% discount rate is commonly used for socio-economic studies; and a 50-year timeline is a common length of time used for discount rate periods.

58 Pregitzer, K.S., and Euskirchen, E.S. 2004. "Carbon cycling and storage in world forests: biome patterns related to forest age." *Global Change Biology*. 10:2052-2077.

59 Keith, H., Mackey, B.G., and Lindenmayer, D.B. 2009. *Re-evaluation of Forest Biomass Carbon Stocks and Lessons from the World's Most Carbon-Dense Forests*. PNAS. 106:11635-11640.

60 Canadian Forest Ecosystem Classification. www.nrcan.gc.ca/forests/canada/classification/13179

61 Stinson, G. et al. 2011. "An inventory-based analysis of Canada's managed forest carbon dynamics, 1990 to 2008." *Global Change Biology*. 17: 2227-2244.

62 Fredeen, A.L. et al. 2005. "Comparison of coniferous forest carbon stocks between old-growth and young second-growth forests on two soil types in central British Columbia, Canada." *Canadian Journal of Forest Research*. 35: 1411-1421.

TABLE 5: CARBON STORED BY FOREST AGE CLASS IN THE STUDY AREA	
Forest age class	**Carbon stored per hectare (tC/ha)**
Less than 20 years	174
21 to 40 years	209
41 to 60 years	226
61 to 80 years	238
81 to 100 years	238
101 to 120 years	285
121 to 140 years	309
141 to 250 years	339
Greater than 250 years	423
Standing dead tree cover	160

Using these forest carbon content estimates, the amount of carbon stored in forest ecosystems across the study area was estimated based on the forest age class cover data from the B.C. Vegetation Resources Inventory (VRI) geospatial dataset (Figure 4 on page 36).[63] Because of the impact of insect damage due to mountain pine beetle infestation on some of the area's forests, the carbon content per hectare was adjusted for the forest cover area identified as standing dead trees (6.5 per cent of the forest area as reported by the B.C. VRI dataset).[64] Although standing dead trees do store carbon, they will decompose over time. We were unable to model the carbon transfer to the forest soils, so only the soil carbon (160 tC/ha) was included for the forest area identified as standing dead trees (282,956 hectares across all age classes; Table 6 on page 35).

The total forest area reported by the B.C. VRI dataset (4,331,485 hectares) was greater than the forest cover reported by the AAFC land cover dataset (3,613,741 hectares of forest cover plus 384,922 hectares of treed wetland; see Section 3). The difference in forest cover area may be explained by the area (101,711 hectares) that was unclassified (i.e., reported as cloud or shadow) in the land cover dataset and the possible misclassification of some of the snow/ice, rock/rubble and exposed land in the land cover dataset. The BC VRI dataset was used to infer the carbon stored by the forests in the study area; this data was then used to estimate the forest carbon storage based on AAFC dataset forest land cover.

Based on the forest age carbon analysis, the total carbon stored was an estimated 1.14 billion tonnes of carbon (Table 7 on page 35).

63 Ministry of Forests, Lands and Natural Resource Operations. VRI Forest Vegetation Composite Polygons and Rank 1 Layer. Forest Analysis and Inventory Branch. (2013 update). https://apps.gov.bc.ca/pub/geometadata/metadataDetail.do?recordUID=47574&recordSet=ISO19115

64 The total forest area reported by the B.C. VRI dataset was 4,331,485 hectares (332,823 more hectares than reported by the land cover dataset cited above for land cover).VRI forest area was used for the forest age/carbon analysis to estimate the total carbon stored by the study area because the forest age data provides a greater characterization of the forest land cover. However, for the overall ecosystem values, the average carbon per hectare was used to estimate the total value based on the total forest cover area as reported by the land cover dataset (3,613,741 plus 384,922 treed wetland; see Section 3).

TABLE 6: TOTAL FOREST AREA INCLUDING DEAD STANDING TREE AREA (B.C. VRI DATASET)

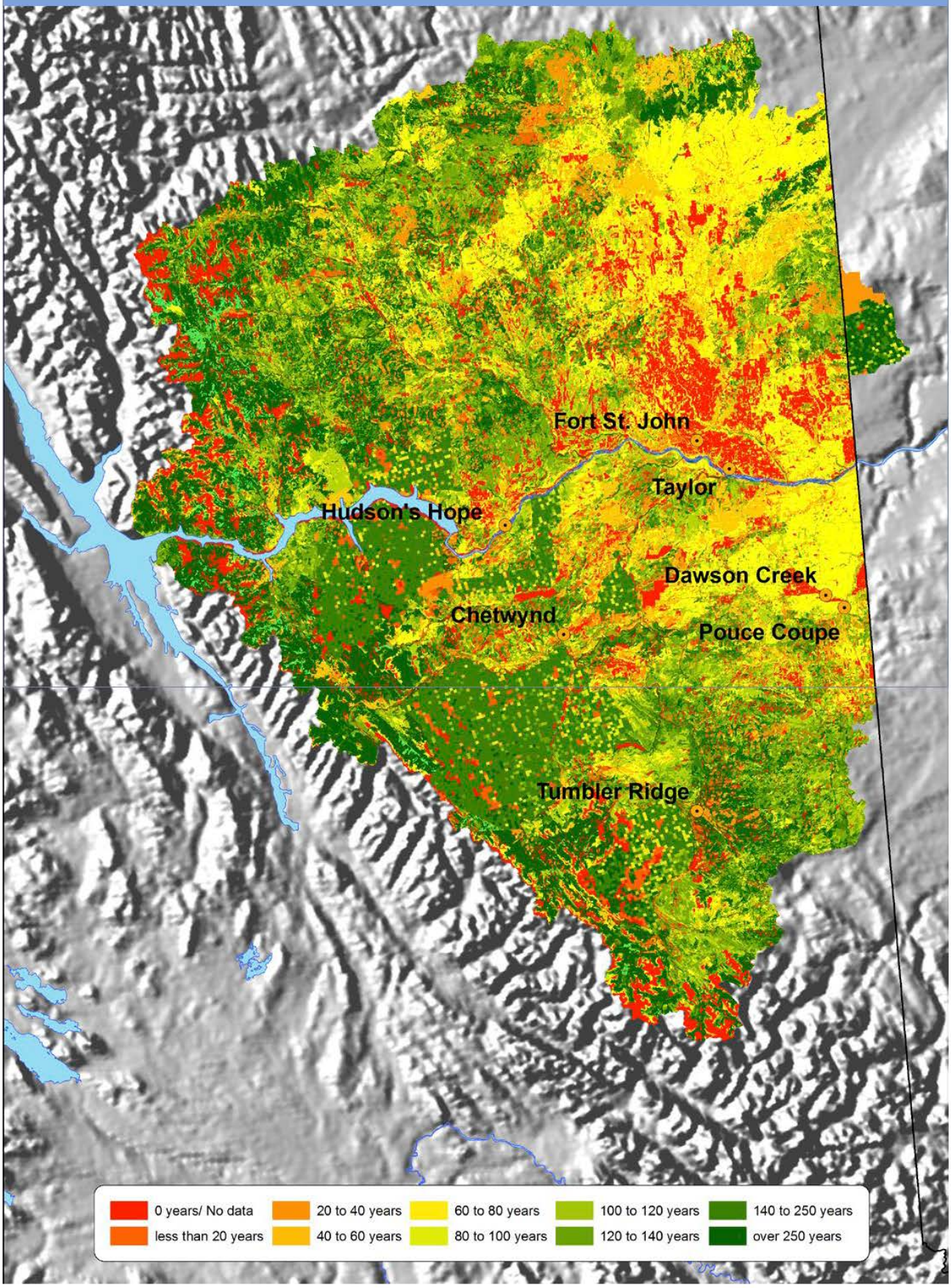
Forest age class	Total forest area* (ha)	Dead standing tree area (ha)	Total forest area excluding dead standing tree area (ha)
Less than 20 years	110,485	236	110,250
21 to 40 years	211,917	1,573	210,344
41 to 60 years	401,995	4,078	397,917
61 to 80 years	897,959	20,749	877,211
81 to 100 years	627,322	65,315	562,007
101 to 120 years	685,939	80,403	605,537
121 to 140 years	556,109	61,696	494,413
141 to 250 years	793,600	48,572	745,028
Greater than 250 years	46,158	335	45,823
Total	4,331,485	282,956	4,048,529

Source: Ministry of Forests, Lands and Natural Resource Operations. VRI Forest Vegetation Composite Polygons and Rank 1 Layer. Forest Analysis and Inventory Branch. (2013 update).

TABLE 7: TOTAL CARBON STORED BY FOREST ECOSYSTEMS IN THE STUDY AREA (B.C. VRI DATASET)

Forest age class	Carbon stored per hectare (tC/ha)	Total area (ha)	Total carbon stored (tC)	Annual value $/ha/year	Total value $/year
Less than 20 years	174	110,250	19,183,437	$779.15	$85,915,563
21 to 40 years	209	210,344	43,919,809	$933.51	$196,700,675
41 to 60 years	226	397,917	90,008,850	$1,010.05	$403,116,542
61 to 80 years	238	877,211	208,337,495	$1,055.63	$933,067,033
81 to 100 years	238	562,007	133,476,663	$1,027.42	$597,792,894
101 to 120 years	285	605,537	172,577,921	$1,210.66	$772,913,049
121 to 140 years	309	494,413	152,649,970	$1,308.75	$683,663,088
141 to 250 years	339	745,028	252,316,300	$1,467.72	$1,130,031,930
Greater than 250 years	423	45,823	19,383,321	$1,885.91	$86,810,767
Standing dead tree cover	160	282,956	45,204,330	$715.49	$202,453,572
Total		4,331,485	1,137,058,097		$5,092,465,112

FIGURE 4: MAP OF FOREST AGE DISTRIBUTION IN THE PEACE RIVER WATERSHED STUDY AREA



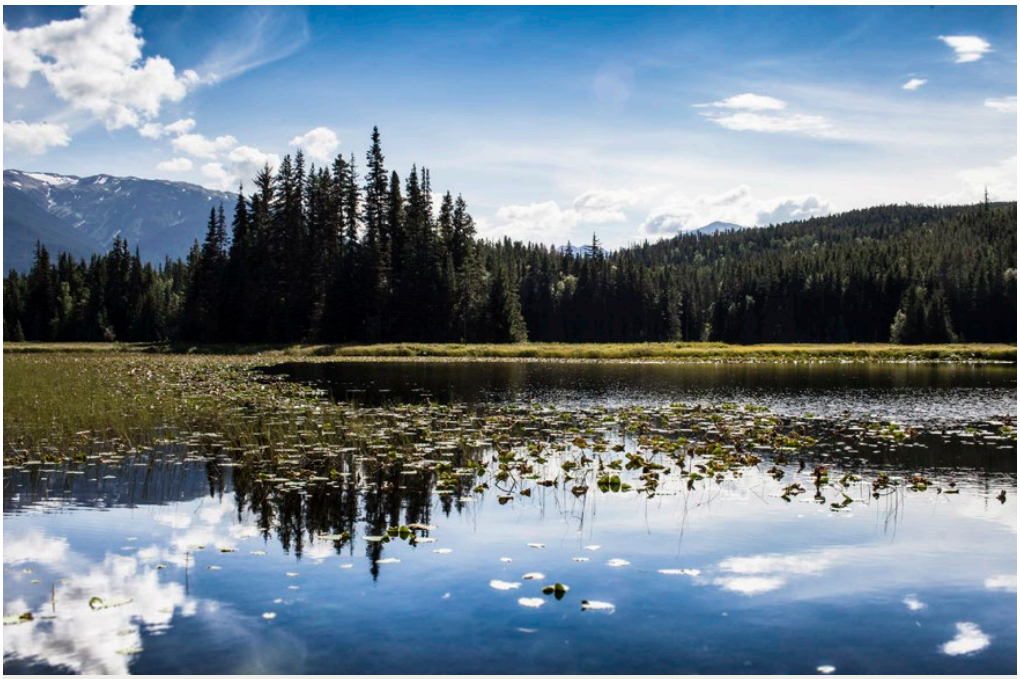


PHOTO COURTESY ZACK EMBREE, *FRACTURED LAND* DOCUMENTARY

STORED CARBON ANNUAL VALUE

The amount of carbon stored in an ecosystem is measured at a fixed point in time. In order to estimate an annual value for our reporting purposes, the central SCC value was converted to a carbon annuity, based on the carbon annuity account (CAA) concept. A CAA (carbon annuity account) is an account where the carbon value is placed into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the account.[a] Annual carbon values were calculated based on three per cent earnings over 50 years to estimate a range of annual values for carbon stored by ecosystems. Therefore, the annual values used were: a central value of $4.48/tC/year ($1.22/tCO2/year); a low-end value of $1.58/tC/year ($0.43/tCO2/year); and a high-end value of $7.46/tC/year ($2.03/tCO2/year).

[a] Swingland, I. (ed). 2003. *Capturing Carbon and Conserving Biodiversity: The Market Approach.* Earthscan Publications. London, U.K. http://books.google.ca/books?id=oPz8P6cZKUQC&printsec=frontcover#v=onepage&q&f=false; Feng, H. et al. 2002. "The Time Path and Implementation of Carbon Sequestration." *American Journal of Agricultural Economics.* 84:134-149.

The carbon stored and its value is at a fixed point in time. Therefore, in order to estimate an annual value for our reporting purposes, the central SCC value was converted to a carbon annuity, based on the carbon annuity account (CAA) concept.[65] The annual value was calculated based on three per cent earnings over 50 years to estimate the annual value for carbon stored by forests ($4.48/tC/year or $1.22/t$CO_2$/year).[66] Therefore, the first estimate of the total annual value for carbon storage by forests was an estimated $5.09 billion per year, or $1,175.69/ha/year.[67]

Forest carbon storage was also estimated using the forest land cover from the AAFC land cover dataset reported in Section 3. In order to estimate the carbon stored by forests using the AAFC forest land cover area, the average carbon per hectare derived from the forest age carbon analysis (262.5 tC per hectare; 1.14 billion tC / 4.3 million hectares) was applied to each hectare of forest land cover, as well as a partial amount for the tree biomass reported as treed wetland.

