Nova Scotia Watershed Assessment Program Part A – Discussion Paper

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1. Introduction

1.1 Overview of project

The Nova Scotia Watershed Assessment Program (NSWAP) was initiated to increase our knowledge on the current state of watersheds in Nova Scotia. Leading up to the launch of the Water For Life Water Resource Management Strategy a knowledge gap on the pattern of watershed issues faced in the Province was identified. Watersheds that were most impacted or at risk and a provincial-scale summary of the status of watersheds in Nova Scotia was unavailable. In 2010, a decision was made to implement the NSWAP in two parts (A and B), in order to increase feasibility. Part A was designed to be an initial and simplified assessment of the watersheds of Nova Scotia. In December 2010, the NSWAP Part A was launched as the first research project under the Nova Scotia Water Strategy (Government of Nova Scotia 2010). In January 2011 work began on the project, and it was completed seven months later, in July 2011. This work was completed by a team comprised of researchers from Dalhousie University (Dr. Shannon Sterling, Peter Horne and Anthony Kelly), Nova Scotia Environment (Kevin Garroway) and Nova Scotia Department of Natural Resources (Gavin Kennedy). This discussion paper has been prepared as a companion document for the purpose of analyzing the results from the Part A study of the NSWAP project. This paper will present the direction of the project for the future.

1.2 Objectives

The purpose of the NSWAP Part A was to assess the current health of watersheds in Nova Scotia through the following goals:

1. create an inventory of provincial watershed data;
2. design a series of metrics (i.e. variables) that uses available information to characterize and evaluate the state of watersheds in Nova Scotia;
3. rank watersheds based on these variables to identify priority watersheds;
4. identify knowledge gaps that need to be addressed to make watershed assessments; and
5. create a standardized provincial-scale spatial database that is accessible to stakeholders involved in water resource management.

1.3 Description of project outputs

The first step in the project was to gather readily available, geospatial, provincial scale data. Next, based on the available data that was gathered during the initial stage of NSWAP Part A, 11 watershed variables were identified that could be calculated across the province to be used as indicators of environmental status at the watershed level.

Variables:

1. Human Landuse
2. Acidification
3. Acid Rock Drainage
4. Stream Road Crossings
5. Roads within 100m of Streams
6. Road Density
7. Streams Bound by Human Landuse
8. Stream Length Behind Dams
9. Dam Density
10. Surface Water Withdrawal
11. Groundwater Withdrawal

These 11 variables were calculated spatially using GIS geoprocessing techniques and the results of each calculation were mapped (i.e. Indicator Maps). These 11 variables were then considered to be indicators of environmental status and could be used for calculations of common watershed values at risk. Based on the indicator variables, four Watershed Values were identified, calculated, and mapped (water quality, terrestrial ecosystem, hydrologic change, and in-stream habitat).

An easier way to describe the common watershed values at risk maps would be to consider them as categories of environmental health or stress. What is being looked at is the sum of rankings of indicator variables that are relevant to four key watershed values that humans commonly alter:

1. Water quality;
2. Terrestrial ecosystems;
3. Timing and magnitude of river flow; and
4. In-stream habitat for aquatic species.

1.3.1 Watersheds in Nova Scotia

In Nova Scotia the commonly used convention for mapping watersheds has been to separate the landscape into 46 “Primary Watersheds” using a classification that is not consistent with the scientific definition. The “Primary Watersheds” of Nova Scotia are not hydrologic units, which means that the Primary Watershed of Nova Scotia represent a larger drainage area than what is considered to be a true, hydrologic, watershed. In order to maintain the “Primary Watershed” structure, but to gain hydrologic meaning for the NSWAP, we divided each of the 46 Primary Watersheds into two parts: 1) the largest hydrologically defined watershed (now referred to as the Major watershed) and 2) the remaining residual watersheds based on the province's secondary watershed layer (now referred to as the Residual watershed).

1.3.2 Water Quality

The Water Quality watershed values category was calculated by using five of the 11 indicator variables: 1) Proportion of Watershed with Human Land Use, 2) Acidification Index, 3) Acid Rock Drainage Risk, 4) Stream/Road Crossings, and 5) Length of Road Within 100 m of Streams. These 5 variables were identified as contributing to water quality in various ways such as lowering pH due to application of road salt, high run-off of contaminants from roadways and other human land use activities, exposure of acid bearing rock and the influence of acid rain.

