Comments on Recommendations by the International Red River Board on proposed nutrient concentration objectives and nutrient load targets for the Red River at the boundary between the United States and Canada

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12 February 2020

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The present submission comments on three documents:

- Proposed Nutrient Concentration Objectives and Loading Targets for the Red River at the US/Canada Boundary, **hereafter referred to as IRRB**
- Consensus report for the International Joint Commission on RESPEC 2016 report "The development of a stressor-response model for the Red River of the North", **hereafter referred to as Consensus report**
- THE DEVELOPMENT OF A STRESSOR RESPONSE MODEL FOR THE RED RIVER OF THE NORTH Topical Report RSI-2611, **hereafter referred to as RESPEC 2016**

Nutrients and primary production

The regulation of phosphorus and nitrogen in the Red River (and in other sources feeding Lake Winnipeg) is critically important because, even when nutrient concentrations in river water might not seem in themselves excessive or even be demonstrably impairing, the load flows continuously into a lake that functions as an impoundment where nutrients become a cumulative problem and create a nutrient pool of longer residence time and internal cycling, relieved only by its outflows and whatever resources are harvested from within it, and mitigated by whatever sediment sinks remain undisturbed. Although existing inflows and innumerable point sources already overwhelm Lake Winnipeg at times, more adverse impact is expected as new tracts of residential development continue to proceed, new agricultural operations appear within its sphere, and the Lake Manitoba channel is completed and starts transferring water rich in nutrients and total dissolved solids into Lake Winnipeg. Regulation is an unavoidable step in limiting further adverse impact, and perhaps assisting in eventual, or at least partial, refurbishment of this magnificent lake.

Phosphorus and nitrogen constitute fundamental nutrient drivers of primary production in aquatic ecosystems. Primary production includes macrophyte growth, phytoplankton and periphyton. In ecosystems where macrophyte standing crop (submerged and emergent) is high (Canfield et al., 1983), attendant phytoplankton and periphyton production is low because of direct competition from aggressive macrophyte nutrient absorption and synthesis of allelopathic algal inhibitors (e.g. Pip, 1992), as is the case in many of our Manitoba lakes where, even though total nutrient loads may be elevated, the water appears clear. Therefore algal density may not always reflect the trophic status of a system.

Freshwater macrophytes in the study area show identifiable preferences for water body and bottom sediment types (Pip, 1979), as well as well-defined tolerance ranges for chemical parameters, and many species can be used as water quality indicators (Pip, 1984, 1988a). Almost all of the freshwater macrophytes in the Red River Basin are perennials. For those species which are rooted (i.e. the majority of species), much of their productivity and biomass is found beneath the surface of the bottom sediments.

In Lake Winnipeg, macrophyte growth is highly sporadic and is dominated by emergents. Factors which discourage submerged species include the large extent of high energy environments typical of a large lake, unstable sediments, and more recently (in the past four decades), increased light attenuation. With good light penetration, depth of much of the lake, particularly the south basin, is not in itself a barrier to submerged macrophyte growth. Because of the dearth of macrophyte production in relation to the water volume, exacerbated by the catastrophically reduced extent of wetlands where macrophytes can thrive, assimilate and sequester nutrients, primary production in Lake Winnipeg is heavily weighted towards algae. Similarly in the Red River, macrophytes form a scattered component of total primary production because of limited light penetration, water flow and its effect on sediment stability, and **periodic flooding**, which prevents establishment of stable vascular plant communities since the various species rely on defined ranges of water depth (related to thermocline and hydrostatic pressures) in which they can survive (Pip and Sutherland-Guy, 1987; Pip, 1991; Pip and Simmons, 1986). The RESPEC 2016 report excludes macrophytes from its metrics.

Trophic status

Trophic status classifications have been proposed both for lacustrine (e.g. Forsberg and Ryding, 1980)(Table 1) and lotic systems (e.g. Dodds et al., 1998). Most indexing systems are based on phosphorus and nitrogen concentrations, although various additional correlated/modifying parameters have been proposed, e.g. chlorophyll, transparency, dissolved oxygen and carbon.

Table 1. Lake classification according to trophic nutrient boundaries (Forsberg and Ryding, 1980). **Note: <u>1 mg/m^3 = 0.001 mg/L</u>**

Trophic status	**Total phosphorus mg/m^3**	**Total nitrogen mg/m^3**
Oligotrophic	<15	<400
Mesotrophic	15-25	400-600
Eutrophic	>25	>600

The proposed IRRB objectives of 0.15 mg/L total phosphorus and 1.15 mg/L total nitrogen are therefore excessive in relation to classification indices such as in Table 1, and also compared to existing concentrations in many Manitoba waters. They are in fact hypertrophic, which has also been pointed out in the Consensus report (page 10, par.1): “the values of TP exceed those expected for hypereutrophic conditions in lakes and TN are close to or exceed those values (Nurnberg 1996), so would not be expected to protect downstream Lake Winnipeg. These considerations suggest that the target numbers in the initial RESPEC report could be significantly above those that would be expected to protect biotic integrity and water quality.”

Furthermore recall that these are the objectives **at the Canada-U.S. boundary,** and do not include Canadian nutrient accrual between the international boundary and the lake.

While "minimally impacted" sites are routinely evaluated to estimate target concentrations, in the present circumstances it must be questioned whether such sites exist within the Red River study area. Given the extensive anthropogenic modification of the adjacent and surrounding landscapes, and given that most of these modifications are irreversible, i.e. the river can never be returned to its baseline pre-impact state (i.e. "reference condition"), it is implicit that targets can only reflect existing nutrient levels at the lower end of the water quality spectrum, while they aspire to constrain continued eruptions at the upper end. However an inherent problem is the fact that individual sites are not self-contained: the water flows through all of the sites and mixes as it proceeds. Therefore even if unimpacted sites exist, they are contaminated by contributions from other upstream sites. This has the effect of overestimation at the "lower" (i.e. "minimal") sites, and underestimation at the "upper" sites.

Accordingly we see in the IRRB report (page 5): "*With information from these analyses, nutrient objectives were determined by using the results from sites least influenced by high total phosphorus and total nitrogen effects. Substantial consideration was also given to results from sites meeting regional regulatory limits on primary productivity measures. This process resulted in recommended nutrient concentration objectives of 0.15 milligrams per liter (mg/L) for total phosphorus and 1.15 mg/L for total nitrogen."* Thus because of the inability to establish pre-impact state, target concentrations were calculated based on data from "least influenced", but **already influenced** sites, and from sites that did not exceed "regional regulatory limits" which are set and altered using a variety of rationales, expediencies and weighting. Since the chosen reference site values were already elevated compared to "reference conditions", the resultant calculated objectives were likely overestimated.

For the above reasons, the proposed objectives are not stringent enough to adequately protect downstream water quality, given that these shall form the baseline upon which all the other additional inputs will be superimposed as the river flows on its way to Lake Winnipeg.

Nutrients and algal communities

The composition and biomass of phytoplankton and periphyton communities depends in large part on the concentrations of the **readily assimilable forms** of phosphorus and nitrogen. Silica concentrations constitute an additional factor in determining the quality of algal composition since diatom (bacillariophyte) blooms form an important component of the algal bloom cycle in Lake Winnipeg (Kling, 1998). In some years, bluegreen (cyanobacterial) blooms, which are highly visible because they concentrate at or near the water surface, may be supplanted by diatom blooms, which tend to proliferate deeper in the water column, and in such years it may be erroneously assumed based on visual characteristics that no bloom was present.