According to the AAFC land cover dataset, the total forest cover in the study area was 3,613,741 hectares, plus 384,922 hectares of treed wetland. Using the average carbon stored per hectare of forest derived from the above analysis (262.5 tC/ha), the carbon stored by forest cover was an estimated 948.6 million tonnes. In addition, there were 384,922 hectares of treed wetlands in the study area. The aboveground carbon stored in the tree biomass was estimated at 102.8 tonnes of carbon per hectare.[68] As a result, an additional 39.6 million tonnes of carbon was stored by trees on wetlands, worth $177.1 million per year ($460.19/ha/year). Therefore, the second estimate of total forest carbon in the study area was 988.2 million tonnes of carbon, worth an estimated $4.43 billion per year (total forest carbon multiplied by the annual value of $4.48/tC/year).[69]

The annual value for carbon stored by forests, in terms of the avoided costs of carbon emissions to the atmosphere, ranged from an estimated $4.43 billion to $5.09 billion per year.

Thus, the annual value for carbon stored by forests, in terms of the avoided costs of carbon emissions to the atmosphere, ranged from an estimated $4.43 billion per year (based on the average carbon per hectare derived from the forest age carbon analysis and the AAFC land cover dataset forest area), to $5.09 billion per year (based on the forest carbon estimates per forest age class and the B.C. VRI dataset forest area).

The low and high SCC values from the U.S. estimates were used for sensitivity analysis (in order to capture the uncertainties of climate change impacts). The low-end value ($40.63/tC) and the high-end value ($192.06/tC) were reported in the preceding section on the economic value of stored carbon (2012 C$). These values were converted to annual values as a carbon annuity. Therefore, the low-end value was an estimated $1.58/tC/year and the high-end value was $7.46/tC/year. Based on the low and high annual SCC estimates, the total value for carbon stored by forests ranged from: 1) $1.8 billion per year ($414.51/ha/year) to $8.5 billion per year ($1,959.52/ha/year), based on the B.C. VRI forest area; and 2) $1.56 billion to $7.38 billion per year, based on the AAFC forest and tree-covered wetland cover area.[70]

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65 A CAA is an account where the full carbon value is placed directly into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account. Swingland, I. (ed). 2003. *Capturing Carbon and Conserving Biodiversity: The Market Approach*. Earthscan Publications. London, U.K. http://books.google.ca/books?id=oPz8P6cZKUQC&printsec=frontcover#v=onepage&q&f=false; Feng, H. et al. 2002. "The Time Path and Implementation of Carbon Sequestration." *American Journal of Agricultural Economics*. 84:134-149.

66 Calculation: ($30,250 x 0.03887). The 3% rate over 50 years was used because a 3% discount rate is commonly used for socio-economic studies; and a 50-year timeline is a common length of time used for discount rate periods.

67 Calculation: 1,137,058,097 tonnes of carbon multiplied by $4.48/tC/year.

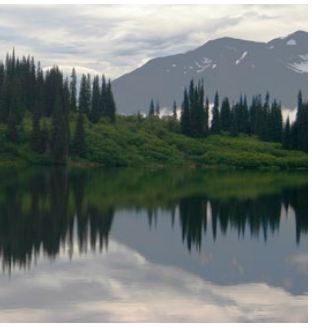
68 The above-ground stored carbon for treed wetlands was estimated as 102.8 tC/ha using the forest ecosystem carbon storage average of 262.5 tC/ha, minus the average soil carbon storage for forests (159.8 tC/ha) from the analysis of the study area's soil organic carbon storage by land cover type. The soil organic carbon data was extracted from: Tarnocai, C., and Lacelle, B. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada. The carbon stored in treed wetland soils is reported in the wetlands soils carbon storage section.

69 The total forest carbon included the aboveground tree biomass carbon for treed wetland areas. The soil carbon stored in treed wetland areas was included in the wetland carbon section.

70 Included the aboveground tree biomass from treed wetland. The above-ground carbon stored in treed wetlands ranged from a low of $62.5 million to a high of $295.2 million.

In summary, the value for stored carbon ranged from $1.8 billion to $8.5 billion per year, and from $1.56 billion to $7.38 billion per year, based on the B.C. VRI dataset and the AAFC land cover dataset, respectively. The central value for carbon stored by forests was estimated to range from $4.43 billion to $5.09 billion per year depending on the dataset input.

For comparison purposes, the value of carbon was estimated based on the 2012 B.C. Carbon Tax rate of $30 per tonne of CO_2 ($110.10/tC), or an annual value of $4.28/tC/year. The total annual value of carbon, using the provincial carbon tax rate, was $4.06 billion to $4.87 billion ($1,123.30/ha/year), based on the B.C. VRI dataset and the B.C. land cover dataset, respectively. The range in value based on the carbon tax rate was close in value to the central estimates above.



Wetlands globally cover only six to nine per cent of the Earth's surface, but contain about 35 per cent of global land-based carbon

PHOTO COURTESY JEAN-GUY DAILLAIRE/FLICKR CREATIVE COMMONS

The value of forest carbon was also estimated based on the price set by the B.C. government for the purchase of carbon offsets, which had been offered by the Pacific Carbon Trust (the former Crown Corporation was taken over by the Climate Investment Branch of the Ministry of Environment in March 2014). The price to sell carbon offsets was set at $25 per tonne of carbon dioxide equivalent ($91.75/tC), and the average price paid to forestry and energy companies for offset projects was $11.30/t$CO_2$e in 2012 ($41.47/tC).[71] The annualized values were estimated at $3.57/tC/year and $1.61/tC/year, respectively, based on an annuity approach (see Section 5.2.2.1). Therefore, the estimated value based on the provincial offset prices ranged from $1.5 billion to $3.4 billion per year—values also within the range of the annual SCC values reported above.

The carbon values reported here are average values per forest age class aggregated across the study area. This study also considered how these values might be adopted at a smaller scale for land-use decision making. For example, using the forest age carbon analysis, it was estimated that the cost of clearing one hectare of forest for other land use would result in a loss of stored carbon ranging from approximately 14.3 tC/ha (for a 10- to 20-year-old forest) to 263.3 tC/ha (for a 250-year-old or greater forest). Thus, the cost was estimated to range from $1,641.23/ha to $30,334.53/ha (depending on forest age), based on the social costs incurred due to the release of carbon ($115.23/tC; see Section 5.2.2.1), and $590.65/ha to $10,916.93/ha based on the option of a carbon offset price.

The annual rate of carbon accumulation referred to as carbon sequestration is often included as an ecosystem service value for forests. The estimates for average carbon sequestered per year were based on the forest age carbon analysis (excluding soil carbon). The average aboveground carbon sequestered per year was 1.18 tC/ha/year, worth an estimated $138/ha/year. This average value could be used when interpreting the costs of land-use change for forest lands. For example, the cost of clearing one hectare of forest could be estimated at $138/ha/year in terms of forgone annual carbon sequestration, based on the annual social costs incurred ($115.23/tC; see Section 5.2.2.1).

Carbon Stored in Wetland Soils

Wetlands play an important role in landscape function, including cycling of carbon, water and nutrients, purification of water, regulation of water flows and provision of habitats. In particular, wetlands store significant amounts of carbon in their rich organic soils and peat. For example, wetlands globally cover only six to nine per cent of the Earth's surface, but contain about 35 per cent of global land-based carbon, and may currently provide an annual net carbon sink of about 830 Mt each year.[72] In the study area, freshwater wetlands covered a total of 518,788 hectares. This included treed wetlands (384,922 ha), shrub-covered wetlands (131,523 ha) and grass-covered wetlands (2,344 ha).

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71 Pacific Carbon Trust. www.pacificcarbontrust.com. "BC Carbon Offset Program To Be Folded Into Climate Action Secretariat As Pacific Carbon Trust Winds Down." (Nov. 26, 2013). www.mondaq.com/canada/x/277426/Climate+Change/BC+Carbon+Offset+Program+to+be+Folded+into+Climate+Action+Secretariat+as+Pacific+Carbon+Trust+Winds+Down; "Pacific Carbon Trust's growing surplus approaches $30 million, fuelling calls for its elimination." (July 12, 2013). The Vancouver Sun. www.vancouversun.com/business/Pacific+Carbon+Trust+growing+surplus+approaches+million+fuelling+calls+elimination/8649076/story.html

72 Mitsch, W.J. et al. 2013. "Wetlands, Carbon and Climate Change." *Landscape Ecology*. 28: 583-597.

The carbon stored in wetland soils was determined using the Canadian Soil Organic Carbon Database (CSOCD).[73] The soil organic carbon data was extracted by land cover type from this geo-referenced database. According to CSOCD, the carbon stored in wetland soils in the study area was an estimated 253.9 million tonnes.

In order to estimate the value for carbon stored by wetland soils, the annual central social cost of carbon (SCC) value ($4.48/tC/year; see Section 5.2.2.1), was multiplied by the soil carbon stored per hectare of wetland (159.7 tC/ha for grass-covered wetlands, 471.5 tC/ha for treed wetlands and 547.9 tC/ha for shrub-covered wetlands).[74] The estimated annual values for soil carbon storage were $715/ha/year for grass wetlands, $2,112/ha/year for treed wetlands and $2,454/ha/year for shrub wetlands.[75]

The total value for carbon stored in wetland soils was therefore an estimated $1.14 billion per year. Using the low-end and high-end SCC values to take into account the uncertainty associated with the impacts of climate change, the total value was estimated to range from $400.9 million to $1.9 billion per year.

The annual carbon sequestration rate was calculated based on the average forest carbon sequestration rates for boreal freshwater wetlands, reported by Mitsch et al. (2013). Using the average rate for net carbon retention (0.29 tonnes per hectare per year), the annual rate of net carbon uptake was worth an estimated $33.42 per hectare (0.29 tC/ha multiplied by $115.23), or $17.3 million per year.

Also considered were the marginal value of losses due to the drainage of wetland, and the benefits of restoring wetlands. For example, a study on the restoration of prairie wetlands found that restoration results in a net increase of 0.89 tonnes of soil carbon per hectare per year (3.25 tCO_2e/ha/year). The same study reported that approximately 89 tonnes of soil carbon per hectare is lost when seasonal or permanent wetlands are drained. The results from this study were used to estimate a value for changes in wetland area. Thus, the value for restored wetland area was estimated at $102.05/ha/year (0.89 tC/ha/year multiplied by $115.23), and the cost of losses in wetland area was estimated at $10,256 per hectare, or $398.60/ha/year as an annualized value over 50 years (see Section 5.2.2.1 for economic value of stored carbon).

The total value for carbon stored in wetland soils was estimated at $1.14 billion per year.

PHOTO COURTESY TODD PIERSON/FLICKR CREATIVE COMMONS

Carbon Stored in Grassland, Shrubland and Cropland Soils

The amount of carbon stored in grassland, shrubland and cropland soils was determined using data from the Canadian Soil Organic Carbon Database.[76] Data was extracted spatially from this geo-referenced database for each land cover type. To estimate the value of the carbon stored by each land cover type, the average carbon per hectare was calculated from the CSOCD data, then multiplied by the annualized dollar value per tonne of carbon ($115.23/tC annualized to $4.48/tC/year; see Section 5.2.2.1).

The average carbon stored by grassland soils was 205.7 tC/ha, worth an estimated $921.32/ha/year. The average carbon stored by shrubland soils was 346.5 tC/ha, worth an estimated $1,552.03/ha/year. The average carbon stored by perennial cropland and pasture was 239.8 tC/ha, worth an estimated $1,073.77/ha/year. The average carbon stored by annual cropland soils was 263.8 tC/ha, worth an estimated $1,181.55/ha/year (Table 8).

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73 Tarnocai, C., and Lacelle, B. 1996. *Soil Organic Carbon Database of Canada*. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.

74 See Section 5.2.2.1 for explanation of annual value for SCC. A CAA is an account where the full carbon price is made directly into an annuity account, and as long as the sink remains in place, the carbon provides an annual earning/value from the annuity account; Swingland, I. (ed). 2003. *Capturing Carbon and Conserving Biodiversity: The Market Approach*. Earthscan Publications. London, U.K. http://books.google.ca/books?id=oPz8P6cZKUQC&printsec=frontcover#v=onepage&q&f=false; Feng, H. et al. 2002. "The Time Path and Implementation of Carbon Sequestration." *American Journal of Agricultural Economics*. 84:134-149.

75 The annuity coefficient applied to the full carbon value was based on 3% earnings over 50 years to estimate the annual value of the carbon storage. Calculation: (tC/ha * $4.48/tC/year). The 3% rate over 50 years was used because a 3% discount rate is a commonly used rate for socio-economic studies; and a 50-year timeline is a common length of time used for discount rate periods.

76 Tarnocai and Lacelle, supra note 73.

TABLE 8: CARBON STORED IN GRASSLAND, SHRUBLAND, PASTURE AND CROPLAND SOILS				
Land cover type	Average soil carbon (tC/ha)	Total carbon stored (tC)	Annual value ($/ha/year)	Total value ($/year)
Grassland	205.7	89,571,084	$921.32	$401,155,950
Shrubland	346.5	82,284,931	$1,552.03	$368,523,951
Perennial cropland/pasture	239.8	57,893,795	$1,073.77	$259,285,021
Annual cropland	263.8	32,122,393	$1,181.55	$143,864,388
Total		261,872,204		$1,172,829,309

It is important to note that these values do not reflect the impact of land use on soil carbon, because the CSOCD provides general soil organic carbon content based on soil types, climate and land capability. The higher carbon storage rate reported for annual cropland was likely a result of crop cultivation taking place on the carbon-rich, highly productive soils in the Peace River valley.

