North Saskatchewan Watershed Alliance

Economic Activity and Ecosystem Services in the North Saskatchewan River Basin

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9504 – 49 Street
Edmonton AB T6B 2M9
Tel: (780) 442-6363
Fax: (780 495-0610
Email: water@nswa.ab.ca

http://www.nswa.ab.ca

The North Saskatchewan Watershed Alliance (NSWA) is a non-profit society whose purpose is to protect and improve water quality and ecosystem functioning in the North Saskatchewan River watershed in Alberta. The organization is guided by a Board of Directors composed of member organizations from within the watershed. It is designated the Watershed Planning and Advisory Council (WPAC) for the North Saskatchewan River under the Government of Alberta's *Water for Life Strategy.*

This report was prepared under contract to NSWA by John Thompson, Watrecon Consulting in collaboration with Mark Anielski, Anielski Management Inc.

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Executive Summary

In 2007, the gross domestic product (GDP) for Alberta was $256.9 billion. This represents the value of all final goods and services produced within Alberta for that year. It is generally considered to be a basic measure of the province's overall economic output and well-being. However, there is increasing recognition that the well-being of a society is based on more than just economic output. Recent studies have demonstrated that society also benefits from various ecological functions or ecosystem services (air, water and land, among others) that are not normally factored into GDP estimates. Furthermore, the ability of ecosystems to provide the full range of goods and services can actually be impaired by economic activities. Thus, there is growing recognition that sustainable development requires balancing the impacts of economic activity with the environment's ability to continue to provide ecosystem services that benefit people.

As part of the process of developing a watershed management plan for the North Saskatchewan River Basin (NSRB), the North Saskatchewan Watershed Alliance (NSWA) has expressed interest in determining the economic importance of both economic activity and ecosystem services within the basin. The objective of this study was to provide preliminary estimates of the value of services being provided by ecosystems and the value of economic activity for each of the sub-basins in the NRSB. The intent of this report is to provide some initial background information on the relative importance and values of economic activity and ecosystem services in each sub-basin. It is expected that, as the requirements for additional economic studies become apparent, this analysis will provide the foundations for future studies.

Economic Activity

In 2007 the value of economic activity (GDP) in the NSRB was estimated to be $79.1 billion, or 31% of the Alberta total. Historically, estimates of GDP at a sub-provincial level have been difficult to estimate because the requisite economic information is not collected or analyzed at a regional or local level. However, through use of a new methodology that estimates GDP based on industrial employment profiles and average GDP per job coefficients for the various industries, it was possible to estimate GDP for individual communities or regions. GDP estimates for the various sub-basins were then estimated using the industry employment profiles for the communities and rural areas within each sub-basin at the time of the 2006 census.

The resulting estimates are provided in the following table. It shows that the bulk of economic output is located in the central part of the NSRB, with 86% occurring in the Strawberry, Sturgeon, and Beaverhill sub-basins; these sub-basins also account for 89% of the population. Further assessment of the information shows that the City of Edmonton, which straddles all three of these sub-basins, accounts for 58% of GDP in the entire NSRB, followed by Strathcona County at 8%, St. Albert at 5% and Lloydminster at 2%. None of the other communities or rural areas contributed more than 1.9% of GDP in the basin. In total, economic activity in the five sub-basins upstream from Edmonton accounted for 6.3% of basin GDP while the sub-basins between Edmonton and the Saskatchewan border accounted for 7.8%.

Value of Economic Activity and Ecosystem Services in the NSRB ($ millions)

Sub-Basin	Economic Activity	Ecosystem Services	Total	Percent from Economic Activity
Cline	$20.3	$858.9	$879.2	2%
Clearwater	$167.9	$1,183.9	$1,351.8	12%
Ram	$1,390.7	$3,403.0	$4,793.7	29%
Brazeau	$192.9	$2,810.7	$3,003.6	6%
Modeste	$3,212.0	$1,893.3	$5,105.3	63%
Strawberry	$20,417.2	$861.6	$21,278.8	96%
Sturgeon	$9,455.4	$534.3	$9,989.7	95%
Beaverhill	$38,069.9	$1,187.3	$39,257.2	97%
White Earth	$1,305.5	$1,641.3	$2,946.8	44%
Frog	$1,252.4	$1,601.6	$2,854.0	44%
Vermilion	$1,755.2	$979.3	$2,734.5	64%
Monnery	$1,880.7	$715.2	$2,595.9	72%
TOTAL	**$79,120.2**	**$17,670.4**	**$96,790.6**	**82%**

Ecosystem Services

The value of ecosystem services in the NSRB is conservatively estimated to be $17.7 billion, or about $3,652 per hectare of ecological land (i.e. land that is not built-up or developed, or consists of rock or ice). This estimate was based on the mix of land cover types in the basin and in each of the sub-basins combined with estimates of the value of ecosystem services produced by each land cover type. As there are no studies that have specifically examined the functioning and value of services being produced by ecosystems in the NSRB, the study relied on value estimates drawn from similar studies undertaken elsewhere in Canada, particularly recent studies undertaken in Ontario. The study considered 10 types of ecosystem services for 14 land cover types, and found quantifiable values for 74 of the possible combinations. The resulting estimates of the total value of ecosystem services within each sub-basin are also found in the summary table.

The highest values of ecological services were attributed to coniferous forests, rivers and wetlands. The most valuable ecosystem service functions were found to be water regulation (by rivers, streams, and wetlands), water supply (by wetlands and urban rivers), disturbance avoidance (by wetlands), and recreation benefits (from a host of land cover types). Accordingly, the sub-basins at the upper end of the NSRB (the Ram and Brazeau) generated the highest value of ecosystem services. Some of the lowest values were found in the Strawberry and Sturgeon sub-basins, which are highly populated and have a high percentage of disturbed lands. The Monnery sub-basin, which has little forest and few lakes and wetlands, also generated low levels of ecosystem services.

Summary

Based on this assessment, it is concluded that the overall well-being of residents of the NSRB as measured in economic terms is on the order of $96.8 billion. This represents the value of economic activity ($79.1 billion) generated by residents of the NSRB in combination with the value of ecosystem services generated by the landscape ($17.7 billion). In six of the 12 sub-basins the value of economic activity exceeded the value of ecosystem services. These include the Strawberry, Sturgeon and Beaverhill sub-basins, which accommodated 89% of the population of the NSRB in 2006, as well as the Modeste, Vermilion and Monnery sub-basins. In the other six sub-basins, which only accounted for 4.5% of the NSRB population, the value of ecosystem services being generated by the landscape exceeded the value of economic activity. For the five sub-basins upstream of the City of Edmonton, the value of ecosystem services ($10.2 billion) was actually double the value of economic activity ($5.0 billion). Downstream from the City of Edmonton, the value of ecosystem services ($4.9 billion) was 80% of the value of economic activity ($6.0 billion).

Overall, the results of the analysis demonstrate the relative importance of ecosystem services in the upper parts of the NSRB and that, in the less populated parts of the basin, the value of ecosystem services and economic activity were reasonably similar. Only in the most populated parts of the NSRB was the value of economic activity considerably larger than the value of ecological services being generated.

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1.0 Introduction

There is increasing recognition that the economic well-being of a society is based on a combination of two factors:

- the employment and incomes resulting from economic production, and
- the benefits that society obtains from various ecological functions or ecosystem services (air, water and land, among others).

Knowledge of these two types of benefits is essential for effective management of water, land, air and other resources. Without considering both, it is possible to pursue economic development that may compromise the provision of ecosystem services, such that, on balance, a society's economic well-being may actually decline. Sustainable development involves attempting to balance the impacts of economic activity with the environment's ability to continue to provide ecosystem services that benefit people, and therefore requires knowledge of each.

The North Saskatchewan Watershed Alliance (NSWA) is in the process of developing a watershed management plan for the North Saskatchewan River Basin (NSRB). As background to developing this plan, the NSWA has commissioned various studies to better understand how the basin functions and to assess the potential implications of various watershed management strategies. In 2009, NSWA commissioned Watrecon Consulting to undertake an initial assessment of the current levels of economic activity and the provision of ecosystem services in each of the 12 sub-basins in the North Saskatchewan River watershed. The objective of the study was to prepare a preliminary estimate of the value of ecosystem services and the value of economic activity for each of the sub-basins.

This study is not intended to represent a rigorous assessment of the benefits of economic activity or of ecosystem services. There is, at present, limited information on the extent and value of economic activity in each of the sub-basins, and there is even less information on the value of ecosystem services associated with the mix of land cover in each sub-basin. Consequently, this report is intended to provide some initial background information on the relative importance and values of economic activity and ecosystem services in each sub-basin. It is expected that, as the requirements for additional economic studies become apparent, this analysis will provide the foundations for future studies.

2.0 Economic Activity

The conventional measure of the value of economic activity is gross domestic product (GDP) which reports the value of all goods and services produced in a calendar year. The gross domestic product includes only the value of final goods and services that are sold, not goods and services used to make another product. For example, GDP estimates include the value of oil being exported but not the value of oil that is used to produce gasoline or petrochemicals. The governments of Canada and Alberta annually report GDP as measures of the overall health of their respective economies.

2.1 Methodology

The challenge in estimating the value of economic activity within the NSRB or any of its sub-basins is that estimates of GDP are simply not reported at this scale. This lack of GDP information at a sub-provincial scale has always been problematic in assessing the economic effects of potential projects or for assessing the contributions of any region or community to the larger provincial economy.

To address the lack of regional GDP information, a new approach was developed that estimates GDP based on the employment by industry profile for individual communities or regions. Data on regional employment are available. The 2006 Census provides information on employment in 10 industry categories for most communities and rural areas in each-sub-basin; data for smaller communities may be suppressed due to concerns about confidentially. Furthermore, Statistics Canada has begun releasing employment by industry for individual communities using 20 categories. Thus, there is good and consistent employment information (although slightly dated) for all of the larger communities in each sub-basin.

Information from Alberta Finance can then be used to convert the labour profiles into estimates of GDP. As part of its reporting of economic multipliers for various industry categories in the province, Alberta Finance, Statistics (2009) reports the direct and indirect GDP, labour income and employment that would result from an investment of $1 million in each of 59 industry groups based on its 2005 version of the Alberta Input-Output model. This information can then be used to estimate the average GDP and average labour income per new job created in each industry in 2007.

For example, information from the most recent economic multiplier tables indicates that a $1 million investment in the oil and gas extraction industry would be expected to generate:

- $899,000 in direct and indirect GDP, of which $741,100 would be direct GDP[1]
- $154,000 in direct and indirect labour income, of which $71,600 would be direct income

[1] *These numbers have been rounded for demonstration purposes. Direct GDP is actually calculated to be $741,138 and direct employment is 0.561 jobs, such that the average GDP per job is $1,321,102.*

- 1.7 direct and indirect jobs in 2007, of which 0.6 jobs would be direct jobs

Thus, each new job in the oil and gas extraction industry is associated with direct GDP of $1.32 million and direct labour income of $127,700. So, theoretically, the total GDP for a region can be estimated by multiplying the number of jobs in each industry with the average GDP per jobs in each industry.

To test this hypothesis, the employment profile for Alberta was combined with the average GDP per job to see if the resulting estimate matched the known provincial GDP. Part of the challenge in making this calculation is that multiplier information is available for 59 industry groups, while the provincial labour information is reported for 430 separate industry groupings based on Standard Industrial Classification (SIC) codes. By matching SIC codes with the industry codes used in the multiplier tables, it was possible to determine employment estimates for 57 of the 59 industry groups used in the multiplier tables[2]. By combining the employment estimates for 2006 with the GDP per job estimates for 2007, the total Alberta GDP was estimated to be $257.4 billion[3]. GDP for Alberta in 2007, as reported by Statistics Canada, was $256.9 billion. Given that the two numbers are nearly identical, it can be concluded that this method for calculating GDP based on employment is accurate at a provincial level.