Readily assimilable forms of nutrients are also those most soluble. While total loads constitute the potential long-term nutrient pools within a system, those chemical forms that are most immediately available, i.e. inorganic soluble species, elicit the most immediate algal response. Nutrients bound in organic molecules may be present as dissolved organic matter, or as seston (particulates). Seston is in turn comprised of plankton (living cells) and tripton (nonliving particulates and detritus). Note that in the RESPEC 2016 report (e.g. pages 18, 57, D-6), seston is incorrectly defined and is NOT synonymous with phytoplankton.

For phosphorus, orthophosphate is easily assimilable, while for nitrogen, the optimal forms for primary producers are nitrate, nitrite, and ammonia. The two latter nitrogen forms are indicative of anoxic conditions and are toxic to aquatic invertebrates and fish: presence of ammonia in the Red River (RESPEC report 2016, Table 2-3) is a source of concern, particularly downstream of urban wastewater treatment plant outfalls into the river (City of Winnipeg, 2002). Microbial conversion in aerobic environments proceeds from ammonia to nitrite to nitrate (nitrification); in anaerobic conditions reverse microbial denitrification may occur.

Phytoplankton may also assimilate a number of dissolved organic matter molecules. In addition to non-nitrogen/phosphorus carbohydrates and organic acids, nitrogen and/or phosphorus containing molecules such as amino acids, amines and phosphates may be absorbed by phytoplankton in supplementary heterotrophic nutrition. Some algae can ingest particulate organic matter, including bacteria, by phagocytosis, e.g. euglenids, chrysophyceans and dinoflagellates, to accompany photoautotrophy (mixotrophy)(Saad et al., 2016). These taxa generally occupy minor ecological roles in Manitoba freshwaters. However in much of the organic fractions the nutrients are present in large refractory chemical complexes and are inaccessible for utilization by algae until they are degraded further by microbial action (Pick and Lean, 1987). Where microbial decomposition is impaired, refractory nutrients may be unavailable for longer periods of time, and may indeed become sequestered in the sediments. While all chemical forms are included in the measurement of total phosphorus and nitrogen metrics, only the assimilable forms have practical predictive value for algal growth (e.g. Pip and Allegro, 2010).

It must be noted that phosphorus uptake by algae may not immediately translate into corresponding rates of growth. In cases of abundant available phosphorus, algae may indulge in the phenomenon of “luxury consumption”, where nutrients are absorbed in excess of cellular requirements and internally stored. Phosphorus, for example, may be hoarded in the form of polyphosphate (Stevenson and Stoermer, 1982; Graham and Wilcox, 2000).

Water chemistry and other data metrics

It is not clear in the RESPEC 2016 report (page 30) what the post-collection durations and transport/storage conditions were, as these could affect some of the parameters through continued bacterial activity and chemical reaction in the sample containers (e.g. nitrification

and denitrification). It is also not clear whether the samples were analyzed immediately on arrival at the lab. It is worrisome that soluble reactive phosphorus was abandoned because holding times could not be consistently met (RESPEC 2016, page 30); therefore other parameters (e.g. ammonia) could be compromised as well. We are also not told which analytical methods were used, as detection efficiency and accuracy may vary depending on specific methodology and instrumentation: we are told that both Manitoba and the U.S. used the same methods, so somebody must know what they were.

Particularly problematic are the parameters of dissolved oxygen and pH, **which must be measured *in situ*** (there are portable meters for this), as they change significantly during sample collection, transportation and storage and **vary with temperature**. These parameters measured in the lab always bear little resemblance to the values actually in the field. Recreating the same sample temperature in the lab, however, does not restore the original values due to irreversible changes in the sample.

Total dissolved solids, a fundamental water quality parameter, is missing from the analytical list, even though it is easily measured in the field with portable electronic sensors, or in the lab by evaporation and gravimetric methods. Although specific conductivity appears on the list, it has little biological relevance as it registers only electrically charged entities such as ions and carboxylated organic acids, but excludes electrically neutral inorganic and organic materials. Specific conductivity is not necessarily directly related to total dissolved solids.

Under Land Use in the RESPEC 2016 report (pages 31 ff.), the land use categories seem to omit confined animal feeding operations and feedlots, which do not appear to fall under 'Agriculture (row crops)', nor 'Pasture (animal graze land)', nor 'High-Intensity Crops', nor is it clear whether fertilizer mass total expressed as total kilograms of nitrogen and phosphorus included manure application, or only chemical fertilizers.

A study of Manitoba lentic and lotic surface waters and land use found that nitrate was particularly elevated with land uses associated with urban effluent (sewage) and livestock production (Pip, 2005). The highest mean nitrate concentrations were found in south central (Red River basin) and central (Interlake) regions of the province. Nitrate in these regions was highly significantly associated with dissolved organic matter and total dissolved solids, indicating inputs of these three parameters to adjacent water bodies were linked.

The last paragraph on page 3 of the Consensus Report describes an alternative approach to assess relationships between nutrients and chlorophyll *a.* This approach is highly reasonable and desirable, but it has stopped short of further exploration of the data:

1. Correlations between chlorophyll *a* and nutrients are often **exponential** (Pip, 1988b), yet no attempt was made in either the alternative approach or RESPEC 2016 to subject data to standard statistical analysis or to transform them as appropriate to elicit hidden associations

2. Algal response to nutrient availability occurs relatively quickly, i.e. to readily available, therefore easily assimilable, nutrient forms. The refractory component is irrelevant in the short term.

3. On the other hand algal response is not instantaneous, but shows a short period of lag behind changes in external nutrient concentrations (Pip and Allegro, 2010; Pip and Bowman, 2014), as algae adjust their physiology and reproduction rates. None of the documents under scrutiny included cross-function correlation analysis to identify these responses.

4. Aside from total suspended solids, light intensity and spectral quality, **temperature** is a significant cofactor that is also correlated with chlorophyll *a* (Pip, 1988b; Pip and Bowman, 2014), yet temperature seems to have been excluded from the analysis, even though it may likely have been a confounding factor.

5. Statistical metrics (*r, p* and N*)* for the simple linear correlations that were shown in the alternative approach of the Consensus report are not provided, yet we see terms like "strong relationship" (last paragraph on page 3). Does "strong" mean "statistically significant"? Were statistical tests even done, e.g. Pearson correlation? Or were the "relationships" assessed on the basis of eyeballing the scatterplots (of raw, untransformed data) in Figs. 1 and 2 (Consensus report)?

6. The authors of the Consensus Report repeatedly refer to the paucity of data available for examination. Surely then, comprehensive conclusions cannot be reliably drawn without additional information. Especially, the advanced multivariate model presented in the RESPEC 2016 report is of limited application unless we can be assured of the rigorous and replicable foundation of data on which the model is built. As it is, there are questions about methodology (field and lab), data integrity and processing, and interpretation of the results. We are not even apprised of the degree of variation among the three replicates collected for each of the periphyton samples. If there was a large amount of variation among replicates, we cannot confidently average them without getting random numbers.