1.3.3 Terrestrial Ecosystem

The Terrestrial Ecosystem watershed values category was calculated by using four of the 11 indicator variables: 1) Proportion of Watershed with Human Land Use, 2) Acidification Index, 3) Portion of Stream Bounded by Human Land Use, and 4) Road Density. This watershed value at risk variable was developed to gauge the risk to terrestrial ecosystem production through alteration of landcover throughout the watersheds.

1.3.4 Hydrologic Change

The Hydrologic Change watershed values category was calculated by using five of the 11 indicator variables: 1) Proportion of Watershed with Human Land Use, 2) Dam Density, Road Density, Surface Water Usage, and Groundwater Usage. These indicator variables each contribute to affecting the quantity of water available for natural ecosystem functions. The water usage variables were calculated as indicators of how much water was being withdrawn from a watershed, but were not compared to water availability within each watershed. Hydrologic Change represents a measure of the risk of change in magnitude and timing of water flows, and therefore potential risk for flooding and water availability within each watershed.

1.3.5 In-Stream Habitat

The 4th watershed values category that was calculated was In-Stream Habitat. This category used eight of the 11 indicator variables: 1) Portion of Stream Bounded by Human Land Use, 2) Portion of Stream Length Behind Dams, 3) Stream/Road Crossings, 4) Length of Road Within 100m of Streams, 5) Road Density, 6) Proportion of Watershed with Human Land Use, 7) Acidification Index, and 8) Acid Rock Drainage Risk. The In-stream Habitat watershed value at risk variable measures the amount of stress faced by streams by considering contaminants from roadways, development, and deforestation of riparian zones, and impacts from habitat fracturing due to water control structures.

1.3.6 Geodatabase

All of the data used for this project was stored in a geodatabase at Nova Scotia Environment and Dalhousie University. The Geodatabase houses the raw data that was used to calculate the 11 indicator variables, the geoprocessing models that were developed to calculate each of the variables and the common watershed values at risk. The Geodatabase was developed in ESRI's ArcGIS 9.3 software and is stored in the 'filegeodatabase' format. Some of the processing work was completed using ESRI's ArcGIS 10 software and reverted back to the 9.3 software architecture to ensure compatibility with NSE's current software license.

1.3.7 Watershed Ranking and Report Cards

Also stored in the geodatabase are the rankings for the 46 watersheds in Nova Scotia. For each of the 46 watersheds the indicator variables were summed and ranked to give an indication of how each watershed compared to the rest of the province. The ranking system used was a relative ranking technique whereby each of the 46 watersheds was compared to each other and not against a threshold of environmental quality. This ranking system ensures that there will always be a "Best" and a "Worst" ranked watershed, regardless of the true level of impact being discussed. The ranking was mapped and presented as a visual representation of watershed performance across the province. A report card was developed for each watershed which displayed each of the calculated indicator values along with the rank for each watershed. While useful in a series the report cards need more refinement prior to release. Once a thorough examination of good water management practices has been completed the report cards will have more inherent value and will be released as a series.

2. Discussion

2.1 Acidification

The continuing effect of acidification of soils and freshwaters (from acid precipitation) in Nova Scotia appears to have the most impact in the south-western watersheds and along the eastern shore. Acidification in Nova Scotia threatens aquatic habitat in lowered average pH, increased levels of toxic ionic aluminum (Dennis and Clair, 2012) and decreased levels of calcium in soils and freshwaters, as well as increased incidence of acidic episodes and toxic ionic aluminum this has resulted in reduced aquatic and terrestrial productivity. Twenty-five years of lake monitoring show that the freshwater water quality has not improved, despite air pollution emission reductions in the 1990s (Clair et al., 2011). The geology of these areas (plus numerous wetlands and proximity to sea salt events) results in soils that are less able to buffer acid precipitation. There is also a portion of low acid neutralization capacity in the Parrsboro area (and northern Cape Breton) (Clair et al., 2007). The data used in this project was generated by Clair *et al,* 2007. These findings are consistent with the State of the Environment Report from 1998.