Based on this conclusion, it appears that the methodology can also be used to develop regional and sub-regional estimates of GDP. There will, however, be greater inaccuracies in estimates for regions and sub-regions. One reason is that the provincial average GDP per job estimates cannot account for any variability in output per job in different parts of Alberta. For example, the methodology assumes that someone working in the oil and gas extraction industry in the upper part of the basin will generate the same GDP as a corresponding worker in a lower part of the basin, and this may not be correct. The regional economic activity coefficients used to estimate GDP based on employment by industry are summarized inTable 1.

In addition, as noted earlier, regional employment data are only reported for 20 industries so it was necessary to collapse the 57 categories from the multiplier tables into 18 industry groups[4]. Table 2 shows how the list of 57 categories in the multiplier assessment was collapsed into the 18 industry employment categories. As a result of collapsing categories, the accuracy of the regional GDP estimates will be reduced.

A third problem is that people do not always work in the same part of the basin where they live. A review of census data for 2006 indicates that a fairly high number of rural residents commute

[2] *It was not possible to estimate employment in the non-profit institutions serving households (excluding education) and the non-profit education services industries.*

[3] *While combining values for different years (2006 employment data and 2007 GDP per job) is problematic, the reported data are the most recent and accurate information available. However, the calculated provincial GDP based on using the 2006 and 2007 information is so close to the actual 2007 provincial GDP estimates that the errors of using data from two different years is concluded to be very small.*

[4] *The multiplier tables did not have information for two of the industries listed in the employment data, so some employment industries had to be combined.*

to jobs in communities, and these communities may not be in the same sub-basins as their residences. Thus, the estimates contained in the report relate to economic activity based on the residence of the worker rather than where the work actually occurred.

Despite these methodological challenges, this approach provides a mechanism by which the economic activity in each of the 12 sub-basins can be quantified and valued. The resulting estimates of total GDP for each sub-basin are order-of-magnitude estimates of economic value that demonstrate the relative economic importance of each of the sub-basins. The information will assist basin residents and others in understanding the unique characteristics of each sub-basin and to provide a yardstick for comparing the value of ecosystem services in each sub-basin.

Table 1: Economic Activity Coefficients Used to Calculate Regional Economic Activity

Industry of Employment		Economic Activity per Job (2007)	
		Average GDP	Average Labour Income
11	Agriculture, forestry, fishing and hunting	$65,338	$18,841
21	Mining and oil and gas extraction	$660,779	$112,100
22	Utilities	$490,246	$91,263
23	Construction	$106,605	$85,608
31-33	Manufacturing	$128,112	$73,077
41	Wholesale Trade	$102,858	$64,856
44-45	Retail Trade	$39,238	$31,309
48-49	Transportation and warehousing	$178,932	$61,813
51	Information and cultural industries	$168,855	$67,487
52-53	Finance, insurance, real estate, rental and leasing	$268,714	$127,325
54-55	Professional, scientific and technical services	$78,751	$63,024
56	Administrative and support, waste management	$65,310	$46,580
61	Educational services	$39,410	$36,266
62	Health care and social assistance	$67,355	$67,355
71	Arts, entertainment and recreation	$27,646	$20,911
72	Accommodation and food services	$38,695	$28,090
81	Other services (except public administration)	$43,703	$34,096
91	Public administration	$100,681	$76,768
Source: Calculated using data from Alberta Finance, Statistics (2009)			

2.2 Value of Economic Activity in the NSRB

Based on 2006 employment estimates and the 2007 economic activity coefficients, the NSRB generated about $79.1 billion in economic activity. This represents about 31% of Alberta's GDP in 2007. Estimates of GDP by sub-basin and industry of employment are provided in Table 3. Figure 1 shows the sub-basin boundaries and the urban and rural communities within each sub-basin.

Table 3 shows that the bulk of economic output is located in the central part of the NSRB, with 86% occurring in the Strawberry, Sturgeon, and Beaverhill sub-basins; these sub-basins also account for 89% of the population. Further assessment of the information shows that the City of Edmonton, which straddles all three of these sub-basins, accounts for 58% of GDP in the entire NSRB, followed by Strathcona County at 8%, St. Albert at 5% and Lloydminster at 2%.

Table 2: Correlation Between Employment Categories: Multiplier Tables and Regional Employment

CATEGORIES FROM ALBERTA MULTIPLIER TABLES		REGIONAL EMPLOYMENT CATEGORIES	
11A	Crop and animal production	11	Agriculture, forestry, fishing and hunting
113	Forestry and logging		
114	Fishing, hunting and trapping		
115	Support activities for agriculture and forestry		
211	Oil and gas extraction	21	Mining and oil and gas extraction
212	Mining (Except oil and gas extraction)		
213	Support activities for mining and oil and gas extraction		
22A	Electric power generation, transmission and distribution	22	Utilities
22B	Natural gas distribution, water, sewage and other systems		
230	Construction	23	Construction
311	Food manufacturing	31-33	Manufacturing
312	Beverage and tobacco product manufacturing		
31A	Textile and textile product mills		
315	Clothing manufacturing		
316	Leather and allied product manufacturing		
321	Wood product manufacturing		
322	Paper manufacturing		
323	Printing and related support activities		
324	Petroleum and coal products manufacturing		
325	Chemical manufacturing		
326	Plastics and rubber products manufacturing		
327	Non-metallic mineral product manufacturing		
331	Primary metal manufacturing		
332	Fabricated metal products manufacturing		
333	Machinery manufacturing		
334	Computer and electronic product manufacturing		
335	Electrical equipment, appliances and component manufacturing		
336	Transportation equipment manufacturing		
337	Furniture and related product manufacturing		
339	Miscellaneous manufacturing		
410	Wholesale trade	41	Wholesale trade
4A0	Retail trade	44-45	Retail trade
484	Truck transportation	48-49	Transportation and warehousing
485	Transit and ground passenger transportation		
486	Pipeline transportation, air, rail, water & scenic and sightseeing transportation and support industries		
48A	Transportation		
49A	Postal service and couriers and messengers		
493	Warehousing and storage		
512	Motion picture and sound recording studios	51	Information and cultural industries
513	Broadcasting and telecommunications		
51A	Publishing industries, information services and data processing services		
5A0	Finance, insurance, real estate and rental and leasing	52-53	Finance, insurance, real estate and rental and leasing
541	Professional, scientific and technical services	54	Professional, scientific and technical services
561	Administration and support services	56	Administration and support, waste management and remediation services
562	Waste management and remediation services		
610	Educational services	61	Educational services
GS2	Universities and government education services		
620	Health care and social services	62	Health care and social assistance
GS1	Hospitals and government nursing and residential care facilities		
710	Arts, entertainment and recreation	71	Arts, entertainment and recreation
720	Accommodation and food services	72	Accommodation and food services
811	Repair and maintenance	81	Other services (except public administration)
813	Grant making, civic and professional organizations		
81A	Personal and laundry services and private households		
GS4	Other municipal government services	91	Public administration
GS5	Other provincial government services		
GS6	Other federal government services		

Figure 1: Municipal and Sub-basin Boundaries in the North Saskatchewan River Basin