7. "*We conclude that the data from these sites is adequate to derive the TN & TP targets, but suggest that presentation of the simple relationships (approaches similar to Figure 1 & 2 here) is required to help support these conclusions in light of relatively low explanatory power of the multivariate analyses."* (Consensus Report, page 5, par. 1). Certainly the presentation of data in RESPEC 2016 is confusing, obfuscating, or missing. As for multivariate analysis, it is in fact highly useful in identifying the relative contributions of intercorrelated variables towards the variability of the dependent variables (in this case chlorophyll *a*)(e.g. Tatsuoka, 1971; Pip and Robinson, 1982a and b; Pip, 1988b). Frustration with the "low explanatory power" is due more to inadequate clarity of explanation and communication of the results, which obviously have not conveyed the interpretation of the analysis in easily understandable or even meaningful terms. However the other extreme, relying only on "simple relationships" can lead to

inaccurate and even erroneous conclusions. The remedy is to report (or conduct) the rest of the statistical analysis (see further discussion below). However an adeuate basis of data is required.

8. "*We also note that more stringent targets may be merited*" (Consensus Report, page 5, par.1). **Agreed**.

9. "*Analyses of invertebrate data, for example, could strengthen the results here, but they will also be influenced by high TSS so will have similar problems of analyses."* (Consensus Report, page 5, par.1). Benthic invertebrates in the Red River are governed in large part by dissolved oxygen levels and particle size distribution of the sediments (e.g. Pip, 1995). In the Assiniboine River, freshwater mussels for example are found only on compacted lenses of silt and clay, and not in surrounding loose and unstable sediments (Pip, 1995). However biota present in the trophic chain or ecosystem may influence or modify algal community composition and abundance, for example grazers and filter feeders (zooplankton, native mussels, aquatic insects, fish), parasites of algae (viruses, bacteria, chytridiaceous and biflagellated phycomycetous fungi), and interspecific competition among members within the algal community, and may thus present confounding factors.

CONCERN #2 in the Consensus Report: The need for nitrogen targets

"*The Hall and Associates document states that "TN is generally not considered a nutrient of concern with regard to eutrophication in rivers because TP is generally considered the limiting nutrient for fresh water systems"* (Consensus Report, page 5, par. 3). In fact, many refurbishment strategies around the world recognize the importance of addressing **both** phosphorus and nitrogen (e.g. Jeppesen et al., 2007 among many others: see discussion by Pip (2014)). Nitrogen is a fundamental macroelement for all plant growth. While phosphorus is generally accepted as the primary limiting factor in many freshwater aquatic ecosystems, both phosphorus and nitrogen must be considered in the development of algal blooms (Stanley et al., 2003; Lewis and Wurtsbaugh, 2008).

While phosphorus is associated with the most common nutrient limitation in Lake Winnipeg, nitrogen limitation may also occur, particularly in late summer. According to the Redfield Ratio (Correll, 1998), nitrogen limitation occurs below a *total* N/P ratio of 7:1 in terms of mass proportion. Nitrogen limitation in Lake Winnipeg has been documented historically (Kling, 1998) as well as currently (Pip and Allegro, 2010).

In Lake Winnipeg, nitrate as well as orthophosphate have been demonstrated to correlate with chlorophyll *a* as representative of **total** algal biomass (Pip and Bowman, 2014). Similarly both parameters were correlated with chlorophyll *a* both horizontally and vertically in Shoal Lake, a Precambrian Shield lake (Pip, 1988b). Pip and Bowman (2014) proposed that nitrogen availability may boost non-nitrogen-fixing cyanobacteria as well as eukaryotic algal species. Indeed the toxic cyanobacterium *Microcystis* is non-nitrogen fixing, and may show more growth

and produce more toxin under increased nitrogen concentrations (e.g. Orr and Jones, 1998; see discussion in Pip, 2014). Bloom toxicity in Lake Winnipeg, as indexed by microcystin, was found to be related to both orthophosphate and nitrate, as well as the ratio of the two (Pip and Allegro, 2010; Pip and Bowman, 2014). Furthermore the neurotoxin BMAA was significantly correlated with immediately preceding nitrate concentrations as well as the nitrate/orthophosphate ratio (Pip et al., 2016). Thus nitrate plays an identifiable role in Lake Winnipeg in influencing algal biomass, bloom composition and bloom toxicity.

CONCERN 5: "Reported effects on taxonomic metrics and algal growth may not be related to instream nutrient concentrations but may be caused by adjacent land use characteristics." (Consensus Report, page 7). It is hard to dissect this argument because instream nutrient concentrations are inextricably linked to the land use characteristics that contribute much of these nutrients. It is not possible to isolate the water from the land in which it sits: what happens on the land will echo in the water as there is no impervious barrier between them. This is the whole point of setting targets and objectives. If we were to be concerned only with autochthonous nutrient sources, we would be unable to regulate them and targets would be irrelevant. We wish to address the **allochthonous contributions** associated with the land use, as many of these can be modified and managed.

Besides categorization of land use, practices within the type of land use must be re-evaluated in favor of less environmentally stressful methods. For example, a study by Pip and Reinisch (2012) found that stream water quality was significantly adversely affected in terms of orthophosphate, nitrate, and total dissolved and suspended solids by the application of livestock waste to cropland in the fall when wet weather conditions are more prevalent and no crops are present to assimilate the nutrients.

Interpretation of periphyton growth

Periphyton and phytoplankton are separate and competing communities, and parameters such as chlorophyll and biomass are not necessarily related between the two. Indeed the RESPEC 2016 report (page 15, par. 1) illustrated this in that phytoplankton and periphyton chlorophyll *a* were inversely related with downstream progression, a typical response of periphyton to increased shading from particulates (plankton and tripton) and/or light absorption by dissolved organic matter (e.g. humolimnic and tannic acids) in the water column. Therefore an inherent contradiction exists in the fundamental premise of the RESPEC 2016 report: the aim was to find a relationship between algal production and nutrient concentrations, however phytoplankton and periphyton responded inversely to each other, an expected phenomenon. Resultant models for each respective community would therefore not agree. Thus phytoplankton and periphyton within a system are additive, plus the macrophyte production. The relative contribution of periphyton to total primary production is greatest in oligotrophic waters (Vadeboncoeur et al., 2008), which the Red River is not. Since the periphyton and macrophyte

components in the Red River are *expected* to be less impactful on the system as a whole than the phytoplankton (subject to verification), the practical resolution of this enigma given the constraints of a limited budget would be to give precedence to the phytoplankton, particularly since the latter are more independent of supplementary nutrient sources associated with the host surface (see below) and are more accurately and easily quantified. While the phytoplankton physically occupy three spatial axes, the periphyton occupy two.

CONCERN 3: "The primary assessment metric, Periphyton growth, was based on surface mounted samplers that have nothing to do with actual plant growth conditions in the river."

I concur with the above concern that surface mounted samplers do not provide a representative assessment of "actual plant growth conditions in the river". I also take issue with the statement: "*While periphyton growing on slides near the water surface are not completely natural, they do represent species that occur in the system and would grow on other surfaces."* (Consensus Report, page 3, par. 2). This is not supported based on the reasons given further below. Incidentally, Lowe and Gale (1980), cited by RESPEC 2016, recommended frosted acrylic as superior to glass if artificial substrates must be used.

An enormous difference exists in terms of periphyton composition and abundance between nonliving and living substrates. Nonliving substrates offer textures and leachable chemicals that are alien to those offered by living macrophytes (for epiphytic periphyton) and animal biota such as mussels, gastropod shells, crayfish, turtles, fish and other aquatic creatures (for epizoic periphyton). Many periphyton species have **affinities for particular substrate types**, and will not be found in quantity on other materials. In the case of nonliving substrates, different kinds of substances, chemical composition and particle size are associated with specific and predictable periphyton compositions and these are classified as such: for example epilithic, epipsammic, epipelic, etc. Nonliving substrates may also be organic, for example logs and garbage.