The total carbon stored by all four cover types in Table 8 was an estimated 261.9 million tonnes. The cumulative value for soil carbon storage by grassland, shrubland, perennial cropland/pasture and annual cropland was therefore approximately $1.17 billion per year (261,872,204 tC multiplied by $4.48). Using the low and high SCC values for sensitivity analysis (see Section 5.2.2.1), to account for the uncertainties of climate change, the cumulative value was estimated to range from $413.5 million to $1.95 billion per year.

The annual carbon sequestration rates were included for grassland, shrubland and perennial cropland and pasture. Carbon sequestration rates were based on the marginal increase in carbon sequestration resulting from the conservation of natural cover. Smith et al. (2001) reported that conservation measures that maintained a natural cover such as grassland and perennial cover resulted in an increase of 0.49 tonnes of carbon per hectare per year.[77] The average SCC from Section 5.2.2.1 ($115.23/tC) was used in this study; the value was not annualized because carbon sequestration rates are reported per annum. Thus, the annual carbon sequestration was an estimated $56.20/ha/year. The cumulative value for annual carbon sequestration by the three natural cover types was an estimated $51.4 million per year (including $13,345,501 per year by shrublands, $24,472,049 per year by grasslands and $13,571,667 per year by perennial crop lands and pasture).

5.2.3 FLOOD CONTROL AND WATER SUPPLY — WETLANDS

Wetlands provide many ecosystem services that contribute to human well-being, including: providing food, fuelwood and water; maintaining flood control, water supply and water quality; and habitat and cultural services such as the provision of nesting areas and recreation. Wetland systems throughout watersheds affect the health and productivity of downstream human communities and the productivity of freshwater ecosystems. In regions where agricultural land use is present, wetlands can reduce the levels of excess nutrients flowing into rivers and lakes. Wetlands recharge water supplies to aboveground water bodies such as lakes and rivers as well as groundwater, and control floods by storing large amounts of water and regulating its flow.

77 Smith W.N. et al. 2001. "Estimated changes in soil carbon associated with agricultural practices in Canada." *Canadian Journal of Soil Science*. 81:221-227.

Wetlands recharge water supplies to aboveground water bodies such as lakes and rivers as well as groundwater, and control floods by storing large amounts of water and regulating its flow.

PHOTO COURTESY WAYNE SAWCHUCK/PICTURE BC

Local studies on the economic value of wetland ecosystem services in the study area could not be found. As a result, the value of flood control and water supply provided by wetlands was transferred from a global study that provided average values for Canada.[78] The study is the most recent meta-analysis for wetland values in agricultural landscapes of North America and Europe. It reports average values for three regulating services: flood control, water supply and nutrient recycling. A meta-analysis synthesizes the results of multiple studies that examine similar ecosystems (in the case of ecosystem services), synthesizes site results for transfer valuations, and uses statistical analyses to identify and quantify characteristics that define variations in the values.

The overall average values reported for wetlands from 66 separate value estimates were: $7,971/ha/year for flood control services; $3,902/ha/year for water supply; and $6,664/ha/year for nutrient recycling services (2012 C$). However, only the results based on estimates from studies in Canada were used, totalling US$256.67/ha/year (2007 $) for all three ecosystem services. The most common valuation methods used to estimate these ecosystem services were the cost of replacing the service with constructed infrastructure (i.e., the cost of constructing flood control measures equal to the protection provided by one hectare of wetland). Regional estimates for transfer values were provided by further analysis using a statistical model (meta-regression model), and a GIS-based analysis of population size surrounding each wetland, the total area of wetlands (i.e., value per hectare was lower in larger wetlands) and wetland abundance (i.e., as the area of other wetlands increases, the per-hectare value decreases).

The results of the meta-analysis were reported by country. The estimated average value for Canada for all three services was US $223/ha/year (2007 $). This value was an average based on analysis of 3,560 wetland sites across Canada (8 million hectares in area). This value was converted to 2012 Canadian dollars ($256.67/ha/year), then multiplied by the total wetland area (518,788 ha). The total value was therefore an estimated $133.2 million per year.

78 Brander, L., Brouwer, R., and Wagtendonk, A. 2013. "Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis." *Ecological Engineering*. 56: 89-96.

5.2.4 WASTE TREATMENT — WETLANDS

Wetlands absorb nutrients, such as nitrogen (N) and phosphorus (P), which occur naturally in the environment. These nutrients are present in excessive amounts in the runoff from agricultural areas, both in livestock manure and because of the large amounts of fertilizers applied to croplands. The amount that a wetland can absorb varies depending on its type, size, plants and soils. Estimates range from 80.3 to 770 kilograms per hectare per year for phosphorus removal, and 350 to 32,000 kilograms per hectare per year for nitrogen removal.[79] These are important functions because excessive nutrients and sediments can reduce the availability of oxygen in water, which in turn can kill fish, reduce recreational opportunities and habitat for waterfowl, and affect drinking water quality.

The low-end wetland nutrient removal rates were applied to wetland cover in the study area to estimate the area's capacity to absorb nutrients. The results showed that the study area's wetlands have the capacity to remove 41.7 million kilograms of phosphorus and 181.6 million kilograms of nitrogen each year (across 518,788 hectares of wetlands).[80]

Wetlands absorb nutrients present in excessive amounts in runoff from agricultural areas, both in livestock manure and because of the large amounts of fertilizers applied to croplands.

PHOTO COURTESY ZACK EMBREE, FRACTURED LAND DOCUMENTARY

Residual soil nitrogen (RSN) is the amount of nitrogen that has been applied to soils but not removed by the harvested portion of crops. In other words, it is the difference between all nitrogen inputs, including fertilizers, manure and natural processes, and the nitrogen removed by the crops harvested and through natural processes such as volatilization and denitrification.[81] According to an Agriculture and Agri-Food Canada report, the majority of farmland in British Columbia in 2006 was in the very low to moderate categories in terms of the residual soil nitrogen on farmlands (0 to 30 kg N/ha; average of 20 kg N/ha). The risk of contamination of water was determined by the ability of natural ecosystems to regulate, filter and absorb nutrients in runoff.[82] In B.C., the majority of farmland (88 per cent) was in the very low to low risk classes (0.1 to 9.9 kg of N/ha) in terms of the risk of contamination.[83] This information was verified visually using the AAFC report's online map display for the Peace River Watershed, which illustrated that the majority of the PRW had very low risk in both categories.[84]

Based on the estimated average residual soil nitrogen and the risk of water contamination by nitrogen indicators, the estimated nitrogen loss from the primary study area's agricultural lands was 608,794 kilograms per year, based on an annual loss of an average 5 kilograms N/ha (i.e., very low risk of contamination). The total excess nitrogen was evenly distributed across the wetland area for valuation purposes. Therefore, it was estimated that an average of 1.17 kg of excess nitrogen was treated per hectare of wetland.

The capacity for phosphorus removal by the study area's wetlands (41.7 M kg P) was calculated using a low-end estimate from the literature (80.3 kg/ha/year) multiplied by the wetland area (518,788 hectares). The average excess phosphorus for British Columbia agricultural lands (4 kg/ha/yr) was then used to estimate the total excess phosphorus for the study area. Based on the B.C. average excess phosphorus, the total excess phosphorous from agricultural lands was an estimated 487,035 kg/year. The total excess phosphorous was evenly distributed across the wetlands in the study area for valuation purposes. Therefore, it was estimated that an average 0.94 kg of excess phosphorous was treated per hectare of wetland.

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79 Olewiler, N. 2004. *The Value of Natural Capital in Settled Areas of Canada*. Ducks Unlimited and Nature Conservancy of Canada.

80 Calculation: 518,788 hectares of wetlands multiplied by the low-end estimates of removal rates of 80.3 kg/ha/year of phosphorus and 350 kg/ha/yr of nitrogen.

81 Eilers, W., MacKay, R., Graham, L., and Lefebvre, A. (eds). 2010. *Environmental Sustainability of Canadian Agriculture: Agri-Environmental Indicator Report Series — Report #3*. Agriculture and Agri-Food Canada, Ottawa, Canada. http://publications.gc.ca/collections/collection_2011/agr/A22-201-2011-eng.pdf (accessed January 2014).

82 Ibid.

83 Across Canada, the average nitrate loss from agricultural lands increased by 25% from 6 kilograms per hectare in 1981 to 7.6 kilograms per hectare in 2001, and nitrate concentration in water was 24% higher in 2001 than in 1981.

84 Agriculture and Agri-Food Canada. Agri-Environmental Indicators application. Modified Jan. 9, 2013. http://atlas.agr.gc.ca/agmaf/index_eng.html#context=aei-iae_en.xml

The replacement costs for removing nitrogen (N) and phosphorus (P) by waste treatment plants were estimated as $6.82 per kilogram of nitrogen and $49.10 per kilogram of phosphorus (2012 $).[85] The respective average replacement costs were used as a proxy for the value of wetland waste treatment services for excess nitrogen and phosphorous. The average annual value for excess nitrogen removal by the study area's wetlands was thus estimated as $8 per hectare (1.17 kg/ha/year multiplied by $6.82), and the average annual value for excess phosphorous removal was estimated as approximately $46.10 per hectare (0.94 kg/ha/year multiplied by $49.10).

The two average replacement values for excess nitrogen and phosphorus removal were tallied to estimate the total value of waste treatment by wetlands as $28.1 million per year ($54.10/ha/year).

5.2.5 WASTE TREATMENT AND SEDIMENT REDUCTION — GRASSLAND AND PERENNIAL COVER

Treatment of phosphorus and sediment removal were evaluated as ecosystem services provided by grasslands and perennial cover/pasture. The values were transferred from a study undertaken in the Grand River watershed in Ontario.[86] This study reported the net value of conserving natural cover or restoring tiled lands to natural cover. The average values (converted to 2012 $) were $27.93/ha/year for phosphorus reduction and $6.60/ha/year for sediment reduction. The net values reflected the avoided costs for water treatment for each type of service. These values were applied to the grassland and the perennial/pasture in the study area. The annual value for grasslands was $12.2 million for the avoided costs of phosphorus treatment, and $2.9 million for the avoided costs of sediment removal. The annual value for perennial cropland/pasture was $6.7 million for the avoided costs of phosphorus treatment, and $1.6 million in avoided costs of sediment removal.

Forests and wetlands can help purify water sources by filtering, storing and transforming pollutants as rain falls and as water moves across the landscape to rivers, streams and lakes.

PHOTO COURTESY JONATHAN BRENNECKE/FLICKR CREATIVE COMMONS

5.2.6 WATER FILTRATION — FORESTS

A safe and reliable source of water is critical for all living things. Poor water quality degrades water supplies, fish habitat and recreational areas. Forests and wetlands can help purify water sources by filtering, storing and transforming pollutants as rain falls and as water moves across the landscape to rivers, streams and lakes.

Forested watersheds are vital for a clean and regular supply of drinking water. Protected forests provide higher-quality water with less sediment and fewer pollutants than water from watersheds with unprotected forests.[87] A U.S. study found that the cost of treatment for surface water supplies varies depending on the percentage of forest cover in the water source area.[88] This analysis showed that a 10 per cent loss in forest cover across a watershed resulted in a 20 per cent increase in water treatment costs. In other words, as forest cover declined, water treatment costs grew. Similarly, a study undertaken in France demonstrated that an increase in forest land cover led to a decrease in water treatment costs. This study found that one hectare of restored forest would generate an average savings of 138 per year (C$209.24) on household

85 Olewiler, supra note 79. The costs of removing nitrogen (N) and phosphorus (P) by waste treatment plants were reported to range from $3 to $8.50 per kilogram of nitrogen and $22 to $61 per kilogram of phosphorus based on rates in Metro Vancouver (2003 $).

86 Ibid.

87 Dudley, N., and Stolton, S. 2003. *Running Pure: The importance of forest protected areas to drinking water*. World Bank/WWF Alliance for Forest Conservation and Sustainable Use. Washington, D.C.

88 Ernst, C., Gullick, R., and Nixon, K. 2007. "Protecting the Source: Conserving forest to protect water." In *The Economic Benefits of Land Conservation*. The Trust for Public Land. www.tpl.org/protecting-source

water bills in the region studied, based on a decrease in the cost of drinking water supply of 0.015 per cubic metre of water when afforestation took place on agricultural lands.[89]

The statistical relationship between forest cover and cost of water treatment established by the U.S. study was used to estimate the value of water filtration services provided by forest cover in the study area. Therefore, the economic value of water filtration services was calculated based on the avoided costs provided by the current level of forest cover.[90]

First, the current proportion of forest cover in the study area's watershed was assessed (approximately 70 per cent forested lands). Then the current cost of water treatment was researched, based on the cost of water treatment in Fort St. John ($2.78 per cubic metre).[91] The annual residential water used in the PRW (3.4 million cubic metres) was estimated based on the number of households in the B.C. PRW (20,935 households; an estimate based on the current population) and the average daily water use by households in Fort St. John (450 litres/day).[92] As a proxy value for the total forested area, it is estimated that the total value of the avoided costs of water treatment was $24.7 million per year ($6.23/ha/year). This calculation was based on a model that calculated the avoided costs for each 10 per cent loss in forest cover, based on the correlation between water treatment costs and forest cover.

A marginal cost for this value was also calculated, based on our economic model. If forest cover were to decline from 70 per cent to 60 per cent, the cost for water treatment was estimated to increase from $2.78 to $3.34 per cubic metre, resulting in an additional annual cost of $1.9 million per year. Used as a proxy to value the water filtration services provided by forests, the marginal value of a 10 per cent loss was an estimated $4.83/ha/year (or a total value of $1.9 million). If forest cover declined by one per cent, the estimated marginal value was $2.96/ha/year.