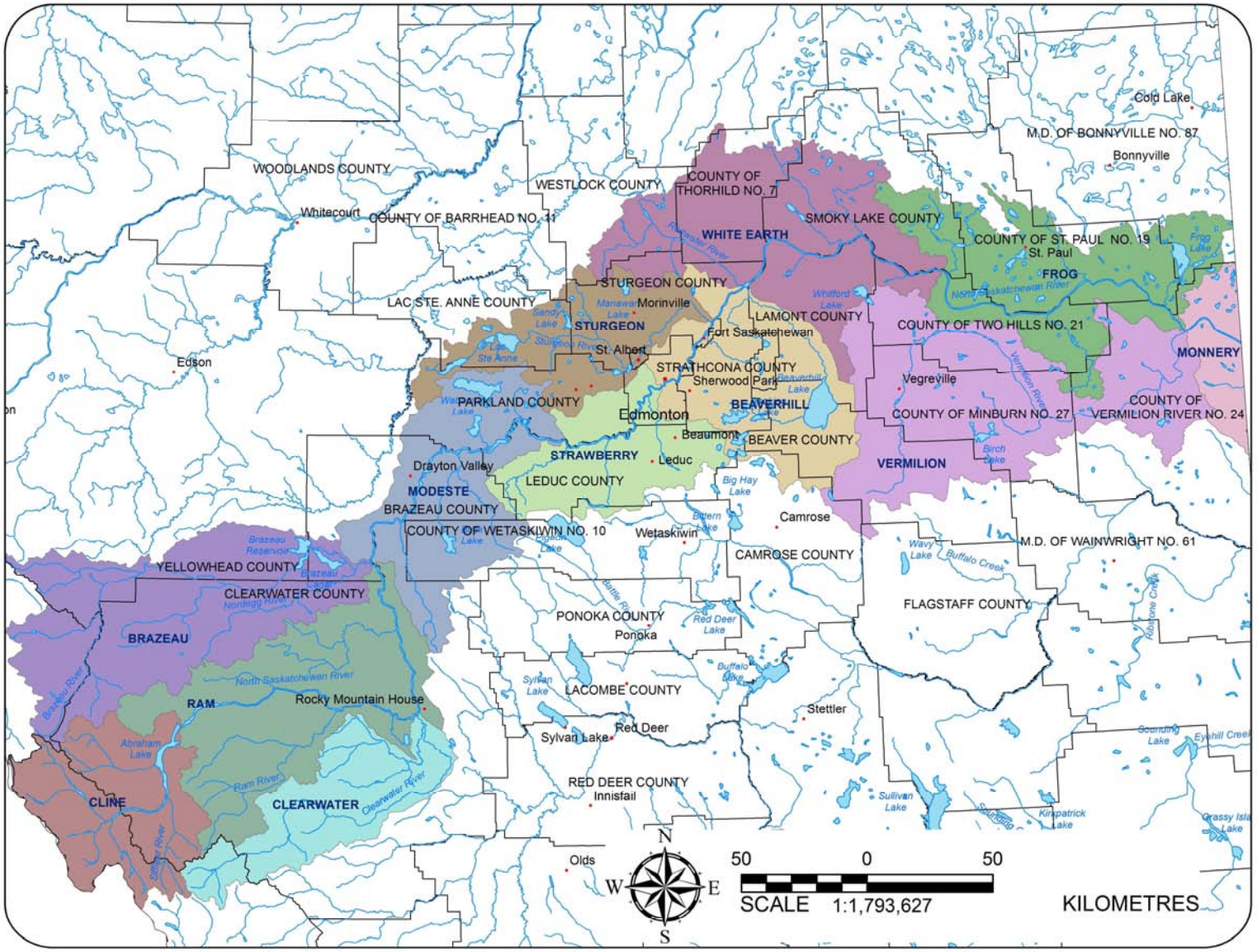


Table 3: Estimates of GDP ($Millions) by Sub-Basin and Industry of Employment

	Cline	Brazeau	Ram	Clearwater	Modeste	Strawberry	Sturgeon	Beaverhill	White Earth	Vermilion	Frog	Monnery	TOTAL
Agriculture, forestry, fishing and hunting	$0.6	$11.4	$55.8	$11.8	$74.1	$141.2	$125.8	$185.4	$121.9	$166.0	$74.7	$20.0	$988.7
Mining and oil and gas extraction	$5.0	$105.2	$778.7	$92.7	$1,547.1	$4,283.9	$2,055.7	$6,553.4	$468.4	$670.0	$628.6	$1,124.4	$18,313.1
Utilities	$0.1	$2.4	$20.8	$2.1	$175.8	$801.9	$503.4	$1,602.3	$52.9	$66.7	$36.3	$32.9	$3,297.7
Construction	$0.7	$14.2	$103.1	$12.6	$226.4	$1,703.7	$884.3	$3,279.3	$111.0	$100.2	$59.3	$83.9	$6,578.6
Manufacturing	$0.2	$5.5	$46.5	$4.4	$159.8	$1,878.1	$628.1	$3,749.0	$84.7	$60.6	$37.9	$59.3	$6,714.1
Wholesale Trade	$0.1	$1.8	$18.1	$1.5	$75.8	$921.2	$467.7	$1,814.2	$29.8	$60.9	$18.0	$43.1	$3,452.3
Retail Trade	$0.8	$3.7	$33.7	$3.8	$75.7	$774.5	$331.4	$1,515.5	$31.0	$51.4	$38.3	$53.3	$2,912.9
Transportation and warehousing	$1.5	$12.3	$71.4	$10.0	$252.6	$1,615.7	$721.6	$2,857.0	$102.0	$114.8	$67.5	$69.2	$5,895.6
Information and cultural industries	$0.1	$1.2	$9.1	$1.2	$60.0	$568.2	$243.4	$1,155.1	$13.2	$22.1	$11.9	$21.8	$2,107.4
Finance, insurance, real estate and rental and leasing	$1.2	$10.3	$76.6	$8.7	$169.6	$2,480.8	$1,206.3	$4,987.5	$77.9	$113.0	$68.2	$160.6	$9,360.8
Professional, scientific and technical services	$0.4	$2.9	$29.9	$3.0	$67.0	$982.0	$381.6	$1,992.8	$20.2	$38.1	$14.7	$42.3	$3,574.9
Administrative and support, waste management	$0.3	$2.2	$16.8	$1.5	$37.0	$486.9	$141.1	$934.9	$16.9	$19.3	$10.7	$16.7	$1,684.2
Educational Services	$0.2	$2.2	$17.7	$1.7	$38.5	$474.4	$209.9	$963.1	$20.7	$33.2	$25.9	$28.5	$1,816.0
Health care and social assistance	$0.4	$5.0	$39.1	$4.3	$87.7	$1,175.1	$506.8	$2,367.3	$56.0	$107.7	$68.6	$53.8	$4,472.0
Arts, entertainment and recreation	$0.7	$0.3	$2.0	$0.3	$7.8	$88.1	$35.1	$177.7	$2.6	$2.9	$3.3	$2.5	$323.4
Accommodation and food services	$7.2	$2.1	$20.3	$2.3	$35.8	$480.1	$154.1	$898.5	$16.2	$23.1	$11.6	$22.5	$1,673.8
Other services (except public administration)	$0.3	$3.3	$23.0	$3.2	$51.4	$442.9	$190.0	$797.9	$23.3	$24.4	$22.2	$28.6	$1,610.5
Public administration	$0.4	$7.0	$28.0	$2.8	$69.9	$1,118.6	$669.1	$2,239.0	$56.5	$81.0	$54.4	$17.5	$4,344.3
TOTAL	**$20.3**	**$192.9**	**$1,390.7**	**$167.9**	**$3,212.0**	**$20,417.2**	**$9,455.4**	**$38,069.9**	**$1,305.5**	**$1,755.2**	**$1,252.4**	**$1,880.7**	**$79,120.2**
Percent of Total	0.03%	0.24%	1.76%	0.21%	4.06%	25.81%	11.95%	48.12%	1.65%	2.22%	1.58%	2.38%	100.00%

None of the other communities or rural areas contributed more than 1.9% of GDP in the basin. In total, economic activity in the five sub-basins upstream from Edmonton accounted for 6.3% of basin GDP while the sub-basins between Edmonton and the Saskatchewan border accounted for 7.8%.

Of the various industrial sectors in the NSRB, the mining and oil and gas extraction industries accounted for the largest portion of basin GDP. This sector accounted for 23.1% of basin GDP, with the next largest industry, the finance, insurance, real estate and rental and leasing industry, accounting for 11.8%. Table 4 shows that other industries that made relatively large contributions to basin GDP included manufacturing (8.5%), construction (8.3%) and transportation and warehousing (7.5%). Within the NSRB, the agriculture, forestry, fishing and hunting industry only contributed 1.2% of GDP, the second lowest of all the industries.

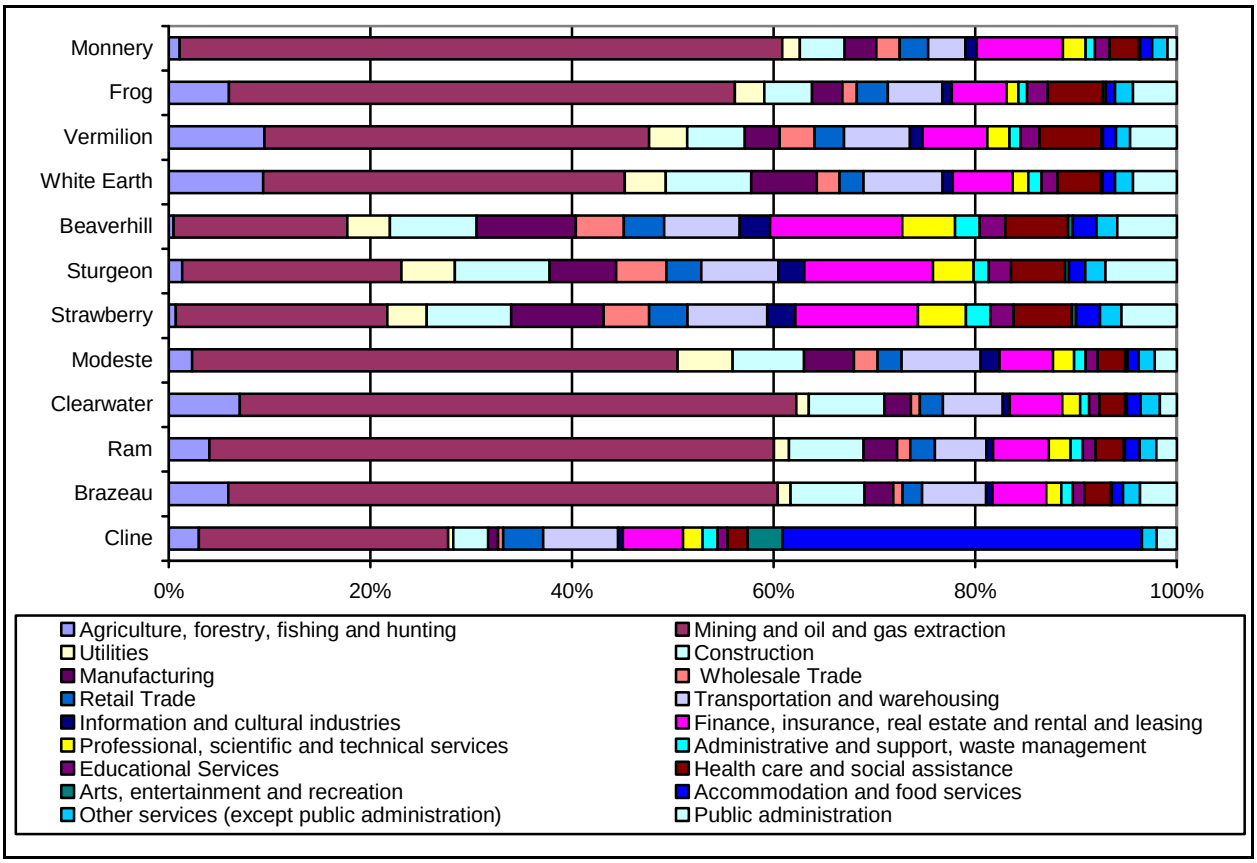
Table 4: Relative Importance of Various Industries to GDP in the North Saskatchewan River Basin

Industry of Employment	Percent of NSRB GDP
Mining and oil and gas extraction	23.1%
Finance, insurance, real estate and rental and leasing	11.8%
Manufacturing	8.5%
Construction	8.3%
Transportation and warehousing	7.5%
Health care and social assistance	5.7%
Public administration	5.5%
Professional, scientific and technical services	4.5%
Wholesale Trade	4.4%
Utilities	4.2%
Retail Trade	3.7%
Information and cultural industries	2.7%
Educational Services	2.3%
Administrative and support, waste management	2.1%
Accommodation and food services	2.1%
Other services (except public administration)	2.0%
Agriculture, forestry, fishing and hunting	1.2%
Arts, entertainment and recreation	0.4%

It should be noted that the estimates in Table 3 and Table 4 describe the importance of the various industries in terms of the direct employment (and related GDP) in each industry. However, economic activity in one industry can generate economic activity in other industries (indirect and induced effects), and these spin-off effects show up as direct employment in the other industries. For example, for every 100 direct jobs in construction there are 84 indirect jobs in other supporting industries. In agriculture, there are 81 indirect jobs for every 100 direct jobs. These interactions are not considered in assessing the relative importance of the various industries, as this would represent double counting in calculating total GDP in each sub-basin.

The relative importance of various industries in contributing GDP in each of the sub-basins is described in Figure 2. Over all, four distinct patterns are apparent. As expected the three sub-basins that contain parts of the Edmonton, St. Albert and Strathcona County (Strawberry, Sturgeon and Beaverhill) all have similar profiles, with little or no GDP generated by agriculture, and the mining and oil and gas extraction industries accounting for only about 20% of GDP. In these three sub-basins, the balance of GDP is generated by the various services industries (trade, health, education, public administration, and finance and insurance.

Figure 2: Importance of Various Industries in Generating GDP in the 12 Sub-basins

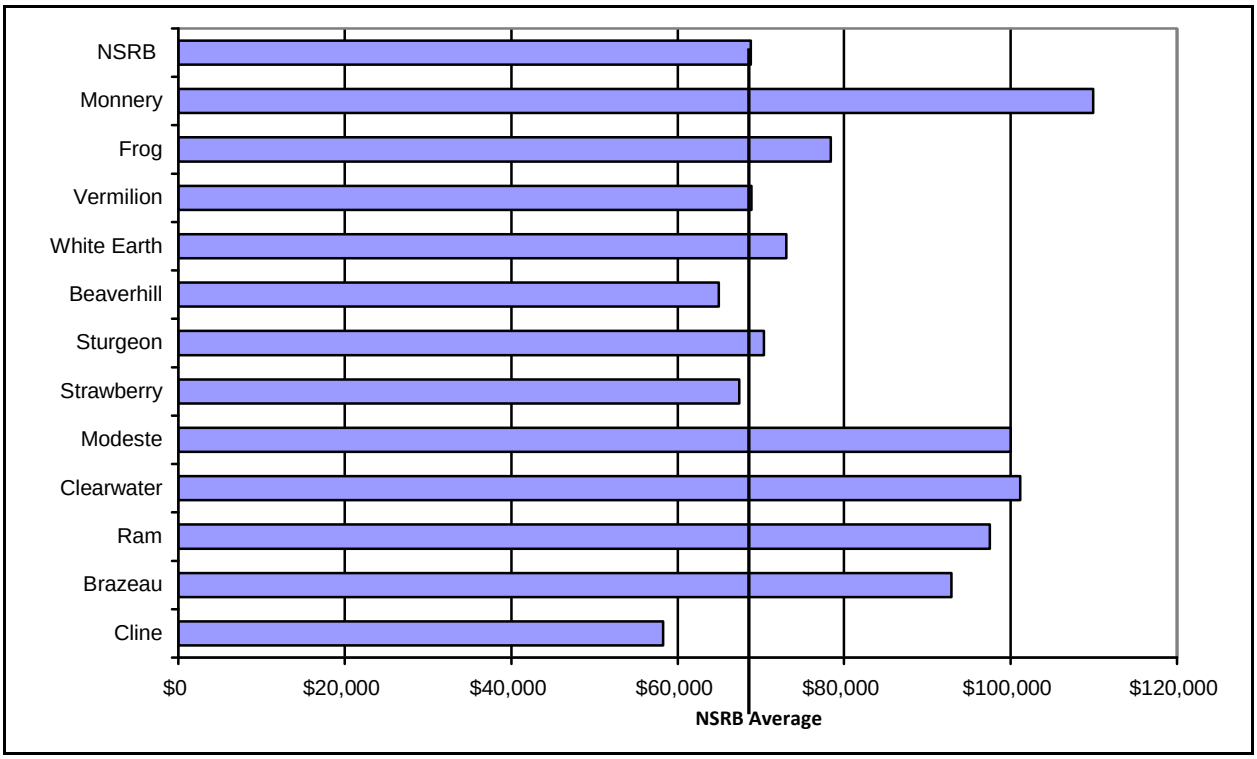


A second pattern is apparent in three of the sub-basins downstream from Edmonton. The profiles for the Vermilion and White Earth sub-basins are quite similar, with agriculture accounting for 6% to 9% of total GDP. While these two sub-basins rely on the mining and oil and gas extractions industries for a large percentage of their GDP (36% to 38%), they are less reliant on these industries than most of the other sub-basins. The third group, consisting of the Brazeau, Ram, Clearwater, Modeste, Frog and Vermilion obtain at least 48% and as much as 60% of their GDP from the mining and oil and gas extraction industries. In fact the Monnery sub-basin, which contains Lloydminster, depends on that industry for 60% of its GDP and, in that regard, its economy is more similar to those of Ram and Brazeau sub-basins. It should be noted that the highest reliance on GDP associated with the utilities industry was found in the