However the most complex systems are the epiphytic communities on living macrophytes. These substrates are dynamic microenvironments which engage in active metabolism, produce a diverse array of exudates that may provide nutrients to the periphyton, or conversely may inhibit their growth as allelopathic compounds (Pip, 1992). Periphytic algae can absorb and utilize at least 21 organic compounds (Tuchman, 1996), and may derive substantial amounts of macronutrients from their host: for example some periphytic diatoms may obtain >50% of their phosphorus intake from the macrophyte host (Wetzel, 1996). Epiphytic periphyton are enormously flexible opportunists and efficient consumers with respect to nutrition sources. Pip and Robinson (1982a and b) found that **in terms of cell surface area** (i.e. assimilative surface available for nutrient absorption), the relative contribution of each algal species to total algal community metabolism was **similar for both inorganic and soluble organic carbon uptake** on each respective macrophyte species. Eukaryotic freshwater algae are evolutionarily descended from heterotrophic protists and have retained alternate nutrient utilization mechanisms (Tuchman, 1996) that enable them to survive in situations where photosynthesis falls below the

compensation point or conventional inorganic nutrients are in short supply. Therefore epiphytes hold a significant advantage over periphyton on nonliving surfaces in that they have access to a much wider and more diverse choice of nutrients produced by the macrophyte host.

The statement: "*Algae that are in the river colonize the periphytometers, and they are subject to the same forms and concentrations of nutrients that occur throughout the river."* (Consensus Report, page 6, par. 4) is incorrect: certainly not true for epiphytes or epizoic organisms on interactive living surfaces, and not true for other natural surfaces, inorganic materials as well as organic debris, that **differ in chemical composition/leachate** from the sampler material (i.e. glass). Macrophyte surfaces expose the attached periphyton to great variations in concentrations of oxygen and carbon dioxide, pH, phosphates, amines and silica, organic acids, carbohydrates, alcohols, esters, etc. Furthermore the host surface competes for nutrients against its attached periphyton. Macrophyte biochemistry is in turn influenced by light, depth, temperature and water chemistry (Pip, 1987, 1989; Pip and Sutherland-Guy, 1989; Sutherland-Guy and Pip, 1989).

The composition and biomass of freshwater periphytic communities change seasonally (Pip and Robinson 1982a and b) with the temporal alteration of the textural and biochemical attributes of the substrate, as well as with the changing contributions of the associated bacterial and fungal components that are integral to the periphytic community.

Epiphytic communities are much more diverse but also more ephemeral than periphyton on nonliving substrates because the host surface undergoes growth, senescence and death, as well as biochemical changes (Pip and Philipp, 1989. In turn, periphytic communities exert various influences on their macrophyte substrate: they reduce light penetration available for photosynthesis, absorb inorganic and organic carbon, and release extracellular materials that may affect host metabolism, for example organic and inorganic nutrients or nutrient binding compounds (for example the well-known iron-chelating hydroxamate siderochromes). In highly eutrophic/hypertrophic conditions, periphyton may overwhelm their hosts and cause their death.

The unique combination of microtopographical and physiological attributes of each macrophyte species results in **different periphyton communities on different macrophyte hosts** (Pip and Robinson 1982a and b, 1985).

More than 90% of all freshwater algal species can enter periphytic communities: this includes almost all of the pennate diatoms, a majority of centric diatoms, and many chlorophytes, euglenoids, dinoflagellates and cyanobacteria. It is important to note that many species found in periphyton communities also exist in phytoplankton, thereby overlapping between the two, while some are periphytic only. It should be further noted that some algae can be epiphycoperiphytic, i.e. the host is another, larger alga (Graham and Wilcox, 2000), such as filamentous chlorophytes (e.g. in Manitoba *Ulothrix, Stigeoclonium, Oedogonium, Cladophora,* etc.); in practical analytical terms, these are treated as part of the periphytic biomass.

Although nutrient availability is an important factor, it needs to be considered in the context of incident solar radiation (angle of incidence and photoperiod), turbidity, temperature, and water depth. Indeed disturbance, light conditions and grazing are thought to be more important for periphyton growth than nutrient availability (Borchardt, 1996; Graham and Wilcox, 2000). According to the RESPEC 2016 report (page 24), the sampler glass slides were positioned only "approximately 1 inch" (=2.5 cm) below the water surface. This appeared to be well within the potential for emersion in rough conditions (bobbing) or turbulence due to oscillations of lapping waves or slapping from boat wakes. According to Fig. 6-1 of the RESPEC 2016 report (page 24), the plastic shield would provide only limited protection, primarily from the direction of surface current, but less so from disturbance from other directions or vertical motion.

Periphyton are particularly sensitive to shear stresses that can perturb communities or cause disturbance-sensitive species to slough off (Graham and Wilcox, 2000). According to the latter authors, both biomass and morphological type of algae can be affected by velocity of current and disturbance. Periphyton become more vulnerable to water motion with increasing community maturity, as organisms at the attachment base senesce and die, promoting autogenic sloughing (Biggs, 1996). While the RESPEC 2016 report (page 26, also a typo referring to the figure in line 1, par. 1) indicated that "samplers were not placed in areas of strong currents", there are no other data regarding how currents compared among the different sampler locations. This is relevant in that it might have contributed to variability among the results. For example Biggs (1996) found that as water flow increased, periphyton chlorophyll *a* decreased despite high nitrogen concentrations. However this is not a linear relationship: "periphytic algal density is often higher in intermediate current velocities than in slow- or fast-moving water" (Graham and Wilcox, 2000). Therefore the relationship may be site dependent, and given that it may be a source of error, should be considered.

Given the extended periods of time the samplers were deployed, how much loss of vegetations (shedding) occurred from the glass slides over this time? Given the appearance of the vegetations in Figure 6-5 (RESPEC 2016, page 27), there was growth and trailing of filamentous algae (cyanobacteria and possibly chlorophytes): how were losses from these minimized and accounted for, and how were these dealt with in quantitative analyses? Since the apparatus was anchored in 2-3 meters of water, how was disturbance minimized from the approach of the retrieval boat (RESPEC 2016, page D-3), and how was periphyton loss minimized/preserved as the apparatus was lifted from the water? The report states there was "no biomass sloughing" (RESPEC 2016, page 35, par. 3): how was this checked? There appears to be no catchment phytoplankton net on the apparatus.

It is not clear (RESPEC 2016, page D-5) which side of the glass slides was used for quantitative analysis: the smooth side, the frosted side, or both sides? Was this consistent? Smooth and frosted textures yield differences (Lowe and Gale, 1980).

Phytoplankton samples were collected by a van Dorn apparatus "within the top 0.5 meter", i.e. near the surface as well. The extrapolation of plankton tow net samples to quantitative

measures is problematic as described (RESPEC 2016, page D-6). It is impossible to relate net samples accurately to liters. We are not told whether the boat was stationary during the tow or whether it was travelling. If stationary, the current velocity would have to be corrected for the drag created by the water passing through the relatively fine mesh (plus clogging by trapped biota) which would slow the filtration rate, resulting in underestimation. Water collected by van Dorn apparatus would on the other hand allow for precise measurement of volume, AND it would allow for sampling at different depths in the vertical column. Phytoplankton sampling provided a missed opportunity to evaluate zooplankton as well.