It is useful for comparison to consider the total replacement cost for water. If daily residential water use in the PRW had to be replaced by bottled water, the daily cost would be $14.1 million (9.4 million litres at $1.50 per litre), or the equivalent of $5.2 billion per year.

5.2.7 POLLINATION

About 30 per cent of the world's food production comes from crops that depend on pollinators such as bees, insects, bats and birds.[93] The value of bee pollination for crops in Canada has been conservatively estimated at $1.42 billion per year (2012 $).[94]

Honeybees provide about 90 per cent of managed pollination services, but wild bees add significant value to crops. For example, the contribution of wild pollinator services in the United States is estimated to be more than $3 billion annually.[95] Visits by bumblebees can increase tomato fruit set by 45 per cent and fruit weight by 200 per cent; and wild pollinators produce larger and more symmetrical apples in orchards, increasing

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89 Abildtrup, J., Garcia, S., and Stenger, A. 2013. "Effect of forest land use on cost of drinking water supply: a spatial econometric analysis." *Ecological Economics*. 92:126-136.

90 Ernst, C., Gullick, R., and Nixon, K. 2007. "Protecting the Source: Conserving forest to protect water." In *The Economic Benefits of Land Conservation*. The Trust for Public Land. www.tpl.org/protecting-source

91 Fisher, E. 2013. "Fort St. John water treatment plant could reach capacity in 5 to 10 years." Energetic City. http://energeticcity.ca/article/news/2013/06/25/fort-st-john-water-treatment-plant-could-reach-capacity-in-5-to-10-years

92 Municipal water use per person was reported by the Conference Board of Canada from municipal statistics from Environment Canada. See: www.conferenceboard.ca/hcp/details/environment/water-consumption.aspx

93 Klein, A.-M., et al. 2007. "Importance of pollinators in changing landscapes for world crops." *Proceedings of the Royal Society B*. 274:303-313.

94 Environment Canada. 2003. "Protecting Plant Pollinators." *Envirozine*. Issue 33 (June 26, 2003). www.ec.gc.ca/EnviroZine/english/issues/33/feature3_e.cfm (accessed February 2008)

95 Losey, J.E., and Vaughan, M. 2006. "The Economic Value of Ecological Services Provided by Insects." *BioScience*. 56:311-323.

The proximity of natural habitat to cropland is significant for optimum yields and increases farm production.

PHOTO COURTESY KYLEWITH/ FLICKR CREATIVE COMMONS

returns by $250 per hectare.[96] The proximity of natural habitat to cropland is significant for optimum yields and increases farm production. For example, a Canadian study demonstrated that increases in canola yield were correlated to the close proximity of uncultivated areas providing nectar. Similarly, studies that examined pollination services and the surrounding land use found that natural habitat near farms increased pollination services.[97]

Many pollinators are in decline because of habitat destruction and pesticide use. Diverse habitats that are home to a variety of flowers provide the best forage for pollinators. Flower-rich field borders, windbreaks such as hedgerows, forests and riparian buffers encourage a wide variety of pollinators.[98]

According to the B.C. government, the Peace River valley is unique in offering ideal climate conditions and nectar forage availability for honeybees during the summer. This area is among the most productive honey-producing regions in the world. Average honey yield per colony often exceeds 200 pounds, and individual colonies may sometimes produce in excess of 400 pounds in one season.[99]

The B.C. Ministry of Agriculture estimated the value of pollination in the province at $391.3 million in 2008 (2012 $), however, pollination values were not provided by district.[100] For the PRW, it was estimated that approximately 31 per cent of the provincial pollination value was attributable to the Peace River Regional District, and about 43.7 per cent of the district's pollination value was attributable to the study area. Thus, the pollination value for the study area was an estimated $39.9 million. The total pollination value for the study area was attributed to the land cover types that provide pollinator habitat and nectar, including grasslands, shrublands and perennial croplands/pasture (total of 914,332 ha). Therefore, the value per hectare was $43.62/ha/year ($39,885,653 / 914,332 hectares).

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96 Greenleaf, S.S., and Kremen, C. 2006. "Wild bee species increase tomato production and respond differently to surrounding land use in Northern California." *Biological Conservation*. 133:81-87; Kevan, P.G. 1997. "Honeybees for better apples and much higher yields: study shows pollination services pay dividends." *Canadian Fruitgrower*. (May 1997): 14, 16. (cited by FAO)

97 Greenleaf and Kremen, supra note 96; Greenleaf, S.S., and Kremen, C. 2006. "Wild bees enhance honey bees' pollination of hybrid sunflower." *Proceedings of the National Academy of Sciences*. 103:13890-13895.

98 Environment Canada. 2003. "Protecting Plant Pollinators." *Envirozine*. Issue 33 (June 26, 2003).

99 Apiculture Factsheet 101. www.agf.gov.bc.ca/apiculture/factsheets/101_hist.htm

100 Estimated annual value of Honeybee and Bumblebee Pollination in BC (2008). B.C. Ministry of Agriculture and Lands. www.agf.gov.bc.ca/apiculture/statistics/pollin.value2008.pdf

5.3 Habitat Values

Habitat refers to the biological and physical space and processes in which wild species meet their needs. Ecosystems provide physical structure, adequate food availability, a suitable climate and temperature, and protection from predators. Habitat also provides refuge and nursery functions. The biological diversity of habitat creates the physical structure and complexity of ecosystems that provide resiliency and ecosystem services.

The Peace River is home to important sport fish species, as well as key habitat for nesting and migratory birds, along the river and in upland areas. Twelve species of fish are common in the Peace River, downstream of the Peace Canyon Dam between Hudson's Hope and Fort St. John. The most abundant fish species are mountain whitefish, Arctic grayling, rainbow trout, lake whitefish and walleye. Bull trout, Kokanee and northern pike are also present, but in lower numbers. The Peace River valley and uplands provide habitat for nesting and migratory waterfowl. Songbirds, some of which are rare in British Columbia, regularly migrate through the area. In addition, the south-facing banks of the Peace River and its major tributaries provide extensive areas of critical ungulate (deer, moose) wintering habitat.

The Peace River is home to key habitat for nesting and migratory birds, along the river and in upland areas.

PHOTO COURTESY RICK LECHE/ FLICKR CREATIVE COMMONS

Given that the study area offers important habitat for migratory birds, a value for the habitat provided by wetlands was included. The value was transferred from a 2004 wetland meta-analysis, which used 246 individual wetland valuations based on several different valuation approaches and metrics (e.g., willingness to pay for wetlands, marginal value per acre). About 60 per cent of the study's values were from the U.S., Canada, Australia and Europe. According to these results, the average value for wetland habitat was $379.43 per hectare per year (converted to 2012 C$).[101] This average value was transferred to the wetlands in the study area. Thus, the total value for habitat provided by wetlands was an estimated $196.8 million per year ($379.43 multiplied by 518,788 hectares of wetlands).

Despite the importance of the study area for numerous species (e.g., caribou and grizzly bears), other habitat values were not included because of a lack of available ecosystem services valuation information.

5.4 Recreation Values

The Peace River Valley and its greater watershed attract visitors from within British Columbia as well as tourists from across Canada and other countries. The area provides beautiful landscapes, recreational opportunities and wildlife viewing. Recreational activities include hiking, swimming, camping, hunting, fishing, kayaking, canoeing, river boating, horseback riding, geocaching, birding and photography.

According to an Environment Canada survey, B.C. residents spent $1.9 billion in 1996, equivalent to $2.59 billion in 2012, on recreational activities associated with natural areas.[102] This survey is likely an underestimate of the economic impact of outdoor recreation in the province. For example, a B.C. government study reported that wildlife viewers spent $6.2 billion on wildlife viewing activities in the province in 1996.[103] In addition, recreational users were asked how much more money they were willing to pay to maintain their recreational activities. In B.C., the willingness to pay beyond expenditures was a total of $342 million in 1996, equivalent to $465 million in 2012 dollars.

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101 Brander, L., and Schuyt, K. 2004. *Economic Values of the World's Wetlands*. Institute for Environmental Studies and WWF-International. Gland, Switzerland/Amsterdam, the Netherlands. Meta-analysis refers to a quantitative analysis of statistical summary indicators reported in a series of similar empirical studies.

102 Duwors, E. et al. 1999. *The Importance of Nature to Canadians: The Economic Significance of Nature-Related Activities*. Environmental Economics Branch. Environment Canada. Ottawa, Canada.

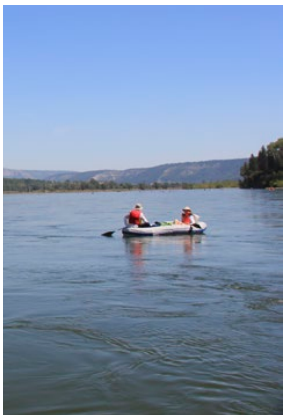
103 *1998 Economic Value of Wildlife Activities in B.C.* Wildlife Branch. Ministry of Environment, Lands and Parks. (reported in Tourism B.C. Wildlife Viewing Product Overview. April 2009. www.destinationbc.ca/getattachment/Research/Research-by-Activity/Land-based/Wildlife_Viewing_Sector_Profile.pdf.aspx)

This included outdoor activities in natural areas, wildlife viewing and recreational fishing and hunting. The average yearly amount spent per participant by activity was $1,225.79 (2012 $) per year for outdoor activities, and $570.77 (2012 $) per year for wildlife viewing. The above figures were used to estimate values for outdoor activities in natural areas and wildlife viewing for the study area. In order to interpret these values, it was estimated that the number of residents within the study area participating in outdoor recreation was 47,627 people (91 per cent of the population).[104] The rate of participation was taken from a recent outdoor recreation survey undertaken in British Columbia, which reported that 91 per cent of B.C. residents participate in outdoor recreation.[105] As a result, it was estimated that the direct economic value for outdoor activities in natural areas and wildlife viewing was $85.6 million ($58.4 million and $27.2 million, respectively).[106]

The value of freshwater recreational fishing was estimated based on a 2010 study commissioned by the Freshwater Fisheries Society of BC. This study reported that more than 3.8 million freshwater angling days took place in B.C. in 2010, which had a direct economic impact of $545.7 million per year.[107] We calculated that, on average, each angling day had a value of $143.03 ($545.7 million / 3,815,416). According to the same report, 64,186 of the total annual angling days took place within the Peace region. It was therefore estimated that the economic impact of freshwater angling in the Peace region was approximately $9.2 million. The boundaries of the Peace region within the above report were not specified, but we estimated that about 82.5 per cent ($7.6 million) could be attributed to the study area, based on the fact that the majority of the greater Peace district's population resides within the study area.[108] The value per hectare of freshwater in the study area was therefore estimated at $98.67/ha/year for recreational fishing.

The marginal value for nature-related recreation for the study area was also estimated. The 1996 study from Environment Canada reported that the willingness to pay (WTP) beyond current expenditures for nature-related recreational activities was $224.64 per year for outdoor activities in natural areas, $144.87 per year for wildlife viewing and $189.03 per year for recreational fishing (2012 $). Thus, the marginal value for recreation in the study area was an estimated $32.2 million per year in terms of the economic value placed on outdoor recreational experiences beyond current expenses paid.

The total value of nature-related recreation within the study area was therefore an estimated $119.7 million per year (2012 $), including $85.6 million for outdoor activities and wildlife viewing in natural areas (plus $17.6 million in contingent WTP economic value), and $7.6 million for recreational fishing (plus $9 million in contingent WTP economic value). The annual values were attributed to the study area's land cover as $21.13 per hectare for outdoor activities and wildlife viewing in forest, wetland, grassland and shrubland cover (4,882,140 hectares), and $215.97 per hectare for freshwater fishing (angling) in freshwater areas (76,751 hectares).



The average yearly amount spent per participant was $1,226 for outdoor activities and $571 for wildlife viewing.

PHOTO COURTESY DON HOFFMANN

104 Total population of residents participating in outdoor recreation was calculated as 91% of the estimated population for the study area based on the Peace River Regional District's total population. The total population was estimated as 52,337 as reported by B.C. 2012 statistics (includes Fort St. John, Dawson Creek, Chetwynd, Hudson's Hope, Pouce Coupe, Tumbler Ridge, Taylor, and 50% of unincorporated areas).

105 Sorensen-Lawrence, L. et al. 2013. *2009/10 Outdoor Recreation Study: BC Resident Participation*. Prepared by NRG Research Group, and B.C. Ministry of Jobs, Tourism and Skills Training. Tourism BC. www.destinationbc.ca/getattachment/Research/Research-by-Activity/Other/Outdoor-Recreation-for-Distribution-14Jan13-FINAL-DRAFT-%282%29.pdf.aspx

106 Values were calculated using the estimated number of participants in the study area multiplied by the average amount spent annually on each activity.

107 Bailey, M., and Sumaila, U.R. 2012. *Freshwater Angling and the B.C. Economy*. Report prepared for Freshwater Fisheries Society of BC. (Summary report is available at: http://www.gofishbc.com/documents/pdf/news-and-events/2013_BC_Freshwater_Sport_Fishing_Economic_Impact_Report.pdf)

108 Percent of Peace River Regional District population located within the study area was estimated using B.C. 2012 statistics.

5.5 Cultural and Spiritual Values

5.5.1 ANCESTRAL AND CURRENT FIRST NATIONS CULTURAL VALUES

The Peace River valley boasts a culturally rich history. Indigenous peoples have lived in the Peace River region for centuries.

The study area is located within the boundaries of Treaty 8, which was the eighth treaty signed between First Nations and the Canadian government in 1899. The treaty allowed for the sharing of lands in northeastern B.C., northern Alberta and northwestern Saskatchewan. The First Nations Reserves within the study area (11,443 hectares), include East Moberly Lake 169, West Moberly Lake 168A, Beaton River No. 204 (North Parcel), Beaton River 204 (South Parcel), Halfway River 168, Blueberry River No. 205, Doig River 206 and Finlay Bay Indian Reserve No. 21.[109]

For First Nations in the region, the land and waters of the Peace Valley are an integral part of their identity, their stories, their songs and their language. The valley is shared among First Nations groups for historic, cultural and subsistence purposes. Communities continue to share their culture with younger generations through trapping, fishing, hunting, the collection of medicinal plants, crafts, ceremonies, canoes and drums.

