REVIEW OF THE CLASS ENVIRONMENTAL ASSESSMENT TO ADDRESS OUTFALL CAPACITY LIMITATIONS AT THE DUFFIN CREEK WATER POLLUTION CONTROL PLANT

Martin T. Auer, PhD, 2014

Review

Class Environmental Assessment to Address Outfall Capacity Limitations at the Duffin Creek Water Pollution Control Plant

Martin T. Auer, Ph.D.

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Summary

Based on my having conducted decades of peer-reviewed scientific research on attached algae in the Great Lakes, with particular attention to *Cladophora*, I was asked to review Chapter 5 of the Regions' ESR which addresses nuisance growth of that alga in the Ajax nearshore. Specifically, I was asked to determine if the high concentrations of phosphorus observed along the Ajax waterfront associated with the discharge from the Duffin Creek WPCP were acknowledged in the ESR to be a cause of the nuisance growth of *Cladophora* and related water quality degradation and odour impacts being experienced by Ajax residents. To the contrary, the ESR fails to acknowledge that the Duffin Creek WPCP plays a significant role in stimulating nuisance growth of *Cladophora*; rather the ESR asserts that the primary drivers of such nuisance growth are rising water temperatures associated with a global climate change and the ecosystem engineering activities of invasive mussels. Noting the capacity of mussels to extract soluble reactive phosphorus, the bioavailable form, from largely unavailable particulate forms of phosphorus, the ESR asserts that that there is sufficient phosphorous available from offshore Lake Ontario water to enable the mussels to stimulate nuisance conditions of *Cladophora* growth. Alternatively, the ESR draws attention local nonpoint sources and the longshore transport of phosphorus discharged at other locations as drivers of nuisance conditions.

I have reviewed the reasoning used in the ESR to make these assertions, and have concluded (a) there is no basis in the scientific literature to assert, let alone conclude, that rising lake temperatures are a primary cause of nuisance *Cladophora* growth in Lake Ontario; and (b) based on studies by other scientists as well as my own studies and field work, invasive mussels (which transform phosphorus) could not cause the nuisance algae conditions found along the Ajax shoreline in the absence of the very large quantities of phosphorus being discharged in the Duffin Creek WPCP effluent. In short, no phosphorus … no *Cladophora*.

The primary driver for nuisance conditions of *Cladophora* growth at Ajax is the discharge from the Duffin Creek WPCP which supplies 97% of the bioavailable (soluble reactive) phosphorus delivered during the months when *Cladophora* grows and which delivers that load directly over prime habitat for colonization by attached algae. Unfortunately, the ESR focuses on peripheral issues, to the exclusion of the Duffin Creek WPCP. The ESR also leaves the reader with the sense that reducing phosphorous discharges would require technologies and supporting science beyond that presently available. This is far from the truth, as the required treatment technologies are now widely applied across Canada and the US.

Unless steps are taken to implement reductions of soluble reactive and bioavailable particulate phosphorous from the Duffin Creek WPCP discharge, drawing upon technologies already used successfully elsewhere, the growth of nuisance algae along the Ajax lakefront will continue, as will the nuisance conditions to which Ajax residents are subjected.

In addition to the primary theses addressed above, the ESR contains several statements that are incorrect or misleading. These are summarized here, with supporting information below:

- It is incorrect to imply that the phosphorus management efforts initiated starting in 1970 were implemented to address nuisance growth of *Cladophora*. As discussed below, those management efforts focused on whole-lake manifestations of eutrophication.
- It is incorrect to imply that conditions of *Cladophora* growth were used as metrics for the success of P-management programs and, although there were apparently marked reductions in *Cladophora* standing crop in response to P-management, it is inappropriate to characterize the response as eradication of nuisance conditions.
- While *Cladophora* is systemic in its presence in Lake Ontario, nuisance conditions are not. Nuisance conditions are only systemic where urban influences are exerted.
- What is generally perceived as resurgence in *Cladophora* growth may be more a response to an expanded area of colonization than to mussel-mediated phosphorus cycling.
- A robust and diverse body of knowledge exists today with respect to the phosphorus-*Cladophora* dynamic and its management. Over the past decade, beginning with publications, there has been an unprecedented increase in the understanding of factors mediating *Cladophora* growth and the need for P-management to reduce or eliminate nuisance conditions. The scientific basis for action and the technologies to implement management decisions are available to the Great Lakes community as never before.
- There is no evidence that upwelling events represent a source of phosphorus to the Ajax nearshore.
- It is concluded here that while the Niagara River and regional tributary sources have impacts on the lakewide phosphorus budget, they do not play a significant role in supporting nuisance growth of *Cladophora*.
- The ESR's invocation of a need to discharge phosphorus to Lake Ontario to insure support of zooplankton and fish populations is not consistent with either the views of leading scientists or with the position presently taken in binational policy.
- Lost in the averaging of phosphorus levels across the entire nearshore is the fact that, in areas such as Ajax, urban influences increase phosphorus concentrations to levels capable of stimulating nuisance growth.
- In preparing this ESR, the Regions have looked to the TRCA and its network of scientists for the water quality information used to support proposed activities at the Duffin Creek WPCP, however, key issues and key findings from that work have gone unrecognized.
- Nuisance growth of *Cladophora*, recognized as a major stakeholder concern in this ESR, occurs because no regulatory framework is in place to address its cause – excessive phosphorus discharge. To say that no net effects of the proposed solution are anticipated because the Duffin Creek WPCP meets all present federal and provincial regulations is incorrect, disingenuous and misleading.
- Treatment technologies capable of reducing phosphorus levels to the degree required to eliminate nuisance growth of *Cladophora* are widely applied in Canada and the U.S.

Credentials

Dr. Auer is a recognized expert on filamentous, attached algae in the Great Lakes, with particular attention to *Cladophora*. He has published 14 papers in the peer-reviewed scientific literature on topics relating to field observations (Auer et al. 1981), light and temperature requirements (Graham et al. 1982; Auer et al. 1983; Graham et al. 1985), phosphorus nutrition (Auer and Canale 1981; Auer and Canale 1982a,b), zebra mussel interactions (Auer et al. 2010; Dayton et al. 2014), modeling (Canale and Auer 1982a,b; Canale et al. 1982; Tomlinson et al. 2010) and management (Canale et al. 1983).

In 2006, Dr. Auer was invited to lead a work group providing technical information on phosphorus and *Cladophora* supporting revision of the Great Lakes Water Quality Agreement. In 2011, he performed a peer review of a water quality monitoring program conducted in the Ajax nearshore by the Toronto Region Conversation Authority. Dr. Auer has delivered presentations on *Cladophora* at several academic and research institutions and has presented on the topic at the annual meeting of the International Association for Great Lakes Research. Dr. Auer is recognized as being at the forefront of *Cladophora* research by the authors of the ESR (p. 5-1).

Foundation

Chapter 5 of the *Class Environmental Assessment to Address Outfall Capacity Limitations at the Duffin Creek Water Pollution Control Plant* (CH2M Hill 2013) focuses largely on nuisance growth of *Cladophora*, the issue which "has been the foremost concern in public and stakeholder meetings during this Class EA" (CH2M Hill 2013, p. 5-1). Before proceeding with the ESR review, it is important to establish three points relating to *Cladophora* growth that provide a foundation for all further consideration and discussion.

1) *Cladophora* grows attached to solid substrate, including bedrock, boulders, cobbles, zebra mussel beds and constructed shoreline features. The alga will not colonize lake bottom habitat where solid substrate is absent;
2) Given the presence of solid substrate, *Cladophora* can colonize the lake bottom from the extreme nearshore lakeward to the depth of light penetration. The offshore distance colonized is determined by water depth and transparency; and
3) The availability of bioavailable phosphorus determines if and to what extent substrate with the required light environment will be colonized. Where phosphorus levels are not sufficient, substrate will not be colonized and *Cladophora* will be absent. Where phosphorus levels are sufficient, colonization will range from a simple presence (where phosphorus levels are low) to an abundant growth (where phosphorus levels are high) often termed nuisance conditions.

These three points provide the scientific context within which environmental impact and management efforts to restore degraded water quality and lost beneficial uses should be considered with respect to the proposed process.

