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Water Quality Status and Trends of Nutrients in Major Drainage Areas of Canada

Technical Summary

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Water quality status and trends of nutrients in major drainage areas of Canada
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Issued also in French under title:

État et tendances de la qualité de l'eau pour les nutriments dans les bassins
versants importants du Canada
Sommaire technique

ISBN 978-1-100-18515-6

Cat. No.: En154-63/2011E-PDF

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Water Science and Technology Directorate
Environment Canada

Acknowledgements

This project was completed through the efforts of many dedicated Environment Canada experts across the country and through collaboration with water quality managers in several provincial Environment Departments.

Scientific data analysis and interpretation were provided by Monique de Jong (Vancouver, BC), Alice Dove (Burlington, ON), Nancy Glozier (Saskatoon, SK), Serge L'Italien (Montreal, QC), Emily McIvor (Saskatoon, SK), Denis Parent (Dartmouth, NS), Myriam Rondeau (Montreal, QC), Sarah Ross (Winnipeg, MB), and Andrea Ryan (Vancouver, BC).

Robert Kent and Jean-François Bibeault directed the project. Coordination and national synthesis of the results were provided by Robert J. Phillips and Vincent Mercier with important writing contributions from Murray Charlton. Mapping and data management for the project were provided by Michael Meunier and Alain Baillargeon. Geneviève Carr, Don Anderson, and Geneviève Tardif also contributed to this project, as well as Sophie Lalonde, Nathalie Gratton and Nathalie LeBlanc in the final revisions and verifications of the report.

Executive Summary

Severe algal blooms in Lake Winnipeg, Lake Simcoe and blooms of cyanobacteria in eastern Canadian lakes have been occurring in recent years, as well as re-emerging problems in Lake Ontario and Lake Erie, and in other Canadian water bodies. Not since the 1970's, when Great Lakes algal blooms prompted legislation limiting phosphate levels in laundry detergents and sewage effluents, has public concern for nutrient loadings to aquatic environments been so high.

This report is a first-ever national level assessment of nutrients in Canadian watersheds based on data from Environment Canada water quality monitoring sites¹ operated in conjunction with federal, provincial and territorial partners. Environment Canada (EC) water quality monitoring scientists from across the country have collaborated in writing this report in order to ensure standardization of approach, statistical technique, and use of common interpretative scheme.

Current trophic status of water at monitoring sites was assessed by examining three recent years (2004 – 2006) of nutrient data based on 4 key parameters² for 376 federally-partnered sites across Canada. Of particular interest, the median phosphorus concentrations were used to classify the trophic state of the water in accordance with the CCME-accepted scheme based on total phosphorus (TP) giving indication of relative water enrichment level based on nutrients.

For rivers, at a national scale we observe a general pattern of increasing phosphorus concentrations with distance downstream within a given river area due largely to increases in suspended sediments and anthropogenic loads downstream. Highest phosphorus concentrations were observed upstream of Lake Winnipeg at sites in the Nelson River Drainage Area. In the headwaters of rivers in the Pacific drainage area and the upper Great Lakes, phosphorus concentrations are generally low. They are intermediate in the lower Great Lakes (Erie and Ontario) and parts of the Maritimes.

The current status of nitrogen concentrations (2004-2006) appears to reflect patterns in atmospheric deposition with added input from regional anthropogenic sources. In the lower Great Lakes, relatively intense anthropogenic nitrogen inputs include agriculture, urbanization and industrialization. In Prince Edward Island and parts of the Lower Mainland elevated nitrogen levels are consistent with the intensity of agricultural activity.

For the 1990-2006 water quality trends period, 75 federally-partnered monitoring sites from across the country were used as they met the QA/QC requirements for long-term phosphorus trend analysis. While phosphorus has increased at 21% of these sites nationally, it has actually declined at nearly 31% of sites. No statistically significant change was detected in total phosphorus at approximately half the monitoring sites. Of the four large ocean drainage areas used in this

¹ Includes sites operated in collaboration with partners from other federal departments and agencies (Parks Canada, Prairie Provinces Water Board) as well as provincial and territorial governments

² Total Phosphorus (TP), Total Nitrogen (TN), Total Dissolved Phosphorus (TDP) and Nitrate-Nitrite (N-N).

report, increasing phosphorus trends were more common in central Canadian rivers which are part of Hudson's Bay and Arctic Ocean Drainage Areas. Sites with decreasing phosphorus trends were more common in the Atlantic and Pacific Ocean Drainage Areas.

For long-term nitrogen trends, a total of 84 federal and joint federal-provincial-territorial monitoring sites met the QA/QC requirements for trend analysis (9 more sites than for phosphorus). Most notable are increasing trends in nitrate-nitrite concentrations for all Great Lakes sites and for 7 of 10 least-impacted sites³ nationally. Similarly, 30 of 39 other national sites showing trends have significantly increasing nitrate-nitrite trends. Rising inputs from atmospheric deposition of nitrous oxide (NO_x) compounds may be the most significant source for this increase.

Other key findings from the report include:

- Seven of nine hyper-eutrophic sites are in the Nelson River Drainage Area;
- 5 sites exceeded the nitrate ecosystem health guideline of 2.9 mg/L. The highest nitrate concentrations (found in Prince Edward Island, lower Great Lakes and Lower Mainland B.C.);
- Increasing trends for phosphorus and nitrogen tend to not coincide; only 1 of 39 sites with sufficient data shows increasing trends for all four nutrient parameters.
- In the same vein, phosphorus concentrations:
 - tend to generally increase downstream, whereas nitrogen concentrations do not;
 - undergo a progressive shift toward bioavailable phosphorus downstream through the Great Lakes to a maximum of 88% total dissolved phosphorus at Wolfe Island site. The amounts of bioavailable phosphorus also vary between onshore and offshore.
- Surface water nitrate concentrations in Prince Edward Island reflect an increasing nutrient load consistent with research findings of shallow aquifer nitrate cycling;
- Increased erosional regimes in high-flow rivers, including those in Canada's North, are augmenting sediment loads thereby increasing total phosphorus concentrations.

When looking at all the data, it clearly appears that the national and major drainage overview must be supplemented by site specific contextual explanation as there are many factors that are at play, both natural and human related.

Improvement of a representative network would improve capacity to assess evolution of nutrients over time and space thus giving a better understanding of how often, how broad and how important the problem is or will be in the future.

³ Least-impacted sites are typically remote sites or those in headwater areas relatively free of anthropogenic inputs other than atmospheric deposition. The term "reference" site is avoided as it can be associated with "pristine".

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1 INTRODUCTION

Severe algal blooms in Lake Winnipeg, Lake Simcoe and blooms of cyanobacteria in eastern Canadian lakes have been occurring in recent years, as well as re-emerging problems in Lake Ontario and Lake Erie, and in other Canadian water bodies.

Not since the 1970's, when Great Lakes algal blooms prompted legislation limiting phosphate levels in laundry detergents and sewage effluents, has public concern for nutrient loadings to aquatic environments been so high.

This report is a first-ever national level assessment of nutrients in Canadian watersheds based on data from Environment Canada water quality monitoring sites operated in conjunction with federal, provincial and territorial partners. Environment Canada water quality monitoring scientists from across the country have collaborated in writing this report in order to ensure standardization of approach, statistical technique, and use of common interpretative scheme.

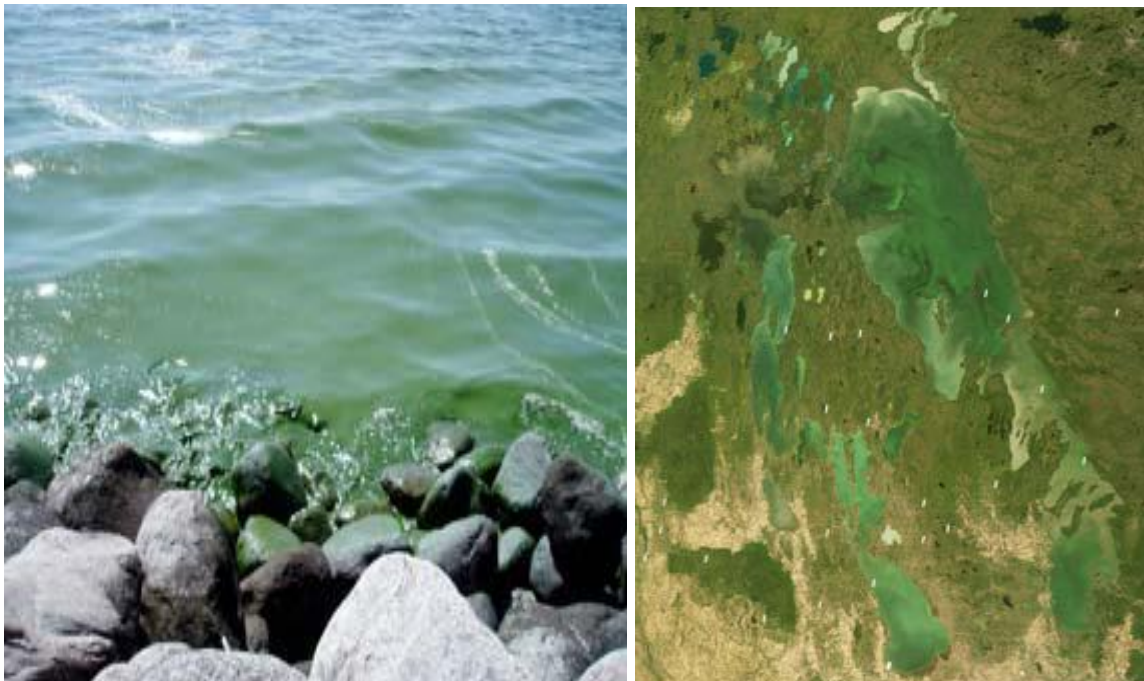


Figure 1 Left- algal bloom at Victoria Beach, South Area Lake Winnipeg August 17, 2008. Right- satellite photo shows algae in Lake Winnipeg , September 3, 2006.

Source: <http://www.fortwhyte.org/files/File/SlowTheFlow-LiquidAssets-Spring2009.pdf>

An extensive examination of nutrients sources, loadings and potential impacts on soil, water and sediment in Canada was carried out by Canadian federal scientists in a report entitled: *Nutrients and Their Impact on the Canadian Environment* (Chambers et al., 2001a). However, other than selected case studies, it did not present a national analysis of nutrient concentrations in water across Canada.

This report focuses on phosphorus and nitrogen, mostly from major rivers, many of which cross international and provincial boundaries, and the Great Lakes (including their connecting channels). It presents “current status” from recent sampling seasons (2004-2006) and trends analyses (i.e. change over time) for data collected from 1990 to 2006. Contextual information on the relative pressures within the drainage areas are provided, as well as interpretations for explaining trends or nutrient levels at specific sites, where possible. The present report does not provide an in-depth account of the relative contributions of environmental drivers, such as atmospheric deposition, point source pollution and land management practices, responsible for the observed levels and trends at larger spatial scales. However, it does identify areas where further investigative studies should be conducted.

2 NUTRIENTS IN CANADIAN WATERWAYS: CONCERNS AND THREATS

For decades, phosphorus (P) has been considered a crucial nutrient for growth of aquatic plants and algae and a key regulator of the overall productivity of inland aquatic ecosystems (Vollenweider, 1968; Dillon, 1975, Schindler, 1977; Smith, 1983) and possibly in low salinity estuarine environments (see for e.g. Schindler et. al. 2008; Schindler and Hecky, 2009). Noxious algal blooms and dense mats of rooted aquatic plants (water weeds) are commonly observed in lakes and rivers that are phosphorus-enriched. Abundant growths of aquatic plants can lead to shifts in community composition toward less desirable pollution tolerant species which may include invasive species (Arnott and Vanni, 1996; Dove, 2009). In addition, potentially toxic cyanobacteria can result in taste and odour problems for drinking water, health risks and closures of recreational waters. Cyanobacterial blooms can occur under certain water body conditions related to nutrient loadings, and complex biological and physicochemical factors (Watson et. al. 2007; Watson et. al. 2008). Decaying plant matter as well as unsightly and un-navigable plant growths can also clog intake pipes and impair navigation and the aesthetic and recreational value of aquatic ecosystems. Additionally, fish kills can occur as a result of concurrent declines in dissolved oxygen (Chambers et. al, 2001b).

Phosphorus enrichment of surface waters has become a wide-spread issue in Canada. Between 2005 and 2007, 32% of all water quality monitoring sites (108 out of 336 sites in total) in Canada exceeded water quality guidelines for phosphorus more than half of the time (EC, 2010). The 2001 National Water Research Institute document entitled “Threats to Sources of Drinking Water and Aquatic Ecosystem Health in Canada” (Environment Canada, 2001) cites nutrients as one of fifteen key threats to water quality in Canada (including human health).

Nitrogen and phosphorus are naturally occurring substances, but concentrations of both nutrients in aquatic environments have increased as a result of human development of the landscape. Releases to water are linked to a number of key threats including municipal wastewater effluents, urban runoff, landfills and waste disposal, agricultural and forestry land use, dams/diversions and climate change (EC, 2001). Nitrogen and phosphorus releases to Canada’s surface waters occur

via non-point source inputs, surface run-off and subsurface groundwater flow, as well as through atmospheric deposition.

The introduction of chemical fertilizers more than a century ago increased nutrient availability on a global scale. Industrial production techniques such as the Haber Process, which transforms atmospheric nitrogen (N_2) and hydrogen (H_2) into products such as ammonium nitrate ($NH_3(NO_3)$), meant that an almost limitless supply of nitrogen fertilizer was available⁴. Similarly, phosphorus concentration in soils was no longer limited by local soil characteristics and natural weathering, nor restricted to fertilization by natural sources such as compost and animal manure⁵. Mining of apatite-bearing phosphate rock facilitated industrial production of phosphorus and nitrogen-phosphorus-potassium fertilizers. To supplement limited soil productivity, Canadian agricultural sector consumption of apatite phosphate rock was estimated to approximately one billion tons *per annum*.

In Canada the area of fertilized farmland increased by 37% between 1980 and 2005.⁶ In 2001, an estimated 178 million tonnes of manure were produced in Canada, up 13.9% from 1981⁷. Phosphorus surplus (i.e. phosphorus input in excess of crop needs) is estimated to have more than doubled between 1990–1992 and 2002–2004⁸.

In 2008, over 116 000 tones of ammonia, nitrate and phosphorus were released directly to water from large industrial facilities reporting to the National Pollutant Release Inventory⁹. The largest single source of these nutrients was water and sewage systems (85.8%), followed by pulp, paper and paperboard mills (5.3%) and waste treatment and disposal (2.3%).

3 DATA SELECTION AND NUTRIENT ANALYSES

Parameter selection

The parameters chosen for study here are those that have been routinely monitored at most sites across the country and include:

- **Total Phosphorus (TP):** a measure of all forms of phosphorus in water (including phosphorus found in organic matter, bound to suspended sediment and dissolved in the water).

⁴ <http://www.ias.ac.in/resonance/Sept2002/pdf/Sept2002p69-77.pdf>

⁵ It may be noteworthy that, at current rates of consumption, global supply of phosphorus is expected to be exhausted in approximately 350 years. Ref: "How Long Will it Last?". *New Scientist* 194 (2605) (May 26, 2007, p. 38-39).

⁶ Statistics Canada, Census of Agriculture, CANSIM table 153-0039 (accessed June 2, 2008).

⁷ Nancy Hofmann and Martin S. Beaulieu, 2006, *A Geographical Profile of Manure Production in Canada, 2001*, Statistics Canada Catalogue no. 21-601-M, Ottawa.

⁸ Organisation for Economic Co-operation and Development. 2008. Environment Performance of Agriculture in OECD Countries since 1990. Paris, France, www.oecd.org/tad/env/indicators (accessed on August 19, 2008).

⁹ Environment Canada. National Pollutant Release Inventory (NPRI) – 2008 Facility Data Summary. <http://www.ec.gc.ca/inrp-npri/default.asp?lang=en&n=CFA83D44-1> (accessed July 20, 2010)

- **Total Dissolved Phosphorus (TDP):** total phosphorus for a water sample that has been filtered through a membrane (0.45 µm). This fraction can be readily taken up by plants.
- **Total Nitrogen (TN):** a measure of all forms of nitrogen in water (including nitrogen found in organic matter, bound to suspended sediments, and dissolved in water).
- **Nitrate + Nitrite (NO₃+NO₂):** a measure of the total amounts of nitrate and nitrite ions in water. These can be taken up by plants and also be toxic to animals at sufficient concentrations.

Data analysis and site selection

In total, data from 376 sites nationally, including 273 which were combined to represent 7 Great Lakes areas, were utilized for trophic status analysis. Trophic categories are based on the CCME-endorsed concentration ranges for total phosphorus (see table below). The concentrations are based on a 3-year median value calculated from recent (2004-2006) data.

Trophic categories based on total phosphorus concentrations

TP Concentration (mg/L)	Trophic Status
< 0.004	Ultra-oligotrophic
0.004-0.010	Oligotrophic
0.010-0.020	Mesotrophic
0.020-0.035	Meso-eutrophic
0.035-0.100	Eutrophic
> 0.100	Hyper-eutrophic

Source: Canadian Council of Ministers of the Environment, 2004.