Modeste sub-basin, which is the location of most of thermal power generating capacity in the basin. The fourth pattern is apparent for the Cline sub-basin. The Cline sub-basin is located at the upper end of the watershed, partly in Banff and Jasper National Parks, and relies on the accommodation and food services industry for 36% of its GDP, mostly from tourism and recreation.

In addition to the pattern of GDP generation being different in each sub-basin, there is some variability within NSRB in terms of the average GDP per capita. This variability is shown in Figure 3, with the overall average for the basin being about $68,800 in GDP per person. The highest per capita economic activity occurred in the Monnery sub-basin, where the average GDP per capita was $109,900, which is nearly 60% higher than the basin average. Average GDP in the upper part of the basin (Brazeau, Ram, Clearwater and Modeste sub-basins) was next highest, ranging from $92,900 to $100,000. The lowest economic output per capita was in the Cline sub-basin, where the average GDP was only $58,300, which reflects season employment in the tourism industry. For the middle part of the basin (the Strawberry, Sturgeon and Beaverhill sub-basins) which contain the vast majority of the population, the average GDP per capita matched the basin average. Average GDP per capita in the Vermilion basin also matched the basin average.

Figure 3: Average GDP per Capita in the 12 Sub-basins



The average GDP per capita in four of the upstream basins (Brazeau, Ram, Clearwater and Modeste) ranged from $92,900 to $101,200, and this was at least 35% higher than the basin

average and reflects the importance of the employment in the mining and oil and gas extraction industries.

3.0 Ecosystem Services

Ecosystem services (which are also referred to as ecological goods and services or EG&S) are the benefits that people obtain, either directly or indirectly, from a multitude of resources and processes that are provided by natural ecosystems. Ecosystem services sustain air and water quality, provide clean drinking water, sequester carbon, produce food, decompose wastes, and support and enhance human quality of life. While ecosystem services play a vital role in supporting the human well-being, their role and importance is poorly understood and seldom considered in resource management decisions. There is currently an increasing interest in assessing the value of ecosystem services in order to provide communities and resource managers with better information on the importance of natural capital assets. This study provides a preliminary assessment of the scope and value of some of the ecosystem services within the NSRB.

3.1 What are Ecosystem Services?

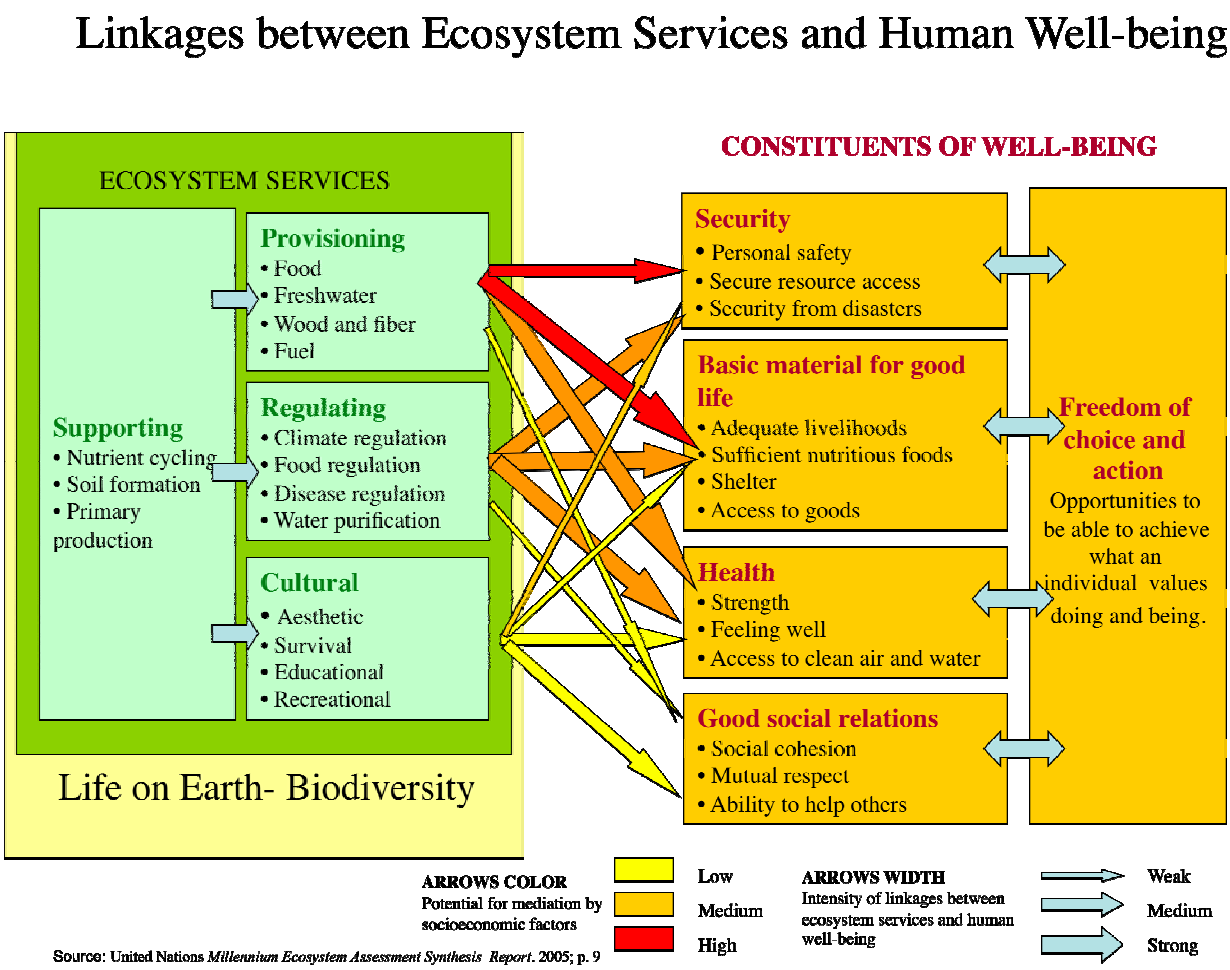
Ecosystem services can be measured in ecological (biophysical) terms. They can also be translated into economic terms through valuation studies. Ecosystem services directly support human well-being and can represent a significant part of the total economic value of the landscape and economy. Yet, the economic value of ecosystem services is currently not included in economic measures of well-being, like GDP, and are thus assumed to be of 'zero' monetary value[5]. However, as we seek to find a harmonious balance between optimizing economic benefits and maintaining ecosystem services, it is essential that we understand and measure the economic value of the ecosystem services in support of human well-being. With this information we are better able to understand the tradeoffs between conserving ecosystem integrity (thus ecosystem services) and land development.

While scientists and environmentalists have discussed ecosystem services for decades, these services were popularized and their definitions formalized in 2004 by the United Nations Millennium Ecosystem Assessment (MA), a four-year study involving more than 1,300 scientists worldwide.[6] Figure 4 demonstrates the relationship between ecosystem services and human well-being.

[5] *Value comes from the Latin valorum which means 'to be worthy or strong.'*

[6] *Millennium Ecosystem Assessment (2005). The Millennium Ecosystem Assessment concluded that about 60 per cent of the world's ecosystems are being used at an unsustainable rate.*

Figure 4: Ecosystem Services and Human Well-being



3.2 What Ecosystem Services are considered for the NSRB?

For the purposes of assessing the ecosystem service values for the NSRB, we considered a potential 18 ecosystem services which have been considered in previous studies[7]. These are summarized in Table 5.

Table 5: Types of Ecosystem Functions, Goods and Services

Ecosystem Service	Ecosystem Function	Examples of Services
1. Gas regulation	Role of ecosystems in bio-geochemical cycles (e.g. CO2/O2 balance, ozone layer)	UVb protection by ozone, maintenance of air quality
2. Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favourable climate, carbon regulation, cloud formation
3. Disturbance prevention	Influence of ecosystem structure on environmental disturbances	Storm protection, flood control, drought recovery
4. Water regulation	Role of land cover in regulating runoff and river discharge	Drainage, natural irrigation, transportation
5. Water supply	Filtering, retention and storage of fresh water	Provision of water by watersheds, reservoirs and aquifers
6. Soil retention	Role of the vegetation root matrix and soil biota in soil retention	Prevention of soil loss/damage from erosion/ siltation; storage of silt in lakes, and wetlands; maintenance of arable land
7. Soil formation	Weathering of rock, accumulation of organic matter	Maintenance of productivity on arable land; maintenance of natural productive soils
8. Nutrient cycling	Role of biota in storage and re-cycling of nutrients (e.g. nitrogen)	Maintenance of healthy soils and productive ecosystems; nitrogen fixation
9. Waste treatment	Role of vegetation and biota in removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, filtering of dust particles, abatement of noise pollution
10. Pollination	Role of biota in the movement of floral Gametes	Pollination of wild plant species and crops
11. Biological control	Population and pest populations	Control of pests and diseases, reduction of herbivory (crop damage)
12. Habitat	Role of biodiversity to provide suitable living and reproductive space	Biological and genetic diversity, nurseries, refugia, habitat for migratory species
13. Food production	Conversion of solar energy, and nutrient and water support for food	Provision of food (agriculture, range), harvest of wild species (e.g. berries, fish, mushrooms)
14. Raw materials	Conversion of solar energy, nutrient and water support for natural resources	Lumber, fuels, fodder, fertilizer, ornamental resources
15. Genetic resources	Genetic materials and evolution in wild plants and animals	Improve crop resistance to pathogens and crop pests, health care
16. Medicinal resources	Biochemical substances in and other medicinal uses of biota	Drugs and pharmaceuticals, chemical models & tools
17. Recreation	Variety in landscapes	Ecotourism, wildlife viewing, sport fishing, swimming, boating, etc.
18. Education, culture & spirituality	Variety in natural landscapes, natural features and nature	Provides opportunities for cognitive development: scenery, cultural motivation, environmental education, spiritual value, scientific knowledge, aboriginal sites

Sources: Adapted from: De Groot, R.S. 2002. "A typology for the classification, description and valuation of ecosystem functions, goods and services." Ecological Economics. 41: 393-408.