One of the most realistic ways to measure actual algal metabolism is to incubate phytoplankton or periphyton (obtained from various actual submerged natural surfaces) ***in situ*** in sealed vials with radioactive tracers: inorganic for autotrophy, organic for organotrophy, and principal component multivariate analysis (Pip and Robinson, 1982a and b, 1985; Robinson and Pip, 1983).

Grazers, particularly gastropods (Pip and Stewart, 1976), but also a wide variety of larval aquatic insects, tadpoles and fish (Graham and Wilcox, 2000) would seem to have unrestricted access to the slides in the periphyton sampling apparatus; they could have been excluded by netting of appropriate mesh size, although this would have contributed additional periphyton growth over the extended sampling period. Losses from grazing can be substantial (Pip, 1977), and can significantly alter biomass, composition and diversity of periphyton (Biggs, 1996). Many smaller grazers can be selective by preferentially feeding on particular taxa. Are there any data to indicate the extent of such losses in the present study?

A primary objection to surface sampling is that freshwater algae exhibit the phenomenon of **surface inhibition (aka photoinhibition):** i.e. high light intensities near the surface are associated with reduced biomass and diversity due to inhibition of photosynthesis above the light saturation value for each species (Fig. 1). High light intensities cause photo-oxidation of chlorophyll molecules and damage to proteins in the algal electron transport chain (Han, 2000). In addition to high intensities of PAR (400-700 nm, visible light)(Powles, 1984), the higher intensity of damaging ultraviolet light (particularly UV-B) near the surface constitutes another contributor to photoinhibition of photosynthesis (Franklin et al., 2003). Photoinhibition affects eukaryotic algae as well as cyanobacteria, despite the propensity of the latter to float at the surface where they can take advantage of both aquatic and aerial inorganic carbon (Ibelings and Maberly, 1998). Besides photosynthesis, Graham and Turner (1987) also demonstrated significant photoinhibition of respiration in epilithic periphyton in the Experimental Lakes Area in Ontario.

Maximum production occurs at a point below the surface (Fig. 2), unless there is considerable surface shading. The depth of this point depends on water clarity, temperature, chemical stratification and type of algae. As trophic status increases toward eutrophication, this point migrates nearer the surface, and is at the surface only in hypertrophic conditions (Fig. 3). The location of this maximum point varies seasonally as well as with flow conditions and density of

suspended solids, concentration of dissolved organic matter and temperature. Surface sampling is therefore most representative only in hypertrophic states, such as seen in Fig. 3. In such circumstances, the photic zone is narrow and there is no production below it because of intense shading.

The RESPEC 2016 repeatedly cites concerns of high turbidity of the Red River as a barrier to subsurface photosynthesis as justification for surface sampling, without verification of what the light levels actually are and without verification whether primary production actually exists at greater depths in the river. A number of Manitoba submerged macrophytes, for example, can exist at light (PAR) intensities of 0.5-1% of surface light: indeed Pip and Simmons (1986) reported the world's deepest freshwater vascular macrophyte communities from Shoal Lake (at 14 m). Eukaryotic freshwater algae have low light compensation points (i.e. the light intensity where photosynthesis equals respiration)(see discussion in Vadeboncoeur et al., 2008). This point represents the minimum light intensity at which a species can grow relying exclusively on autotrophy. However with supplementary heterotrophy, algae can extend their maximum depth. Algae can also adapt to low light intensities by increasing chlorophyll content (Graham and Wilcox, 2000).

On page 50 of the RESPEC 2016 report we see the startling statement: *"The location of the periphytometers at the water surface should have ensured adequate surface light, although the possibility of limited light appeared to remain because no other explanations were apparent to describe the limited algal growth in the presence of abundant nutrients."* Remarkably, the authors of the report do not seem to have considered photoinhibition. The explanation of limited light **at the surface** is surprising at best, as conditions at the sampling sites were not analogous to those seen in Fig. 3 below. On pages 35-36 the report suggests variable inverse correlations between growth and total suspended solids as evidence of light limitation, without considering confounding factors. Yet how much light limitation would suspended solids cause in 1 inch (2.5 cm) of water? Actual vertical light attenuation profiles in the river are not reported.

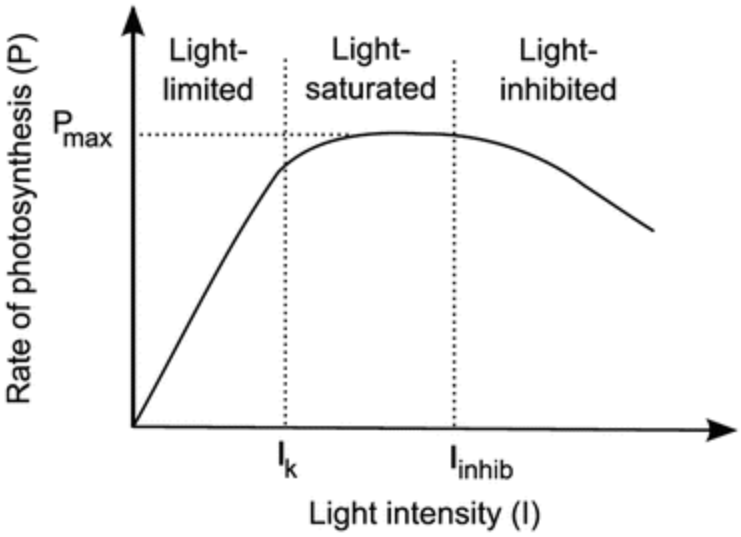

Fig. 1. Light inhibition of eukaryotic algae. https://link.springer.com/chapter/10.1007/978-3-319-51010-1_7

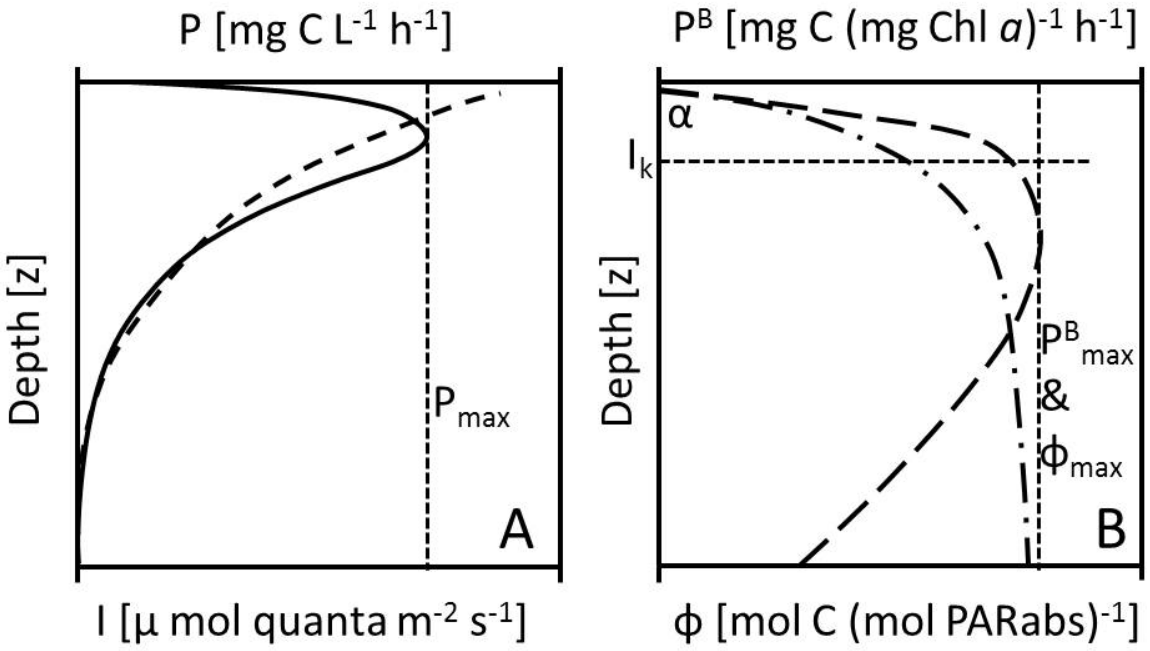

Fig. 2. Vertical algal production as a function of light and depth. Maximum production occurs at a point beneath the surface. https://www.intechopen.com/books/photosynthesis/mass-production-of-microalgae-at-optimal-photosynthetic-rates