2.2 Acid rock drainage

The provincial extent of exposed acid bearing rocks and the relationship to watersheds was examined. The layer created represents areas of the province where construction activity (such as quarries, road building, or urban development) intersects surficial and bedrock geology layers that contain acid bearing rocks. This measure is important in that it can be used to view which watersheds may be impacted by acid episodes in the freshwater from runoff and drainage of the disturbed areas. The high risk areas in the province are along the South and Southwestern shore. Large areas around Halifax, Lahave, Bridgewater, Sheet Harbour and Yarmouth have been exposed to acid bearing rocks. It is clear from viewing this layer alongside the Acidification layer there is spatial correlation between the two layers, which can compound the issue of low pH running through the streams in these areas.

2.3 Water Control Structures

The term "Dam" used in the project should be understood to actually mean "water control structure", because many of the structures included in the database are control structures other than strictly dams (i.e. aboiteaux's). The variety of water control structures across the province is indicative of the many water users in the region. Structures included in this database are used for industry, agriculture, power generation, storage, flood control, and wildlife habitat. Dam density across Nova Scotia varies widely from high density areas in the Annapolis Valley, HRM, the Eastern shore, and along the Northumberland shore, to low density along the south shore and throughout Cape Breton. The highest density is focused in the agriculturally rich areas of the Gaspereau watershed and the residual watersheds located within the primary watershed region.

The Dams layer was also used to assess the watersheds for fish passage. Each structure that did not have fish passage was used to determine the length of stream network that was cut-off for fish habitat. The most affected were the Mersey, the St Croix, and the Meteghan watersheds. There are many areas throughout the province that either have no dams or were missing information on structures (lack of data). Notable, are some "known" structures that are absent from this database (i.e. Cheticamp River dam and many structures along the Wreck Cove hydro facility). Smaller agricultural dams are also missing (as verified from Google Earth and the stream layer). This absence of data leads to this layer and any derived products underestimating the impact of dams in the province.

2.4 Roads

Three map layers were developed to characterize the effect of roadways in the province on rivers: road density, length of roads within 100 m of streams and density of (or number of) stream/road crossings. The road density map layer was calculated to show that for every 'X' km^2 within a watershed there was 'X' km of road. The most impacted watersheds are found in and around HRM, Lahave River and near Antigonish. The spread of impact clearly shows a tendency towards the major commuter areas of the province (i.e. along the highway 102 and the highway 104). The less populated areas of the province show a lower density of roadways. The one standout watershed is Country Harbour near Antigonish. This watershed contains a larger number of 'Tracks' (e.g. logging roads, or ATV trails) that were counted as roads. One of the limitations of this variable is that it does not take into account volume of traffic, paving type, or roadway size as variables in the calculations. Thus, each road is treated equally with the same level of impact across the watersheds.

The frequency of stream/road crossings layer maps the number of crossings per km of stream length. The most impacted watersheds appear along the Fundy coast (Annapolis residuals, Gaspereau residuals), along the Northumberland coast and around the Bras d'Or lakes (Margaree residuals, River Denys residuals, and Grand River residuals). In these watersheds there are many shore-direct streams that must be crossed when roadways are built. In the urban areas (Sackville, Halifax, Sydney, and Yarmouth) there does not appear to be as many crossings, however this is likely due to burying many of the smaller streams to clear land for urbanization.

The proportion of roads within 100 m of streams layer mapped the total length of roadways that are within 100 m of a stream per km of stream length overall. In the most impacted watersheds up to 70% of the total stream length was within 100 m of a roadway. The most impacted watersheds were the Lahave residual, the Sackville major and Country Harbour. Although the Country Harbour watershed ranked high mainly due to the extensive network of tracks that were counted as roads. Tracks are likely less travelled and therefore less impactful than busy roadways that are salted in the winter. Many watersheds along the Northumberland straight were also highly impacted by roadways in close proximity to streams.