For the trends, a total of 75 water quality sites met minimum data requirements¹⁰ for long-term trend analyses for phosphorus whereas a total of 84 sites met requirements for nitrogen nutrient analysis based on nitrate-nitrite. A minimum of 10 years, between the years 1990 and 2006, needed to be sampled to be included in the trend analyses. The Seasonall Kendall test was used to test the presence of a significant increasing or decreasing trend in concentrations where significant seasonality was present in the data. In cases where, seasonality was not inherent in the data, the Mann Kendall test was used.

Results are presented individually and aggregated nationally and by Canada's major drainage areas. Each of these drainage areas has a unique hydrological regime and composition of pollution sources and/or land uses.

The status and trends sites were selected amongst existing federal and joint federal—provincial monitoring sites, designed to respond to many environmental threats under various mandates. As such, distribution of sites is not even across the country, with a higher proportion of sites located in the southern portion of Canada where the threats have historically been greater. Many sites are located

¹⁰ Environment Canada. 2011. Water Quality Status and Trends of Nutrients in Canadian Surface Waters: A National Assessment. Water Science and Technology Directorate. Ottawa, ON. (*draft*)

in major rivers (e.g. Fraser, North and South Saskatchewan, McKenzie, St. Lawrence and Saint John), major lakes (Great Lakes, Great Slave Lake) and smaller rivers along the coasts (Atlantic provinces) or in mountain areas (BC). The upstream drainage areas of these sites have a wide range of agricultural activity (from little or no crop cover and livestock to 83% agricultural land cover and 44 animal units/km², respectively), population density (0 to 1776 persons/km²) and inputs from industrial facilities.

“Least-impacted” sites within a given drainage area are selected for comparative purposes for other sites within the same drainage area as well as to illustrate how ambient or background nutrient concentrations can vary across the country from one area to another. In this way they can serve as benchmarks for comparison with other areas “exposed to” or affected by agricultural or urban land uses or other pressures. In this report, 23 status monitoring sites were considered least-impacted. These sites are shown in italics in the status data tables beneath maps for each drainage area.

Sampling and Analytical Methods

Sampling was conducted by various federal departments including Environment Canada, Parks Canada, Indian and Northern Affairs Canada, and also by provincial/territorial departments under Federal-Provincial/Territorial monitoring programs. All of these agencies have standardized sampling protocols designed to eliminate errors introduced by sampling methods and preservation techniques¹¹. For river and stream sites, sampling consisted of routine grab samples taken at locations and frequencies developed to meet the monitoring program’s objectives and anticipated data uses. Where possible, sites are co-located, or located within proximity to flow monitoring sites. Great Lakes sampling was conducted from the CSS LIMNOS, a research vessel with laboratory space and 24-hour sampling capacity (Williams 1971; Carew and Williams 1975). Sample collection methodology and instrumentation for the period 1968 to 1994 are described in Carew and Williams (1975) and L’Italien and Fay (1993).

Samples from all monitoring programs were analyzed for nutrients using nationally-accepted methods at accredited laboratories across Canada. Laboratories were accredited by the Canadian Association for Laboratory Accreditation Inc. (CALA). A summary of analytical methods for the parameters evaluated in this report are presented in Environment Canada (2011).

The analytical methods for most parameters have remained essentially unchanged since 1990, making it possible to examine the datasets for evidence of temporal trends. Some exceptions do occur where lab methods have changed since 1990.

¹¹ Environment Canada. 2011. Water Quality Status and Trends of Nutrients in Canadian Surface Waters: A National Assessment. Water Science and Technology Directorate. Ottawa, ON. (draft)

4 NATIONAL OVERVIEW OF STATUS AND TRENDS

3.1 National Status of Nitrogen and Phosphorus

Of the four nutrient parameters assessed in this report, total phosphorus (TP) has the best spatial coverage nationally. It is utilized to evaluate trophic status based upon the classification system endorsed by CCME (2004). The median TP concentration range was from less than 0.001 to 0.342 mg/L. Twenty of the 27 eutrophic or hyper-eutrophic sites in Canada are in prairie or large northern rivers. Seven of these rivers have more than 80% of their TP in particulate (granular) form. This particulate phosphorus, most often carried along by the flow of the river as part of total suspended sediments (TSS), is typically not bioavailable¹².

Total phosphorus concentrations at least-impacted sites were more in the range of other sites monitored within a given drainage area; concentrations ranged from 0.001 to 0.15 mg/L.

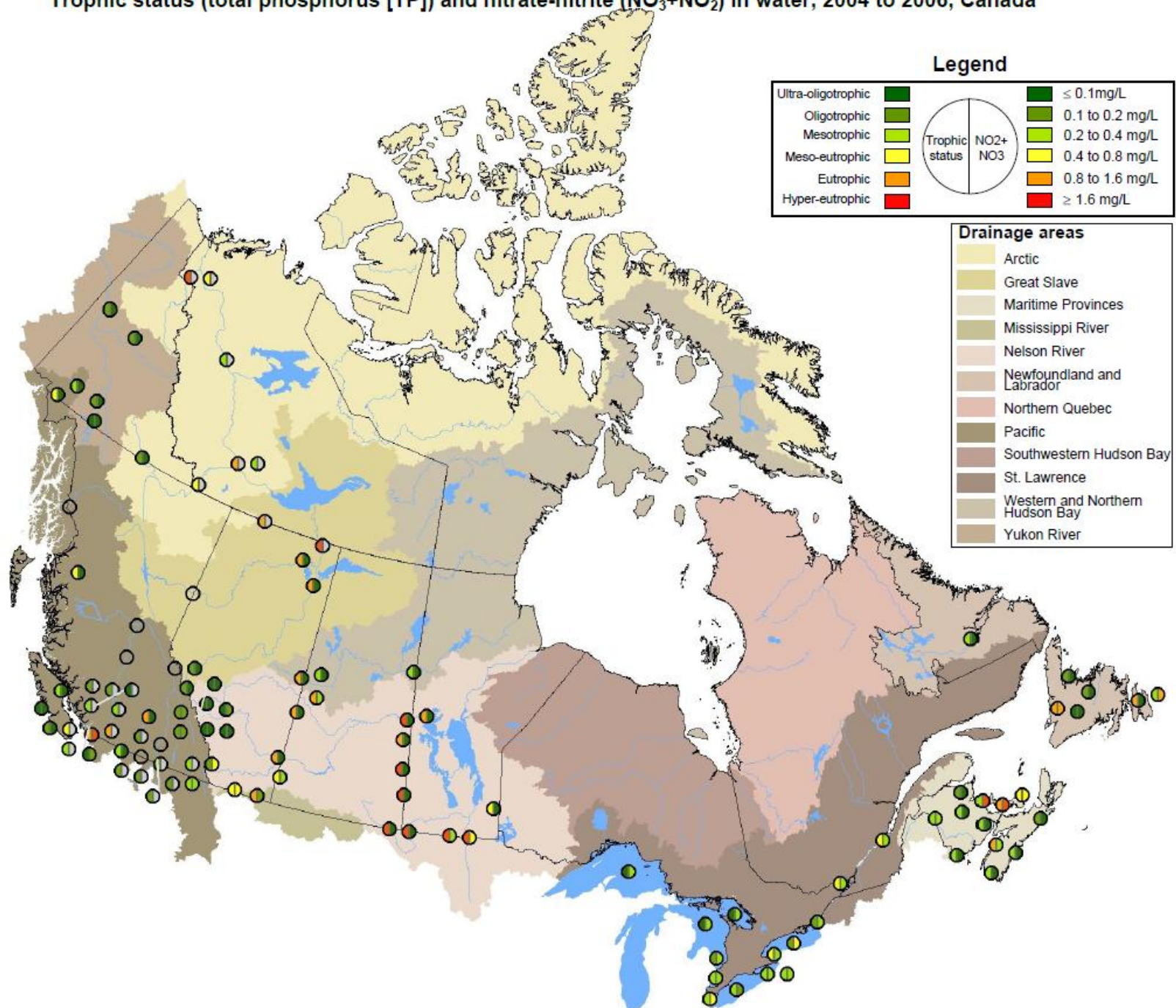
In contrast to those rivers which have a high proportion of particulate phosphorus tied-up in TSS are six hyper-eutrophic rivers in the Assiniboine-Red Drainage Area which have the more bioavailable total dissolved phosphorus (TDP) present at between 49% and 72% of TP.

The median concentration range for nitrogen (measured as nitrate + nitrite) was from below detection limit (generally 0.002 mg/L) to 6.9mg/L. The highest nitrogen levels were found in Prince Edward Island, the Great Lakes (especially Erie and Ontario) and British Columbia; six of these sites exceeded the CCME nitrate guideline for protection of aquatic life (2.9 mg/L). Central and western Canada and Atlantic Canada had relatively low, moderately variable levels.

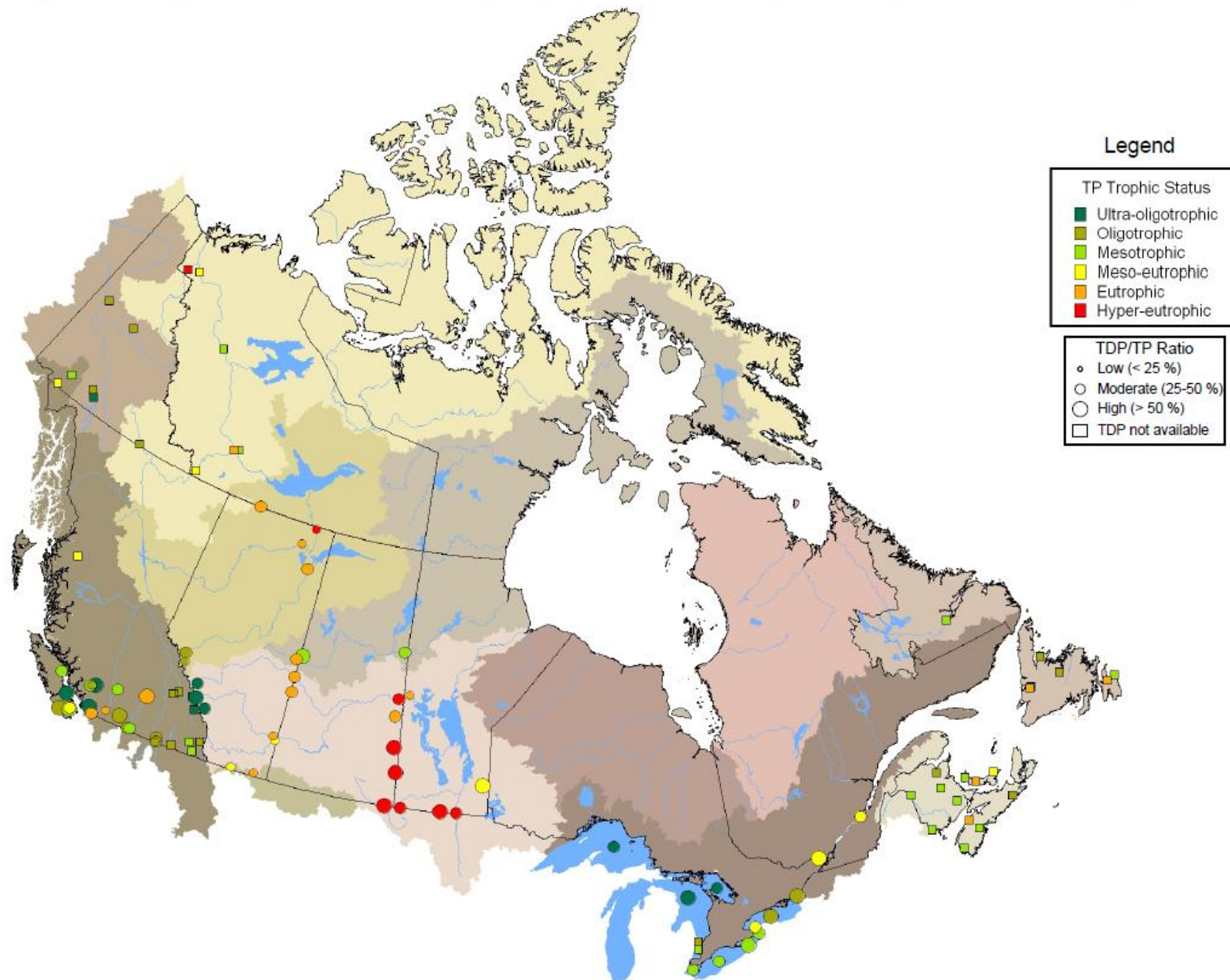
Nitrate concentrations at least-impacted sites ranged from 0.005 to 0.382 mg/L, and were, in general, amongst the lower concentrations observed at the sites monitored nationally.

¹² Over time, particulate P can eventually be converted into more readily bioavailable P through bacterial breakdown and physicochemical reaction. Invasive species such as zebra mussels may also perform this function through filtration/digestion/excretion

Trophic status (total phosphorus [TP]) and nitrate-nitrite ($\text{NO}_3 + \text{NO}_2$) in water, 2004 to 2006, Canada



Total phosphorus (TP) and ratio of total dissolved phosphorus (TDP) and total phosphorus in water, 2004 to 2006, Canada



4.2 National Trends of Nitrogen and Phosphorus

Of the 75 sites with TP data, 16 (or 21%) have increases, 23 (or 31%) have decreases and 36 (or 48%) have no change over the period 1990-2006. For half of the sites with increasing TP, the magnitude of the increase was great enough to change the trophic status category by at least one category (for e.g., oligotrophic to mesotrophic).

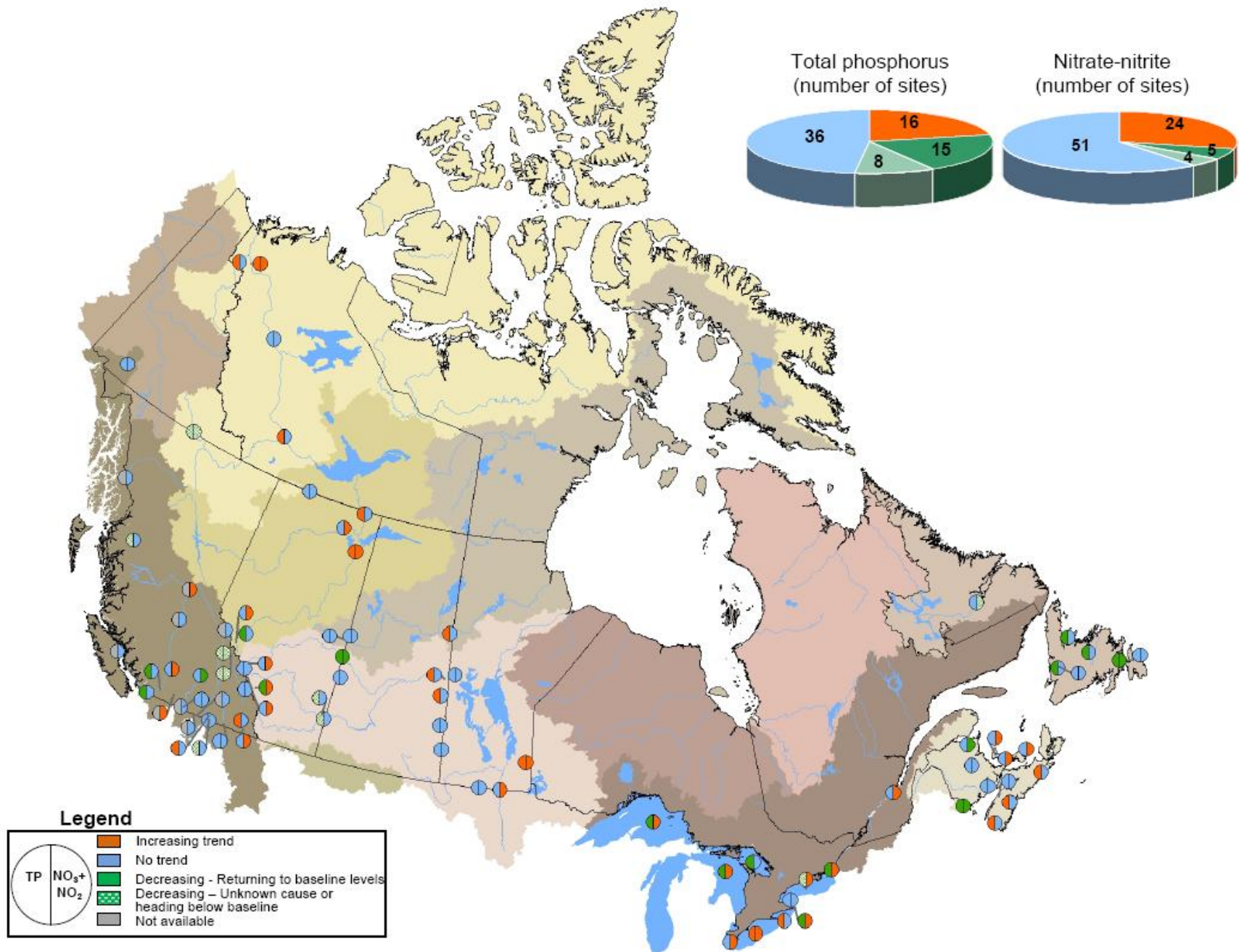
Of the 84 sites tested for nitrate-nitrite trends between 1990 and 2006, 9 sites (11%) show a decrease, 24 sites (29%) show an increasing trend and 51 sites (61%) show no change.