While some studies have been done to estimate the economic value of wilderness to First Nations, such as a willingness-to-pay study conducted for aboriginal communities in Saskatchewan and a study on food replacement costs from other northern communities in western Canada (see *First Nations Cultural Values* on page 50), this study provides instead an overview of the cultural and spiritual values of the Peace region to the local First Nations, as described in their own words in a Traditional Land Use Study (TLUS) prepared by the Treaty 8 Tribal Association in 2012 for BC Hydro's Proposed Site C project.[110] The TLUS identified 796 site-specific use values that were mapped in the Peace River Valley, mostly clustered along the low-lying Peace River flats and adjacent streams. The cultural and spiritual values included:

- Spiritual places
- Burials
- Medicine collection areas
- Teaching areas
- Ceremonial and prayer offering places
- Locations associated with place names and oral histories
- Habitat areas
- Movement corridors
- River crossing areas for ungulates and large carnivores (i.e., grizzly bears)
- Winter fish habitat and spawning areas
- Bear dens
- Moose and ungulate calving areas and winter browse

109 Lee and Hanneman, supra note 1.

110 Candler, C. 2012. *Doig River First Nation, Prophet River First Nation, Halfway River First Nation and West Moberly First Nations Traditional Land Use Study Data and Methodology Report for BC Hydro's Proposed Site C Project*. Prepared on behalf of the four participating First Nations (Doig River First Nation, Prophet River First Nation, West Moberly First Nations and Halfway River First Nation). Submitted to Treaty 8 Tribal Association (T8TA).

Communities continue to share their culture with younger generations through trapping, fishing, hunting, the collection of medicinal plants, crafts, ceremonies, canoes and drums.

- Temporary and permanent or regularly used camping/habitation areas
- Gathering places including locations used for generations
- Fish harvesting sites (i.e., bull trout, dolly varden, rainbow trout, grayling, whitefish)
- Preferred harvesting areas for berries, plant foods and wood materials
- Preferred drinking water sources
- Kill sites for moose, deer, black bear, small birds and furbearers
- Transportation values including trails, horse crossings and boat crossings
- Water routes by canoe and motorboat

Key sites identified included Lynx Creek, Peace River Islands, Bear Flats, Cache Creek, Bison Jump, Halfway River, Moberly River and Hudson's Hope.[111]

Lynx Creek was an ancestral gathering place for Dane-zaa families prior to and after the signing of Treaty 8. It includes permanent camping and habitation areas, preferred hunting and fishing areas, important wildlife habitat and associated oral histories.

Peace River Islands provide wildlife habitat and are considered sacred refuge areas for animals, especially moose and deer during calving and rearing. Hunting for subsistence is restricted. The islands also have specific histories associated with spiritual and cultural importance.

Bear Flats and Cache Creek, located along the river valley, were, like Lynx Creek, ancestral gathering places for Dane-zaa families. These locations are still regularly used for camping and habitation, ceremonies, sacred areas, preferred fishing and hunting sites, significant wildlife habitat, freshwater springs, trail and transportation routes, as well as oral histories.

111 Ibid.

FIRST NATIONS CULTURAL VALUES

Cultural values are irreplaceable, so it is difficult to place a monetary value on them. Since they are vital to First Nations, they are considered invaluable. However, studies have reported non-use values for aboriginal communities. For example, a Saskatchewan study surveyed aboriginal and non-aboriginal households to assess their willingness to pay (WTP) for the protection of wilderness.[a] The aboriginal households on average were willing to pay $84.62/hhld/year (1991 $) in terms of an existence or non-use value (i.e., recreational value was reported as a separate value). If we transferred this value to the First Nation populations in our study area, the WTP of $125.13/hhld/year in 2012 dollars would be multiplied by the estimated number of aboriginal households in the Peace River watershed (2,794 hhlds). The cultural non-use value could then be estimated at $349,613 per year.

In addition, the subsistence values such as wood harvesting, hunting, fishing, trapping, food gathering and the use of natural materials for crafts and medicines for First Nations lands have also been evaluated in other regions of Canada. For example, in a northern Alberta study, the replacement value of subsistence foods and materials was estimated to range from $6,875 to $15,126 (2012 $) per household for northern communities.[b] The replacement cost depends on the amount of subsistence food and materials collected and used by First Nations and the local prices of purchasing food and materials. If we transferred this value for our study area, based on the estimated number of FN households the potential subsistence values for First Nations ranges from $19.2 million to $42.3 million per year. It would be valuable to undertake a study in the future to document subsistence products and values for the PRW region. The WTP and subsistence values were not included in the overall ES total values, but they are reported here for as illustrative examples.

However, this accounting fails to take into account the cultural and spiritual values of subsistence hunting—which often form the fabric of a community's identity. As noted in report *The Cultural and Ecological Value of Boreal Woodland Caribou Habitat*,[c] released in 2013 by the David Suzuki Foundation and the Assembly of First Nations, hunting is often integral to many First Nations as much for its role in strengthening knowledge and relationships, as for providing nutrition and recreation, meaning, health and wellness.

As the report notes: "...[T]he sharing of the harvest is an important source of nutrition and satisfaction for recipients, and a source of respect for generous harvesters.... Economic valuation of this sharing would almost certainly underestimate the true value and motivations for such social institutions."

[a] Kulshreshtha, S.N., and Loewen, K.G. 1997. "Value of Wilderness Protection in Saskatchewan: A Case Study of Existence Values." In: Sustainable Forests: Global Challenges and Local Solutions. Haworth Press.

[b] M.K.Haener and W.L.Adamowicz, "Regional Forest Resource Accounting; a northern Alberta case study," Canadian Journal of Forest Research 30 (2000).

[c] The Cultural and Ecological Value of Boreal Woodland Caribou Habitat, davidsuzuki.org/publications/downloads/2012/Report-Caribou.pdf

In a 2012 northern Alberta study, the replacement value of First Nations land subsistence foods and materials was estimated to range from $6,875 to $15,126 per household for northern communities.

PHOTO COURTESY ZACK EMBREE, *FRACTURED LAND* DOCUMENTARY

Halfway River is an ancestral gathering place for Dane-zaa families that is still used regularly. Traditional use of the area includes cultural sites for permanent camping and habitation, burials, sacred areas, oral histories, preferred fishing areas for bull trout and significant ungulate winter range.

Moberly River values include ancestral gathering places that are still used on both sides of the river, including camping and habitation areas, trails and associated oral histories.

Hudson's Hope was another ancestral gathering place for Dane-zaa families, especially for Halfway River and West Moberly First Nations (formerly the Hudson's Hope Band). It was and still is used as a permanent camping and habitation area. There are multiple burial sites, sacred and ceremonial sites, preferred fishing areas and associated oral histories, including the signing of Treaty 8.

These cultural values are irreplaceable, so it is difficult to place a monetary value on them.

5.5.2 FARMLAND LANDSCAPE CULTURAL VALUES

The value of farmland landscapes was reported for the Fraser Valley in a 2007 study in Abbotsford, B.C. Abbotsford residents indicated that they were willing to pay $113 (2012 $) per hectare per year to protect farmland landscapes.[112] In order to transfer a value for the study area, the total value reported in the original study ($6.4 million/year) was converted to a per-household value ($162.83/hhld/year), based on the number of households in the original study area of Abbotsford. The per-household value was then transferred to the study area, and adopted as the cultural value for farmland landscapes in the Peace River Watershed. The number of households in the study area (20,935 households) was estimated based on the study area's approximate population. Therefore, the total value was an estimated $3.4 million (20,935 hhlds multiplied by $162.83), or an annual value of $9.38 per hectare of farmland ($3,408,781 / 363,230 ha), including annual cropland and perennial cropland and pasture.

112 *Public Amenity Benefits and Ecological Services Provided by Farmland to Local Communities in the Fraser Valley: A Case Study in Abbotsford, B.C.* 2007. Strengthening Farming Report. File Number 800.100-1. B.C. Ministry of Agriculture and Lands.

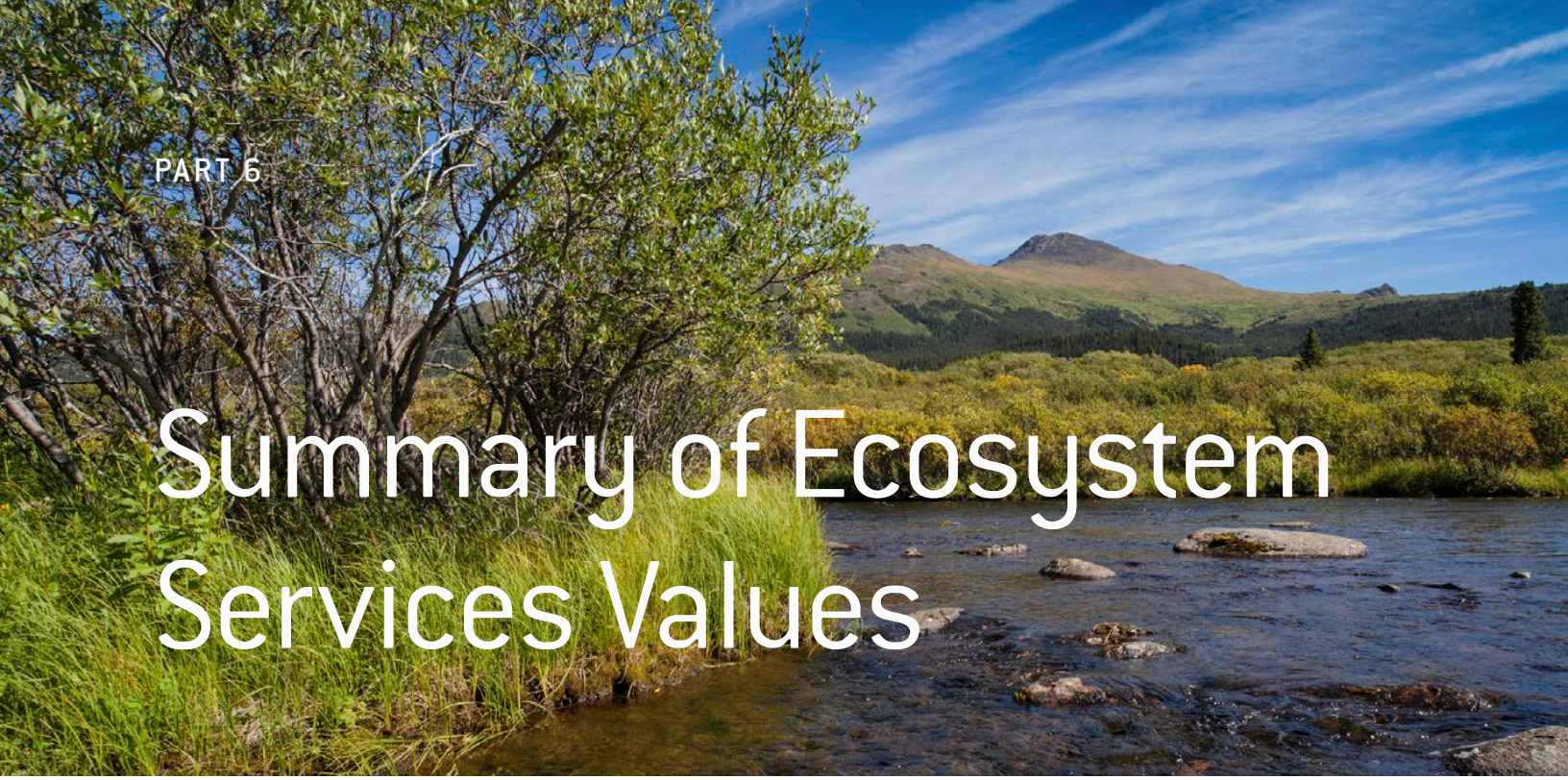
5.5.2 WILDERNESS PROTECTION CULTURAL VALUE

Non-use existence values for the protection of wilderness were considered within the study area. The results of a B.C. province-wide mail survey that was undertaken to determine the value that residents place on wilderness protection were used.[113] The survey asked a referendum-type question regarding how much more taxes and fees households would be willing to pay to double protected wilderness terrain (defined as roadless, undeveloped areas) across the province. This survey found that B.C. households were willing to pay, on average, between $108 and $130 annually ($138 to $166/year in 2012 $). An average of the two values, $152/hhld/year (2012 $), was used, with an estimate that about 50 per cent of the population of the PRW would be willing to pay this amount (approximately 54 per cent of residents returned their survey). Given the average value of $152/hhld/year, it was estimated that the willingness to protect additional wilderness in the PRW was a conservative $1.6 million per year, based on only 50 per cent of the population, or $0.76/ha/year (for the forests greater than 100 years old; 2,081,807 hectares).

It was estimated that the value of the willingness of B.C. residents to pay to protect additional wilderness in the Peace River Watershed was a conservative $1.6 million per year.

PHOTO COURTESY DON HOFFMANN

113 Reid, R., Stone, M., and Whiteley, T. 1995. *Economic Value of Wilderness Protection and Recreation in B.C.* WP-6-012. BC Ministry of Environment, Lands and Parks.