2.5 Human Landuse

Landuse was assessed as the percentage of land within a watershed affected by human land uses. The data for this layer came from the Department of Natural Resources Forest Inventory Database (FID) which mapped landuse parcels by aerial photography interpretation (See Section 5: Data List for full list of data sources). The assessment considered parcels of land that had been disturbed for an anthropogenic purpose in the past 50 years, and included landcover types such as agriculture, urbanization, transportation, and forestry. The potential impact of landuse on the watersheds was assessed in two ways, one with all the landcover types combined and again as each activity separated. When all combined we see that the most potentially impacted watersheds range from 63% - 75% of the land area within the watershed disturbed by a human landuse. The most impacted watersheds are found along the Northumberland Strait including the Tracadie, South/West, French, East/West/Middle Pictou, and River John. Rivers flowing into the Bay of Fundy are also highly impacted, including the Gaspereau and the Salmon/Debert watersheds.

When the landuse layer is broken down into the individual components the distribution of specific potential impacts across the province can be seen. The urban category includes activities such as landfills and urban development. The most impacted areas by urbanization are the Sackville watersheds (major and residuals) with up to 19% of the total watershed area developed. The LaHave watershed appears impacted with up to 15% of the land area developed. Other areas that stand out as developed are along the highway 102 corridor, the Western shore, the Cape Breton Regional Municipality and the Gaspereau watershed.

The forestry category is defined by clear cuts in the DNR FID layer. The most impacted areas by forestry activities are in Northern Nova Scotia and along the Eastern Shore. The French (major and residual), the Country Harbour (major), the East/Middle/West Pictou (major and residual) the Salmon/Debert, and the St. Mary's (residual) watersheds are the most impacted. These watersheds contain up to 13% of the total watershed area cleared by forestry activities.

The transportation category is defined by roads, rail lines, power corridors, gravel pits and pipeline corridors. The most impacted watershed by transportation is the Sackville (major) watershed with 7% of the total watershed area affected by transportation activity. The next most impacted watersheds are the Salmon/Debert (residual), the LaHave (residual), the East/middle/West Pictou (residual) and the Tracadie (residual) watersheds all with up to 4.5% of the total area affected by transportation landuses.

The agriculture landuse category includes general agriculture, Christmas tree production and tree plantations. The most affected watershed in the province is the Gaspereau watershed with up to 37% of the total watershed area affected by agriculture, mostly farming. The next most impacted watersheds in the province are the Tracadie (residual) and the Tidnish watersheds with up to 29% of the total land area affected by agriculture, mostly due to Christmas tree production and plantations. There are other areas of the province with large agricultural operations, such as in the Annapolis Valley and the Northumberland Strait.

The landuse layer was also used to assess the potential impact of anthropogenic land cover to streams and riparian zones by measuring how much of the total stream length was within 50 m of a human landuse activity for each watershed. This is an important measure as it represents an opportunity to determine which watersheds may need buffer or set-back limits on landuses. The East/Middle/West Pictou (residual), the French (Major and residual), River John (major), and Tracadie (major) were among a dozen watersheds that have human landuse within 50 m of over 40% of the total stream length within the watershed.

2.6 Water Withdrawal

A measure of water usage was created for this project. Both groundwater use and surface water use information were extracted from water withdrawal approval records. The information used was based on approved daily volume of water withdrawals and not on pump rate information. The Gaspereau (residual), Annapolis (major), East/Indian (residual), and Clam harbour (residual) watersheds were among the most used in the province for surface water withdrawals. The Gaspereau (residual), Shubenacadie/Stewiacke (major), and the Salmon/Mira (residual) had the highest rates of groundwater withdrawal. It is vital to mention that without water availability estimates for these watersheds these two layers of water usage do not represent stress to the watersheds, because they need to be placed into the context of a water budget, still to be constructed. Each watershed may contain much more or much less water than is being withdrawn.

3. Summary

3.1 Summary Tables

A series of summary tables have been generated to summarize the “Watershed values” layers create in Part A of the NSWAP project. The tables represent lists of watersheds that ranked in the Top Ten for the most potentially impacted and least potentially impacted for each of the “Watershed values” (i.e. Water Quality, Hydrologic Change, Terrestrial Ecosystem, and In-stream Habitat). The tables are broken into two categories, one for the Major watershed and one for the Residual watersheds. This summary is presented as an example of the type of information that can be extracted from this project, the results here are less important as in the next phase of the project the ranks and the watersheds will change with the refinement of the spatial extent. The results from the next phase will be more meaningful and potential “problem” areas will be easier to manage as the spatial extent will be smaller and local to the community level.