Phosphorus and nitrogen do not always follow the same trends. Thirty-one out of 75 sites (41%) show a concurrent increase (4), decrease (6) or no trend (21) for both parameters, while 45 (60%) have differing trends, including 6 sites with opposite trends. This is attributed to the very different processes driving inputs and cycling of these nutrients. Phosphorus concentrations appear to increase downstream of drainage areas, while it is not the case for nitrogen.

Both the increases and decreases of nitrogen and phosphorus are distributed across Canada. However, some spatial patterns can be discerned. These include:

- decreases in total phosphorus in the Great Lakes, except for Lake Erie, with concurrent increases in nitrate-nitrite,
- increases in nitrate-nitrite in Prince Edward Island at all sites,
- increases in total phosphorus in Nova Scotia (3 of 4 sites) and in the Arctic Drainage (3 of 5 sites), and
- decreases in total phosphorus in western Alberta (3 of 4 sites in the Nelson River Drainage Area), in the Pacific Drainage Area (6 of 8 sites with significant trends), and Newfoundland and Labrador Drainage Area (4 of 7 sites).

Trend in total phosphorus (TP) and nitrate-nitrite (NO_3+NO_2) in water, 1990 to 2006, Canada



5 REGIONAL AND SITE-SPECIFIC STATUS AND TRENDS BY DRAINAGE AREA

The information in this section is presented by drainage area, although the data is primarily analyzed at the site specific level. Nitrogen and phosphorus patterns are discussed below for 10 of the 12 major drainage areas in Canada. Site information is provided in the trophic status table beneath the map of each drainage area. Additional contextual information about each site can be found in the site profile table which is provided in the appendix.

5.1 Arctic Ocean Drainage Area

5.1.1 Great Slave Lake Drainage area (974,854 km²)

Nutrient highlights:

- 9↑ (9 increasing Trends)
- 3↓ (3 decreasing Trends)
- ↔12 (12 quadrants¹³ with no significant Trend)
- Trophic level range from oligotrophic (0.004 mg/L TP) to hyper-eutrophic (0.169mg/L TP)
- Eutrophic and hyper-eutrophic status and increasing P trends at 3 sites
- All TP, TDP, and TN concentrations increase with distance downstream

Although sparsely populated at less than 1 person/km², the Great Slave Lake drainage area is home to the Canadian oil sands industry where roughly 38,000 km² are leased for surface mining and in-situ extraction. A total of 5.8% of its area is considered disturbed¹⁴, the highest among Canada's major drainage areas, and an additional 64,000 km² (6.5%) are used for cropland. However, the largest protected area in Canada (the Wood Buffalo National Park, 44,800 km²) is also located in this area. The increase in economic development mostly happened in the 1990s, which coincides with the period chosen for the trends analysis.

Great Slave Lake (27,048 km²) and Athabasca Lake (7,849 km²) are Canada's fourth and eight largest lakes respectively. The Athabasca River and Peace River (1,923 km) are two important rivers for this drainage area. Though seemingly a remote area, the drainage area has been quite extensively monitored¹⁵.

Overall, the trends are mixed. For most of the nutrients, trends based on sites have been stable (no change), though with more sites showing increase of nutrients concentrations than the reverse. Also, trophic status based on TP would

¹³ A quadrant refers to one-quarter of the circular trend symbol for each site.

¹⁴ Land cover that isn't vegetation, cropland, water, snow and ice, or urban and built-up.

¹⁵ Nutrient monitoring has been a focus within this area for decades and the Northern River Basins Study (NRBS) completed in 1999. One of the eight key focus topics was nutrients. Industrial, agricultural and municipal loadings and influences were examined including key nutrient point source contributions from pulp and paper mills and municipal sewage treatment plants along the Athabasca and Smoky-Wapiti River systems. Additionally provincial and federal environmental agencies are examining limits of nutrient loadings for other parts of the river system (Chambers et.al. 2000; Scrimgeour and Chambers 2000).

be considered highly variable according to the site. The oligotrophic sites (GS01 and GS03) are located upstream while hyper-eutrophic (GS02¹⁶ and GS07) are located downstream. A least-impacted site (GS04¹⁷ on the Hay River just north of the Alberta-NT border) has a eutrophic status, though it may be a more natural influence due to high suspended sediment load in the river. On the contrary, GS-03, downstream of Jasper shows a decreasing TP trend, probably because of a recent positive human response¹⁸.

In another case, the confluence of a river may be driving an increasing trend in phosphorus, although this may be related to natural background (site GS07)¹⁹.

Median concentration and Trophic Status (mg/L)							
Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic Level	
Great Slave Lake Drainage Area	GS01	<i>Athabasca River Above Athabasca Falls</i>	0.091	0.139	0.001	0.005	Oligotrophic
	GS03	<i>Athabasca River At Highway #16 Below Snaring River</i>	0.083	0.143	0.001	0.004	Oligotrophic
	GS02	Athabasca River At 27 Baseline	0.044	0.551	0.016	0.058	Eutrophic
	GS05	Peace River Above Alces River	0.21*	-	0.003	-	-
	GS06	Peace River At Peace Point	0.043	0.47	0.006	0.097	Eutrophic
	GS07	Slave River At Fitzgerald, Alberta	0.001	0.491	0.01	0.169	Hyper-eutrophic
	GS04	<i>Hay River Near Alberta/NT Border</i>	< 2.0	-	0.02	0.055	Eutrophic

Note: italics designate "least impacted sites".

* 30% of samples, or greater, have values that are lower than the detection limit.

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

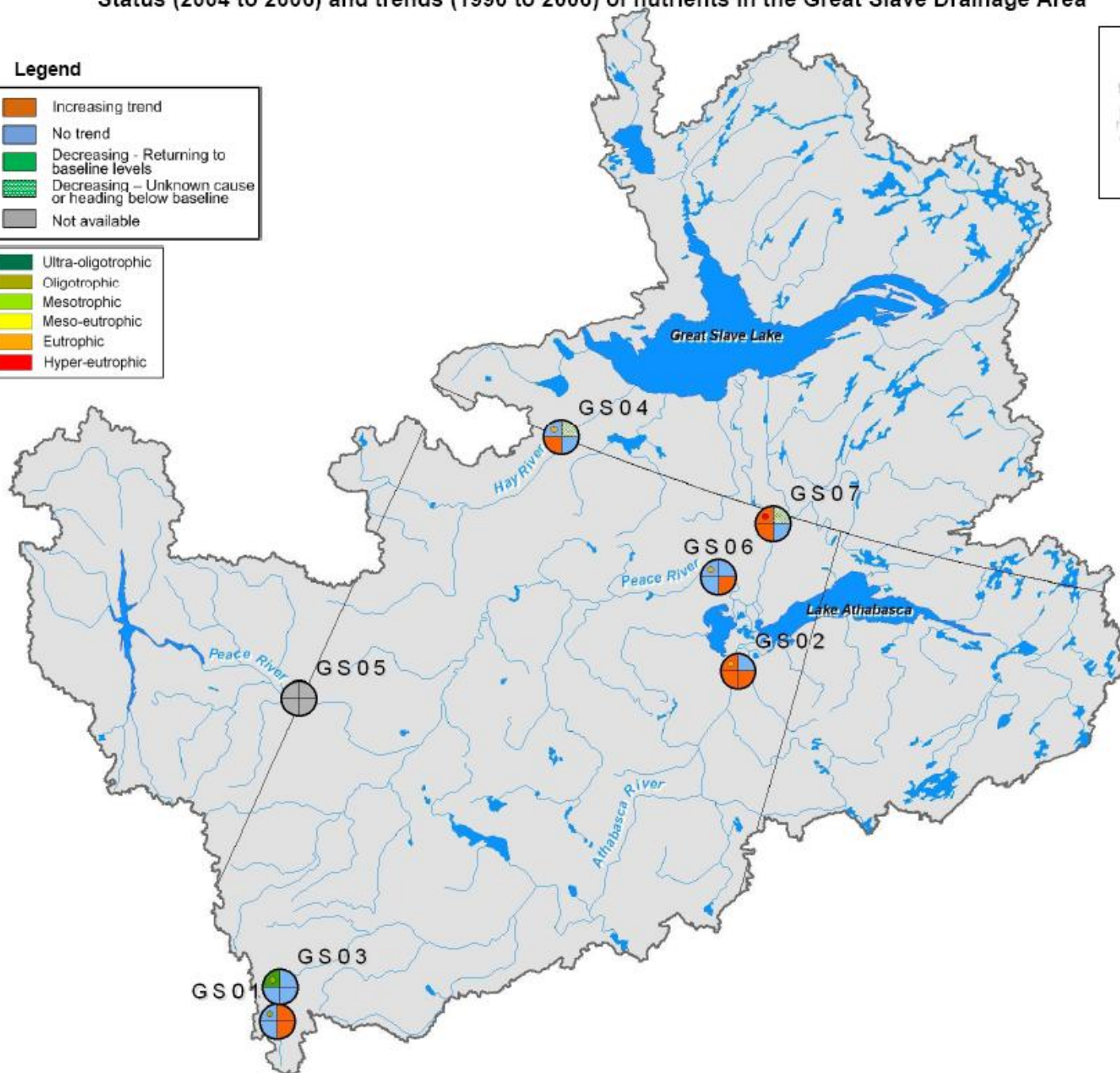
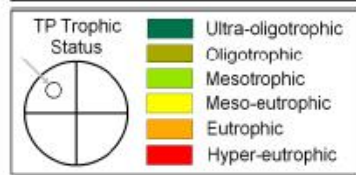
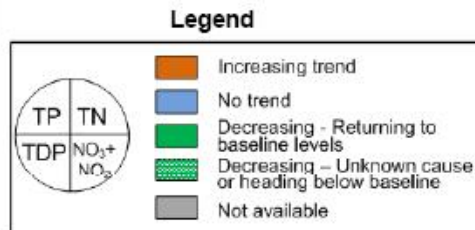
¹⁶ GS02 is about 160 km downstream of Fort McMurray on the Athabasca River but still upstream of Lake Athabasca and the delta-wetlands area. The eutrophic status of this site combined with increasing trends for both TP and TDP as well as for (N-N) nitrate-nitrite is worthy of concern with respect to potential ecosystem effects downstream in the Athabasca-Peace Delta.

¹⁷ The TP median value is 0.55mg/L, however the more bioavailable TDP portion is only 0.02 mg/L or about 3.6% of the total phosphorus

¹⁸ a 2003 upgrading of the town's sewage treatment plant to tertiary treatment with phosphorus removal (Glozier et. al 2004).

¹⁹ Site GS07 is downstream from the confluence of the Peace and Slave rivers north of Lake Athabasca and so receives waters from both the Athabasca and the Peace. Increasing TP and TDP trends in combination with a hyper-eutrophic TP status (0.169mg/L) make further monitoring of nutrient sources and potential ecosystem effects a priority here also. A recent publication by Glozier et. al (2009) found that high TP and TN values at these same sites were in fact associated with natural periods of high suspended sediment load. In fact, over 70% of the total phosphorus concentration in these waters can be explained by seasonal periods of high water discharge and high suspended sediment concentrations. These data demonstrate that classifying sites as hyper-eutrophic based on TP data alone can be misleading.

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Great Slave Drainage Area



5.1.2 Arctic Drainage Drainage Area (2.6 million km²)

Nutrient highlights:

- 8↑ (8 increasing Trends)
- 2↓ (2 decreasing Trends)
- ↔8 (8 quadrants with no significant Trend)
- Trophic level range from oligotrophic to hyper-eutrophic (0.15mg/L TP)
- Eutrophic and hyper-eutrophic status and increasing P trends at 3 sites
- Peel River Site hyper-eutrophic with ↑TDP and ↑ TP trends
- All TP, TDP, and TN concentrations increase with distance downstream

Despite being Canada's largest major drainage area, representing one-quarter of the landmass, it is occupied by less than 0.1% of the population. Although relatively undeveloped, possible threats to the area include fossil fuel exploration and exploitation, mining, and delivery, such as the Mackenzie Valley Pipeline project. Thawing of permafrost induced by climate change will liberate a higher level of sediments in the water, that weren't erodible when the soil was frozen.

This drainage area contains Canada's second largest lake, the Great Bear Lake (30,764 km²), and longest river, the Mackenzie (4,241 km) which drains 60% of the freshwater flowing to the Arctic Ocean from Canada.

Median concentration and Trophic Status (mg/L)							
Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic Level	
Arctic Drainage Area	AR02	<i>Liard River At Upper Crossing</i>	0.045	-	-	0.006	Oligotrophic
	AR01	<i>Liard River At Fort Liard</i>	0.051	-	0.005	0.03	Meso-eutrophic
	AR03	<i>Liard River Near The Mouth</i>	< 2.0	-	0.005	0.05	Eutrophic
	AR07	<i>Peel River Above Fort Mcpherson</i>	0.16	-	0.005	0.15	Hyper-eutrophic
	AR06	<i>Mackenzie River At Strong Point</i>	< 2.0	-	0.005	0.02	Mesotrophic
	AR05	<i>Mackenzie River At Norman Wells</i>	< 2.0	-	0.005	0.01	Mesotrophic
	AR04	<i>Mackenzie River Above Arctic Red River</i>	0.55	-	0.005	0.028	Meso-eutrophic

Note: italics designate "least impacted sites".

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

In the Arctic Drainage Area, sampling sites are concentrated along the Liard River and Mackenzie Rivers. There is also one site on the Peel River, a tributary of the Mackenzie. Nine of 18 quadrants show increasing concentration trends. Particularly noteworthy are increasing TDP trends present at all sites with sufficient data for calculation. Coincident increase in TDP at every site may be indicative of an increase in erosional sources²⁰ in the area. Total and dissolved phosphorus exhibited differing patterns among sites, with median TP

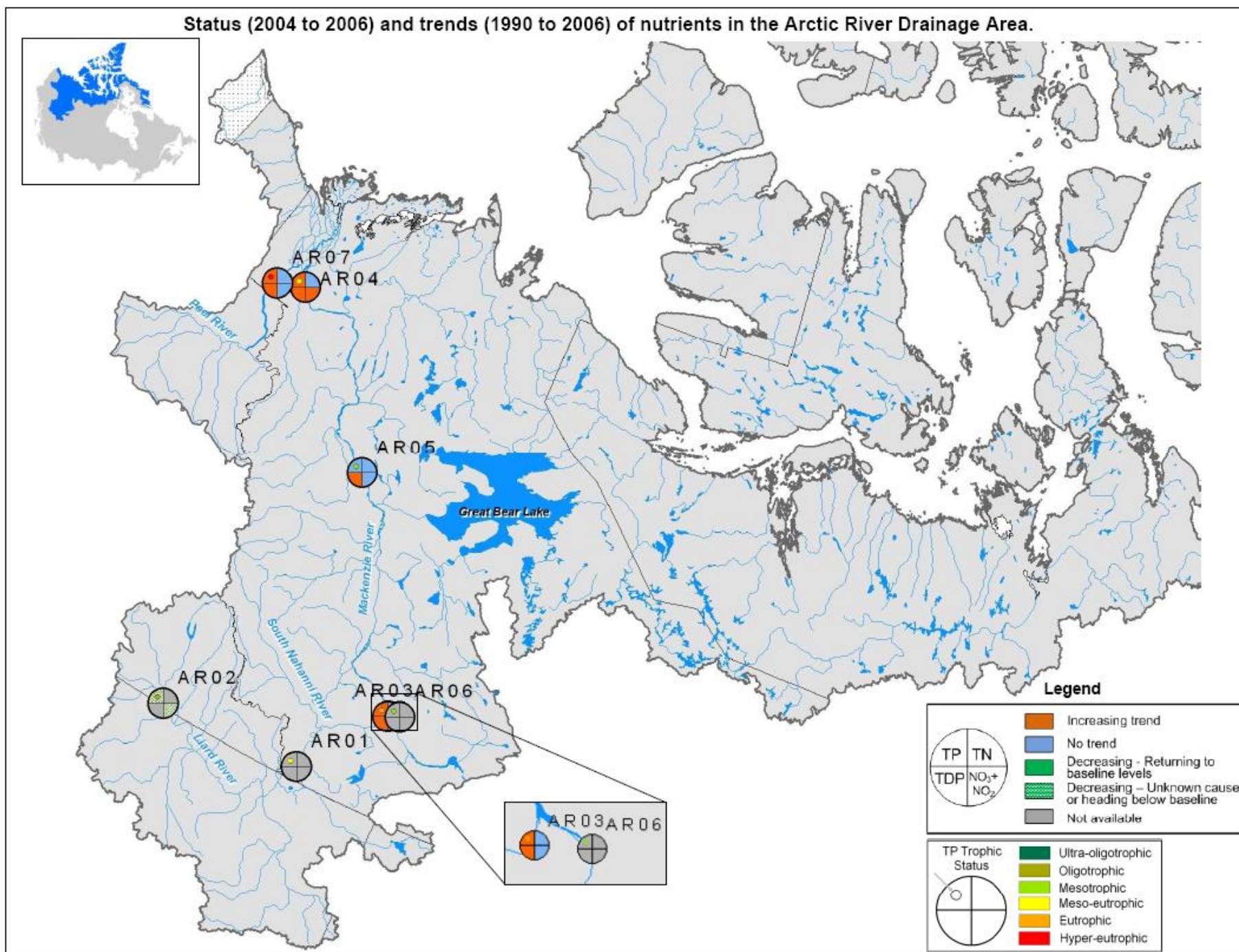
²⁰ Phosphorus may be related to melting permafrost and other climate change and variability scenarios.