[7] *Counting Canada's Natural Capital: Assessing the Real Wealth of Canada's Boreal Ecosystem (Anielski and Wilson, 2007a; 2009a); The Real Wealth of the Mackenzie Region (Anielski and Wilson,2007b; 2009b)*

Because of data limitations it was not feasible in this preliminary analysis of ecosystem services to estimate the value of all potential ecosystem services with respect to landscape features in the NSRB.[8] In previous studies of the value of ecosystem goods and services, such as for the boreal ecosystem (Anielski and Wilson, 2009a) and the Mackenzie watershed (Anielski and Wilson, 2009b), the predominate ecosystem service values were found to be water regulation, water supply and climate regulation (i.e. carbon sequestration) that are associated with the most valuable landscapes including open water, wetlands and forests. For these reasons, this assessment focused on these same three ecosystem service values. While the other 15 potential ecosystem functions listed in Table 5 were considered in the valuation, there was no information on their contributions or values in the NSRB. For this reason, the true value of the total ecosystem service values in the NSRB as described in this analysis tend to be conservative or under-estimated.

3.3 Methodology

The valuation of ecosystem services is a relatively new field of economic analysis. The values derived in this study should be considered conservative estimates of the full potential value of the 18 possible ecosystem functions. It is not feasible or practical in this research study to estimate the value of all ecosystem services in the NRSB through direct valuation studies because of the significant costs and time required to do so. Because of these constraints, a 'value transfer' approach is taken whereby ecosystem service values derived from other studies in Canada with potentially similar landscape and ecological features are applied as proxy ecosystem service values for the NSRB. This is the most prudent approach given that our valuation work was constrained by the lack of valuation studies applicable to the NSRB.

Previous ecosystem service values that were considered as suitable benchmarks for value transfer for this study include:

- *Estimating Ecosystem Services in Southern Ontario* (2009), by Spatial Informatics Group, Austin Troy and Ken Bagstad for Ontario Ministry of Natural Resources (2009).
- Ontario's Wealth, Canada's Future: Appreciating the Value of the Greenbelt's Eco-Services by Sara Wilson (September 2008)
- Counting Canada's Natural Capital: Assessing the Real Wealth of Canada's Boreal Ecosystem by Mark Anielski and Sara Wilson (2007, revised 2009)
- The Real Wealth of the Mackenzie Region by Mark Anielski and Sara Wilson (2007, revised 2009) for the Canadian Boreal Initiative. Natural Credit: Estimating the Value of Natural Capital in the Credit River Watershed by Mike Kennedy and Jeff Wilson, for the Pembina Institute (November 2009)

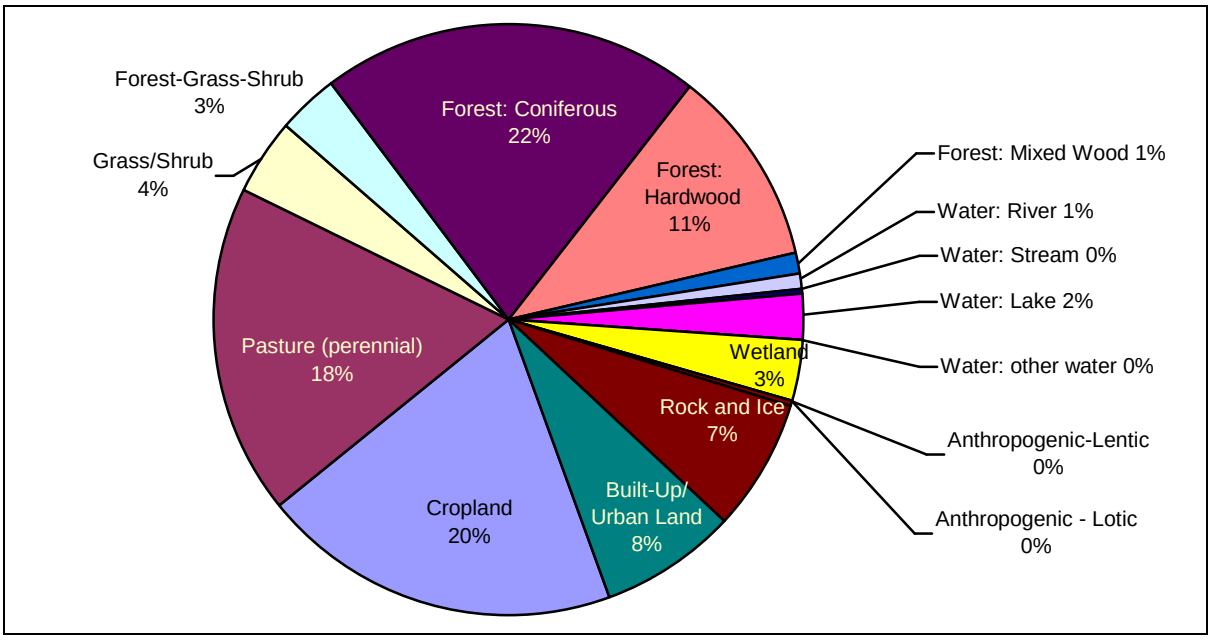
[8] *Many of the ecosystem services identified in the above table have not been valued from other previous studies.*

These studies are particularly useful and relevant because the value estimates are based on a review of previous research relevant to the respective study areas. In particular, the recent study for Southern Ontario was based on an extensive literature review that included references to the earlier work by Anielski and Wilson (2007a; 2007b; 2009a; 2009b) and Sara Wilson's latest 2008 report. For assessing values in the NSRB, we considered the full range of low, medium and high values from these studies as well as a median value[9]. However, the ultimate estimate of the value of ecosystem services for the NSRB is based on the median value for total ecosystem services by land cover type.

3.3.1 Ecological Land Classification and Land Cover

The first step in ecosystem service valuations is to develop a land cover classification data set. Initially, 28 land cover classes were identified, but these were collapsed into the 15 "ecological" land cover classes shown in Figure 5 as well as built-up/urban land. Within the NSRB (which covers 5,681,859 hectares), forests account for 33% of the land cover (coniferous at 21%, hardwood at 11% and mixed wood at 1%). About 38% of the land is used for agricultural purposes, both crops (20%) and pasture (18%). Roughly 7% is mountainous rock and ice. Wetlands cover 3% of the NSRB while other water features (lakes, streams, rivers and other) account for another 3% of the land surface.

Figure 5: Land Cover in the North Saskatchewan River Basin



[9] *The median value is calculated as the value that is in the middle of the full range of observed values.*

The basin also contains small percentages of man-made water bodies including storm water ponds (anthropogenic-lentic land cover) and canals and other moving water (anthropogenic-lotic land cover).

Figure 5 shows that 8% of the NSRB consisted of built-up and urban land. This includes lands used by municipalities, rural residential, facilities, roads, well sites, pipelines, transmission lines, seismic lines, railways, canals, ditches, mines, feedlots, and golf resorts. The built-up and urban land was separated from the other 'ecological' land (and water) land cover types since our interest is in the ecosystem service values of ecological lands. The percentage of each sub-basin classified as urban and built-up land ranged from a high of 25.0% in the Central North-Saskatchewan (Beaverhill) sub-basin to a low of 0.1% in the Cline (headwaters) sub-basin.

Table 6 quantifies the land area by cover type for each of the sub-basins and Figure 6 shows the percentage composition of land classes for each of the 12 sub-basins. An approximate distribution of these land classes within the NSRB is shown in Figure 7.

Figure 6: Composition of Land Cover in the North Saskatchewan River Basin by Sub-Basin

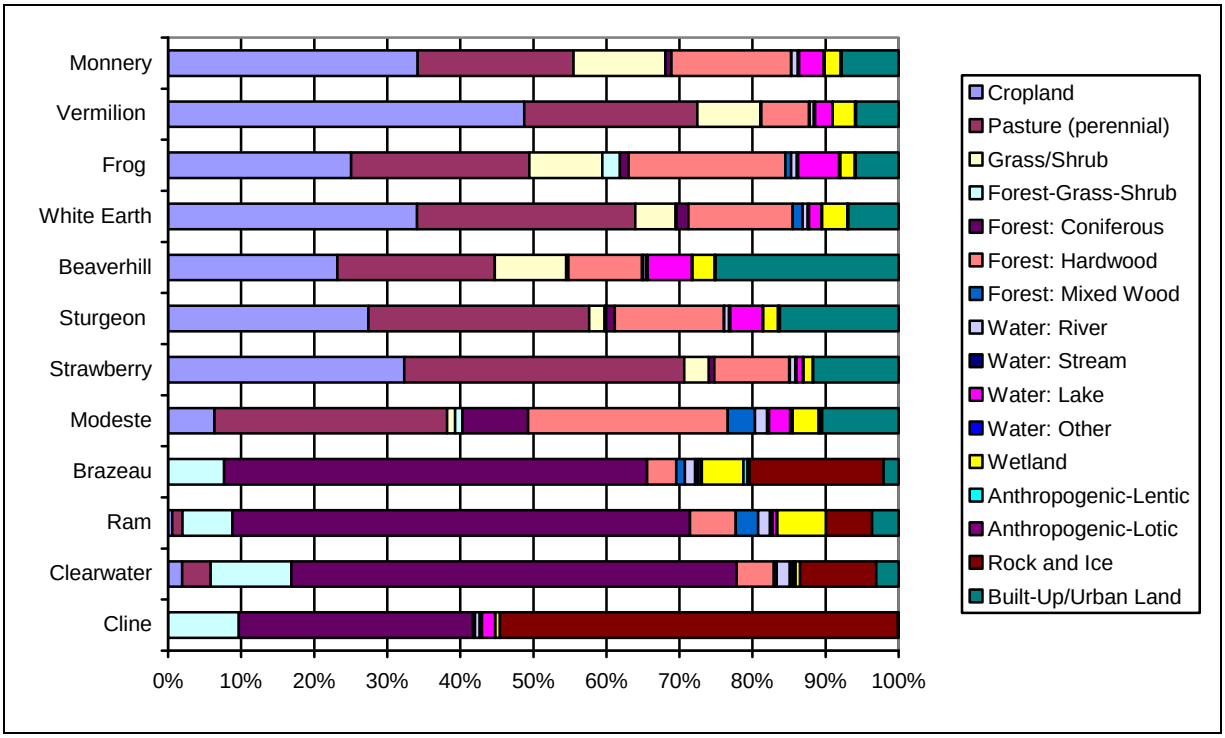


Figure 6 and Figure 7 show that the dominant land cover in the upper portion of the NSRB consisted of coniferous forest, especially in the Clearwater, Ram and Brazeau sub-basins. The highest percentage of exposed rock and ice is found in the Cline sub-basin. Coniferous forest was also found in the Cline and Modeste sub-basins. Hardwood forest types (aspen forests) were found in the Modeste, Frog, White Earth and Monnery sub-basins. Mixedwood forests were found primarily in the Ram and Modeste sub-basins.