Table 1: Water Quality

Top Ten Most Impacted (Potential)		Top Ten Least Impacted (Potential)	
Major	Residual	Major	Residual
1. Sackville	Lahave	1. Missaguash	Missaguash
2. Parrsboro	Tusket	2. Cheticamp	Cheticamp
3. Isle Madame	Gold	3. Margaree	New Harbour/Salmon
4. Lahave	Meteghan	4. North Baddeck	North Baddeck
5. Meteghan	East/Indian	5. River Denys/Big	Country Harbour
6. Country Harbour	Parrsboro	6. Gaspereau	Indian
7. Gold	Sissiboo/Bear	7. Tangier	Tidnish
8. Salmon/Debert	Gaspereau	8. Wreck Cove	Kennetcook
9. East/Indian	Herring Cove/Medway	9. Economy	Mersey
10. New Harbour/Salmon	Sackville	10. Indian	Roseway

Table 2: Hydrologic Change

Top Ten Most Impacted (Potential)		Top Ten Least Impacted (Potential)	
Major	Residual	Major	Residual
1. Sackville	Gaspereau	1. Mersey	Mersey
2. Annapolis	Salmon/Debert	2. Roseway	Missaguash
3. Shubenacadie/Stewiacke	Sackville	3. Barrington	Roseway
4. Tracadie	Clam Harbour	4. Herring Cove/Medway	New Harbour/Salmon
5. Musquodoboit	French	5. Wreck Cove	Tangier
6. East/Middle/West Pictou	East/Middle/West Pictou	6. Cheticamp	Barrington
7. River John	Salmon/Mira	7. Indian	Cheticamp
8. Gaspereau	Sissiboo/Bear	8. Missaguash	Country Harbour
9. Country Harbour	South/West	9. River Denys/Big	North Baddeck
10. French	Annapolis	10. Tangier	Wreck Cove

Table 3: Terrestrial Ecosystem

Top Ten Most Impacted (Potential)		Top Ten Least Impacted (Potential)	
Major	Residual	Major	Residual
1. Parrsboro	French	1. Missaguash	Missaguash
2. Sackville	Gaspereau	2. River Denys/Big	New Harbour/Salmon
3. Tracadie	East/Middle/West Pictou	3. Cheticamp	Mersey
4. East/Middle/West Pictou	Salmon/Debert	4. Mersey	North Baddeck
5. Salmon/Debert	South/West	5. Roseway	Roseway
6. French	Lahave	6. Tangier	Tangier
7. River John	Parrsboro	7. Gaspereau	Cheticamp
8. South/West	Shubenacadie/Stewiacke	8. Barrington	Musquodoboit
9. Country Harbour	Tracadie	9. Margaree	Annapolis
10. New Harbour/Salmon	Tusket	10. Herring Cove/Medway	Barrington

Table 4: In-Stream Habitat

Top Ten Most Impacted (Potential)		Top Ten Least Impacted (Potential)	
Major	Residual	Major	Residual
1. Parrsboro	Lahave	1. Missaguash	Missaguash
2. Sackville	Gaspereau	2. Cheticamp	New Harbour/Salmon
3. Isle Madame	Meteghan	3. River Denys/Big	Cheticamp
4. Meteghan	Tusket	4. Tangier	North Baddeck
5. Salmon/Debert	Gold	5. Margaree	Country Harbour
6. East/Indian	Parrsboro	6. North Baddeck	Mersey
7. Country Harbour	Sissiboo/Bear	7. Roseway	Roseway
8. Lahave	French	8. Wreck Cove	Tangier
9. East/Middle/West Pictou	East/Middle/West Pictou	9. Gaspereau	Indian
10. French	East/ Indian	10. Barrington	Tidnish