"Permafrost is widespread throughout the region, and is continuous in northern areas, such as the Mackenzie Delta where it can extend to a depth of 100 meters" (Benke and Cushing, 2005). Indeed there is evidence that air temperature increased 1.7 °C from 1951 to 2001 (Hartman and Wendler 2005) As a result of this warming trend, some areas of permafrost in the north are thawing, ice breakup can occur earlier and timing of stream flow and movement of carbon and sediment is changing (Hinzman and others, 2005; Walvoord and Striegl, 2007).

concentrations ranging from oligotrophic to hyper-eutrophic. Increases in phosphorus levels, which dominated increasing trends in the area, were not flow related, but could be related to warmer temperatures and permafrost melting. This in turn may have critical implications for nutrient loadings and potential production of algae²¹.

²¹ International Polar Year researchers have carried out a water quality survey of 120 sites on 58 rivers in Canada's Eastern Arctic from Torngat Mountains Northern Labrador to Quttinirpaaq National Park on the northern tip of Ellesmere Island. Monitored parameters include algae and nutrients. Nutrient and ion concentrations were extremely low with rare exceptions attributed to local geology.

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Arctic River Drainage Area.



5.2 Hudson's Bay-James Bay Drainage Area

5.2.1 Western and Northern Hudson Bay Drainage Area (1.25 million km²)

Nutrient highlights:

- 2↑ (2 increasing trends)
- 1↓ (1 decreasing trends)
- ↔9 (9 quadrants with no significant trend)
- Trophic range from mesotrophic to eutrophic (0.070 mg/L TP)
- Two “least-impacted” sites are mesotrophic
- Increases in P at Churchill R not flow related
- ↓TDP trend at HB01 Beaver Crossing may reflect reduction in nutrient flux due to aerated sewage lagoon expansion by City of Cold Lake

Western and Northern Hudson Bay is Canada's second largest drainage area and is occupied by less than 1% of the population. Conditions of the drainage area could be threatened by more recent exploitation of oil sands in the Cold Lake area – one of three key oil sands deposit areas in Alberta²². Hydroelectric developments, mining, northward expansion of forestry activities and thawing of the permafrost could also threaten water quality in the near future.

The Churchill River (1,609 km) and Reindeer Lake (5,658 km²) are important water bodies of the drainage area.

With only three sites located in the same area it is difficult to draw general patterns about the area. Nevertheless, all three sites do present similar characteristics with minor change in nutrients over time.

The trophic status for both the Cold River (HB03) and Churchill River (HB02) monitoring sites was mesotrophic, whereas the Beaver River site (HB01) was classified as eutrophic but with a decreasing trend in total dissolved phosphorus²³.

Median concentration and Trophic Status (mg/L)							
Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level	
Western and Northern Hudson Bay Drainage Area	HB01	Beaver River At Beaver Crossing	0.043	0.941	0.023	0.07	Eutrophic
	HB03	Cold River At Outlet Of Cold Lake	0.005	0.41	0.01	0.02	Mesotrophic
	HB02	Churchill River Below Wasawakasik	0.005	0.388	0.007	0.02	Mesotrophic

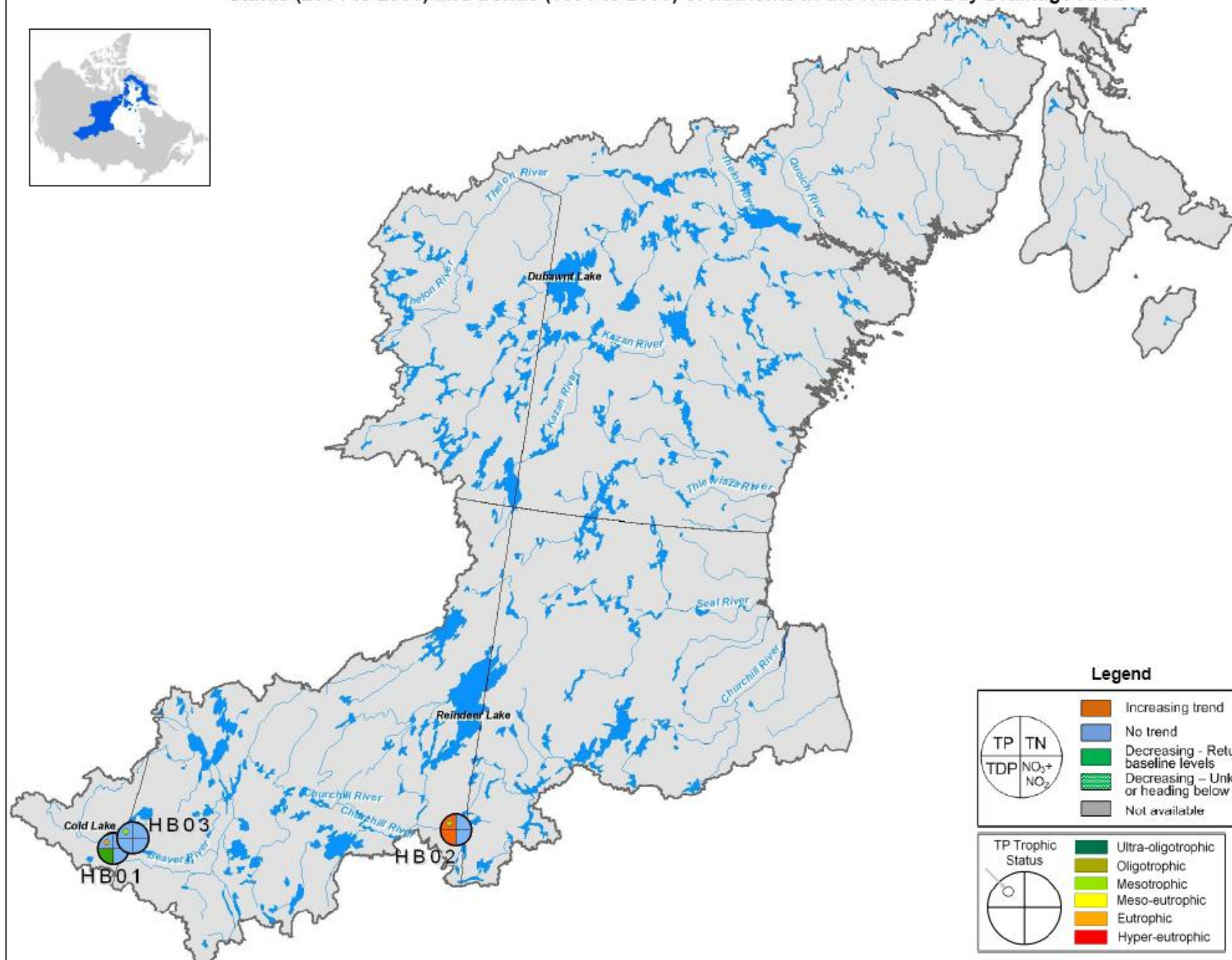
Note: italics designate “least impacted sites”.

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

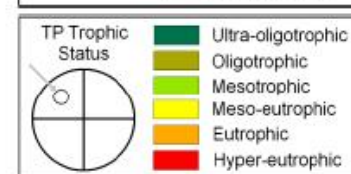
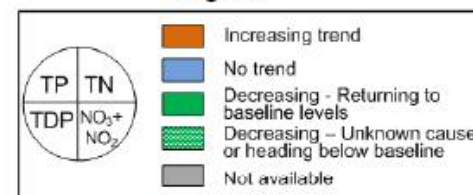
²² Increasing surface water salinity and reduced water levels in the Cold Lake-Beaver River drainage area is coincident with an increase in use of thermal injection oil extraction techniques and groundwater contamination in the area (Alberta Environment, 2006). It is unknown whether increasing P trends hundreds of kilometres downstream at HB02 are in any way related to this industrial activity. HB02 is about 10 km downstream from nearest habitation, the village of Wapaskokimaw, which has less than 500 inhabitants.

²³ This decreasing TDP trend could be related to improved agricultural practices in the area or to improvements in sewage treatment for the city of Cold Lake. A key finding from a recent Alberta Environment report found that nitrate/nitrite and TDP concentrations both decreased in the Beaver River, possibly due to reduction in nutrient flux from the City of Cold Lake's wastewater owing to expansion of an aerated lagoon. The lagoon drains into Marie Creek which joins the Beaver River just upstream of Beaver Crossing, where HB01 is located (Alberta Environment, 2006).

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Hudson Bay Drainage Area



Legend



5.2.2 Nelson River Drainage Area (987,014 km², within Canada)

Nutrient highlights:

- 14↑ (14 increasing trends)
- 12↓ (12 decreasing trends)
- ↔34 (34 quadrants with no significant trend)
- Trophic range from ultra-oligotrophic to hyper-eutrophic (0.342 mg/L TP)
- The 3 “least-impacted” sites are all ultra-oligotrophic (nutrient poor)
- Hyper-eutrophic status for all 6 sites in Assiniboine-Red watershed though only one shows an increasing trend (TN) for period from 1990-2006. High TDP/TP ratio at all 6 sites is consistent with assumption that these waters may already be at or near saturation with respect to phosphorus.
- ↑ Trends for all 4 nutrients and meso-eutrophic status for Winnipeg River site upstream of Lake Winnipeg
- Bow River site upstream of Canmore shows decreasing TP, TDP and TN trends due to STP upgrade at Banff

The Nelson River drainage area is the second most populated drainage area (5 million residents) and includes two of Canada’s fastest growing metropolitan areas, Edmonton and Calgary. This drainage area contains 70% of Canada’s cropland (471,000 km²), covering 48% of its surface – five times more than any other drainage area. Biofuels and global food demand are expected to increase pressure to cultivate the remaining Prairie grassland. Other threats include oil and gas activity in Alberta and Saskatchewan, intense competition for limited water resources, mining and other industries.

The drainage area features Lake Winnipeg which drains 982,000 km² (82% within Canada) with inputs from a number of major prairie rivers. Lake Winnipeg, Canada’s fifth largest continues to suffer from algal blooms every year.

Many rivers are showing stable concentrations trends as “no trend” was measured for 34 nutrient parameter quadrants, and there are just a few additional cases where we see increasing trends compared with decreasing trends²⁴. Many of the nation’s highest nutrient concentrations were found in downstream slow-flowing prairie rivers in this drainage area²⁵. Only the three least-impacted sites (NR03, NR04, and NR07) located in mountain headwaters to the west are low in nutrients. Phosphorus concentrations increased from upstream to downstream in all river drainage areas in this prairie farm belt.

²⁴ One interesting case is the Bow River site upstream of Canmore has decreasing nutrient trends most probably due to a plant upgrade to tertiary sewage treatment with phosphorus removal at Banff (Glozier et. al 2004).

²⁵ Sites indicating nutrients input to lake Winnipeg shows high nutrients levels. NR05 has hyper-eutrophic status and 3 increasing trends for TDP, TP, and TN. Nearby site NR10 also has increasing TDP and TP trends in addition to eutrophic status. Similarly site NR17, the lone site on the Winnipeg River had increasing trends for all 4 nutrient quadrants with meso-eutrophic status.

Also worthy of concern are the six sites in Assiniboine-Red watershed which are all hyper-eutrophic though none show an increasing trend for the period from 1990-2006²⁶.

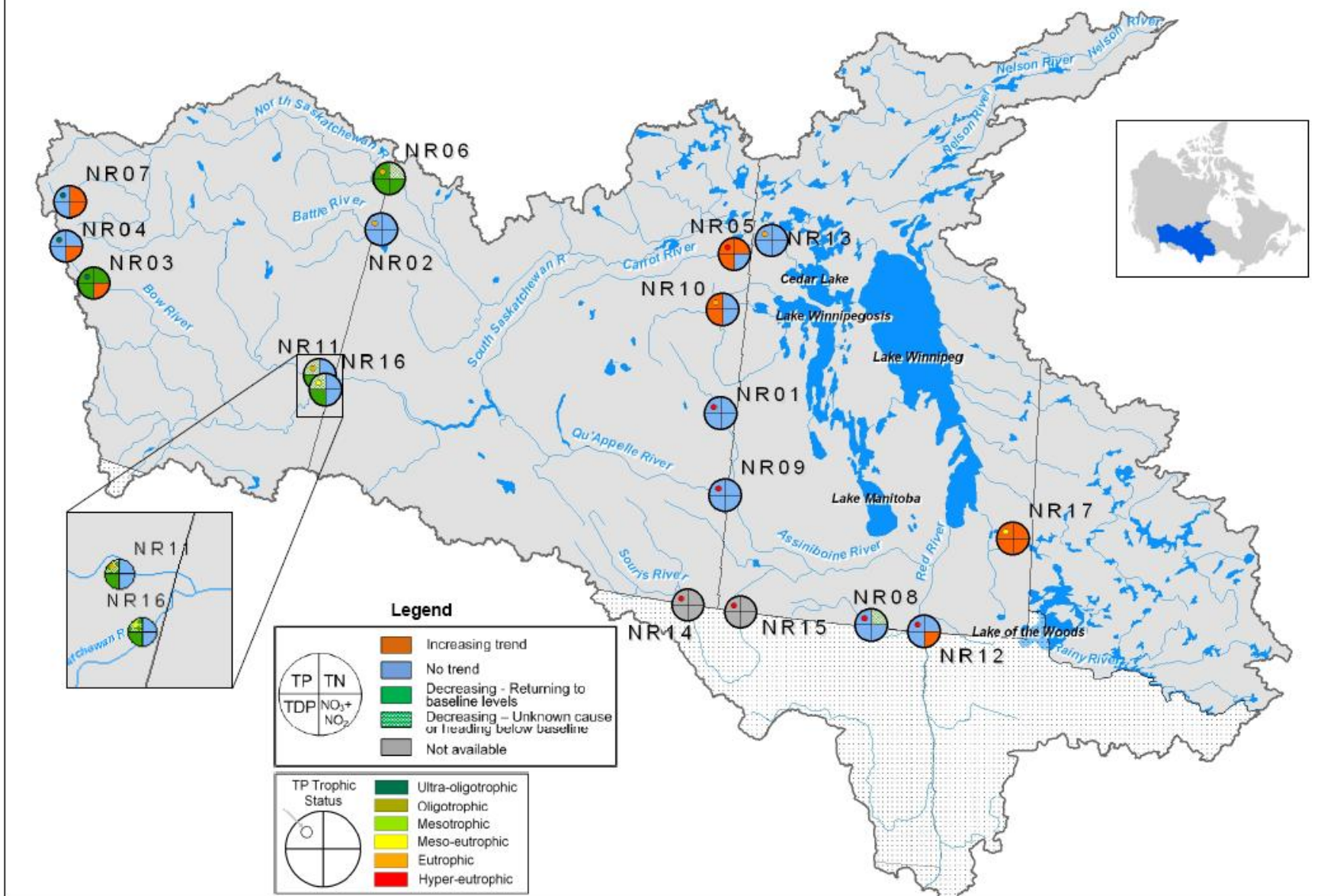
Median concentration and Trophic Status (mg/L)							
	Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level
South Saskatchewan R. Drainage Area	NR04	<i>Bow River At Highway 1 Above Lake Louise</i>	0.066	0.124	0.001	0.001	Ultra-oligotrophic
	NR03	<i>Bow River About 4.5 Km Above Canmore</i>	0.073	0.147	0.001	0.003	Ultra-oligotrophic
	NR11	Red Deer River Near Bindloss, Alberta	0.038	0.587	0.008	0.053	Eutrophic
	NR16	South Saskatchewan River At Hwy 41	0.34	0.721	0.005	0.025	Meso-eutrophic
North Saskatchewan R. Drainage Area	NR07	<i>North Saskatchewan River At Whirlpool Point</i>	0.099	0.138	0.001	0.003	Ultra-oligotrophic
	NR06	North Saskatchewan River At Highway #17 Bridge	0.247	0.629	0.014	0.047	Eutrophic
	NR02	Battle River Near Unwin, Saskatchewan	0.005	1.036	0.023	0.061	Eutrophic
Lower Saskatchewan Drainage Area	NR10	Red Deer River At Erwood,	0.081	1.158	0.023	0.051	Eutrophic
	NR05	Carrot River Near Turnberry,	0.031	1.332	0.052	0.13	Hyper-eutrophic
	NR13	Saskatchewan River Above Carrot River	0.038	0.607	0.01	0.059	Eutrophic
Winnipeg Drainage Area	NR17	Winnipeg River At Pointe Du Bois	0.073	0.533	0.017	0.029	Meso-eutrophic
Assiniboine-Red Drainage Area	NR01	Assiniboine River At Hwy 8 Bridge	0.03	1.395	0.065	0.116	Hyper-eutrophic
	NR09	Qu'appelle River Approx. 3.2km. South	0.083	1.139	0.143	0.2	Hyper-eutrophic
	NR14	Souris River Near Sherwood N.D.	0.032	1.38	0.1	0.175	Hyper-eutrophic
	NR15	Souris River Near Westhope	0.014	2.58	0.169	0.342	Hyper-eutrophic
	NR08	Pembina River At Windygates, Manitoba	0.253	1.349	0.222	0.304	Hyper-eutrophic
	NR12	Red River At Emerson, Manitoba	0.423	1.563	0.135	0.295	Hyper-eutrophic

Note: italics designate "least impacted sites".