Review

Chapter 5 of the *Environmental Study Report* (hereafter, ESR) recognizes that nuisance growth of *Cladophora* fouls the beaches of the Ajax waterfront (ESR, p. 5-1; see also Auer 2014). Attention given the matter by stakeholders (ESR, p. 5-1) at public meetings reflects concern that nuisance growth of *Cladophora* at Ajax is caused by phosphorus discharges from the Duffin Creek WPCP and that the proposed increase in the plant's effluent volume would exacerbate nuisance conditions, leading to further loss of beneficial uses. Reviews of conditions along the Ajax nearshore of Lake Ontario (Auer 2011; Higgins et al. 2012; Auer 2014) support stakeholder concerns.

The ESR also recognizes that management of the nuisance growth of *Cladophora* must focus on phosphorus (ESR, p. 5-1) as other factors governing colonization (e.g. presence of solid substrate; the light environment) are natural features of the ecosystem not influenced by anthropogenic activity (ESR, p. 5-5). Given acknowledgement of the primary importance of phosphorus, attention appropriately turns to the provenance of that phosphorus as the driving force for nuisance growth of *Cladophora*.

Here, the ESR adopts two lines of reasoning to support the position that phosphorus discharged by the Duffin Creek WPCP does not play a major role in stimulating nuisance growth of *Cladophora*: (1) the assertion that rising water temperatures, associated with global climate change, are a primary driver and (2) the assertion that the ecosystem engineering activities of invasive mussels are a primary driver,

> *The broad consensus that emerges from this scientific literature is that the proliferation of invasive zebra and quagga mussels combined with rising lake water temperatures (as a result of global climate change) are the primary drivers for the nuisance Cladophora growth we are currently seeing (Hecky et al. 2004; Higgins et al. 2008).* [ESR, p. 5-1]

This review will thus address these two lines of reasoning within the context of factors controlling *Cladophora* as presented above.

Temperature as a primary driver of nuisance growth

The paragraph asserting that temperature changes associated with global climate change are a primary driver for nuisance *Cladophora* growth cites work by Hecky et al. (2004) and Higgins et al. (2008). The ESR provides little supporting information or necessary documentation in the primary literature. First, no source is cited for the implication that temperatures in the Lake Ontario nearshore are changing. Second, neither of the literature sources cited in the ESR as supporting the assertion that climate change-mediated increases in water temperature are drivers of nuisance *Cladophora* growth actually treat the issue at all.

Graham et al. (1982) determined the temperature optima for *Cladophora* in laboratory experiments conducted using algae isolated from Lake Huron. This optimum range, 13-17 °C, was successfully used in model simulations of *Cladophora* growth in Lakes Huron (Canale and Auer 1982; Tomlinson et al. 2010) and Michigan (Tomlinson et al. 2010). Optimum temperatures occur in spring to early summer as nearshore waters warm from the turnover value of 4 °C to maximum summer values of ~22 °C (averaged over the Jul-Sep interval; Malkin et al. 2008). The anticipated effect of a warming trend would be to alter the timing of occurrence for the interval of optimum temperatures, but not the amount of time that temperatures remained within the optimum range. Malkin et al. (2008) tested this hypothesis by simulating the timing of occurrence of peak *Cladophora* biomass levels in the Lake Ontario nearshore for temperature increases of 1 and 2 °C. No difference in timing was predicted for the 2004 baseline year, while peak biomass was reached 7-10 days earlier for a 2 °C temperature increase in the 2005 baseline year. Even this modest impact was not, however, clearly evident in field studies conducted by Vodacek (2012) in the Lake Ontario nearshore at Rochester, NY. At this site, annual beachfront accumulation of *Cladophora* biomass was not well correlated (r^2 <0.30) with the rate of warming of nearshore waters in spring. Extending their simulations to consideration of temperature effects on peak biomass, Malkin et al. (2008) concluded that temperature differences (average summer surface temperature 4.2 °C colder in 2004 than in 2005) had little impact on peak *Cladophora* biomass.

Thus, it is concluded in this review that there is no basis in the scientific literature (let alone a *broad consensus*; ESR, p. 5-1) that "*rising lake water temperatures (as a result of global climate change) are* [a primary driver] *for the nuisance Cladophora growth"* presently observed along the Ajax waterfront of Lake Ontario.