4. Next Steps

The first phase of the NSWAP project has brought together a large amount of geospatial information and provided a cursory look at the cumulative effects of some of this information on the watersheds in Nova Scotia. The NSWAP Part A looked at provincial scale data from an impact or stressor perspective. Thus far the approach for NSWAP Part A was a simple quantitative study where the data was summarized and relatively ranked, but not held against environmental thresholds, such as CCME water quality guidelines or DFO water availability requirements. NSWAP Part A, phase I, was not meant to be an in-depth statistical study, but more about data gathering, a proof of concept for the approach, and a cursory look at watershed health in Nova Scotia. The next phase of work on NSWAP Part A (phase II) will continue with the next steps focused on gathering more provincial scale data that reflex's some of the good water management practices across the province. An assessment of where good management techniques have been employed in the province will be conducted to compliment and contrast the impacts assessment that has been completed to date.

Work will also continue on enhancing the spatial resolution of how the watersheds are studied across the province. The watershed scale will be refined and enhanced to include more secondary watersheds which will help to bring the focus of risks closer to the community level. The method chosen to represent watershed scale up to this point in the project maintained the long standing Primary watershed divisions used on many maps in the province, however recently new GIS layers have become available which will allow the enhancement of this scale and allow the reporting of better quality information going forward. A new watershed scale methodology will be created and employed going forward in this project. The results will create a more meaningful assessment of watershed health and community health.

Finally, in the next phase of the NSWAP project the Water Quality variables that have been calculated will be further analyzed using real-world water quality data collected from around the province. The mapping layers will be refined based on the findings of the comparative analysis.

5. Data List

Data Layer	Type	Description	Year last update	Source
NS Hydrologic Network	Flow-line	Stream network for Nova Scotia	Missing	Nova Scotia Hydrographic Network is derived from the Nova Scotia Topographic Database (NSTDB).
	Coastline	Outline of the coast and Islands	2007	
	Obstacle	Dams both man-made and natural	2005	
	Shoreline Bank	Outline of river banks, lakes and shorelines	2007	
	Virtual Lines Separating Water Bodies	Line of intersection for lakes , rivers and coastlines	2007	
	Rapids	Area of rapids	2006	
	Virtual Neat Line	Connecting line segment end-points of rivers, lakes, and coastlines	2006	
Dam_From_NSE_Oct_2010	Dam	Water control structure inventory, in progress.	2010	Nova Scotia Environment
	Fish Ladder	Presence or absence of fish ladder. No indication of functioning status.	2010	
NS Topographic Database	Road Network	Roads within Nova Scotia	2004	Nova Scotia Topographic Database (NSTDB) Copyright Her Majesty the Queen in Right of the Province of Nova Scotia
	Contours	Contour lines at 5 m intervals	2005	
	Culverts	Culvert lines	2003	
NS Forestry Landcover	Land Cover	Land cover class (e.g., Forested, Urban, Wetlands, Barren)	2006	Nova Scotia Department of Natural Resources
	Wetland	Marsh, swamp, saltmarsh, open water, bog or fen	Missing	
National Soils Database	Soil Drainage	Rating of soil drainage from very poor to rapid	1960's	CanSIS
NS Watersheds	Primary Watersheds	Primary watersheds within NS	*2010*	Province of Nova Scotia
	Secondary Watersheds	Secondary watersheds within NS	*2010*	
NS_Agri_Inventory	Agricultural	Agricultural land use within NS	1997	Agricultural Lands Inventory Program
Geology	Surficial	Surfical geology for the Province of NS	1993	Province of Nova Scotia, compiled by R. R. Stea, H. Conley and Y. Brown, 1992
	Bedrock	Bedrock geology for the Province of NS	2000	Province of Nova Scotia, compiled by J. D. Keppie, 2000
RLUL	Multiple Land Uses	Multiple land use types (e.g., parks, wilderness sites)		Province of Nova Scotia
Water Withdrawal	Groundwater	Groundwater withdrawal from wells	2010	Nova Scotia Department of Natural Resources
	Surface Water	Surface water withdrawal	2010	Province of Nova Scotia
IDW_Alk	Acid Neutralization Capacity	Gran titration ANC interpolated from stream measurements throughout Nova Scotia	2007	Tomas A. Clair, Environnent Canada

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