Figure 7: Land Cover in the North Saskatchewan River Watershed

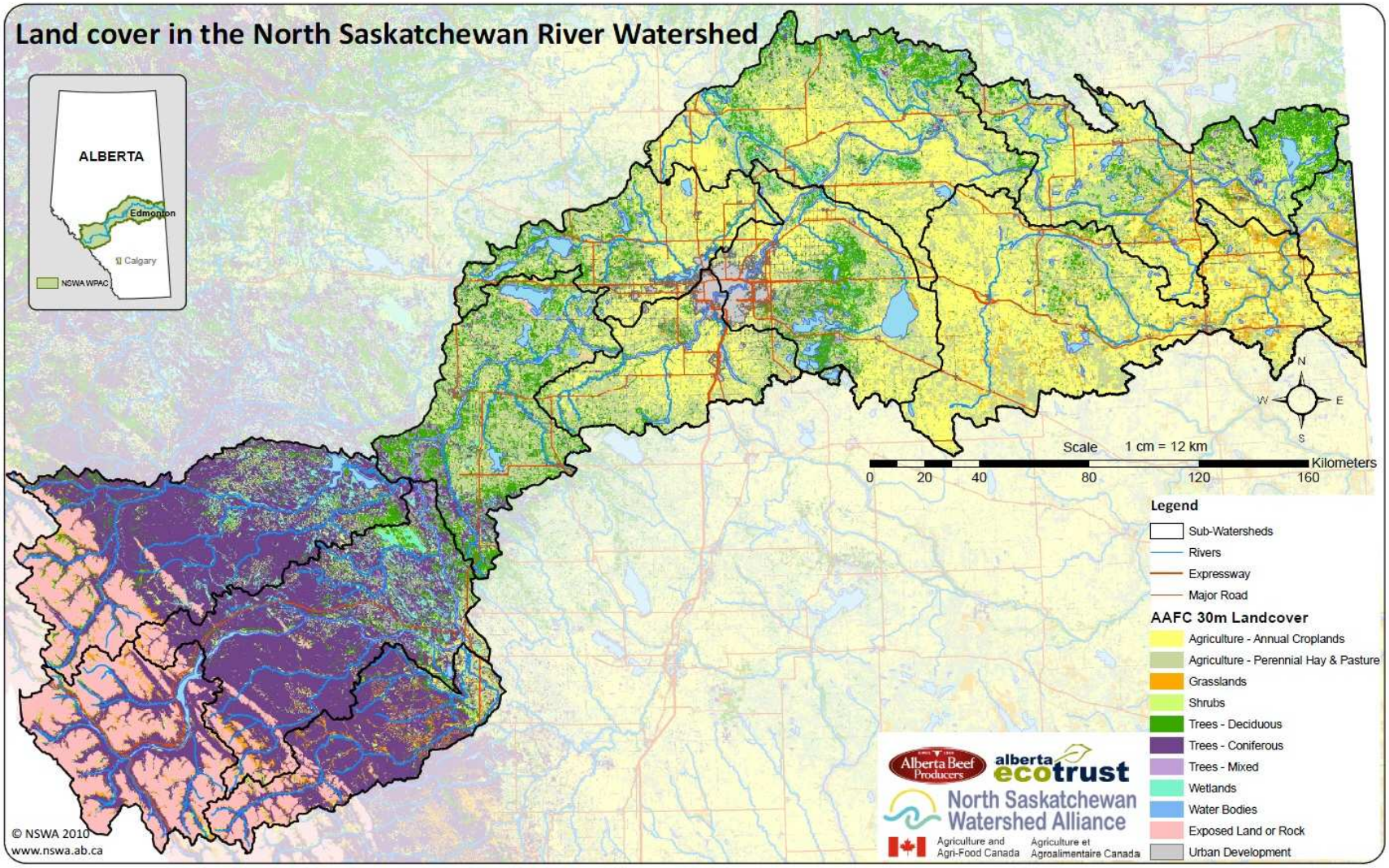


Table 6: Land Cover Types by Sub-Basin, North Saskatchewan River Basin (Hectares)

Land Cover Type	Sub-Basins												NSRB
	Cline	Clear-water	Ram	Brazeau	Modeste	Straw-berry	Sturgeon	Beaver-hill	White Earth	Frog	Vermilion	Monnery	
Cropland		6,229	3,441	3	30,036	100,352	91,083	102,266	221,951	137,055	383,392	41,909	1,117,716
Pasture (perennial)		12,592	8,908		150,118	118,950	100,388	95,208	194,622	133,251	186,417	26,165	1,026,618
Grass/Shrub					5,072	10,406	6,990	43,069	36,011	54,557	68,020	15,427	239,551
Forest-Grass-Shrub	37,367	35,674	42,231	52,832	4,754		704		915	13,128			187,604
Forest: Coniferous	124,018	196,871	388,661	399,099	42,428	2,364	3,918	1,385	10,322	6,630	859	1,003	1,177,558
Forest: Hardwood	794	16,330	38,947	27,433	128,782	31,807	49,635	44,488	93,183	117,333	51,328	20,083	620,142
Forest: Mixed Wood	142	1,295	18,845	8,291	17,660	242	239	638	8,771	4,209	872	76	61,281
Water: River	2,580	5,763	9,986	9,508	7,733	2,286	2,076	2,100	4,714	4,431	4,250	1,068	56,496
Water: Stream	1,220	1,441	2,357	2,589	1,227	601	621	665	983	910	1,329	235	14,177
Water: Lake	6,980	927	3,364	2,735	13,618	2,619	14,526	26,768	11,178	30,589	18,834	4,122	136,260
Water: other water	149	237	756	1,025	1,817	304	525	271	565	944	184	174	6,949
Wetland	2,334	1,922	41,226	39,191	16,740	3,924	6,685	13,418	22,658	10,883	24,140	2,671	185,792
Anthropogenic-Lentic		7		4,060	702	44	152	282	104	15	611	12	5,990
Anthropogenic-Lentic				1,645	11		0	0	19		74		1,750
Rock and Ice	210,669	33,645	39,020	126,523	1,460	131	765	317	732	736	393	129	414,520
Ecological Lands (Subtotal)	386,253	312,931	597,743	674,932	422,159	274,028	278,307	330,875	606,728	514,671	740,703	113,073	5,252,404
Built-Up/Urban Land	370	9,967	22,629	14,242	49,373	36,305	53,919	110,545	44,693	31,990	45,838	9,585	429,455
Total Land/Water Area	**386,623**	**322,898**	**620,373**	**689,174**	**471,532**	**310,333**	**332,226**	**441,420**	**651,420**	**546,660**	**786,541**	**122,658**	**5,681,859**

In the Modeste and downstream sub-basins, agriculture was the predominant land use, consisting mainly of pasture in the Modeste, Strawberry and Sturgeon sub-basins but featuring higher percentages of cropland in the lowest reaches. The Vermilion and Strawberry sub-basins had the highest percentages of agricultural land use.

The highest percentages of built-up/urban land were found in the Beaverhill and Sturgeon sub-basins, which contain much of Edmonton, St. Albert, Strathcona County and other large population centers.

In terms of water features, the Ram sub-basin had the highest percentage of wetlands while relatively high percentages of lakes were found in the Beaverhill and Frog sub-basins.

3.3.2 Valuation of Ecosystem Services

Using the estimated area of land cover (in hectares) we can then attach ecosystem service values (in dollars per hectare) for that land cover type to estimate the total value of ecosystem services for each land cover type. The resulting value estimates are referred to as Ecosystem Service Product (ESP) values. For the most part, we assume that any urban and built-up areas represent formerly undisturbed ecological lands that have been converted for human development purposes and thus have lost most if not all of their former ecological integrity and ecosystem services.[10] In a recent 2009 study for Ontario, it was assumed that any built-up or urban areas had no ecosystem service values, with the exception of urban forests and urban/suburban open water bodies (rivers). Areas consisting of rock and ice were also assumed to be generating no ecosystem services and have no ESP values.

All ESP values are expressed in 2008 Canadian dollars and are based on dollar per hectare by land cover type; previous study estimates of ecosystem service values were inflated to 2008 dollars using the Canadian GDP Implicit Price index. It should be noted that the estimates are only relevant for the current 2008 reporting year. While we might assume that ecosystem service values will remain relatively constant, in real dollars, over time, this may not be true due to changes in the stock of natural capital and changes in the integrity of ecosystem services. As natural capital stocks are depleted or ecosystems degraded, their economic value should increase to reflect higher scarcity and their increasing economic value to continue to support human well-being. Thus it is important to continually monitor the relative stock of various land cover types and the ecological integrity (ecosystem functions) of each cover type to adjust the marginal value of ecosystem services over time.

Based on our concordance of ecosystem service values from the previously noted benchmark studies, we derived a range of ESP values by land cover type as shown in Table 7. The ecosystem service values we used to derive estimates for the ESP values for the NSRB are

[10] *In the Real Wealth of the Mackenzie study (Anielski and Wilson, 2009b), the ecosystem services and respective values for urban and built-up land cover were assumed to be 10% of the optimum ecosystem service value for the original grasslands, water bodies and mixed wood forests that were assumed to be the original undisturbed land features.*

marked with an asterix. Those land cover types without ecosystem service values that are not marked with an asterix reflect values that do not necessarily apply to the NSRB. The criteria for choosing the values for individual land cover types were based on

a) using a conservative (lower-bound) estimate and

b) relevance to the NSRB study area.

For example, we applied the ESP value for open water: urban/suburban river from the Ontario study to an estimate of the area of water bodies found within municipal boundaries within the NSRB.

Table 8 shows the breakdown of ecosystem service values by ecosystem functions for each of the land cover types within the NSRB. The table shows that relatively few of the 18 potential ecosystem functions (from the taxonomy of values in Table 5) were valued for the various land cover types due to the limitations in the studies that were available and of relevance to the NSRB. The total value for each land cover type can then be calculated as the sum of the values for the selected ecosystem functions.

Table 7: Comparison of Ecosystem Service Values for Land Cover Types from Previous studies ($ 2008 per Hectare)

Land Cover Type Ecosystem Service Values	Ontario OMNR (2009)	Wilson (Greenbelt)	Anielski/ Wilson (Mackenzie)	Kennedy/ Wilson (Credit River, Ont.)	Median Values	Average Values
Agriculture/Cropland	$291*	$551	$95	$687	$421	$406
Grassland/pasture/hayfield*	$354*	$2,113	$404		$404	$957
Forest: non-urban	$4,443*	$6,221	$954	$6,419	$5,382	$4,509
Forest: urban	$25,842			$9,714	$17,778	$17,778
Forest: suburban	$14,776				$14,776	$14,776
Forest: adjacent to stream	$4,552			$18,826	$11,689	$11,689
Forest: hedgerow	$1,024	$1,841	$477		$1,024	$1,114
Urban herbaceous green space	$43,788	$229	$249		$249	$14,755
Open water: river	$55,553	$13,740*	$13,696	$13,401	$13,718	$24,098
Open water: urban/suburban river	$236,391*				$236,391	$236,391
Open water: inland lake	$5,050*				$5,050	$5,050
Open water: great lake near shore	$794				$794	$794
Open water: estuary/tidal bay	$1,852				$1,852	$1,852
Wetlands: non-urban, non-coastal	$15,151*	$15,287	$7,336	$31,682	$15,219	$17,364
Wetlands: urban/suburban	$161,419				$161,419	$161,419
Wetlands: Great Lakes coastal	$14,761				$14,761	$14,761
Beaches (general)	$89,608	$2,403			$46,006	$46,006
Urban		$-	$126		$63	$63
Idle Land		$1,829			$1,829	$1,829
Orchards		$542			$542	$542
Expose rock/ice[11]						

[11] *Previous studies of ecological goods and services do not provide estimates of the value of ecosystem services associated with exposed rock and ice though we might speculate that there may be some water supply regulatory services associated with this land cover type. This is an area for future ecosystem service valuation research.*

Table 8: Value of Ecosystem Services by Ecosystem Function ($ per hectare)

Land Cover Type	Value Source Study	1. Climate Regulation	3. Disturbance avoidance	4. Water regulation	5. Water supply	6. Soil retention	10. Pollination	12. Habitat/ Biodiversity	17. Recreation	18. Culture (Aesthetic /Amenity)	18. Other Cultural
Agriculture/Cropland	(Ontario OMNR)	31					28		137		95
Pasture/grassland	(Ontario OMNR)	19	5	25		4	19	95	53		134
Grass/Shrub	(Ontario OMNR)	19	5	25		4	19	95	53		134
Forest-Grass-Shrub	(Ontario OMNR)	992					25				7
Forest-Coniferous	(Ontario OMNR)	992		513				2,428	270		240
Forest-Hardwood	(Ontario OMNR)	992		513				2,428	270		240
Forest-Mixedwood	(Ontario OMNR)	992		513				2,428	270		240
Water: River	Wilson, S. (2008)				9,599	4,011					
Water: Urban/Suburban River	(Ontario OMNR)			45,768	17,690				172,691	242	
Water: Stream	Wilson, S. (2008)				9,599	4,011					
Water: Lake	(Ontario OMNR)			612					3,820	593	25
Water: other water	(Ontario OMNR)			612					3,820	593	25
Wetland: Non-urban	(Ontario OMNR)	14		2,779				75	3,551	6,446	2,286
Wetland: Urban	(Ontario OMNR)	14	99,318	3,168	48,929				9,861	129	
Anthropogenic - Lentic	(Ontario OMNR)			612					3,820	593	25
Anthropogenic - Lotic	(Ontario OMNR)			612					3,820	593	25

Note: The numbers assigned to each of the ecosystem service functions are in accordance with the ecosystem services taxonomy from Table 5.