<u>Mussels as a primary driver of nuisance growth</u>

The paragraph asserting that proliferation of invasive zebra and quagga mussels are a primary driver for nuisance *Cladophora* growth is largely drawn from the seminal work on the nearshore phosphorus shunt by Hecky et al. (2004) and the comprehensive review of *Cladophora* ecology published by Higgins et al. (2008).

Hecky et al. (2004) refer to the activities of mussels in the Great Lakes nearshore as ecosystem engineering. Four of those activities have application to the focus of this ESR. The first two mussel-mediated activities, as described by Hecky et al. (2004) and Higgins et al. (2008) relate to habitat and the area available for colonization,

1) *Increasing the bottom area available for colonization*. Because *Cladophora* can attach directly to mussel shells, otherwise marginal substrate may be colonized;

2) *Increasing the depth to which substrate may be colonized*. By filtering particulate matter from the water column, mussels increase the transparency of the water column and light sufficient to support *Cladophora* growth extends to deeper waters. This, in turn, further increases the amount of bottom area available for colonization.

These two activities correspond directly to the first and second foundational conditions introduced at the beginning of this review. Both have been shown to significantly impact the distribution of *Cladophora* and, where colonization is supported, have the potential to increase annual biomass production. However, in order for their impacts to be made manifest, the phosphorus requirements of *Cladophora* must be met. No phosphorus … no *Cladophora*. For this reason, the habitat-related activities of mussels, although important are not considered relevant to management. In other words, *Cladophora* growth is controlled by limiting the amount of phosphorus available to it as SRP.

The next two activities relate to the transformation of phosphorus forms and the cycling of phosphorus within the nearshore (Hecky et al. 2004; Higgins et al. 2008),

3) *Reducing competition for phosphorus from phytoplankton.* The filtering activity of mussels removes phytoplankton from the water, thus reducing competition for phosphorus between *Cladophora* and phytoplankton. The potential for reduced competition for phosphorus resources seems quite plausible, but to the knowledge of the reviewer, its significance has not been quantified or demonstrated.

4) *Increasing the bioavailability of phosphorus*. Phosphorus is present in the soluble reactive (SRP), dissolved organic (DOP) and particulate (PP) forms. SRP is directly and completely available for uptake by algae. A fraction of the DOP may be converted to SRP by microbial activity and a fraction of the PP may be converted to SRP through biogeochemical processes. Phosphorus contained in particles harvested from the water column by mussels may become liberated during gut passage and released back to the water as SRP, the bioavailable form.

These two activities, involving phosphorus transformations and alterations to pathways of phosphorus cycling in the nearshore, have the potential to increase the phosphorus resource base available to *Cladophora*. However, in order for their impacts to be made manifest, phosphorus must be supplied to the mussels. No phosphorus … no *Cladophora*. Thus, in this case as well, the activities of mussels may make the ecosystem more sensitive to phosphorus pollution, but they are not the primary driver of nuisance conditions. Mussels do not make phosphorus and phosphorus is <u>the</u> driver of *Cladophora* growth.

Higgins et al. (2012) surveyed *Cladophora* and its phosphorus nutrition at seven sites around Lake Ontario having different levels of urban impact. Their work offers strong support for the reviewer's position with respect to the role of mussels, stating that, "there was little evidence that P from metabolic waste products of mussels was sufficient to produce severe blooms in the absence of local enrichment" (Higgins et al. 2012, p. 116). Mussels do not make phosphorus. It was concluded that the "P load from local watersheds appeared to be the underlying driver for the spatial variability in *Cladophora* biomass" (Higgins et al. 2012, p. 116). Phosphorus is <u>the</u> driver.

<u>Phosphorus provenance</u>

Both Hecky et al. (2004) and Higgins et al. (2012) recognized the primary role of phosphorus in driving *Cladophora* growth, stating that, "effective management of *Cladophora* blooms in Lake Ontario should occur through managing P loading at local scales while ensuring lake-wide P concentrations do not increase" (Higgins et al. 2012, p. 116) and that, "increased regulation of nonpoint sources, as well as more stringent controls on point sources of phosphorus may be required to offset the consequences of mussel invasion and maintain beneficial uses of the nearshore" (Hecky et al. 2004, p. 1292). These statements from leading scientists intimately familiar with the issue confirm that phosphorus is <u>the</u> driver of nuisance conditions of *Cladophora* growth and dictates that characterization of phosphorus provenance be the focus of management efforts to restore degraded water quality and lost beneficial use.