PART 6

Summary of Ecosystem Services Values

THE TOTAL ECOSYSTEM SERVICES VALUE reported is incomplete because it was not possible to quantify and value all of the ES provided by the study area's ecosystems. However, using the ecological and economic data that were available, several values were estimated for key ES. The ES values included in this valuation were water supply, air filtration, carbon storage, carbon sequestration, flood control, water filtration, erosion control, habitat, recreational and cultural services. The total annual value for carbon stored in the study area was estimated at $6.7 billion to $7.4 billion per year (central values). The total annual value for all the other ecosystem services was estimated to range from $879.4 million per year ($167.65/ha/year) to $1.74 billion per year ($332.73/ha/year), with a central value of $1.2 billion per year ($231.60/ha/year) (Table 9 on page 54).[114] Carbon storage, carbon sequestration and the habitat value of wetlands accounted for the greatest value per hectare. Carbon storage was reported separately because while it is an ecosystem service, it is a fixed asset that was annualized for reporting purposes. This value will inevitably become more mainstream as reducing degradation and deforestation develops as a financial mechanism to mitigate climate change.

The total annual ecosystem services values by land cover type are provided in Table 10 on page 55. The values by land cover type range from $249 per hectare for water to $3,455 per hectare for treed wetlands, based on our reported central values. Table 10 provides the annual values excluding the carbon storage annual value, ranging from $9 per hectare for annual cropland to $883.21 per hectare for treed wetlands.

Figure 5 on page 56 illustrates the distribution of ecosystem service values across the Peace River Watershed, as valued in the study. The values in Table 10 were used as the average annual value per hectare for each land cover type.

In finance, the net present value (NPV), or net present worth, is the total value of incoming annual value over a set amount of time, discounted over the time period at a set rate. In other words, the NPV compresses a stream of future benefits into a single present value amount. The NPV can be calculated for a specific time period using different discount rates. Discount rates are commonly used to assess the economic benefits of investment for decision-making. Benefits are discounted over time to reflect: 1) that people generally value

The ecosystem service values included in this valuation were water supply, air filtration, carbon storage, carbon sequestration, flood control, water filtration, erosion control, habitat, recreational and cultural services.

PHOTO COURTESY ZACK EMBREE, *FRACTURED LAND* DOCUMENTARY

114 Each annual value per hectare was calculated by dividing the total ES value by the total land cover area (e.g., for central value: $7.42 billion / 5,245,370 hectares). The total land cover area used for valuation excludes: unclassified land, snow/ice, rock/rubble, exposed land, developed land and cloud cover area (366,429 hectares).

TABLE 9: SUMMARY OF THE ECOSYSTEM SERVICES VALUES FOR THE PEACE RIVER WATERSHED STUDY AREA

Ecosystem service	Annual value $/hectare/year (2012 Cdn$)	Total annual value $/year (2012 Cdn$)
Water supply	$32.60	$2,502,441
Air filtration by trees	$3.51	$12,684,230
Forest ecosystem carbon storage (1.14 billion tonnes based on BC VRI forest age/carbon analysis; 948.6 million tonnes using average/ha and AAFC data)	Central value $1,175.69 ($4.48/tC) $460.19 (treed wetland – aboveground biomass only)	Range from $1.56 billion to $8.5 billion; central value $4,425,760,501 to $5,092,465,112
Wetland soil carbon storage (253.9 million tonnes)	$715.24 to $2,453.85	Range from $401 million to $1.89 billion; central value of $1,137,249,649
Other soil carbon storage (261.9 million tonnes)	$921.32 (grassland) $1,073.77 (pasture) $1,552.03 (shrubland) $1,181.55 (cropland)	Range from $413.5 million to $1.95 billion; central value of $1,172,829,309
Carbon sequestration	$138.08 (forest) $33.42 (wetland) $56.20 (shrubland/ grassland/ perennial cover)	Range from $285.5 million to $1.15 billion; central value of $620,855,368
Wetland flood control, water supply, nutrient recycling	$256.67 (wetland)	$133,157,316
Water filtration	$6.23 (forest, treed wetland)	$22,529,524
Erosion control/Sediment retention	$6.60 (grassland/perennial cover)	$4,467,440
Waste treatment	$27.93 (perennial cover/grassland) $54.10 (wetland)	$46,970,791
Pollination	$43.63 (shrubland/ grassland, perennial cover/pasture)	$39,895,056
Habitat	$379.43 (wetlands) $41 (perennial cover/pasture)	$206,744,044
Recreation	$21.47 (forest, wetland, shrubland, grassland) $215.97 (water)	$119,738,498
Cultural values	$9.38 (farmlands) $0.39 (protection of forest, wetland)	$5,258,881

TABLE 10: SUMMARY OF THE ECOSYSTEM SERVICES VALUES BY LAND COVER TYPE (2012 $)		
Land Cover Type	Annual value (excluding carbon storage values) $/hectare/year	Annual Value (including carbon storage values) $/hectare/year
Forest	$169.34	$1,345
Shrubland	$121.35	$1,673
Grassland	$155.88	$1,077
Treed wetlands	$883.21	$3,455
Shrub wetlands	$745.13	$3,199
Grass/herb wetlands	$745.13	$1,460
Water	$248.57	$249
Annual cropland	$9.38	$1,191
Perennial cropland/pasture	$184.75	$1,259

immediate benefits over benefits in the future; and 2) manufactured capital depreciates over time resulting in lower values in the future.

Over a 50-year period at 3 per cent, the central NPV was $204.6 billion (a low of $83.7 billion to a high of $333.7 billion); at zero per cent, the central NPV was $397.5 billion (a low of $162.6 billion to a high of $648.5 billion); and at five per cent, the central NPV was $145.1 billion (a low of $59.4 billion to a high of $236.8 billion). The central NPV per person was estimated at $3.9 million per person (central value at 3% discount rate), with a range of $2.8 million to $7.6 million per person (central value at 5% and 0% respectively). Without carbon storage included, the central NPV was 31.3 billion at 3 per cent, 60.7 billion at zero per cent, and $22.1 billion at 5 per cent. Therefore, the central NPV per person was 597,283 , with a range from 423,792 per person to $1.2 million (central value at 5% and 0% respectively).

FIGURE 5: AVERAGE ECOSYSTEM SERVICE VALUES BY LAND COVER TYPE IN THE B.C. PEACE RIVER WATERSHED (INCLUDES FOREST CARBON VALUES)

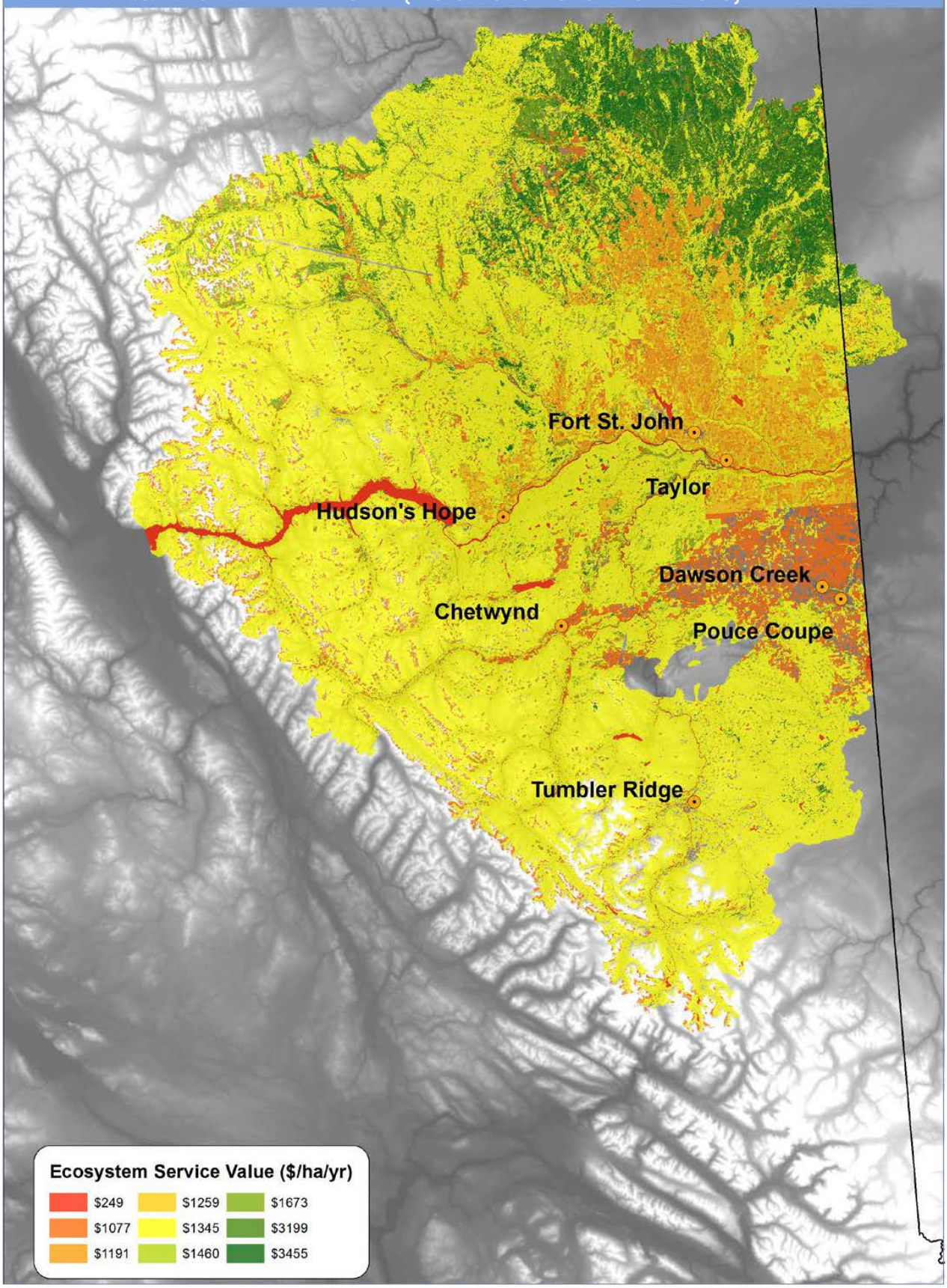
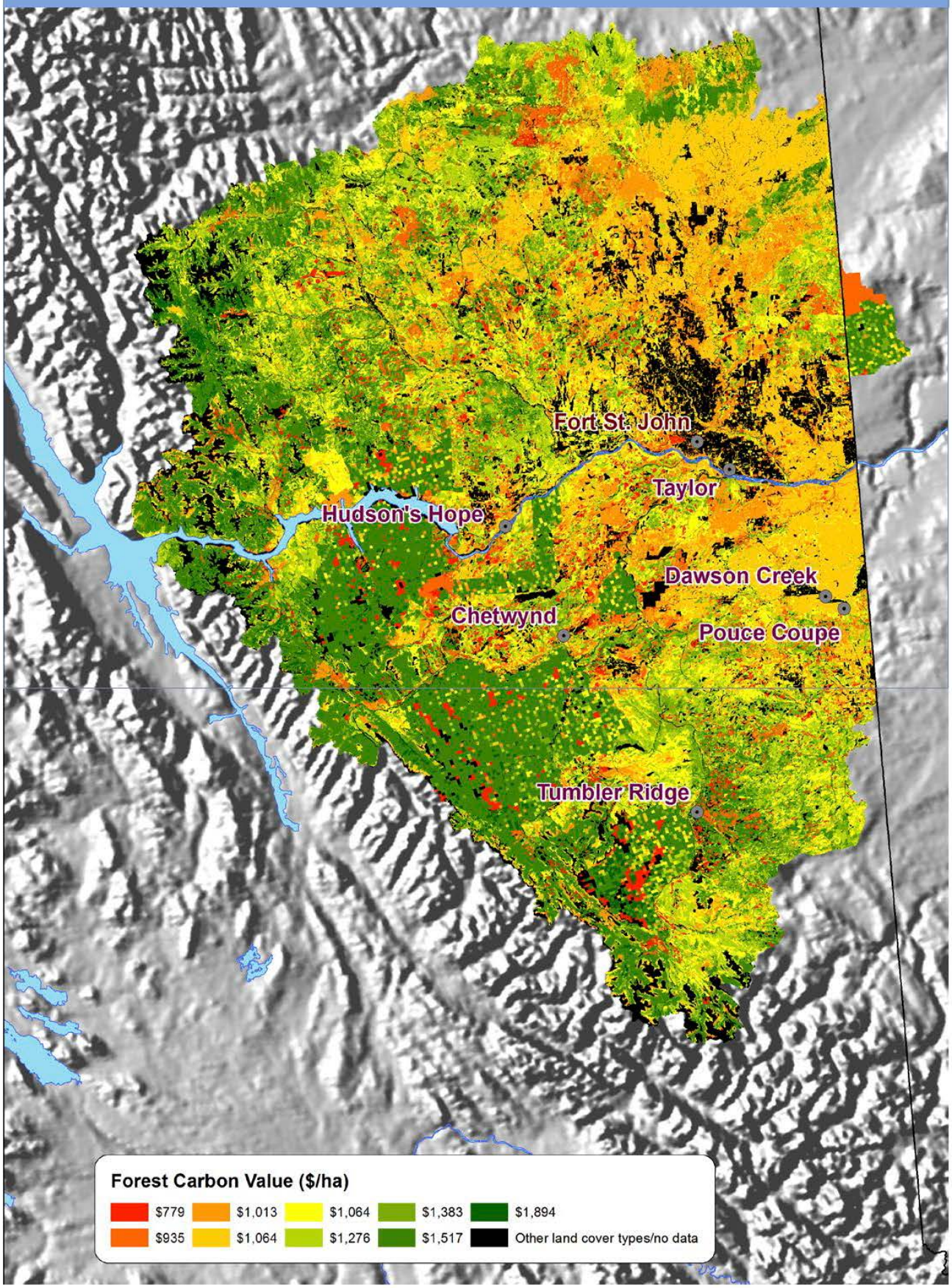
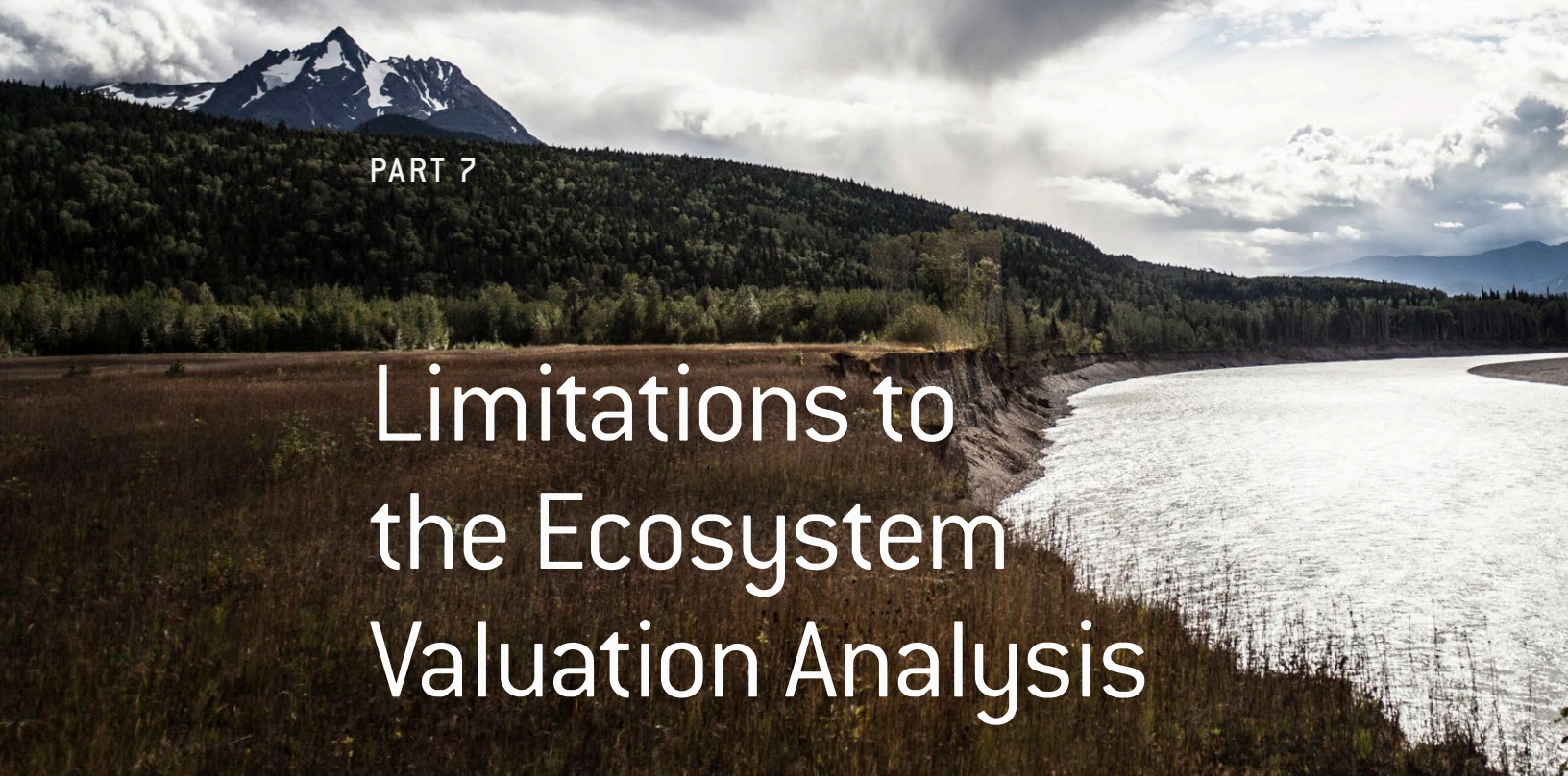