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3.4 Ecosystem Service Valuation Results

The total values of ecosystem services in each of the sub-basins within the NSRB were then estimated using the values for individual land cover types selected from Table 7 and applied to the total area of land cover types as per Table 6. The resulting estimates, termed Ecosystem Service Product values, are provided in Table 9 and indicate that ecosystem services within the NSRB were conservatively estimated at roughly $17.7 billion in 2008 or roughly $3,652 per hectare per year for the total *ecological land* area within the watershed. Within the NSRB, the highest total ESP values revealed were for the Ram sub-basin at $3,403 million and the lowest value was for the Sturgeon sub-basin at $534 million.

The highest ESP values in the NSRB are attributed to coniferous forests, rivers and wetlands; this is typical of other similar studies. The most valuable ecosystem service functions are water regulation (by rivers, streams, and wetlands), water supply (by wetlands and urban rivers), disturbance avoidance[12] (by wetlands), and recreation benefits[13] (from a host of land cover types).

Climate regulation service values are typically the most important services provided by forests, other vegetation, and wetlands helping to sequester and store carbon. In this study of the NSRB we used average climate regulation service values for forests, grasslands and wetlands from the Ontario OMNR benchmark study. However, we recognize that climate regulation service values will fluctuate depending on whether a unit of land cover is a net absorber or net releaser of carbon and, as a result, climate regulation values may change from a positive benefit in one year to a climate liability the next depending on climatic and other factors. Thus assigning a consistent value for climate regulation is problematic. Some future work that could address this issue is described in Section 3.5.

Notwithstanding these and other valuation challenges, we believe our estimates of the average ESP value of $3,652 for NSRB is relatively conservative, having selected from the lower range of transfer values from the Ontario OMNR benchmark study and given that only 9 out of a potential 18 ecosystem functions have been valued. Compared with other previous studies our estimated average ESP value is comparable with:

- $3,758/ha/yr from the Anielski and Wilson's study of the Mackenzie watershed (2009)
- $3,775/ha/yr from Wilson's study for Ontario's Greenbelt watershed (2008)
- $3,911/ha/.yr from the Kennedy and Wilson's study of the Credit River Watershed in Ontario (2009).

[12] *The ability of natural environments to shield us and our infrastructure from the effects of wind, waves, and flood waters resulting from extreme weather conditions.*

[13] *Note that one of the challenges with valuing recreation benefits associated with the natural environment is that these benefits may have already been counted in the GDP for recreation and tourism expenditures. Avoiding the possibility of double counting is a significant challenge in valuing nature's services to human well-being.*

Table 9: Total Value of Ecosystem Services by Land Cover Type and Sub-basin, NSRB

Land Cover Category	Sub-Basins ($ millions)												NSRB
	Cline	Clear-water	Ram	Brazeau	Modeste	Straw-berry	Sturgeon	Beaver-hill	White Earth	Frog	Vermilion	Monnery	
Agriculture/ Cropland		$1.8	$1.0	$0.0	$8.7	$29.2	$26.5	$29.8	$64.6	$39.9	$111.6	$12.2	$325.3
Pasture (perennial)		$4.5	$3.2		$53.1	$42.1	$35.5	$33.7	$68.9	$47.2	$66.0	$9.3	$363.4
Grass/Shrub					$1.8	$3.7	$2.5	$15.2	$12.7	$19.3	$24.1	$5.5	$84.8
Forest-Grass-Shrub	$38.3	$36.5	$43.2	$54.1	$4.9		$0.7		$0.9	$13.4			$192.1
Forest: Coniferous	$551.0	$874.7	$1,726.8	$1,773.2	$188.5	$10.5	$17.4	$6.2	$45.9	$29.5	$3.8	$4.5	$5,231.9
Forest: Hardwood	$3.5	$72.6	$173.0	$121.9	$572.2	$141.3	$220.5	$197.7	$414.0	$521.3	$228.1	$89.2	$2,755.3
Forest: Mixed Wood	$0.6	$5.8	$83.7	$36.8	$78.5	$1.1	$1.1	$2.8	$39.0	$18.7	$3.9	$0.3	$272.3
Water: River	$176.4	$133.3	$694.2	$147.5	$632.9	$551.0	$43.5	$551.5	$578.5	$575.6	$58.4	$528.8	$4,671.6
Water: Stream	$16.8	$19.8	$32.4	$35.6	$16.9	$8.3	$8.5	$9.1	$13.5	$12.5	$18.3	$3.2	$194.8
Water: Lake	$35.2	$4.7	$17.0	$13.8	$68.8	$13.2	$73.4	$135.2	$56.5	$154.5	$95.1	$20.8	$688.1
Water: other water	$0.8	$1.2	$3.8	$5.2	$9.2	$1.5	$2.7	$1.4	$2.9	$4.8	$0.9	$0.9	$35.1
Wetland	$36.3	$29.1	$624.6	$593.8	$254.3	$59.5	$101.3	$203.3	$343.3	$164.9	$365.7	$40.5	$2,816.5
Anthropogenic - Lentic		$0.0		$20.5	$3.5	$0.2	$0.8	$1.4	$0.5	$0.1	$3.1	$0.1	$30.2
Anthropogenic - Lotic				$8.3	$0.1		$0.0	$0.0	$0.1		$0.4		$8.8
Rock and Ice *													
Total Ecological Service Product Value	**$858.9**	**$1,183.9**	**$3,403.0**	**$2,810.7**	**$1,893.3**	**$861.6**	**$534.3**	**$1,187.3**	**$1,641.3**	**$1,601.6**	**$979.3**	**$715.2**	**$17,670.3**

Notes: 1. Water-river ecosystem service values and wetlands ecosystem service values are a combination of values attributed to the urban-suburban portion of river and wetland areas (including a buffer zone) and non-urban river areas. For example, of the estimated 56,496 hectares of area designated as rivers, there are an estimated 17,495 hectares (31.0%) of river area within urban and sub-urban zones. According to the Ontario OMNR 2009 study, the average ecosystem service value of an urban-suburban river is estimated at an average of $236,391/ha compared with a lower value for non-urban river ecosystem services of $13,740/ha we used to value the non-urban river areas (based on Sara Wilson's study of the Greenbelt ecosystem in Ontario). There are only an estimated 11 hectares of urban-suburban wetlands of a total 185,792 hectares of wetlands in the total NSRB area. Only urban/suburban rivers and wetlands are assigned a differential value, not other bodies of water.

** Previous studies of ecological goods and services do not provide estimates of the value of ecosystem services associated with exposed rock and ice though we might speculate that there may be some water supply regulatory services associated with this land cover type. Rock and ice is the predominant land cover in the Cline sub-basin (54.5% of the total sub-basin) and Brazeau (18.4% of the sub-basin).*

Thus, the values in Table 9 provide estimates of the values of ecosystem services in the NSRB that are reasonably consistent with the results of other Canadian studies of the value of ecosystem services.

3.5 Opportunities to Enhance the Estimates of Ecosystem Services

The foregoing analysis provides an initial assessment of the value of ecosystem services in the NSRB based on readily available information drawn from various other studies that have been completed to date. These estimates should be considered preliminary because the estimates may not adequately reflect potential unique landscape characteristics of the NSRB or full knowledge of the range of ecological goods and services being generated by these landscapes.

Various other data sources could be used to improve the quality of the estimates. Possible data sources that could be considered in future studies of the value of ecosystem services in the NSRB include the following:

- **Net biome productivity** (NBP) data by sub-basin. NBP is an estimate of the annual net absorption (or release) of carbon by forests and wetlands which was originally developed by Prof. Jeng Chen, a geographer, and his research associate Gang Mo at the University of Toronto in the development of carbon cycle account of Canada's forests.[14] The NBP data shows net flux of carbon between 1960 and 2003 for all of Canada. Raw data was then geospatially mapped at the sub-basin scale for all of Canada by Global Forest Watch Canada.[15] The NSRB sub-basin data was clipped from the national NBP data base. NBP data are a useful indicator for valuing carbon and thus climate regulation services, which are generally one of the most significant ecosystem services.

The table shows that depending on the period of reporting, a sub-basin may be a net carbon sink or become a net source of carbon depending on land use impacts, climatic conditions, the affects of fire or other ecological factors. According to these statistics, the NSRB watershed has changed from a high net carbon sink averaging 4.29 million tonnes of CO_2 per year for the period 1990-1994 to a low net sink of 0.21 million tonnes of CO_2 per year for the period from 2000 to 2003. When attempting to value this carbon flux based on emerging carbon markets, Table 10 shows that there can be significant shifts in carbon flux by sub-basin within the

[14] *Prof. Jing M. Chen, a professor at the University of Toronto's Department of Geography, conducts studies into climate change and biogeochemical cycle modeling. His analysis of Canada's NBP (net biome productivity) estimates for all of Canada's landscapes is unique in Canada and has yet to be discovered. Global Forest Watch Canada was the first organization to access and use Dr. Chen's data as a basis of producing a carbon budget for Canada. Dr. Chen's analysis, which spans the period 1901-2003, is based on estimates of annual Net Primary Productivity (NPP) and then makes adjustments to account for the impacts of land cover changes (e.g. land use impacts, impacts of fire, etc.) on the net carbon balance of ecosystems. NBP is a considered appropriate for accounting for the net carbon balance of large areas and longer periods of time. The NSRB analysis used a custom file of Dr. Chen's original raw NBP data, at the 1 square kilometer resolution, and was analyzed by Global Forest Watch Canada and organized by sub-basin for the NSRB.*

[15] *The results of the analysis of both NBP and soil organic carbon by Global Forest Watch Canada has not been formally released. The analysis served as the basis of the forthcoming (2010) report on the Canadian Index of Well-being that focused on Ecosystem Health originally prepared by Mark Anielski in 2009.*

watershed from an asset (as a net carbon storage) to a global climate liability (as a net carbon releaser).

Table 10: Net Biome Productivity (NBP) for North Saskatchewan Watershed by Sub-Basin

	Average tonnes of CO_2 per year		
Sub-Basin	**2000-2003**	**1995-1999**	**1990-1994**
Cline	-85,438	-14,761	37,684
Clearwater	146,631	442,459	797,539
Ram	173,411	853,914	1,629,579
Brazeau	22,879	506,416	1,116,164
Modeste	189,273	421,621	592,881
Strawberry	2,316	4,914	6,944
Sturgeon	16,126	33,848	44,080
Beaverhill	10,889	39,900	74,259
White Earth	-236,359	20,611	14,750
Frog	-26,112	25,110	-14,383
Vermilion	437	1,266	1,552
Monnery	-6,547	-3,663	-12,900
NSRB Total	207,505	2,331,635	4,288,149
Note: Negative numbers indicate net releases of carbon while positive numbers indicate the volume of carbon being stored.			