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

²⁶ Extremely high TDP/TP ratios (a range of 49% to 73% TDP) at these 6 sites is consistent with an assumption that these waters may already be at or very near saturation with respect to phosphorus, partially explaining the lack of increasing P-concentration trends for the time-period analyzed. Additional nutrient trend analysis for dates preceding 1990 may provide insight should these datasets be available

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Nelson River Drainage Area



5.3 Atlantic Drainage Area

5.3.1 Great Lakes – St. Lawrence Drainage Area (957,285 km², in Canada)

Nutrient highlights (7 Great Lakes sites²⁷ and 5 connecting channel sites):

- 19↑ (19 increasing trends)
- 10↓ (10 decreasing trends)
- ↔14 (14 quadrants with no significant trend)
- Trophic range from ultra-oligotrophic in Upper Great Lakes to meso-eutrophic in Lake Erie (0.032 mg/L TP).
- ↑TP trend in Lake Erie
- ↓P trends in lakes Superior, Huron, Georgian Bay and Ontario
- ↑Nitrate-Nitrite trends at 8 of 11 sites
- Even where the overall P concentration is declining (TP↓) the bioavailable portion of phosphorus is increasing (TDP↑)
- Phosphorus' bioavailable fraction (TDP/TP) increases steadily downstream throughout the Great Lakes system reaching 78% in Lake Ontario and peaking at 88% at Wolfe Island at the start of the St. Lawrence River
- Opposing trend tendencies for N ↑ versus P↓ at 6 of 11 sites with trends
- Concentrations of NO₃+NO₂ are high relative to other sites monitored nationally and have increased steadily in all of the Great Lakes even in Superior and Huron. TN also showed an increasing upstream-to-downstream pattern in the basin consistent with increasing anthropogenic inputs downstream.
- Lake N-N concentrations are typically highest in the spring due to seasonal in-lake cycling, then decrease during the summer before increasing again in the fall. Certain localized nearshore regions also tend to have higher concentrations of TN, especially when compared with the open lake data.

The Great Lakes - St. Lawrence drainage area is the most populated in Canada with 19 million residents in the Canadian portion and close to 45 million people when considering the U.S. portion. It is second to the Nelson River drainage area in land covered by cropland with 83,000 km², representing 9% of its area. In addition, there were 259 facilities reporting substance releases to water in the National Pollutant Release Inventory (NPRI) in 2008 – more than any other major drainage area with 55% of all facilities.

The economic value of the various uses made of the river is estimated to be 165 billion dollars over 20 years from marine transportation, industrial operations, fish and wildlife harvesting activities & recreational activities. Freight transported by water is estimated at 100 million tonnes a year, representing 20,000 direct and indirect jobs. One third of Canada's tonnage transits through Québec ports.

The Great Lakes – St. Lawrence system drains more than 25% of the Earth's freshwater supply. Based on the Canadian portion only, Lake Huron is Canada's largest lake, while Lake Superior, Erie, and Ontario are third, sixth and seventh,

²⁷ Given the relative homogeneity of the data collected from the 255 open water sites in the Great Lakes, the status and trend data from 255 lake sites in the Great Lakes have been rolled into one representative site for each lake; exception is Lake Erie which has 3 basins.

respectively. Flow is up to 8 000 m³ at the outlet of Lake Ontario and goes up to 10 000m³ at the outlet of the St. Lawrence River (estuary saline point). Lake Ontario and the St. Lawrence River are partially regulated.

Increasing nitrate trends reported are consistent with other studies and published work outlining that nitrate concentrations have increased five-fold in Lake Superior over the last century (Bennett 1986; Sterner et. al, 2007²⁸ For phosphorus, although the trends for total phosphorus is decreasing, there is an increasing trends fro dissolved phosphorus which is more readily available for plants (bio-available). The decreasing trends are noticed at 6 of 11 sites, but not in Lake Erie where the central and eastern basins have increasing TP trends²⁹.

	Median concentration and Trophic Status (mg/L)						
	Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic Level
St. Clair River	SL11	Point Edward	0.343	0.51	-	0.007	Oligotrophic
	SL12	Port Lambton	0.353	0.513	-	0.011	Mesotrophic
Niagara River	SL01	Fort Erie	0.295	0.521	0.006	0.017	Mesotrophic
	SL09	Niagara-on-the-Lake	0.305	0.529	0.007	0.021	Meso-eutrophic
St. Lawrence River	SL14	Wolfe Island	0.366	0.57	0.007	0.008	Oligotrophic
	SL10	Ottawa River	0.21	n/a	0.014	0.025	Meso-eutrophic
	SL13	St. Lawrence River	0.34	n/a	0.015	0.032	Meso-eutrophic
Great Lakes	SL08	Lake Superior	0.374	0.485	0.001	0.003	Ultra-oligotrophic
	SL06	Lake Huron	0.349	0.475	0.002	0.004	Ultra-oligotrophic
	SL02	Georgian Bay	0.33	0.455	0.001	0.003	Ultra-oligotrophic
	SL05	Lake Erie Western Area	0.73	0.943	0.006	0.014	Mesotrophic
	SL03	Lake Erie Central Area	0.189	0.401	0.005	0.011	Mesotrophic
	SL04	Lake Erie Eastern Area	0.314	0.548	0.005	0.01	Mesotrophic
	SL07	Lake Ontario	0.451	0.643	0.005	0.007	Oligotrophic

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

Moving eastward with the flow direction, Lake Ontario shows decreasing trends for both TDP and TP however, at the end of the Great Lakes at Wolfe Island (Site SL14) the same diametrically opposed P-trends occur; dissolved phosphorus (TDP) concentration is increasing despite the fact that the overall phosphorus concentration (TP) is decreasing. In fact, the percentage of TP which is in the dissolved form is nearly 88%³⁰. The trend is especially pronounced in the

²⁸ Atmospheric deposition of NO_x species has frequently been cited as the most probable cause for nitrate increases in North America and the Great Lakes (Jeffries 1995; Jeffries and Maron, 1997; Ostrom et. al 1998). Recent nitrate isotopic studies point to the in-lake conversion of ammonia (and other nitrogen forms) into nitrate as another potentially major contributing factor. (Sterner et. al. 2007).

²⁹ Nowhere is this more conclusive than in the Niagara River where the Fort Erie site (SL01) actually has an increasing TDP trend despite a decreasing TP trend. The same theme, though not as dramatic, applies to the other site on the Niagara River (SL09) which also has an increasing TDP trend but this time a stable TP concentration trend (neither upwards nor downwards).

³⁰ This phenomenon may be due in part to settling of particulate phosphorus in lakes (particularly large lakes) where flows diminish compared to rivers. In the lower lakes this phenomenon has also been directly related to the role of invasive *Dreissena* (Zebra mussel) species and their prolific growth and filtration capacity which rapidly cycles nutrients (Arnott and Vanni, 1996). Dove (2010 in press) outlines that although TP concentrations have declined in Lake Ontario since phosphorus reduction initiatives were put in place,

nearshore³¹ where we may see increasing nuisance growth of algae and possibly eutrophication resulting from these algal blooms. Weight of evidence indicates that the open lake is experiencing “oligotrophication”³² rather than eutrophication.

Starting with the Upper Great Lakes the percentages of phosphorus in dissolved form is increasing from upstream to downstream location in the Lakes:

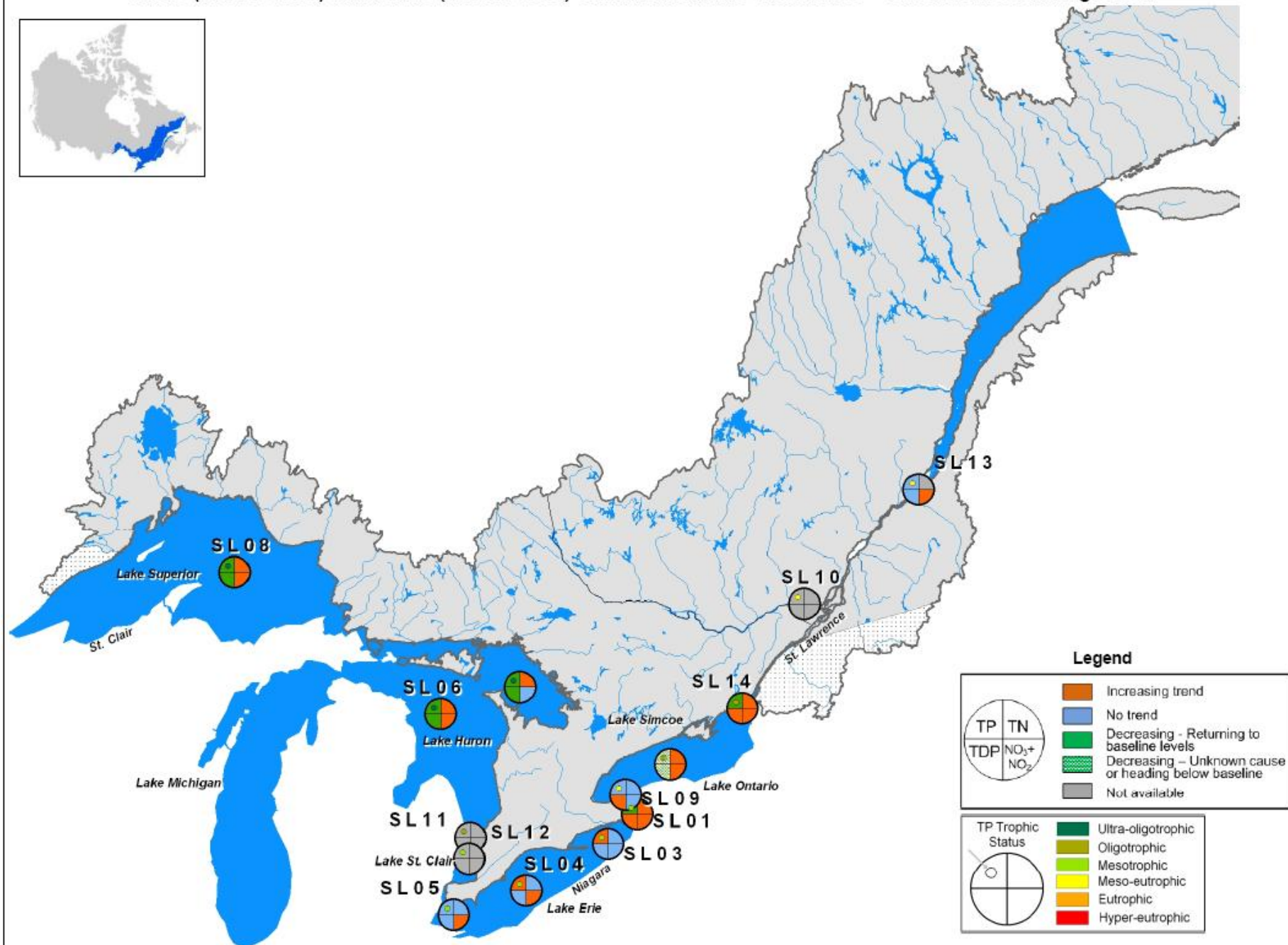
- 33% in Lake Superior and Georgian Bay
- 44% in Lake Huron
- 43-50% in Lake Erie
- 78% in Lake Ontario
- 88% at Wolfe Island (“headwaters” of St. Lawrence River)

the enormous filtering capacity of *Dreissena* has also reduced particulate phosphorus in the lake while increasing the more bioavailable dissolved portion (TDP).

³¹ Away from shorelines, in the open lake areas of Lake Ontario, P-levels are very low (oligotrophic) and productivity of phytoplankton and zooplankton has declined. As a result the benthic community has suffered a 98% loss of *Diporeia* (an important benthic prey species) and prey fish abundance has declined.

³² Oligotrophication can be considered as a process where nutrients are less and less available

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Great Lakes – St. Lawrence Drainage Area



5.3.2 Maritime Drainage Area (163,989 km²)

Nutrient highlights:

- 9↑ (9 increasing trends)
- 6↓ (6 decreasing trends)
- ↔13 (13 quadrants with no significant trend)
- Trophic range from oligotrophic to eutrophic (0.045 mg/L TP)
- 3 Nova Scotia sites have same trends, stable N-N, ↑TP and ↓TN
- ↑TN and ↑N-N at all 3 PEI sites
- Nitrate-Nitrite is 66%, 92%, and 97% of TN at the 3 PEI sites
- 2 PEI sites exceed the CCME Nitrate guideline for protection of aquatic life (2.9 mg/L). Site on Wilmot River site has median value of 6.9 mg/L
- ↓TP and N-N trends on St Croix river likely related to decline in pulp and paper effluent loadings
- No TDP data for entire region; recommended to add to analytical suite

The Maritime Drainage Area is second among areas in population density with more than 11 residents/km² and fourth most populated with 1.9 million residents. At total of 9% of the drainage area area is agricultural, with the more intense activities located in Prince Edward Island, northwestern New-Brunswick and Nova Scotia's Annapolis Valley. Other pressures include mining, pulp and paper and forestry.

Compared to the rest of the country, many rivers in the maritime drainage area are relatively short and discharge relatively rapidly into coastal waters. At 673 km, the St-John River is the longest in the Maritime drainage area and boasts a rich history in colonization, commercial development, forestry, agriculture, fishing, and hunting.

Phosphorus has been identified as an important limiting factor in Prince Edward Island (PEI) estuaries where surface waters draining the island discharge very quickly (Meeuwig, 1998)³³. Mill River and Wilmot River both have significant agricultural activities within their watersheds representing 31 and 82% of watershed land-use, respectively (PEI DEEF, 2000)³⁴. In contrast Bear River is a watershed where there is little agricultural activity and only a small rural population. Land cover upstream of the Bear River site is primarily forested and agricultural activities represent only 9% of the land use. Although nitrogen concentrations were lower here than other PEI rivers, they were elevated relative to other sites considered nationally; the NO₃+NO₂ concentration is in the 90th percentile of concentrations measured in this report. Groundwater discharge to PEI rivers can range between 60-70% of flow and can be the dominant source of water during critical periods (PEI DTE-EC, 1999)³⁵. Regarding other sites in the

³³ A major concern in PEI relates to elevated N-concentrations. Median concentrations of both TN and NO₃+NO₂ measured at Wilmot River and Mill River are the highest values measured in this national study.

³⁴ The main source of nitrogen within the PEI basin is from agricultural activities and to a lesser degree from rural development. In general, nitrate concentrations relate to the amount of cleared land and the level of row crop production in each watershed (PEI DFAE, 2003).

³⁵ A recent nitrogen stable isotope study reported that mixing 25% or less of seasonal recharge with older, less impacted GW accounts for the observed characteristics of GW from domestic wells, implying that the

Maritime Drainage Area, in Nova Scotia 3 of the 4 sites have the exact same trend profiles; a decreasing trend for TN is juxtaposed with an increasing trend for TP. In New Brunswick, no sites have increasing nutrient trends³⁶.