FIGURE 6: CARBON VALUES BY FOREST AGE CLASS FOR B.C. PEACE RIVER WATERSHED





PART 7

Limitations to the Ecosystem Valuation Analysis

In this report, the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value.

PHOTO COURTESY ZACK EMBREE, *FRACTURED LAND* DOCUMENTARY

THE RESULTS OF THIS FIRST ATTEMPT to assign monetary value to the ecosystem services provided by the PRW in B.C. have important and significant implications for the region's future land-use planning, cumulative effects analysis and the restoration and management of the area's natural capital. Ecosystem services produce enormous economic value to society, although valuation exercises do have limitations that must be noted. In this report, the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value.

Valuation techniques in general are uncertain, resulting from gaps in knowledge about ecosystem dynamics, ecosystem function and services, and technical issues. In the case of a value transferred from a previous study or meta-analysis, the analysis estimates the economic value of a given ecosystem (e.g., wetlands). Like any economic analysis, this methodology has strengths and weaknesses. For example, per-hectare values assessed for one location may be different based on the type of ecosystem, the web of biodiversity and species present, the climate, the population size and the human preferences for use and non-use values.

According to economic theory, even within a single ecosystem, the value per hectare depends on the size of the ecosystem. For example, the theory of supply and demand applied to ecosystem services would mean that as the size of the ecosystem or the flow of ecosystem services decreases, the per hectare value would be expected to increase and vice versa. In other words, the marginal cost per hectare is generally expected to increase as the quantity supplied decreases. However, it is important to remember that ecosystems do not behave like markets. When we value ecosystem services, we are valuing ecosystem functions. Ecosystems generally do not function well as they diminish in size and quality. So, although the value for the demand of an ecosystem service may go up as the availability of an ecosystem type dwindles, it does not necessarily reflect the true value of the ecosystem service supplied since the quality or integrity of the service may have diminished. In fact, the functionality of ecosystems is dependent on inter-relationships within functional units such as watersheds, which are compromised once below a certain threshold of ecosystem cover (e.g., percentage of forest cover in a watershed).

This study reports average values per hectare and aggregated total values. Gathering the information needed to estimate all of the specific values for each ecosystem service for every ecosystem within the study area was not feasible. Therefore, the full value of all the wetlands, forests and other ecosystem types in the study area could not be ascertained.

In general, valuations of ecosystems in a large geographic area cannot be undertaken in terms of an exchange value, because it is improbable that a transaction would result in selling or buying the whole area. Therefore, the average value estimates for large areas, as opposed to marginal unit values per hectare, are more comparable to national income account aggregates and not exchange values.[115] For example, the GDP calculates aggregate values for public goods for which no market transaction is possible. The value of ecosystem services in large geographic areas is comparable to these kinds of aggregates. A large, complex area such as the Peace River Watershed is suited to this approach. The use of average ecosystem values has also been criticized based on the argument that ecosystems vary from region to region. Although each forest or wetland ecosystem is unique in some way, ecosystems of a given type have many similar characteristics.

7.1 Geographical Information Data Limitations

This valuation approach involves assigning values to land cover types, which are reliant on the quality, accuracy and categorical precision of land cover datasets. GIS data layers are increasingly accurate, but are generally not current given the time and expense of updating data sources. Therefore, they may be out of date due to land-use changes that occurred after the data was sourced, inaccurate satellite readings and other factors.

The ecological integrity and level of ecosystem functionality is difficult to measure using GIS data. It is possible that ecosystems identified in land cover data may have greater or diminished ecological integrity, and therefore may provide higher or lower values than those assumed by this analysis or by the primary study's valuation in the case of transferred values. This factor could result in an underestimate or overestimate of the current values. However, because we were unable to value many of the ecosystem services in this study, the overall values would be an underestimate.

Many ecosystem services valuations assume spatial homogeneity of services within ecosystems. In other words, by applying an average value across a landscape, the analysis is based on the assumption that each hectare of a land cover type, such as forest, produces the same ecosystem services. Although this is not true, it is important to note that average values often reflect a mid-range of services that takes this into account, especially when meta-analysis values are used. However, there is a need for more dynamic spatial analyses for ecosystem services that include variance across the landscape. For example, this study used forest age class spatial data to assign a range of carbon storage values based on the forest area for each age class.

One of the greatest limitations in ecosystem valuations is the lack of ecosystem services studies, especially at the regional and site-specific level. This results in a significant underestimate of the value of ecosystem services. More complete valuation coverage would increase the values shown in this report.

Willingness to pay (WTP) survey-based values were used for some of the valuations in this report. There are limitations to WTP estimates because they are based on the current willingness to pay or proxies, which are limited by people's incomes, perceptions and knowledge base. This places a bias in the valuation output.

One of the greatest limitations in ecosystem valuations is the lack of ecosystem services studies, especially at the regional and site-specific level. This results in a significant underestimate of the value of ecosystem services.

IMAGE: GOOGLE EARTH SATELLITE

115 Farber, S., and Howarth, R.B. 2002. "The Dynamics and Value of Ecosystem Services: Integrating Economic and Ecological Perspectives: Accounting for the Value of Ecosystem Services." *Ecological Economics*. 41:421-429.

PART 8

Conclusions

The total annual value for carbon stored in the Peace River Watershed was estimated at $6.7 billion to $7.4 billion per year (central values); and the total value for the other ecosystem service (ES) values was estimated to range from $879.4 million to $1.74 billion per year in economic benefits.

PHOTO COURTESY ZACK EMBREE, FRACTURED LAND DOCUMENTARY

THE PEACE RIVER WATERSHED is a region rich in culture, history and natural capital. Its natural areas provide a plethora of ecosystem services that are essential to local communities, First Nations, farmers, and wildlife. These services include freshwater supply, water regulation, clean air, wildlife habitat, climate regulation, food production, cultural well-being and recreational activities.

However, the cumulative effect of resource development across the watershed has had an impact on a large proportion of the area's ecosystems. For example, ecological fragmentation between 1974 and 2010 had an impact on approximately 67 per cent of the watershed. The strain on the region's natural capital will only increase as oil and gas exploration and development, road building, pipeline expansion and logging continue across the landscape. In addition, the proposed large-scale Site C dam would impose a third dam site on the Peace River. The proposed hydroelectric development would flood a significant portion of the valley, affecting critical wildlife habitats for local and migratory species, the highly productive farmlands provided by the valley's unique microclimate, as well as ancestral and culturally significant First Nations lands.

This study examined the B.C. Peace River Watershed's ecosystems, including its forests, fields, wetlands and waterways, and developed economic values for many of the key ecosystem services (ES) they provide. The total annual value for carbon stored in the study area was estimated to range from $6.7 billion to $7.4 billion per year (central values); and the total value for the other ES values was estimated to range from $879.4 million ($167.65/ha/year) to $1.7 billion ($332.73/ha/year), with a central value of $1.2 billion per year in economic benefits, ($231.60/ha/year). Over a 50-year period, the net present value of the total ecosystem services values was estimated at a central rate of $204.6 billion at a discount rate of 3 per cent; $3.9 million per person. (The value per person is high because the area has low population density.) The greatest value among the ES valuations was for carbon storage. Benefits from the carbon stored in the Peace River Watershed's ecosystems reach beyond the local population to regional, national and international beneficiaries since carbon storage is a global system that helps regulate the climate.

The ecosystem services values are average values per hectare aggregated across the study area. We also considered how these values might be adopted at a smaller scale for land-use decision-making. For example, using our forest age carbon analysis, it was estimated that the cost of clearing one hectare of forest for other land use would result in a loss of stored carbon ranging from approximately 14.3 tC/ha (for a 10- to 20-year-old forest) to 263.3 tC/ha (for a 250-year-old or greater forest). Thus, the cost was estimated to range from $1,641.23/ha or $30,334.53/ha (depending on forest age), based on the social costs incurred due to the release of carbon ($115.23/tC; see Section 5.2.2.1), or $590.65/ha to $10,916.93/ha based on the option of a carbon offset price. In addition, the average aboveground carbon sequestered per year was estimated at 1.18 tC/ha/year, worth an estimated $138.08/ha/year, based on the average SCC, or $49.03/ha/year based on the option of a carbon offset price. Thus, the additional cost for clearing one hectare of forest could be estimated to be from $49.03 to $136/ha/year in terms of forgone annual carbon sequestration.

A marginal cost for the loss of forest cover was also calculated in terms of water quality, based on the economic model used in this study. For example, if forest cover across the PRW declined by 10 per cent, the cost for water treatment for local communities was estimated to increase to $3.34 from $2.78 per cubic metre. Used as a proxy to value the water filtration services provided by forests, the marginal value of a 10 per cent loss was an estimated $4.83/ha/year. If forest cover declined by one per cent, the estimated marginal value was $2.96/ha/year.

The intent of this report was to give a baseline assessment of the ecosystem services provided by the Peace River Watershed within B.C. The values are incomplete but they do deliver a meaningful estimate of the magnitude of the existing ecosystem values that local communities, First Nations and policy decision-makers can use to reflect on the cost of land-use change and ecological fragmentation in the study area. The values also reflect the economic benefits of protecting and restoring the region's ecosystems, farmlands and cultural heritage. Detailed site valuations for specific ecosystem functions should be undertaken to provide more precise values of marginal changes due to site-level ecosystem alteration, destruction or investment.

It is hoped that this report will encourage discussion about how natural capital in British Columbia and Canada is valued — and undervalued. Decision-makers and the public are encouraged to use this report, and other natural capital valuations, to inform discussion on how best to protect and restore the Peace River Watershed region's ecological integrity and ensure a sustainable future.

Future research will further consider the marginal values of changes in land use in the Peace River Watershed.

Decision-makers and the public are encouraged to use this report, and other natural capital valuations, to inform discussion on how best to protect and restore the Peace River Watershed region's ecological integrity and ensure a sustainable future.

PHOTO COURTESY DANDYFSJ/ FLICKR CREATIVE COMMONS

PART 9

Future Research Recommendations

Given the rapid development across the PRW, it would be prudent to establish natural capital accounts that provide a yearly account of the change in land cover/land use and the impacts of industrial development.