Because of the proliferation of mussels, more attention needs to be paid to point sources such as WPCPs (see Hecky et al. 2004).

Despite having presented temperature (global climate change) and the activities of invasive mussels as the primary drivers for nuisance conditions of *Cladophora* growth, the ESR next directs its attention to phosphorus provenance, recognizing source control as the only option both amenable to management and subject to regulation (ESR, p. 5-5). Four potential phosphorus sources are examined by the ESR: offshore exchange, longshore transport, tributary/nonpoint inputs and WPCP/point inputs. Each of these has been examined explicitly and in detail by Auer (2014).

Supply of phosphorus from offshore waters – as recognized by the ESR (p. 5-6), the offshore waters of Lake Ontario have transitioned from being characterized as eutrophic (TP >20 µgP/L) to oligotrophic (TP <10 µgP/L). Approaching concentrations of 10 µgP/L in 1980, SRP levels have dropped to levels considered P-limiting (Higgins et al. 2012) in the interval since 2001 (Auer 2014). Levels of *Cladophora* production in the strongly P-limited waters of Lake Ontario (Higgins et al. 2012) are dependent on the availability of P and thus offshore waters may support the presence, but not nuisance growth of the alga (Auer 2014). Thus, while *Cladophora* is present in many places along the Lake Ontario nearshore (Auer 2014, Figure 9; ESR, Figure 5-2), nuisance growth is observed only at sites with a significant urban presence, e.g. Ajax (Higgins et al. 2012). For these reasons, nutrient supply from offshore waters is not considered important in relation to phosphorus provenance at urban locations such as the Ajax nearshore.

Supply of phosphorus by longshore transport – Ontario's *Golden Horseshoe*, which includes the Town of Ajax, is one of the largest population concentrations in North America. Tributary and point source discharges of phosphorus are received in this part of Lake Ontario from St. Catharines to Oshawa, Ontario. These inputs are then transported in the alongshore and offshore directions as dictated by the current structure present at any point in time. The ESR (p. 5-4) asserts that tributary inputs of phosphorus (point source inputs are not addressed) received to the west play an important role in influencing sites to the east. The ESR provides no support for this conclusion.

Recognizing that the light environment supporting *Cladophora* growth extends to a distance of ~1 km offshore and adopting a mid-range value for the velocity of offshore transport (2 cm/s; Helm et al. 2012), inputs to the nearshore would be transported beyond the zone of algal colonization in about 14 hours. For this transport time and a mid-range velocity of alongshore transport (6.5 cm/s; Helm et al. 2012), sources discharging within 3.25 km of the Ajax waterfront would have the potential to impact conditions there before being transported offshore beyond the zone of colonization by *Cladophora*. Doubling this distance to provide a conservative estimate, the region of influence by longshore transport would include no wastewater effluent discharges other than the Duffin Creek WPCP. Results of conservative substance monitoring efforts reviewed and conducted (Auer 2011; 2014) offered no clear evidence of impacts on the Ajax nearshore by neighboring WPCPs.

With respect to tributaries, the region of impact would include discharges to the west of Ajax (the Rouge River and Frenchman's Bay and Petticoat Creeks) potentially of interest under prevailing west → east alongshore currents and discharges to the east (Lynde, Carruthers and Duffins Creeks), potentially of interest under prevailing east → west alongshore currents. Total phosphorus loads from the west tributaries total 25% of the combined west tributary – Duffin Creek WPCP input and, for the east tributaries, 20% of the combined east tributary – Duffin Creek WPCP input. Measurements of the amount of phosphorus stored in *Cladophora* (tissue P) in the Ajax nearshore reaches a maximum in the immediate vicinity of the Duffin Creek WPCP outfall and then declines with distance from that point with no evidence of increases as might be stimulated by sources to the east or west. Further, it must be noted that tributary inputs deliver terrigenous phosphorus components that are less bioavailable than those introduced by WPCP effluents (Lambert 2012). For example, Duffins and Carruthers Creeks contribute only 3% of the total SRP load (the completely available P fraction) discharged within the Ajax, Ontario town limits (the balance coming from the Duffin Creek WPCP). Finally tributary inputs are episodic (i.e. often occurring intermittently during seasons unfavorable for *Cladophora* growth) while WPCP discharges are continuous. Given this analysis and the fact that the major local source of phosphorus (the Duffin Creek WPCP) discharges directly to colonizable substrate in the Ajax nearshore, it is difficult to find support for the ESR's assertion (p. 5-4) that tributary inputs received to the west [or east] play an important role in influencing *Cladophora* growth at Ajax.