Median and Trophic Status (mg/L)							
	Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level
Southeastern Atlantic Ocean Drainage Area (N.S.)	MP03	***Lahave River At Northfield	0.015	0.325	-	0.011	Mesotrophic
	MP10	***St. Mary's River At Stillwater	0.04	0.3	-	0.008	Oligotrophic
	MP11	***Tusket River At Wilsons Bridge	0.01	0.4	-	0.012	Mesotrophic
Bay of Fundy and Gulf of St. Lawrence Drainage Area (N.S.)	MP01	***Annapolis River At Wilmot	0.38	0.76	-	0.038	Eutrophic
Gulf of St. Lawrence and Northern Bay of Fundy Drainage Area (N.B.)	MP05	Nepisiguit River At Route 360	0.07	0.15	-	0.009	Oligotrophic
	MP06	Petitcodiac River At Old Highway Bridge	0.025	0.3	-	0.018	Mesotrophic
	<i>MP08</i>	<i>Southwest Miramichi River At Blackville</i>	0.025	0.15	-	0.011	Mesotrophic
Prince Edward Island Drainage Area	MP02	Bear River At St. Margarets	0.451	0.678	-	0.031	Meso-eutrophic
	MP04	Mill River In Bloomfield Park	2.98	3.21	-	0.014	Mesotrophic
	MP12	Wilmot River Near Kelvin Grove	6.915	7.14	-	0.045	Eutrophic
Saint John and Southern Bay of Fundy Drainage Area (N.B.)	MP07	Saint John River At Limestone	0.25	0.5	-	0.012	Mesotrophic
	MP09	St. Croix River At Milltown	0.025	0.15	-	0.012	Mesotrophic

Note: italics designate "least impacted sites"

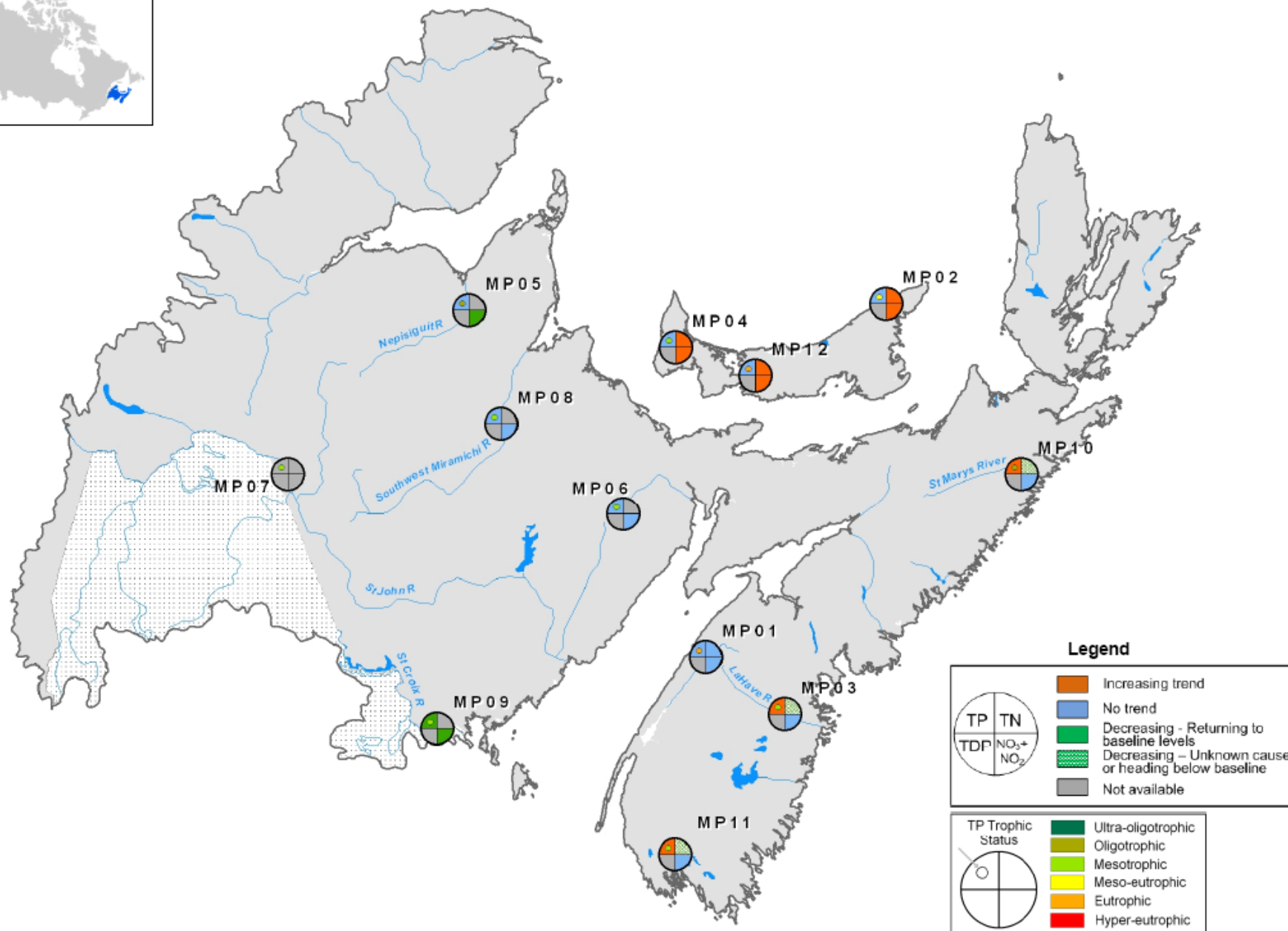
*** Nitrate (NO₃) data only available.

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

greatest proportion of N flux in GW is at this time restricted to relatively shallow portions of the aquifer. This rationale may explain why currently observed nitrate concentrations in deep wells in the watershed are below expected levels based on calculated estimates of nitrate loading to the aquifer (Somers and Savard, 2008). Nitrates are possibly being recycled back to surface waters before they can percolate deeper into aquifers. It may also explain why Bear River surface water nitrate concentrations are so elevated; they are a reflection of groundwater quality much in the same way that groundwater quality is a reflection of surface inputs.

³⁶ The return of the salmon to the Nepisiguit River is one example of ecosystem health improvement; the fishery was virtually destroyed by accidental release of acid mine drainage effluent in 1969 (Cook and Hoos, 1971).

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Maritime Drainage Area



5.3.3 Newfoundland and Labrador Drainage Area (372,075 km²)

Nutrient Highlights:

- Only 1↑ trend (1 increasing trends)
- 8↓ (8 decreasing trends)
- ↔12 (12 quadrants with no significant trend)
- Trophic range from ultra-oligotrophic to eutrophic (0.040 mg/L TP)
- Very low N concentrations at lone site in Labrador at Churchill River; (0.15 mg/L TN and 0.01 mg/L NO₃)
- No TDP data for entire province; recommended to add to analytical suite

With low overall population density (1.3 residents/km²), particularly in Labrador, St. John's is the main major urban center. Expansion of Saint John is linked in part to offshore oil production from the Hibernia, White Rose and Terra Nova facilities.

Urbanization and agricultural activities are relatively low compared to other areas. However, forestry, manufacturing and mining are present in Newfoundland and Labrador. There were 14 commodities in production and nine in development.

	Median concentration and Trophic Status (mg/L)						
	Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level
Southern Newfoundland Area	NF03	Gould's Brook	0.02	0.244	-	0.04	Eutrophic
	NF06	Waterford River At Kilbride	0.81	0.984	-	0.019	Mesotrophic
Northern Newfoundland Area	NF02	Exploits River At Grand Falls	0.05	0.231	-	0.004	Oligotrophic
	NF04	Humber River At Humber Village Bridge	0.08	0.23	-	0.003	Ultra-oligotrophic
	NF07	Wild Cove Brook	0.85	1.51	-	0.037	Eutrophic
	NF05	South West Brook At Baie Verte	0.03	0.422	-	0.006	Oligotrophic
Churchill Area (N.L.)	NF01	Churchill River At Muskrat Falls	0.01	0.154	-	0.016	Mesotrophic

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

In this drainage area, nutrient concentrations varied within fairly modest ranges. Total Nitrogen (TN) concentrations ranged from 0.15 mg/L to the 1.51 mg/L measured at Wild Cove Brook (NF07) which is a small coastal stream³⁷ and Gould's Brook monitoring site³⁸

Located on the coast, most of Newfoundland and Labrador experience extreme weather and precipitation events. Observed changes in precipitation and stream flow was described as the most significant causal factor affecting water quality in the province (Dawe, 2006). The Waterford River at Kilbride (vicinity of St. John's –site NF06) is mesotrophic and is the only site in the province with an increasing

³⁷ NF07 also had a eutrophic TP concentration which may be attributed to industrial point sources in this small (7 km²) watershed (Dawe, 2003).

³⁸ . Median total phosphorus concentrations were eutrophic and highest for the Newfoundland-Labrador drainage area (TP 0.040 mg/L). The relatively small local drainage area could be an influence as nutrient inputs from agricultural activities may not be readily diluted (Dawe, 2003).

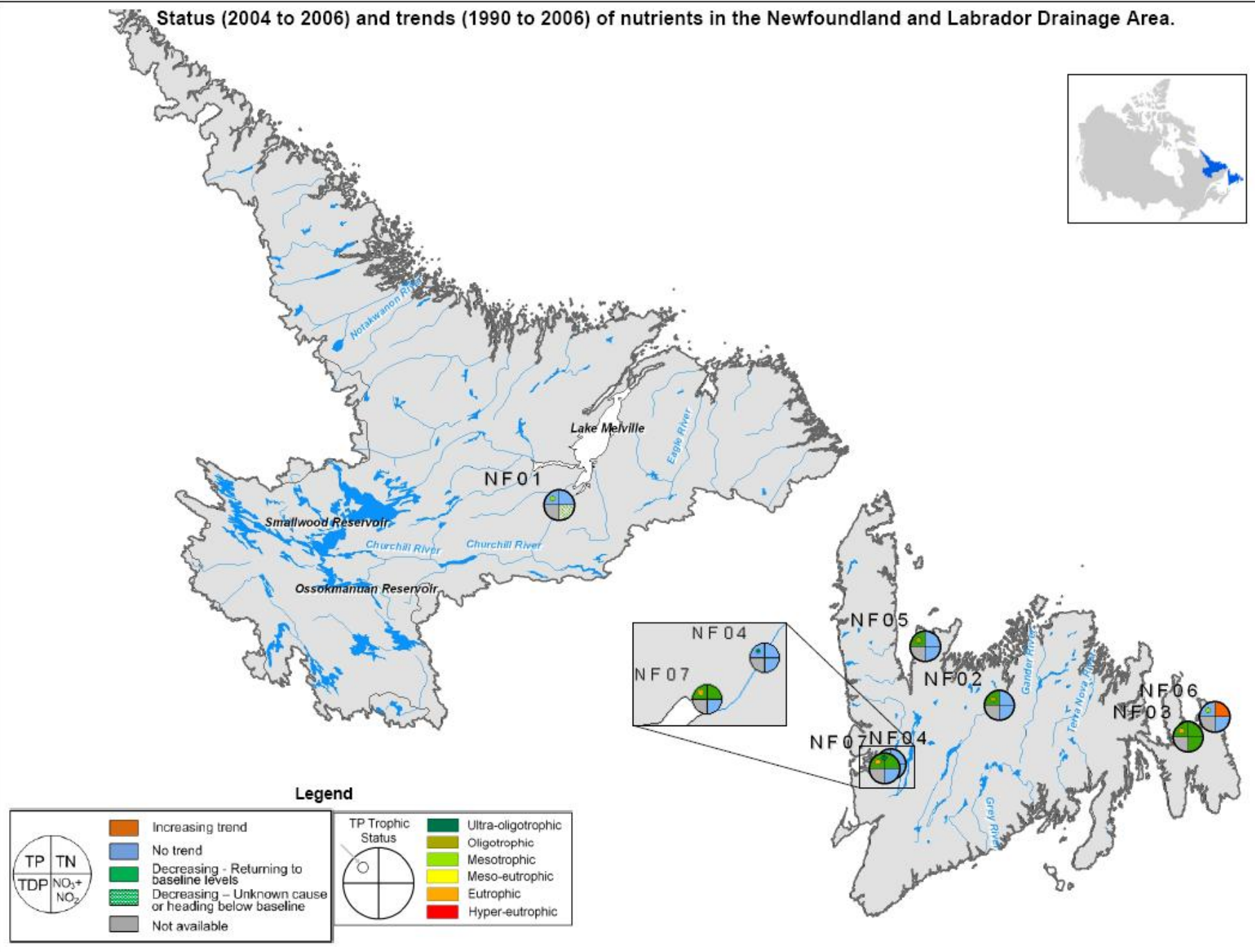
trend³⁹. This site is in close proximity to lakes surveyed by the province in 2007 for blue-green algae blooms⁴⁰. Two sites could be considered eutrophic (NF03 and NF07).

³⁹ Dawe (2003) also discussed a decrease (improving trend) in phosphorus in more developed areas, influenced by localized factors including Phosphorus Control Act regulations implemented in the 1970's. Results of these regulations are most evident in more populated urban areas. An increase in TN may be attributed to increased urbanization and agriculture upstream of St. John's.

⁴⁰

http://www.env.gov.nl.ca/env/waterres/reports/wqma_report_2008/blue_green_algae_report_final_version_2008.pdf.

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the Newfoundland and Labrador Drainage Area.



5.4 Pacific Ocean Drainage Area

5.4.1 Pacific Drainage Area (666,347 km²)

Nutrient highlights:

- 6↑ (6 increasing Trends)
- 9↓ (9 decreasing Trends)
- ↔28 (28 quadrants with no significant Trend)
- Trophic levels from ultra-oligotrophic to eutrophic (0.075 mg/L TP)
- 17 of 31 sites are oligotrophic to ultra-oligotrophic (i.e very low P)
- Eutrophic status at only 3 of 31 sites; on Sumas, Fraser, Salmon rivers
- Eutrophic Sumas R. site (0.075 mg/L TP) also has N-N concentration (2.91 mg/L) exceeding Nitrate Guideline (for protection of aquatic life)
- N-N trend and concentration at Elk River site demonstrates impact of mining sector use of dynamite
- High energy mountain rivers (e.g. Skeena, Fraser at Hope) often have high TP due to high total suspended solids (TSS)
- Some least-impacted areas have N-N values higher than anticipated. Rise in atmospheric deposition postulated as possible cause
- TP data for Quinsam indicate mesotrophy though previously classified as oligotrophic. Fisheries “fertilization” (salmon waste release) probable cause (Kangasniemi, 1989)

The Pacific Drainage Area is the third most populated with 4.0 million residents and has the third highest population density at 6 persons/km². Provincial population growth in British Columbia for the 1991-2006 period is second highest among provinces with most of the growth occurring in the lower Fraser.

Only 1% of Canada’s croplands are situated in the Pacific Drainage Area. However, the southern Okanagan region has the greatest concentration of vineyards in Canada, which also faces important water availability problems. Mining and oil and gas production are also quite prevalent in British Columbia, accounting for almost 10% of the production value in Canada in 2007 (Statistics Canada, 2009).

The Fraser River (1,370 km) and the Columbia River (801 km in Canada), the two largest in this area, drain about 50% of the total surface area.

Only three sites in the entire drainage area are classified as eutrophic. Two of these are in agricultural areas (Sumas R. and Salmon R.) and the third, the Fraser River at Hope, is a turbid river owing to a high total suspended sediments load (TSS)⁴¹, then there are 17 of 31 sites (55%) classified as oligotrophic or ultra-oligotrophic (nutrient-poor). Most least-impacted sites are stable (showing neither an upward or downward trend) and a few declining trends were observed. These sites on the BC and Yukon trend maps have grey parameter quadrants indicating non applicable (n/a) with regards to nutrient trend calculations

⁴¹ The TSS likely contributes to eutrophic classification without necessarily increasing the bioavailable fraction of P. This supposition is supported by the TDP status value for the Fraser site which is only 0.007mg/L or 17.5% of the total phosphorus.

because of data gaps. The sites are however included in this report as there is status data available for them which is presented in the table below.

		Median and Trophic Status (mg/L)						
		Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level
Northern B.C and Southern Yukon Drainage Areas	PA10	Dezadeash River At Haines Junction	0.024	-	-	0.016	Mesotrophic	
	PA01	Alesek River Above Bates River	0.044	-	-	0.035	Meso-eutrophic	
	PA17	Iskut River Below Johnson River	-	-	-	-	-	
	PA34	Skeena River At Usk	0.084	-	-	0.02	Meso-eutrophic	
Vancouver Island and South Coast Drainage Areas	PA31	San Juan River At Island Road	0.069	-	0.003*	0.006	Oligotrophic	
	PA29	Quinsam River Near The Mouth	0.081	-	0.005	0.013	Mesotrophic	
	PA12	Englishman River At Hwy 19	<0.002**	-	0.002*	0.004	Ultra-oligotrophic	
	PA21	Koksilah River At Hwy 1	-	-	0.006	0.012	Mesotrophic	
	PA09	Cowichan River Below Somenos Creek	-	-	0.014	0.031	Meso-eutrophic	
	PA03	Callaghan Creek At Callaghan Lake	-	-	<0.002**	0.001	Ultra-oligotrophic	
	PA04	Callaghan Creek At Hwy 99	-	-	0.002*	0.007	Oligotrophic	
	PA05	Cheakamus River At Cheakamus Lake Road	-	-	<0.002**	0.007	Oligotrophic	
	PA06	Cheakamus River Below Whistler STP	-	-	0.005	0.011	Mesotrophic	
	PA26	North Alouette River At 132 nd Ave	0.142	-	<0.002**	0.002	Ultra-oligotrophic	
Fraser R. Drainage Area	PA15	Fraser River At Red Pass	-	-	<0.002**	-	-	
	PA25	Nechako River At Prince George	-	-	0.005	-	-	
	PA14	Fraser River At Marguerite	-	-	0.01	-	-	
	PA30	Salmon River At Hwy 1 (Salmon Arm)	0.035	-	0.034	0.06	Eutrophic	
	PA36	Thompson River At Spences Bridge	-	-	0.003*	0.011	Mesotrophic	
	PA13	Fraser River At Hope	-	-	0.007	0.04	Eutrophic	
	PA35	Sumas River Near US Border	2.91	-	0.035	0.075	Eutrophic	
Columbia River Area	PA20	Kicking Horse River Above Field, BC	0.132	-	-	0.002*	Ultra-oligotrophic	
	PA02	Beaver River At Hwy 1	0.102	-	-	0.008	Oligotrophic	
	PA16	Illecillewaet River At Park Entrance	0.109	-	-	0.006	Oligotrophic	
	PA07	Columbia River At Birchbank	-	-	<0.002**	0.005	Oligotrophic	
	PA08	Columbia River At Waneta	-	-	0.002*	0.005	Oligotrophic	
	PA28	Pend D'Oreille River At Waneta	-	-	0.002*	0.009	Oligotrophic	
	PA23	Kootenay River At Kootenay Crossing	0.099	-	-	<0.002**	Ultra-oligotrophic	
	PA24	Kootenay River Near Fenwick Station	-	-	-	0.018	Mesotrophic	
	PA37	Elk River Below Sparwood	0.57	-	-	0.006	Oligotrophic	
	PA11	Elk River At Hwy 93, Near Elko	0.379	-	-	0.01	Mesotrophic	
	PA22	Kootenay River At Creston	-	-	-	0.009	Oligotrophic	
	Okanagan Similkameen Kettle R. Drainage Areas	PA27	Okanagan River At Oliver	0.065	-	0.003	0.012	Mesotrophic
		PA32	Similkameen River At Princeton	-	-	0.003*	0.006	Oligotrophic
		PA33	Similkameen River Near US Border	-	-	0.002*	0.005	Oligotrophic
		PA19	Kettle River At Midway	-	-	0.002*	-	-
PA18		Kettle River At Carson Rd. (Grand Forks)	-	-	<0.002**	-	-	