PHOTO COURTESY KYLEWITH/ FLICKR CREATIVE COMMONS

1. Spatial analysis of the human impacts on ecosystems and the supply of ecosystem services should be undertaken using the Global Forest Watch Canada and David Suzuki Foundation report *Atlas of Land Cover, Use and Changes Study*[116] and the baseline valuation study reported here. This should focus on establishing the specific land cover types that have been affected by industrial and human activities within the Peace River Watershed (PRW) in B.C.
2. Research should be undertaken to further develop the marginal values for changes in land use within the PRW. These values will be helpful for site-level project-based management.
3. Further analysis could be undertaken to evaluate different future scenarios and the supply of ecosystem services using GIS-based tools such as InVest.
4. The resolution and detail for land cover data could be improved. It is recommended that a more detailed, high-resolution land cover dataset for the province be developed to enable more detailed study on the current distribution of habitat, ecosystems, land use types, recreational areas and land cover.
5. The state or ecological integrity of the ecosystems or land cover types could not be assessed. It would be helpful in the future to include a rating of the fragmentation or another measure of ecological integrity within GIS land cover datasets.
6. Cultural studies should be undertaken to document the traditional uses of the natural ecosystems within the PRW by First Nations. In addition, it would be helpful to document the subsistence uses and products utilized by the study area's populations.
7. Given the rapid development across the PRW, it would be prudent to establish natural capital accounts that provide a yearly account of the change in land cover/land use and the impacts of industrial development. The total and marginal value for ecosystem services could be part of this account, based on this baseline study.

116 Lee and Hanneman, supra note 1.

APPENDIX 1

Policy Recommendations

by Dr. Faisal Moola, Director General of David Suzuki Foundation's Ontario and Northern Canada Department

1. This study demonstrates the great value that natural areas provide in terms of ecosystem services and natural capital assets. The following policy changes are therefore recommended:

   a. Restoration of natural ecosystems should occur to benefit habitat services, recreational and cultural values. For example, the protection and restoration of wildlife habitat threatened by industrial development would help threatened species in the Peace Region, such as woodland caribou, recover.

   b. The existing network of protected areas in the region should be expanded from 4 per cent to ensure that protected areas represent the diversity of ecosystems within the region, serve as ecological benchmarks and as safeguards against climate change.

   c. Future protected areas should include the establishment of K'ih tsaa?dze Tribal Park and other important areas identified by local First Nations for careful management, such as the Peace Moberly Tract (PMT) and the Area of Critical Community Interest (ACCI) in the Peace River Valley.

   d. Existing and future industrial activities in the Peace Region must be managed through a cumulative impacts planning approach that ensures that the cumulative impacts of development do not impair ecosystems such that they are no longer able to function and provide a full suite of ecosystem services.

   e. The cumulative impacts of ongoing industrial and human development, the cultural values of farming communities, the legal and cultural interests of First Nations, the ecosystem values of the PRW and the unique opportunities for farmland resources in the Peace River Valley need to be seriously considered in making an informed decision regarding the proposed Site C Dam.

Related Ecosystem Service Valuation Studies

1) A report for the B.C. Lower Mainland assessed the total value provided by the study area's natural capital at an estimated $5.4 billion per year, or about $3,959 per hectare.[117] This is an estimated value of $2,449 per person or $6,368 per household each year, based on statistics from the 2006 census.[118] The top three benefit values provided by the study area's ecosystem services were: 1) climate regulation resulting from carbon storage by forests, wetlands, grasslands, shrublands and agricultural soils; 2) water supply due to water filtration services by forests and wetlands; and 3) flood protection and water regulation provided by forest land cover. Climate regulation provided an estimated value of $1.7 billion per year, while water supply provided an estimated $1.6 billion per year, and flood protection and water regulation provided an estimated $1.2 billion per year. The other values determined for the study area included the following benefits: clean air, waste treatment, pollination, salmon habitat, recreation and local food production.

2) Two Canadian studies assessed the economic value of natural capital for Canada's boreal region. The non-market value for the Mackenzie Region's natural capital was estimated at $570 billion per year (an average of $3,426 per hectare), 13.5 times the market value of the region's natural resources.[119] The carbon stored by the Mackenzie watershed was estimated at a value of $339 billion ($820/ha/year).

3) Two recent studies assessed the importance of having farmlands in close proximity to communities. In 2007, a case study by the B.C. Ministry of Agriculture surveyed Abbotsford residents on the value of the benefits provided by farmland in their community. The study found that the present value of the stream of public benefits and ecological services provided by each hectare of farmland was an estimated $29,490 per acre ($72,814 per hectare).[120] This value was estimated to be significantly greater than the value of public benefits from industrial land use ($14,000 per acre), or residential land use ($13,960 per acre). A similar study was undertaken in 2009 to estimate the value of benefits provided by farmland in Metro Vancouver (formerly the Greater Vancouver Regional District). The study

117 Wilson, S. 2010. Natural Capital in B.C.'s Lower Mainland: Valuing the benefits from nature. David Suzuki Foundation and Pacific Parklands Foundation. Vancouver, Canada.

118 Analysis of the 2006 census reported that 2.2 million people live within the study area. Number of households was estimated based on total population from the 2006 census, assuming that there are approximately 2.6 people on average per household.

119 Anielski, M., and Wilson, S. 2007. *The Real Wealth of the Mackenzie Region: Assessing the Natural Capital Values of a Northern Boreal Ecosystem*. (2009 Update). Canadian Boreal Initiative. Ottawa, Canada.

120 *Public Amenity Benefits and Ecological Services Provided by Farmland to Local Communities in the Fraser Valley: A Case Study in Abbotsford, B.C*. 2007. Strengthening Farming Report. File Number 800.100-1. B.C. Ministry of Agriculture and Lands.

was based on a household survey and evaluated the public value of wildlife habitat and groundwater recharge. The results estimated that the value of farmland in Metro Vancouver was about $58,000 per acre per year; this is about 10 times greater than the market value of farm products ($5,750 per acre).[121]

4) In 2008, Earth Economics undertook a study to assess the value of the goods and services provided by the Puget Sound Basin's natural capital. Puget Sound is located south of British Columbia's Lower Mainland region in Washington state. The net present value for drinking water, food, wildlife, climate regulation, flood protection, recreation and esthetics, among other ecosystem services, was between $305 billion and $2.6 trillion (at a 3 per cent discount rate over 100 years).[122] The total area of the Basin is reported as 10.6 million acres (4.3 million hectares), so the net present value per hectare was approximately $71,000 to $605,000 per hectare.

5) In Central Canada, two regional studies have assessed the non-market values of natural capital. One report quantified the value of the ecosystem services provided by southern Ontario's Greenbelt. This report estimated the value of the region's natural capital at $2.6 billion annually (an average of $3,500 per hectare) and almost $8 billion since the Greenbelt was established.[123] A similar report for the Credit Valley Watershed reported that the watershed provides at least $371 million each year for local residents.[124]

121 Robbins, M., Olewiler, N., and Robinson, M. 2009. *An Estimate of the Public Amenity Benefits and Ecological Goods Provided by Farmland in Metro Vancouver*. Fraser Basin Council and Simon Fraser University. B.C. Ministry of Agriculture and Lands.

122 Batker, D., and Kocian, M. 2010. *Valuing the Puget Sound Basin: Revealing our Best Investments*. Earth Economics. Tacoma, Wash.

123 Wilson, S.J. 2008. *Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Servi*ces. Greenbelt Foundation and David Suzuki Foundation.

124 Kennedy, M., and Wilson, J. 2009. *Natural Credit: Estimating the Value of Natural Capital in the Credit River Watershed*. The Pembina Institute and Credit Valley Conservation.

APPENDIX 3

Land Cover Types and Associated Services

ECOSYSTEM/LAND COVER TYPES AND ASSOCIATED ECOSYSTEM SERVICES		
Ecosystem/ land cover class	Associated ecosystem services (typology of ES from TEEB)	
Wetlands	Food Water supply Carbon storage Flood control Waste processing Storage of freshwater Regulation of water flows	Waste treatment Maintenance of life cycles of migratory species Habitat Recreation Cultural/heritage conservation
Lakes & Rivers	Food Water supply Waste treatment Erosion prevention Habitat	Maintenance of life cycles of migratory species Recreation Cultural/heritage conservation Cultural services
Forests	Food Water supply Air quality regulation Carbon storage Flood control Water filtration	Erosion prevention Soil fertility Pollination Biological control Habitat Recreation Cultural services
Grassland & Shrubland	Food Water supply Air quality regulation Carbon storage Flood control Water filtration	Erosion prevention Soil fertility Pollination Biological control Habitat Recreation Cultural services
Agricultural lands	Food Carbon storage Flood control Erosion prevention Soil fertility	Pollination Biological control Habitat Recreation Cultural services

APPENDIX 4

Total Economic Value Framework

Within the Total Economic Value (TEV) framework, values for ES are derived from market values provided by market transactions that are directly related to the ES where available (i.e., direct market valuation approaches). If direct market value is not available, monetary value information can be obtained from other market transactions that are indirectly associated with the ES (i.e., revealed preference approaches). If both direct and indirect price information on ES are unavailable, survey-based information based on a hypothetical market or demand for an ES may be created to determine values (i.e., stated preferences approaches).[125]

TOTAL ECONOMIC VALUE FRAMEWORK FOR EG&S

Market valuation approaches are mostly used for provisioning services such as food, water and raw materials. This is because many of these goods are sold in markets. Cost-based approaches for valuation are based on the costs incurred if ES decline or diminish due to a loss or damage to natural capital (i.e., ecosystems, natural land covers). These approaches include: 1) avoided cost methods, which refer to the costs that would be incurred if ES decline due to degradation or removal of natural land cover; 2) replacement cost methods, which refer to the replacement cost of ES with artificial technology; and 3) mitigation or restoration cost methods, which is the cost of mitigating the effects of or restoring lost ES.

Production function-based approaches estimate how much an ES contributes to a marketed good or service (e.g., maintenance of water quality provides a certain amount of fish for fisheries). These types of valuations are related to the contribution of an ES to either income or productivity.[126] This approach generally uses scientific information on an ES and then examines the impacts of a change in the supply of the ES on economic activities.

Revealed preference valuation techniques are based on values that are "revealed" by people's choices. There are two main approaches: 1) the travel cost method (TC); and 2) the hedonic pricing approach (HP). The TC method is most likely to be used to value recreational activities related to natural areas. This value is based on the costs associated with recreation (i.e., direct expenses and opportunity costs of time, etc.). The HD approach accesses market-related information regarding the impact of proximity to environmental attributes on increased value (e.g., the higher value of houses near green space or waterfront).

Stated preference approaches create a hypothetical market and demand for ES using surveys that provide options in terms of changes in a particular ES. These methods can be used for use and non-use values. There are three main types, including: 1) contingent valuation method (CV); 2) choice modelling (CM); and 3) group valuation (GV). The CV method uses questionnaires to gather information on how much people would be willing to pay to increase or enhance the provision of an ES, or how much they would be willing to accept for the loss or degradation of an ES. CM models the decisions of individuals who are asked to make trade-offs, with two

125 TEEB (2012). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*. Edited by Pushpam Kumar. Routledge, Abingdon and New York.

126 Barbier, E.B. et al. (2009). "The Valuation of Ecosystem Services", in Naeem, S. et al. (eds). *Biodiversity, Ecosystem Functioning, and Human Well-being: An Ecological and Economic Perspective*. Oxford University Press. Oxford, U.K.

or more choices, between options with shared attributes of the ES to be valued. GV combines CV or CM with processes that integrate socio-political issues such as social justice, and non-human values. Stated preference methods are often the only way to estimate non-use values.

LIMITATIONS TO THESE VALUATIONS INCLUDE THE FOLLOWING:

1. Direct market values can be distorted because of subsidies or other aspects that make the market uncompetitive. The result is prices can be inaccurate or underestimated and therefore unreliable for decision-making.
2. Revealed preference values such as travel cost and hedonic pricing can be misleading as they rely on markets providing accurate values as well as the assumption that the values represent the Ecosystem Goods and Services (EG&S) and the pseudo-market value assessed.
3. Stated preference values are based on hypothetical choices and therefore may not be accurate because people might not make the same choices if faced with the same changes or costs in real life.

In order to estimate ES values, value transfer is often adopted because the ecological and economic studies necessary to provide non-market valuations are often not available for each study area. Such studies are limited because of the cost of undertaking them given the expense and time required. Value transfer is the process whereby an ES value is estimated using a valuation for the same EG&S transferred from another study area. Value transfers are taken from study sites that are close matches in terms of socio-economics, demographics and/or ecology.

Value transfers (VT) can take the form of: 1) unit VT; 2) adjusted unit VT; 3) value function transfer; and 4) meta-analytical function transfer. Unit VT involves estimating the value by multiplying the mean unit value from the original site by the quantity of the ES at the transfer site (e.g., value/household or value/unit area). Adjusted unit transfer involves making adjustments to transfer values that reflect variance at the transfer site. Value function transfer involves transferring travel cost, hedonic pricing or stated preference values, with adjustments based on the transfer site plugged into these values (i.e., population, distance, market prices). Meta-analytical function transfer uses values based on multiple study results with adjustments for the characteristics of the transfer site. These values are based on a collection of studies for a particular ES or ecosystem type. They include a more varied sample of values that take into account different site characteristics and valuation approach methods compared to a value transferred from a single study.

PHOTO COURTESY DON HOFFMANN

British Columbia's Peace River Watershed is a vast region of boreal forest, rushing rivers, and rich farmland. It is also the ancestral home of the Dane-Zaa First Nations and several farming and resource-dependent communities. The well-being of the region's communities are intimately tied to the health of the Peace river and its surrounding ecosystems, which provide ecological benefits such as flood control, hunting and fishing opportunities, pollination services, nutrient cycling, and other ecosystem services.

This report provides the first-ever valuation of the PRW's ecosystem services and makes recommendations on how the region's natural capital should be stewarded and sustained into the future.

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