- **Soil Organic carbon** (SOC) data was also considered as a basis for measuring the value of carbon within the NSRB. The original analysis of SOC also came from Global Forest Watch Canada for all of Canada's watersheds at the sub-basin scale. The change in SOC is a useful indicator of general soil health and also serves to estimate how much carbon dioxide is removed from the atmosphere and sequestered in all soils, including agricultural soils. SOC is one of the key indicators used by Agriculture and Agri-Food Canada (AAFC) and is a key component of good soil health and fertility. AAFC has developed an SOC indicator to assess how organic carbon levels are changing over time in Canadian agricultural soils.[16]

Measuring the value of stored carbon in the sub-surface soils and organic matter is possible and could compliment valuation of the annual flux of carbon of surface vegetation.

Table 11 shows the estimated volume of carbon contained in the soils of the NSRB and carbon density (tonnes of carbon per hectare). Stored carbon may be valued based on current market prices of carbon (e.g. in 2008 the average global carbon market value was US$26.00 per tonne of $C0_2$) and valued as an annuity[17]. This method was used to value the

[16] *The soil organic carbon data used for this indicator comes from the soil organic carbon digital database for Canada for all land cover types developed by C. Tarnocai and B. Lacelle. 1996. Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Ottawa, Canada.*

[17] *An annuity is one of a series of annual payments that would ultimately accumulate to the total value of $86 billion or 3.34 billion tonnes of CO_2 at $26 per tonne.*

stored carbon contained within the Mackenzie region watershed by Anielski and Wilson (2007a, 2009a).

Table 11: Stock of Soil Organic Carbon within the NSRB

Sub-Basin	Carbon Mass (tonnes of C)	Carbon Mass (tonnes of $C0_2$)	Carbon Density (tonnes of C per hectare)
Cline	15,091,412	55,385,481	39.59
Clearwater	34,782,038	127,650,081	109.51
Ram	79,559,864	291,984,702	131.94
Brazeau	67,696,933	248,447,742	100.41
Modeste	68,309,143	250,694,554	150.02
Strawberry	66,902,798	245,533,270	224.52
Sturgeon	70,801,062	259,839,899	218.89
Beaverhill	84,766,900	311,094,521	195.80
White Earth	130,900,126	480,403,461	210.69
Frog	81,780,974	300,136,176	147.98
Vermilion	124,565,242	457,154,438	162.84
Monnery	85,577,779	314,070,451	140.26
NRSB Total	**910,734,271**	**3,342,394,775**	**160.29**

- **Breeding Duck Pairs.** This data, which comes from Ducks Unlimited, provides a potential proxy for the ecological health or integrity of duck habitat, including wetlands and open water bodies. Duck breeding pair data is calculated as a range of the number of duck breeding pairs (from less than 10 to 70-80) per hectare of spatial area. While not formally used in our analysis, this could, in future, serve as a proxy for the relative health and thus the relative range in ecosystem service values of wetlands and water bodies within the watershed based on their ecological condition.
- **Index of Biological Integrity** (IBI) is a scientific tool developed by aquatic biologists used to assess and measure the health of aquatic ecosystem. An IBI associates anthropogenic influences on a water body with biological activity in the water body, and is formulated using data developed from biological surveys of indicator fish populations. An IBI for each of the sub-basins within the NSRB would serve as a useful proxy for the integrity of aquatic ecosystems and thus the marginal ecosystem service values associated with water regulation and water supply services as they are impacted by human activity. Unfortunately, IBI statistics of the NSRB were not available. However, a benchmark study for the Battle River watershed[18] shows the potential utility of deriving IBI estimates for the NSRB that could then be used for developing a range of water regulation and water supply service values based on the relative integrity. The multi-metric IBI has shown to be highly sensitive to change in cumulative anthropogenic

[18] *Stevens and Council (2008).*

disturbances (particularly road densities). The IBI may provide the single most defensible, easily understood measure of the health of watercourses.

- **Toxic Release Inventory.** Another data layer considered was an indicator of the concentrations of 49 toxic substances released into the environment (air, land, water) that were self-reported by industries as part of the National Pollution Release Inventory for Canada. Using Global Forest Watch Canada geo spatial data we created a toxicity layer for the NSRB that serves as a proxy for the pressures on ecosystem health from pollution. Area-weighted toxicity is calculated at the sub-basin level for the top 17 toxic substances defined in the *Canadian Environmental Protection Act* (CEPA). With an area-weighted measure we have a pollutant toxicity loading indicator that tells us something about the relative toxicity of each of Canada's sub-basin watersheds. This ratio can be compared over time to determine long term trends in toxicity across Canada. This may be useful in future ecosystem valuation studies to estimate the ecosystem service value losses due to pollution pressures. It was not formally used for this study.

These additional data layers provide useful indicators for future assessment of the relative changes in ecosystem health and thus ecosystem service values related to changes in human or economic activity within the NSRB. They will serve to derive what economists call 'marginal benefits (or costs)' to ecosystem services associated with activity.

4.0 Summary and Conclusions

4.1 Summary of Results

The results of this assessment suggest that the overall well-being of residents of the NSRB is on the order of $96.8 billion. This represents the value of economic activity ($79.1 billion) generated by residents of the NSRB in combination with the value of ecosystem services generated by the landscape ($17.7 billion). The assessment suggests that, if the measure of GDP was adjusted to include the value of ecosystem services, the total measure of well being in the NSRB would increase by 22%.

The values of economic activity and ecosystem services are summarized by sub-basin in Table 12. It shows that for six of the 12 sub-basins, the value of economic activity exceeds the value of ecosystem services. These six sub-basins include the Strawberry, Sturgeon and Beaverhill sub-basins, which accommodated 89% of the population of the NSRB in 2006, as well as the Modeste, Vermilion and Monnery sub-basins. In the other six sub-basins, which only accounted for 4.5% of the NSRB population, the value of ecosystem services being generated by the landscape actually exceeded the value of economic activity being generated in these sub-basins.

Table 12: Value of Economic Activity and Ecosystem Services in the NSRB ($ millions)

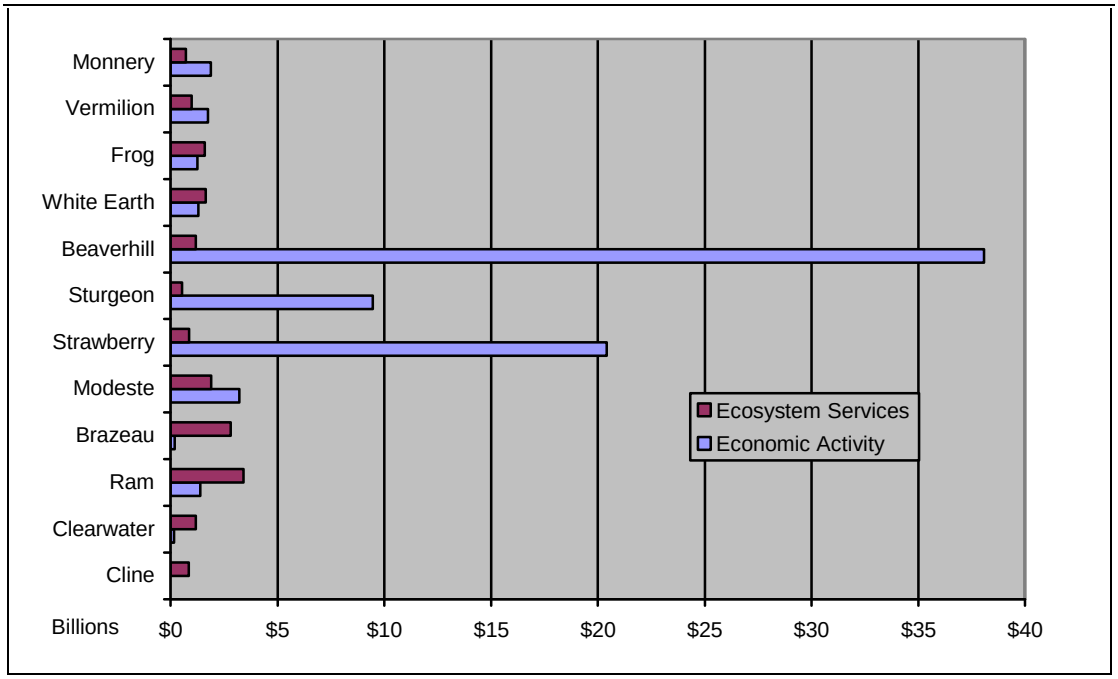
Sub-Basin	Economic Activity	Ecosystem Services	Total	Percent from Economic Activity
Cline	$20.3	$858.9	$879.2	2%
Clearwater	$167.9	$1,183.9	$1,351.8	12%
Ram	$1,390.7	$3,403.0	$4,793.7	29%
Brazeau	$192.9	$2,810.7	$3,003.6	6%
Modeste	$3,212.0	$1,893.3	$5,105.3	63%
Strawberry	$20,417.2	$861.6	$21,278.8	96%
Sturgeon	$9,455.4	$534.3	$9,989.7	95%
Beaverhill	$38,069.9	$1,187.3	$39,257.2	97%
White Earth	$1,305.5	$1,641.3	$2,946.8	44%
Frog	$1,252.4	$1,601.6	$2,854.0	44%
Vermilion	$1,755.2	$979.3	$2,734.5	64%
Monnery	$1,880.7	$715.2	$2,595.9	72%
TOTAL	**$79,120.2**	**$17,670.4**	**$96,790.6**	**82%**

Figure 8 shows the magnitude of the value of economic activity and ecosystem services by sub-basin. It shows that, with the exception of the Strawberry, Sturgeon and Beaverhill sub-basins, the values of ecosystem services being generated in each sub-basin was relatively close to the value of economic activity. Further analysis shows that, for the five sub-basins upstream of the City of Edmonton, the value of ecosystem services ($10.2 billion) was actually double the value

of economic activity ($5.0 billion). Downstream from the City of Edmonton, the value of ecosystem services ($4.9 billion) was only 80% of the value of economic activity ($6.0 billion). Overall, the assessment demonstrates the relative importance of ecosystem services in the upper parts of the NSRB and that, in the less populated parts of the basin, the value of ecosystem services and economic activity were reasonably similar.

Figure 8: Value of Economic Activity and Ecosystem Services by Sub-Basin, NSRB

($ billions)



4.2 Caveats and Conclusions

This is the first estimate of ecosystem service values for the NSRB. We believe these are conservative estimates with only 9 out of 18 potential ecosystem functions evaluated. Further primary valuation research will be required that is relevant to this geographic area of Alberta.

There are several areas of potential improvement including a more accurate accounting of the carbon budget or balance within the watershed and the relevant economic values attributed to these changes. Second, there is an opportunity to evaluate changes in the biological integrity of aquatic systems (e.g. using the IBI as a proxy indicator) and the relative economic value of these changes as they affect human well-being and costs of adequate and clean water supplies. Third, there is an opportunity to begin to understand the marginal benefits (or costs) of maintaining levels of ecosystem integrity and functions as they translate into economic well-being, as measured by the GDP. These are areas for future improvement in state of watershed measurement and reporting.

There are inherent shortcomings to valuing nature's services. This study, like the other benchmark studies referenced, reveal that ecosystem services valuation remains a young science which will require considerably more primary valuation research and development to ensure the relevance of these values particularly to human well-being. The challenge in ecosystem service valuation is determining how these functions benefit human well-being, which are generally measured in monetary terms, as well as ecological well-being, which may or may not be measured in monetary terms.

Notwithstanding these challenges, the ecosystem services valued at $17.7 billion in 2008 are significant relative to the estimated $79.1 in GDP generated in 2007 in the watershed. Ecosystem services represent a significant contribution to both human and ecological well-being. The results demonstrate the need to balance economic benefits for human well-being while maintaining healthy and flourishing ecosystems with integral ecosystem functions that benefit human well-being (in both monetary and non-monetary or quality of life terms) as well as being critical for ecological health. In reality, ecological health can never be adequately valued in money terms. Ecological integrity and resiliency of ecosystems may never find an appropriate price or monetary value but may require measures of resilience and health outside of economic valuation.

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