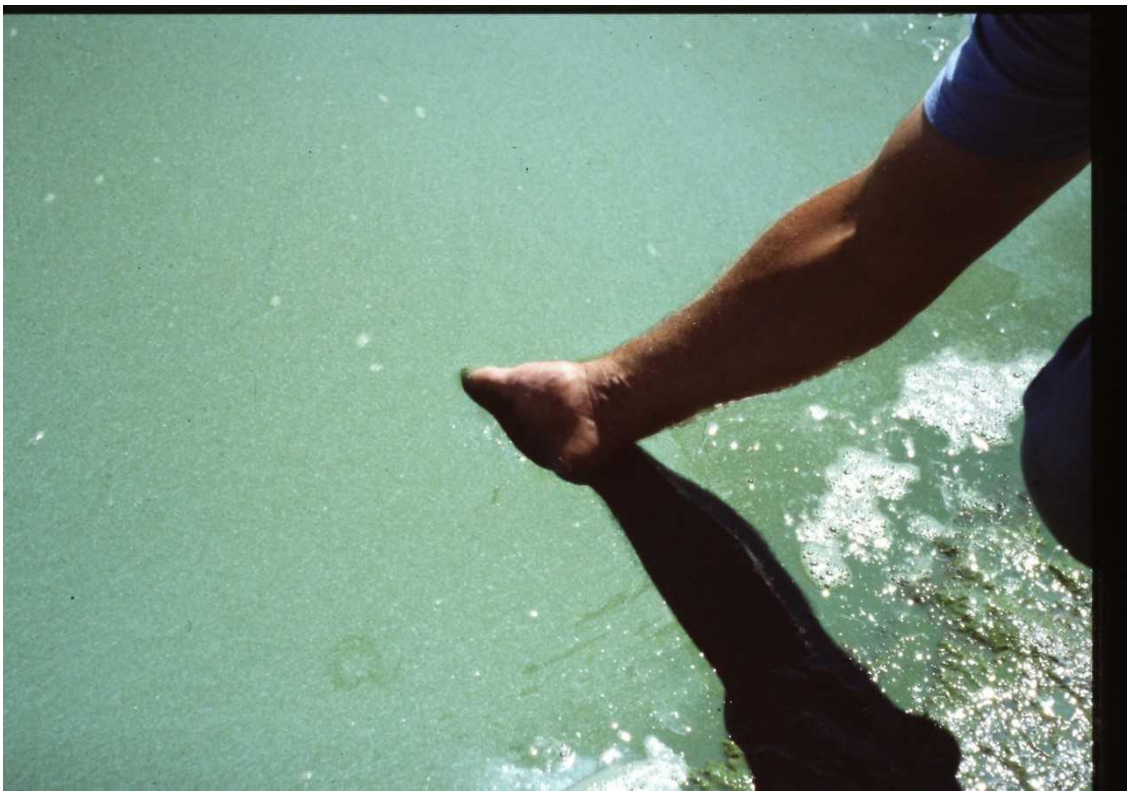

Fig. 3. Hypertrophic conditions at Pine Dock, Lake Winnipeg. Photo by E. Pip

Given that the periphyton samplers were deployed almost at the surface, it is unfortunate that RESPEC 2016 (page 18) chose to focus on diatoms, giving as their rationale the fact that diatoms are prevalent in periphyton (true), and that literature exists regarding diatom response to nutrients. Diatoms are facile auxotrophs/heterotrophs given the opportunity, hence their propensity to occur particularly as epiphytes on macrophytes where they can diversify and supplement their nutrient sources. In these circumstances they are not necessarily depending entirely or even largely on nutrient sources in open water, and changes in their productivity may thus reflect a combination of the nutrient generosity of the host as well as nutrient availability in the water. It should be noted that mandatory nutrients for diatoms include **silica –** thus when silica is in short supply, it does not matter what the phosphorus and nitrogen status is. Limiting silica concentrations can induce cessation of growth and the production of resting stages; silica depletion also prevents cell size regeneration as size reduction proceeds according to the McDonald-Pfitzer rule (Sommer, 1988), and auxospores cannot be formed, which reflects in productivity metrics. Although the RESPEC 2016 report highlighted diatoms, paradoxically apparently it did not assess silica concentrations in the water and this parameter does not appear in the report (e.g. Table 2-3, and page 30).

Diatoms are notorious for frequenting lower vertical strata and for preferences for lower light conditions when sun elevation is low and photoperiods are short (Graham and Wilcox, 2000).

Diatoms are therefore inappropriate for a surface sampler, which however would have been most appropriate for cyanobacteria. The latter are buoyant due to intracellular gas vacuoles, and according to Ibelings and Maberly (1998), "by placing a dense biomass close to the water surface they are able to intercept a large amount of the flux of light and inorganic carbon", and they are able to acclimate, albeit partially, to high light intensities. Why the focus was not on cyanobacteria is puzzling, since these are the most troubling components of noxious algal blooms, the fastest reproducing (because they are prokaryotes), and also the most associated with toxigenic activity and public health concerns. Furthermore, diatoms prefer cooler temperatures, which is why in temperate zones they bloom in early spring, late fall, and under the ice in winter (e.g. Lowe and Gale, 1980). One would not expect to find good diatom colonization during the warm temperatures, high sun elevation and long photoperiods of summer when diatom growth is lowest, especially near the surface, but cyanobacteria do bloom at this time (the samplers were deployed in July (RESPEC 2016, page 24)).

The confusion may have arisen in that although some workers have used diatoms to monitor water quality in rivers, these are **benthic diatoms** (see Rimet and Bouchez, 2012), that live on the bottom where we expect to see them. Indeed, one of the two references cited as support by RESPEC 2016 (page 23, par.1): Raunio and Soininen (2007) - did compare artificial substrates, but this comparison used **benthic epilithic** (i.e. on rocks) communities, which are stable and long-term. The Red River bed contains relatively little rock and is largely clays and sandy clay loams (RESPEC 2016, page 6), and therefore quite different unstable epipelic communities prevail. The OTHER reference cited as support was that of Lowe and Gale (1980): this reference compared **benthic epilithic** communities with artificial substrates placed on the **river bottom**. According to Brown and Austin (1971), "Placement of artificial substrates near the river bottom, in the same environment as the natural substrate, enhances the ecological value of the data collected on them." However Lowe and Gale's (1980) study "also revealed that short term (monthly) colonization rates on clean plates are sometimes poor indicators of changes or trends in the development of the periphyton community on natural substrates.", thereby observing that periphyton on natural and artificial substrates in the same environment may not necessarily correspond. The latter authors have also discussed other disadvantages to the artificial substrate method, including problems with replication.