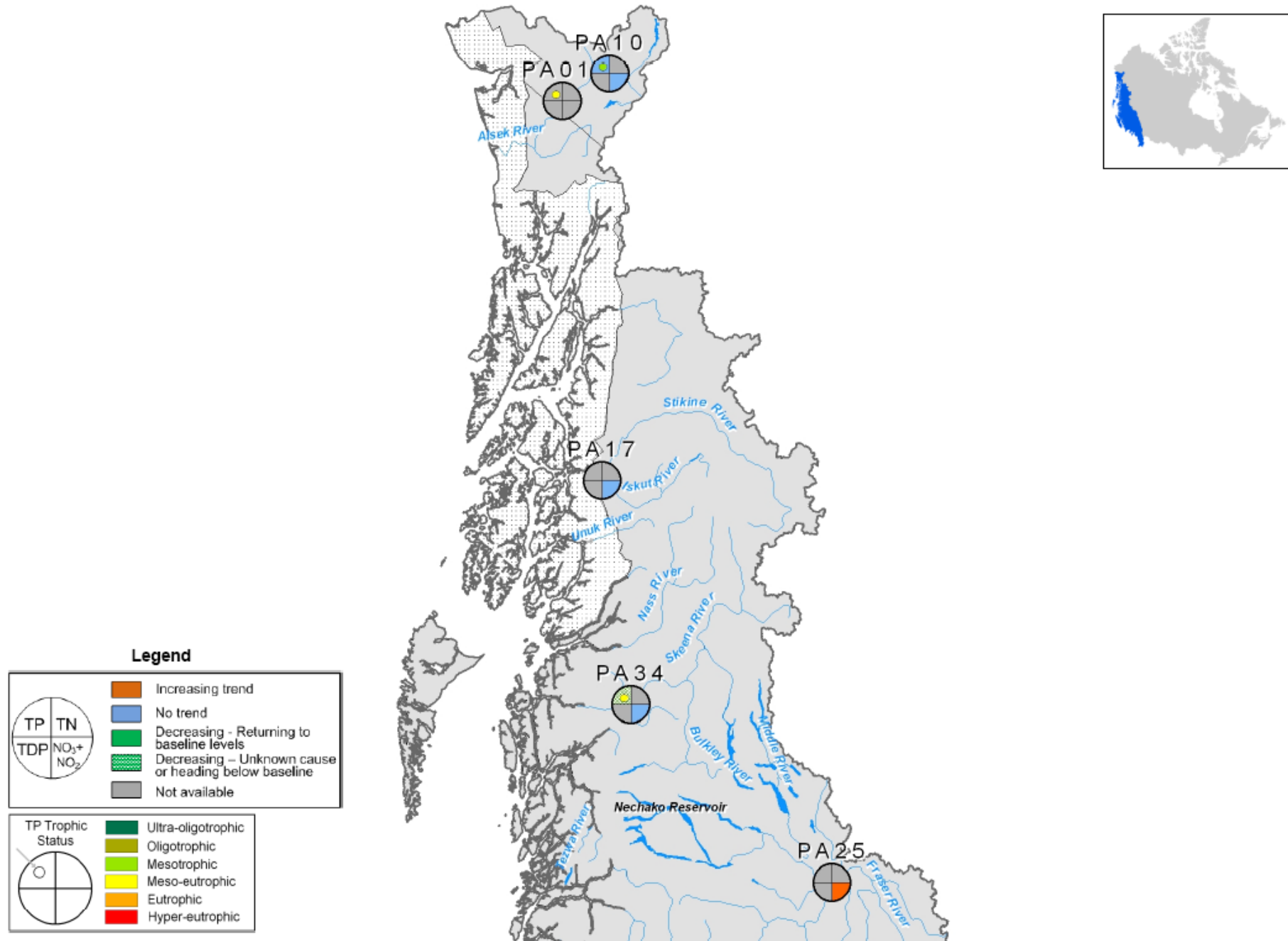
Note: Italics designates “least impacted site”.

* 30% of samples, or greater, have values that are lower than the detection limit.

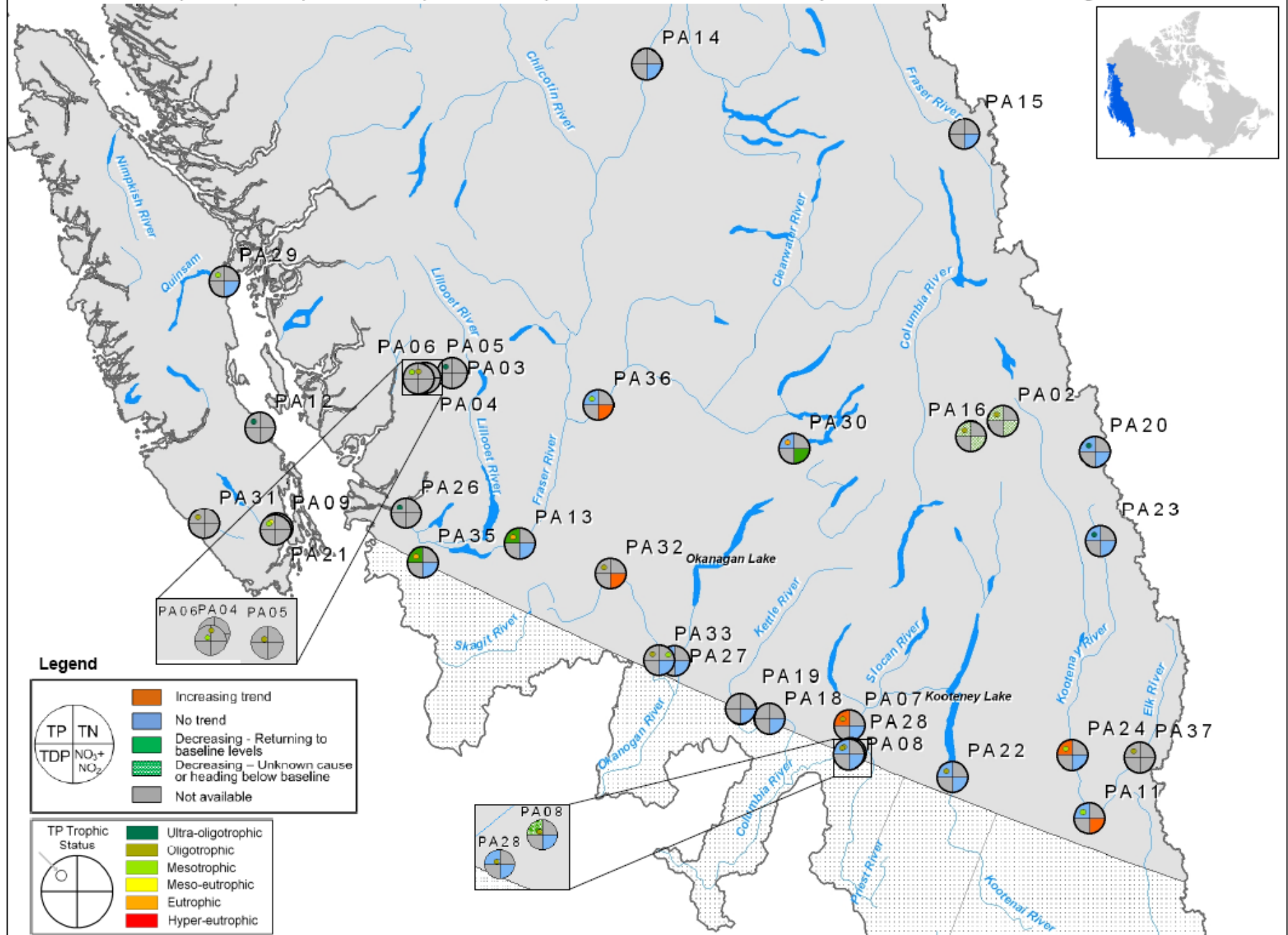
** 50% of samples, or greater, have values that are lower than the detection limit.

Acronyms: NO₃+NO₂, nitrate-nitrite; NT, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the northern portion of the Pacific Drainage Area



Status (2004 to 2006) and trends (1990 to 2006) of nutrients in the southern portion of the Pacific Drainage Area



5.4.2 Yukon River Drainage Area (337,037 km²)

The Yukon River drains an area of more than 337,700 km² in northwestern Canada and central Alaska. There is relatively little agricultural activity and low population density (0.08 persons/km²). However, metal mining (mostly gold) and natural gas production activities and thawing of the permafrost threaten water quality.

The Yukon is described as one of “the last great uncontrolled rivers in the world.” Mean annual discharge near the mouth is over 6,400 m³/sec and more than 75 percent of the annual streamflow runoff occurs during the five month period from May through September when >95% of all sediment transported during an average year also occurs during this period (Brabets et. al, 2000).

In the Yukon River Drainage Area only nitrate-nitrite (N-N) and total phosphorus (TP) data were collected and these data were only available from 2005 onward. All four sites had relatively low total phosphorus concentrations. The Yukon River sites upstream and downstream of Whitehorse had very low median phosphorus concentrations, and are classified as ultra-oligotrophic and oligotrophic. This is consistent with findings of Brabets and Schuster (2008) who note that stream flow in this part of the drainage area is primarily through large headwater lakes which trap much sediment before it can enter the Yukon River; TSS concentrations are usually less than 15 mg/L⁴². Both other sites within the drainage area are on tributary rivers; the South McQuesten River site (YR02) had slightly higher median phosphorus concentrations, but was still classified as oligotrophic⁴³. The North Klondike River site was also classified as oligotrophic⁴³.

Median and Trophic Status (mg/L)						
Map Identifier	Site Name	NO ₃ + NO ₂	TN	TDP	TP	Trophic level
YR03	Yukon River At Marsh Lake Dam	0.003*	-	-	0.004	Ultra-oligotrophic
YR04	Yukon River Above Takhini River, Below Whitehorse	0.003	-	-	0.005	Oligotrophic
YR02	South McQuesten River Below Flat Creek	0.036	-	-	0.008	Oligotrophic
YR01	Klondike River Below Bonanza Creek	0.06	-	-	0.005	Oligotrophic

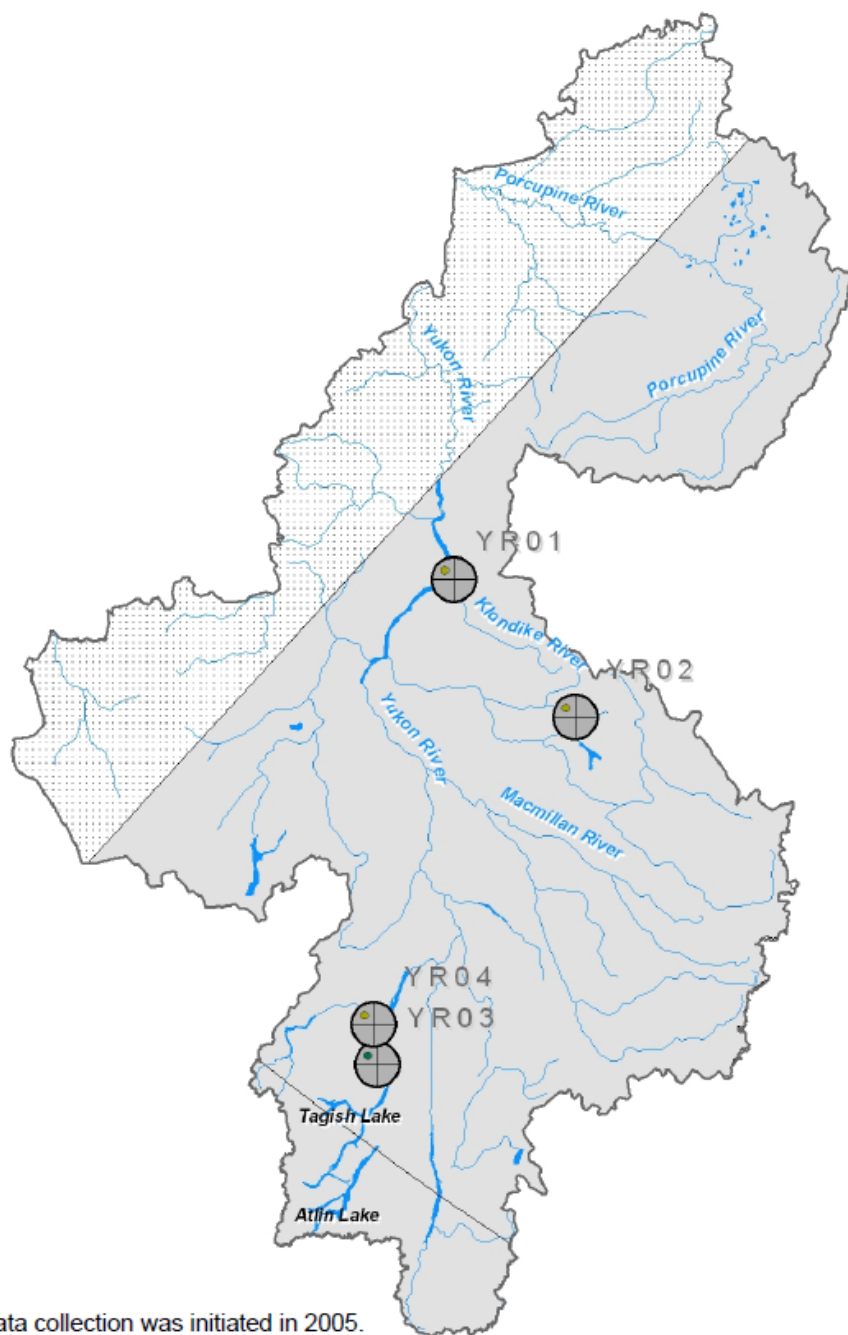
* 30% of samples, or greater, have values that are lower than the detection limit.

Acronyms: NO₃+NO₂, nitrate-nitrite; TN, total nitrogen; TDP, total dissolved phosphorus; TP, total phosphorus.

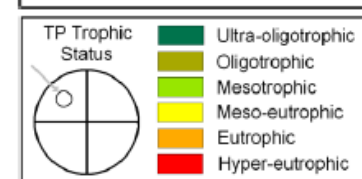
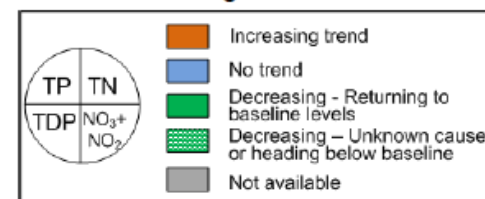
⁴² The slightly higher TP values at Whitehorse (which shift status into the oligotrophic range) may be due in part to inputs from the City’s wastewater treatment plant which discharges upstream of monitoring site YR04.

⁴³ Ongoing placer mining operations and increasing residential development upstream of this site could potentially influence nutrients concentrations.

Status (2005 to 2006) of nutrients in the Yukon River Drainage Area.



Legend



* Trends not available as data collection was initiated in 2005.

6 CONCLUSIONS AND RECOMMENDATIONS

This national nutrients review of federally-partnered water quality sites demonstrates the following key points:

- Increasing trends for P and N tend to not coincide; only 4 of 75 sites show increasing trends for both an N and a P parameter. This is attributed to the very different processes driving inputs and cycling of these two nutrients. In the same vein, P concentrations tend generally to increase downstream whereas N concentrations do not;
- The broad range of nutrient concentrations at federally-partnered sites is due in part to natural variation in geologic, hydrologic, and pedologic settings and in part to anthropogenic contributions to Canadian freshwaters;
- Seven of nine hyper-eutrophic sites are in the Nelson River Drainage Area (i.e. the Prairies). However, nutrient “hotspots” are in general not the focus of EC-partnered monitoring;
- 5 sites exceeded the nitrate ecosystem health guideline of 2.9 mg/L. The highest nitrate concentrations (found in PEI, lower Great Lakes and Lower Mainland B.C.) are attributed to high-intensity agricultural and anthropogenic inputs;
- Only around 35% of sites in this report have data for all of these key parameters. Nation-wide consistency in monitoring of key nutrient parameters is essential for:
 - meaningful interpretation of nutrient trends,
 - evaluation of trophic status based on TP. Essential parameters include TP, as well as TDP, TN, nitrate-nitrite, TSS and flow;
- Additional work in reviewing guidelines according to dissolved phosphorus content is needed as sometimes TP will decrease while TDP will increase;
- An additional step to status and trends is also looking at loadings since quantity discharge matters for eutrophication process and related issues; and
- Explaining trends needs site specific knowledge of the site itself, of its natural surroundings, environmental pressure and localized human response to these pressures.