The biovolume metric (RESPEC 2016, page 29) must take into account variation in cell sizes of an individual taxon. This is true for all eukaryotic species, but is especially important for diatoms, which undergo decreases in frustule size as the season progresses until the critical size of ca. ⅓ of maximum size is reached for the smallest cohorts, resulting in an ever increasing range of cell sizes in the population. How many cells were measured and how was this number statistically determined?

Further comments on the RESPEC 2016 report

The RESPEC 2016 report constantly refers to phosphorus and nitrogen as "stressors" for algae. Stressors are factors which have adverse effects. In that sense, excess nutrients may be stressors for aquatic ecosystems, but for algae, nutrients are stimulants and bounty.

The RESPEC 2016 report offers complete ambiguity on the subject of phaeophytin (page 15, par. 1 and Table 2-3). Other than noting it as a breakdown product of chlorophyll, the report seems undecided what to do with it and what it means, and it is not revisited again. Here is an opportunity missed. Phaeophytin as degraded chlorophyll reflects the deterioration of algal communities, whether due to senescence or to adverse factors, and generally chlorophyll and phaeophytin have an inverse relationship (Pip and Bowman, 2014). Communities in decline show increased phaeophytin concentrations. Pip and Bowman (2014) found that in some years (in Lake Winnipeg), phaeophytin and orthophosphate may be inversely correlated: thus decline in soluble phosphorus availability may negatively impact algal vigor.

On page 37 of the RESPEC 2016 report, "each concentration was relativized to maximum and then added", also page 47. What statistical conversion does this represent? The report frustratingly does not specify whether or which data transformations were used to normalize data as required and appropriate before analysis – e.g. $\log_{10}$, natural log, arcsine, Z-scores, etc.? On page 47: "All data (species and chemistry) were subsequently relativized by maximum…." One cannot apply the same transformation to ALL of the data: some are linear, some are not, some are already exponential (e.g. pH). Figures 7-2 and 7-3 show raw data only. Relationships would have been more informative with appropriate data transformations.

The report does not tell us how the various physical, chemical and biological parameters are intercorrelated: regression and principal components analysis with varimax rotation would give us the respective loadings of the variables on the dependent variable (in this case chlorophyll *a*). It would also identify redundancies among parameters and the number of hyperspace dimensions that should be considered.

The report proceeds directly from raw data to multivariate analysis without first presenting the findings in more understandable terms using data eligibility pretest F tests, selection of parametric vs. nonparametric approaches, or basic statistical tests such as linear and stepwise multiple regressions, t-tests, ANOVA, etc. to quickly separate significant and nonsignificant relationships, which would then direct the analysis to the most suitable multifactorial design (which factors to include and which to exclude) in more advanced multivariate techniques, for example discriminant analysis, factor analysis, univariate and multivariate MANOVA (particularly suited to repetitive measures data)(Tatsuoka, 1971; Sokal and Rohlf, 1981). Appendix G Statistical Output is disappointing in its lack of supporting analysis and the ordination output itself is only partially complete; the large number of iterations are statistically moot as the primary three axes are not even attributed.

Similarly the tables setting out extracted eigenvalues and respective axes are incomplete: identification of each axis using further correlation analysis appears not to have been pursued, and pseudo-canonical correlation values have no significance tests attached. It would have helped to simplify the interpretation by plotting the major identified and attributed axes using either a 3-dimensional plot for the 3 most contributing factors, or a series of 2-dimensional plots for each combination of attributed axes.

As stated above, confounding factors were not considered in the analyses, in some cases data were not even collected, and existing data were hand picked and not all of them were included. Confounding factors (e.g. photoinhibition, temperature, herbicides, heavy metals and many others) were also omitted from interpretation, or at least discussion, of the findings. For example copper (originating from sewage, agricultural chemical fertilizers and swine manure) may have significant inhibitory effects on algae (e.g. Pip and Allegro, 2010), for which reason copper sulphate is utilized as an algaecide.

In the end, the incomplete analysis and modelling presented in the report seems to have little bearing on the calculation of practical meaningful target concentrations. This is aggravated by problems with reliability and replicability of the original data.

The classification of taxa into "metabolism metric groupings" (e.g. Table 7-3) is problematic, as algae can show great metabolic flexibility and rapid adaptation in diverse or changing environments. Nondiatom algae were usually identified to genus (RESPEC 2016, page 28). Since genera contain species that may differ in their ecophysiological characteristics, and since a given algal species may behave differently in different environmental circumstances, even insofar as in toxin production (Pip, 2014), it is risky to lump them together, since we do not know what the species proportions within each class were.

On page 56-57 of the RESPEC 2016 report, it is true dissolved oxygen shows diurnal fluctuation, although in a lotic system these differences are dampened by flow turbulence which injects some aeration. The report omits mention of the diurnal fluctuations in pH and total alkalinity that are characteristic of eutrophic systems as the dissolved carbon dioxide/carbonic acid/bicarbonate/carbonate buffer system proceeds to the right as a result of photosynthetic carbon demand (Ruttner, 1953). As these reactions proceed, insoluble calcium carbonate is precipitated and hydroxyl ions are released, resulting in pH and alkalinity rise during daytime. In small lentic systems, daytime pH may eventually exceed 10. At night, carbon dioxide is replenished in the system through the collective respiration of all aerobic biota, and pH and alkalinity decline. Nocturnal oxygen depletion may be severe enough to impede respiration of aerobic biota. The magnitude of the difference between day and night increases with trophic status, temperature, amount of decomposition of organic matter, and also as the summer progresses. In closed systems, the difference can be used to estimate productivity of the system. In the Red River however, its shallowness and aeration due to flow modify the diurnal dissolved oxygen pattern.

On page 59, par. 1 of the RESPEC 2016 report, it should be appended that only some cyanobacteria are nitrogen fixers. On the other hand, some diatoms (e.g. *Epithemia*) may harbor nitrogen-fixing endosymbionts (Graham and Wilcox, 2000).

Appendix F Algae Taxonomic Results would have been interesting and instructive, but disappointingly these data are not available as the online document has no "attached jump drive".

In the end, one is inclined to agree with the Hall and Associates assessment as itemized in the Consensus report:

CONCERN 1 (page 2): (re: Hall and Associates Review). "The recommended nutrient target limits presented in the report (at 64) were based on a skewed evaluation of non-representative data and are not related to any accepted metric of aquatic life use impairment. Consequently the recommended nutrient target limits are not scientifically defensible."

CONCERN 4 (page 7): "The Report claims to have followed USEPAs stressor response guidance (2010) in developing the proposed nutrient targets, but it is clear that this was not done. The analyses presented in the report are scientifically deficient and do not support the proposed nutrient targets".

Summary comments

The documentation presented thus far suffers from: a) problematic data collection and methodology, and b) incomplete data analysis. However the latter is moot as it is subsumed by the shortcomings of the former. Analysis and interpretation do not take into account confounding factors or an understanding of the biology of the study organisms. We do not see exactly how the multivariate analysis or other information was used to derive the proposed objective concentrations.

The proposed phosphorus and nitrogen objectives are **too high** given that:

1. They are higher than concentrations in much of the surface waters in Manitoba, including many with significant anthropogenic influences.

2. They should present a baseline upon which all of the additional inputs will build as the river flows eventually to Lake Winnipeg.

Both phosphorus and nitrogen must be regulated as both are principal nutrients for the growth of algal blooms.

While algae respond primarily to assimilable forms of nutrients in the short term, total phosphorus and total nitrogen are appropriate targets for objectives because it is assumed

that all of the components – refractory and non-refractory – will form the eventual potential nutrient pool in Lake Winnipeg.