7 APPENDIX – SITE PROFILES

Site ID	Site Description	Water		Population ³		Agriculture ⁴				Land cover ⁶					
		Drainage area (km ²) ¹	Water Yield (km ³ /yr) ²	Total (pers.)	Density (pers. per km ²)	Area with manure application (%)	Area with fertilizer application (%)	Area with crops (%)	Animal units (kg) ⁵	Agriculture (%)	Non-disturbed (%)	Disturbed (%)	Snow and ice (%)	Urban (%)	Water (%)
AR01	LIARD RIVER AT FORT LIARD	218,758	62.26	7,903	0.04	0.0	0.0	0.0	0	0.00	96.06	2.06	0.45	0.00	1.42
AR02	Liard R. at Upper Crossing	16,411	5.40	436	0.03	0.0	0.0	0.0	0	0.00	97.07	1.64	0.06	0.00	1.23
AR03	Liard R. near the mouth	274,201	75.10	8,935	0.03	0.0	0.0	0.0	0	0.00	96.26	1.85	0.51	0.00	1.38
AR04	Mackenzie R. above Arctic Red R.														
AR05	Mackenzie R. at Norman Wells	4,703	0.90	573	0.12					0.00	63.90	30.45	0.00	0.00	5.64
AR06	MACKENZIE RIVER AT STRONG POINT	1,023,110	159.26	411,219	0.4	0.1	1.4	2.4	1,210,304	2.07	82.50	5.40	0.12	0.01	9.90
AR07	Peel R. above Fort McPherson	70,490	15.32	41	0					0.00	95.13	4.03	0.05	0.00	0.79
GS01	Athabaska R. above Athabaska Falls	1,943	1.91	5	0	0.0	0.0	0.0	0	0.09	83.73	0.00	15.32	0.00	0.86
GS02	Athabaska R. at 27 Baseline														
GS03	Athabaska R. at Hwy 16 below Snaring R.	5,545	4.31	4,276	0.77	0.0	0.0	0.0	0	0.04	89.97	0.01	8.43	0.07	1.47
GS04	Hay R. near Alberta/NWT border	47,831	3.96	3,104	0.06					0.00	97.73	1.13	0.00	0.00	1.14
GS05	PEACE RIVER ABOVE ALCES RIVER	50,046	11.59	41,745	0.83	0.1	3.0	5.4	130,648	3.91	95.28	0.11	0.09	0.03	0.57
GS06	Peace R. at Peace Point														
GS07	Slave R. at Fitzgerald, AB	600,061	119.78	378,279	0.63	0.1	2.4	4.1	1,210,304	3.52	86.41	4.25	0.20	0.02	5.60
HB01	Beaver R. at Beaver Crossing	14,492	0.64	29,692	2.05	0.8	3.9	12.6	162,742	9.60	83.64	0.77	0.00	0.05	5.94
HB02	Churchill River below Wasawakasik	212,088	24.66	83,519	0.39	0.1	0.9	2.2	335,701	1.77	73.94	9.03	0.00	0.01	15.25
HB03	Cold R. at outlet of Cold Lake	6,256	0.42	6,189	0.99	0.1	0.9	2.2	8,894	0.24	72.07	13.12	0.00	0.03	14.54
MP01	Annapolis R. at Wilmot	755	0.52	20,718	38.62	1.3	2.6	3.5	4,752	20.80	78.19	0.00	0.00	0.66	0.36
MP02	Bear R. at St. Margarets	14	0.01	89	6.15	0.3	2.1	3.6	23	21.65	78.35	0.00	0.00	0.00	0.00
MP03	LaHave R.	1,254	1.18	5,143	4.1	0.4	1.5	2.3	2,262	0.44	96.28	0.00	0.00	0.00	3.28
MP04	Mill R. in Bloomfield Park	47	0.03	377	7.99	0.5	2.0	3.1	88	14.49	85.51	0.00	0.00	0.00	0.00

		Water		Population ³		Agriculture ⁴				Land cover ⁶					
Site ID	Site Description	Drainage area (km ²) ¹	Water Yield (km ³ /yr) ²	Total (pers.)	Density (pers. per km ²)	Area with manure application (%)	Area with fertilizer application (%)	Area with crops (%)	Animal units (kg) ⁵	Agriculture (%)	Non-disturbed (%)	Disturbed (%)	Snow and ice (%)	Urban (%)	Water (%)
MP05	Nepisiguit R. at Route 360	1,972	1.33	58	0.03	0.0	0.0	0.0	0	0.00	99.78	0.00	0.00	0.00	0.22
MP06	Petitcodiac R. at Old Hwy Bridge	415	0.31	4,064	9.79	2.1	2.5	5.0	3,741	15.74	84.04	0.00	0.00	0.21	0.02
MP07	Saint John R. at Limestone	3,580	2.33	25,692	7.18	0.5	4.2	5.9	8,847	9.47	90.07	0.00	0.00	0.20	0.26
MP08	Southwest Miramichi R. at Blackville	5,107	3.61	5,199	1.02	0.0	0.0	0.0	129	0.39	99.50	0.00	0.00	0.00	0.11
MP09	St. Croix R. at Milltown, NB	186	0.14	2,098	11.29	0.1	0.2	0.4	52	0.00	97.82	0.00	0.00	0.05	2.13
MP10	St. Mary's R.	1,335	1.38	1,147	0.86	0.2	0.5	0.8	507	1.76	97.07	0.00	0.00	0.00	1.17
MP11	Tusket R.	1,068	1.06	595	0.56	0.2	0.2	0.3	1,216	0.12	95.31	0.00	0.00	0.00	4.58
MP12	Wilmot R. near Kelvin Grove	45	0.03	436	9.68	2.8	10.7	16.5	515	83.19	16.81	0.00	0.00	0.00	0.00
MS01	MILK RIVER AT EASTERN CROSSING OF INTL BOUNDARY														
MS02	MILK RIVER AT WESTERN CROSSING OF INTL BOUNDARY														
NF01	Churchill R. at Muskrat Falls														
NF02	Exploits R. at Grand Falls	3,998	3.86	7,525	1.88	0.0	0.0	0.1	351	0.00	93.87	0.00	0.00	0.09	6.05
NF03*	Gould's Brook														
NF04	Lower Humber R.	2,754	3.07	9,699	3.52	0.2	0.2	0.3	1,312	0.00	95.77	0.00	0.00	0.12	4.11
NF05*	South West Brook at Baie Verte														
NF06	Waterford R. at Kilbride	15	0.02	26,645	1776.43	0.2	0.2	0.3	26	0.00	33.96	0.00	0.00	65.89	0.15
NF07*	Wild Cove Brook														
NR01	Assiniboine R. at Hwy 8 bridge	13,019	0.66	37,786	2.9	1.0	35.9	52.5	144,472	42.85	55.46	0.00	0.00	0.22	1.46
NR02	Battle R. near Unwin, SK	24,325	0.63	115,306	4.74	3.1	40.0	52.0	981,915	29.93	68.13	0.00	0.00	0.18	1.76
NR03	Bow R. approx. 4.5 km North of Canmore	3,053	1.61	7,754	2.54	0.0	0.1	0.2	1,331	0.13	93.70	0.56	3.77	0.20	1.63
NR04	Bow R. at Hwy 1 above Lake Louise	321	0.24	4	0.01					0.25	81.22	0.00	15.44	0.00	3.09
NR05	Carrot R. near Turnberry	15,254	0.87	24,358	1.6	0.6	38.4	51.4	110,055	46.90	50.57	0.07	0.00	0.08	2.38

		Water		Population ³		Agriculture ⁴				Land cover ⁵					
Site ID	Site Description	Drainage area (km ²) ¹	Water Yield (km ³ /yr) ²	Total (pers.)	Density (pers. per km ²)	Area with manure application (%)	Area with fertilizer application (%)	Area with crops (%)	Animal units (kg) ⁵	Agriculture (%)	Non-disturbed (%)	Disturbed (%)	Snow and ice (%)	Urban (%)	Water (%)
NR06	N. Saskatchewan R.at Hwy 17 bridge	56,159	8.69	1,133,565	20.18	1.7	19.0	28.7	1,081,011	24.14	72.05	0.07	1.00	0.69	2.06
NR07	N. Saskatchewan R.at Whirlpool Point	1,866	1.71	19	0.01	0.0	0.0	0.0	0	0.00	77.87	0.03	20.93	0.00	1.17
NR08	Pembina R. at Windygates MB	2,576	0.14	4,928	1.91	3.4	48.9	61.6	78,775	47.20	50.64	0.00	0.00	0.07	2.09
NR09	Qu'appelle R.approx. 3.2 km S.of Welby SK	74,466	1.75	313,669	4.21	0.9	37.0	58.4	834,413	40.25	57.86	0.00	0.01	0.25	1.63
NR10	Red Deer R. at Erwood SK	7,246	0.39	5,190	0.72	0.2	13.3	21.1	32,790	18.93	79.56	0.47	0.00	0.04	1.00
NR11	Red Deer R. near Bindloss AB	71,338	6.14	1,408,712	19.75	2.2	24.1	31.9	2,473,645	28.10	69.30	0.04	0.26	0.67	1.64
NR12	Red R. at Emerson MB	22		405	18.83	2.8	77.0	89.6	746	34.47	63.06	0.00	0.00	1.58	0.88
NR13	Saskatchewan R. above Carrot R.	387,592	25.76	3,416,036	8.81	1.4	24.6	35.2	8,165,742	30.84	65.09	0.47	0.19	0.33	3.09
NR14*	SOURIS RIVER NEAR SHERWOOD N.D.														
NR15*	SOURIS RIVER NEAR WESTHOPE	3	0.00	0	0	1.7	40.3	59.5	45	13.92	32.43	0.00	0.00	0.00	53.64
NR16	S. Saskatchewan R. at Hwy 41	39,734	2.78	244,034	6.14	2.0	30.1	38.7	1,746,401	39.15	59.14	0.27	0.00	0.27	1.17
NR17	Winnipeg R. at Pointe du Bois	110,244	21.04	59,327	0.54	0.0	0.1	0.1	6,647	0.11	82.93	0.70	0.00	0.01	16.25
PA01*	Alsek River above Bates River														
PA02	Beaver R. near East Park Gate	479	0.60	2	0	0.0	0.0	0.0	0	0.00	83.87	0.00	15.83	0.00	0.30
PA03	Callaghan Creek at Callaghan Lake	167	0.38	0	0	0.0	0.0	0.1	44	0.00	78.78	0.00	20.29	0.00	0.94
PA04	Callaghan Creek at Hwy 99	205	0.47	1	0	0.0	0.0	0.1	54	0.00	82.67	0.00	16.56	0.00	0.76
PA05*	Cheakamus River at Cheakamus Lake Rd														
PA06	Cheakamus River below Whistler STP	352	0.84	1,888	5.36	0.0	0.0	0.1	93	0.00	76.73	0.00	21.30	0.34	1.63
PA07	Columbia River at Birchbank	76,564	63.59	124,624	1.63	0.0	0.2	0.4	47,390	0.25	91.67	0.74	4.44	0.06	2.83
PA08	Columbia River at Waneta	77,170	63.93	142,337	1.84	0.0	0.2	0.4	47,581	0.25	91.72	0.73	4.41	0.08	2.82

		Water		Population ³		Agriculture ⁴				Land cover ⁵					
Site ID	Site Description	Drainage area (km ²) ¹	Water Yield (km ³ /yr) ²	Total (pers.)	Density (pers. per km ²)	Area with manure application (%)	Area with fertilizer application (%)	Area with crops (%)	Animal units (kg) ⁵	Agriculture (%)	Non-disturbed (%)	Disturbed (%)	Snow and ice (%)	Urban (%)	Water (%)
PA09*	Cowichan River below Somenos Creek														
PA10	Dezadeash R. at Haines Junction	8,361	2.86	442	0.05					0.00	94.64	0.40	0.22	0.00	4.74
PA11	Elk R. at Highway 93 near Elko	4,307	1.96	12,400	2.88	0.1	0.2	0.3	2,195	0.00	98.46	0.22	0.43	0.13	0.76
PA12	Englishman River at Hwy 19														
PA13	Fraser River at Hope	169,399	83.97	290,863	1.72	0.2	0.4	0.8	429,328	0.32	94.89	0.57	2.07	0.06	2.09
PA14	Fraser River at Marguerite	67,046	37.38	72,009	1.07	0.1	0.4	0.7	71,499	0.35	95.48	0.19	2.09	0.04	1.85
PA15	Fraser River at Red Pass	1,711	1.41	28	0.02	0.1	0.3	0.4	1,041	0.16	88.66	2.96	6.19	0.00	2.02
PA16	Illecillewaet R. at Park Entrance	217	0.31	1	0	0.0	0.1	0.1	68	0.00	83.66	0.00	16.08	0.00	0.26
PA17	Iskut River below Johnson River	9,477	15.51	357	0.04	0.0	0.0	0.0	0	0.03	78.76	0.00	19.61	0.00	1.59
PA18	Kettle River at Carson Road Bridge	5,425	1.96	4,882	0.9	0.1	0.5	0.9	9,986	0.06	99.71	0.06	0.00	0.05	0.13
PA19	Kettle River at Midway	4,760	1.72	2,411	0.51	0.1	0.5	0.9	8,734	0.04	99.77	0.07	0.00	0.01	0.11
PA20	Kicking Horse R. above Field	303	0.23	49	0.16	0.0	0.3	0.5	237	0.00	74.88	0.19	24.23	0.00	0.70
PA21*	Koksilah River at Hwy 1														
PA22	Kootenay River at Creston	23,032	10.79	52,290	2.27	0.1	0.3	0.5	24,749	0.22	97.32	1.08	0.55	0.09	0.74
PA23	Kootenay R. at Kootenay Crossing	421	0.20	7	0.02	0.0	0.0	0.0	0	0.00	96.90	0.32	2.60	0.00	0.18
PA24	Kootenay River near Fenwick Station	11,753	5.81	31,538	2.68	0.0	0.2	0.5	12,593	0.13	96.80	1.60	0.91	0.12	0.44
PA25	Nechako River at Prince George	47,242	15.74	60,822	1.29	0.1	0.8	1.1	70,311	0.51	90.80	0.52	0.43	0.04	7.69
PA26*	North Alouette River at 132nd Ave														
PA27	Okanagan River at Oliver	7,517	1.67	287,544	38.25	0.5	2.0	3.4	50,718	0.81	90.12	2.08	0.00	1.18	5.81
PA28	Pend D'Oreille River at Waneta	3,052	0.99	2,500	0.82	0.0	0.1	0.2	1,311	0.03	98.97	0.60	0.00	0.04	0.36
PA29	Quinsam River near the mouth	278	0.46	201	0.72	0.1	0.1	0.2	139	0.00	97.78	0.00	0.00	0.00	2.22

		Water		Population ³		Agriculture ⁴				Land cover ⁶					
Site ID	Site Description	Drainage area (km ²) ¹	Water Yield (km ³ /yr) ²	Total (pers.)	Density (pers. per km ²)	Area with manure application (%)	Area with fertilizer application (%)	Area with crops (%)	Animal units (kg) ⁵	Agriculture (%)	Non-disturbed (%)	Disturbed (%)	Snow and ice (%)	Urban (%)	Water (%)
PA30	Salmon River at Highway 1 Bridge	1,545	0.28	3,962	2.57	0.4	0.9	1.9	10,113	2.26	95.99	1.36	0.00	0.00	0.40
PA31	San Juan River at Island Rd	577	1.24	5	0.01	0.5	0.8	1.1	1,997	0.00	99.97	0.02	0.00	0.00	0.01
PA32	Similkameen River at Princeton	1,258	0.59	647	0.51	0.2	0.4	0.8	3,781	0.00	97.22	2.31	0.00	0.07	0.40
PA33	Similkameen River near International Boundary	7,347	2.37	9,757	1.33	0.2	0.4	0.8	22,076	0.26	98.49	0.90	0.00	0.05	0.30
PA34	Skeena R. at Usk	37,885	26.28	23,164	0.61	0.1	0.2	0.4	23,118	0.00	96.41	0.01	1.25	0.02	2.31
PA35	Sumas R. at International Boundary	0	0.00	6	12.42	4.4	4.4	6.7	23	69.31	0.77	0.00	0.00	0.00	29.92
PA36	Thompson River at Spences Bridge	55,153	29.35	179,030	3.25	0.2	0.5	1.0	193,216	0.52	94.29	0.71	1.65	0.10	2.73
PA37	Elk River below Sparwood	2,849	1.29	6,537	2.29	0.1	0.2	0.3	1,452	0.00	97.99	0.19	0.64	0.07	1.11
SL01 SL02 SL03 SL04 SL05 SL06 SL07	Fort Erie Georgian Bay Lake Erie Eastern Basin Lake Erie Central Basin Lake Erie Western Basin Lake Huron Lake Ontario	216,741	133.10	19,000,000						14.40	69.10		0.00	4.00	12.50
SL08 SL09 SL10 SL11 SL12 SL13 SL14	Lake Superior Niagara-on-the-Lake (NOTL) Ottawa R POINT EDWARD PORT LAMBTON St. Lawrence R. Wolfe Island														
YR01*	North Klondike River at Klondike Hwy														
YR02*	South McQuesten River below Flat Crk														
YR03*	Yukon River at Marsh Lake Dam														
YR04*	Yukon River below Whitehorse														

¹ Henry et al. 2009; ² Bemrose et al. 2004; ³ Statistics Canada. 2007a; ⁴ Statistics Canada. 2007b; ⁵ Beaulieu and Bédard. 2003; ⁶ Natural Ressources Canada. 2008; and * Not available.

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