Addendum: An overview of the problem

There is an undercurrent of justifiable frustration and exasperation expressed by the various participants in the background documents related to the consultation process. All of the groundwork thus far presented seems to enable the expansion of a morass of questions, arguments, ambiguities, errors and confusing dead-ends. In response, I would like to parse the situation in plainspeak below.

First of all, let us stipulate that more than enough evidence exists in the published literature and in various databases to support the following premise as summarized in this flow chart:

Increased nutrient input → Increased primary growth → Increased algae → Bad

Let us also stipulate that current nutrient levels in Lake Winnipeg are too high.

In the most simplistic terms possible, the problem at issue can be visualized as follows:

1. What is the average (over time) concentration of nutrients **(A)** at the Canada/US border?

2. What is the average (over time) concentration of nutrients **(B)** at the entrance of the Red River into Lake Winnipeg?

3. What is the average (over time) concentration of nutrients **(C)** in the south basin of Lake Winnipeg? The north basin is set aside for the moment, although this is where the primary outlet is.

4. **a.** If **(B)** is greater than **(C),** net nutrient increase is expected over time, regardless of the inflow volume. We assume for the purposes of this overview that nutrient losses from outflows and sediment sequestration remain constant.

b. If **(B)** is equal to **(C)**, the *status quo,* unsavory as it is, is maintained. We are assuming for the present purposes that the Red River is hanging by itself in space and all other inputs are ignored.

c. If **(B)** is less than **(C)**, then the situation in the lake as regards **this source** will eventually improve. We assume that other inputs to the lake are not increasing.

5. Scenario **"c"** is the optimal outcome. However if the difference between **(B)** and **(C)** is too great, **"c"** may not be achievable.

6. We calculate the total nutrient loading at locations **A** and **B** as:

average concentration per liter during time period x total flow volume during time period

7. Subtract load **A** from load **B:** this is the load for which Canada is liable, while the US is responsible for load **A**. This is analogous to the actual unrounded allocations derived by IRRB (page 8).

8. We calculate what concentration(s) per liter will achieve condition **"c"**, i.e. where **(B)** will be less than **(C).** This forms the target objective concentration where the river enters the lake. We do not use Selkirk because additional inputs are added between Selkirk and the lake.

This target concentration is what percent of **(B)**? Subtract this percent from 100%: the difference is the percentage by which the total load needs to be reduced **(P)**.

9. Similarly, **(P)** is now used to calculate the target concentration of nutrients at the Canada-US border, based on load **A**.

9. Both Canadians and Americans get together and decide how large **(P)** will be, i.e. what is achievable, and both sides agree to apply the same **(P)** to their respective shares of the total nutrient load**.** Since this percentage is the same for both sides, nobody can feel unfairly treated or discriminated against.

10. Manitoba subsequently repeats this exercise for the other point sources into the lake, but we start with the Red River.

To apply **(P)** to the Red River means that in practical terms each side must address their sources that are contributing to **(B).** Each side can focus on whatever sources it wants in order to bring **(B)** down and meet the target concentrations. To do this, each side identifies the various point sources along feeder streams and tributaries, ditches, and along the main run. The innumerable non-point sources are grouped into stakeholder sectors and addressed through education, legislation, monitoring, enforcement, collaboration with stakeholders and implementation of best practices.

If scenario **"c"** is not achievable, then whatever possible reductions are implemented. We then have to try to take up the slack in other sectors.

Sources that contribute to the phosphorus and nitrogen load of the river are various, including but not limited to:

- Agricultural (livestock waste from confined industrial animal operations and feedlots, cropland runoff of fertilizer)
- Urban sewage effluent from wastewater treatment plants
- Sewage lagoons (small urban and agricultural)
- Wetland destruction (marshes and peatlands)

- Deforestation and denudation of riparian zones
- Residential developments (e.g. lawn and garden fertilizers)
- Cottage developments (e.g. deforestation, lawn and garden chemicals, waste leakage and spills, garbage)
- Municipal drainage projects, and drainage of private land by landowners
- Riverbank and shoreline erosion (McComas, 2002; Pip, 2014)
- Agricultural spills (ammonia, tank rinsing in ditches, lagoon ruptures, illegal manure dumping)
- Direct livestock access to ditches and streams
- Fall application of manure
- Lack of monitoring of failed septic fields and leaking holding tanks
- Potato, meat, sugar and other processing factories (e.g. chemical and pharmaceutical plants) with special waste waivers and disposal arrangements
- Licensing of industrial livestock operations in flood zones

Some of these sources will be easier to address than others: let us start there, but not leave it there.

On page 8 of the IRRB report we see: “For simplicity and because the proportions were close to 50-50, the Committee recommends allocating 50 % of the loads to each country such that 50 % of the nutrient load target calculated at Selkirk, Manitoba would be allocated to the US”. This seems eminently unfair, as the portion of the river between Emerson and Selkirk gains nutrients from agricultural and urban sources, including the City of Winnipeg wastewater treatment plant effluents. It would seem that the nutrient load allocation should be referenced at Emerson.

Of course the above highly simplified approach assumes a number of things, for example that climate and precipitation will remain constant, and that lake outflows and sediment sequestration remain the same. The time period over which concentration and load averages are calculated must be long enough that data perturbations are smoothed out (e.g. flooding, drought, storms), but not so long that the exercise is meaningless. The averaging period of **five years** proposed by IRRB seems a reasonable length of time, provided that **sufficiently frequent sampling** is carried out to yield a good representation of nutrient concentrations (e.g. weekly or bimonthly).

The IRRB report (pages 11-12) proposes that nutrient concentration objectives be applied only during the open water/ice free season. For nutrient load targets (page 12), it is unclear whether the entire year is included or not. “An example of application to water quality and flow data

collected at Emerson, Manitoba by Environment and Climate Change Canada is presented in Figure 5." (IRRB, page 12, par. 2). Figure 5 at first appears missing in the online document, but is actually out of order and follows Figure 7. Figure 5 provides no clue how many data points represent each year or whether they encompass the whole year. Nutrients do not stop flowing to the lake in winter under the ice.

It must be recognized that objectives are a plastic process which must adjust as new information is continually collected. A fuller understanding of the nutrient dynamics of Lake Winnipeg is required with respect to how much of the load actually enters the active nutrient budget and becomes available for algal growth, how much is sequestered in bottom sediment sinks, and how much is lost from the system entirely (e.g. outflows, harvesting of biota). The impact of zebra mussels on algal populations must also be considered.

In any case, draft nutrient objectives for Lake Winnipeg (IRRB, Table 1, page 8) are also too high. It is not specified, but presumably the nutrient concentrations in Table 1 are total phosphorus and total nitrogen values?

At the same time, adequate, thoughtful planning must anticipate and mitigate new and additional nutrient sources that may counter the progress being made. For example, as road access to the east side of the lake is extended, this will eventually open up the area to potentially tens of thousands of cottages, this area being of particular vulnerability because of differences in water quality on the east side of the lake (Pip, 2006). Another projected assault will emanate from the Lake Manitoba flood outlet channel under construction, which will dump huge volumes of nutrients and total dissolved solids into the north basin of Lake Winnipeg, which is already overwhelmed by algal blooms in summer. It will also provide a potential corridor for the invasion of the Lake Manitoba/Winnipegosis system by zebra mussels during periods of low water flow and from increased access by human traffic.

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