Supply of phosphorus from nonpoint sources – at this point, the question of phosphorus provenance comes down to the relative importance of point and nonpoint sources. The ESR notes this, recognizing that tributary and WPCP inputs are considered important drivers of phosphorus concentrations in the nearshore environment (ESR, p. 5-5). The report then focuses on nonpoint source inputs, stating that, "In the region of the Ajax-Pickering waterfront, the Duffins Creek is an important tributary load of phosphorus." The issue here then becomes what is meant by important. Duffins Creek is one of two tributaries discharging directly to the Ajax-Pickering waterfront. Including the other stream with direct discharge (Carruthers Creek), the tributary contribution to SRP levels during the spring-summer *Cladophora* growing season accounts for <3% of the total (Auer 2011; 2014). References to larger tributary contributions of phosphorus presented in the ESR (p. 5-6) are based on the annual loads calculated by Booty et al. (2013) and include wet weather events that most commonly occur outside of the growth season for *Cladophora* and which are rapidly removed by offshore/longshore transport. Based on this analysis, it is difficult to assign particular significance to nonpoint/tributary sources of phosphorus within the time frame important to *Cladophora* growth.

Supply of phosphorus from point sources – the ESR provides little or no information on phosphorus provenance in relation to the Duffin Creek WPCP. This omission is both surprising and significant because, by almost any measure (Malkin et al. 2010; Auer 2011; Makarewicz et al. 2012; Booty 2013), the Duffin Creek WPCP effluent represents the single largest contribution to phosphorus loading at the Ajax waterfront, particularly during the *Cladophora* growing season. During that interval (May-Sep), the Duffin Creek WPCP contributes 84% of the TP and

>97% of the SRP load to the Ajax waterfront. As such, the question of phosphorus provenance at Ajax finds its answer in that effluent, i.e. the SRP comes from the plant.

Phosphorus management

The significance of omitting consideration of the role of the Duffin Creek WPCP in phosphorus provenance becomes apparent in reviewing the options studied and recommendations made in the ESR (p. 5-10, 5-11). Here, the ESR appropriately emphasizes the importance of phosphorus bioavailability, understandably recognizes a need for cost-effective management and then recommends three nonpoint source best management practices as the means for improving water quality conditions in the Ajax nearshore. This despite the fact that <3% of the SRP load comes from nonpoint sources and that >97% during the period of vulnerability originates from a point source, the Duffin Creek WPCP. The ESR supports its focus on nonpoint source control by citing the Province of Ontario's *Draft Great Lakes Strategy* (Government of Ontario 2012), "The International Joint Commission has identified non-point pollution from urban and agricultural watersheds as key sources of the excessive phosphorus loadings into Great Lakes nearshore waters." Two paragraphs later, the *Draft Strategy* warns that, "As Ontario's population continues to grow, there is a need to continually improve our sewage treatment and stormwater management." This point was not recognized by the ESR, despite the fact that >97% of the SRP load during the period of vulnerability originates from a point source, the Duffin Creek WPCP.

Next, the ESR references the IJC's *Lake Erie Ecosystem Priorities* (LEEP, IJC 2013) report's recommendation for efforts in nonpoint source control. The ESR (p. 5-11) sees future phosphorus management in Lake Ontario as following steps "very similar to those outlined in the IJC's LEEP report," i.e. a focus on nonpoint source control. This vision ignores the fact that Lake Erie managers are dealing with a system where phosphorus levels are elevated lakewide and driven by one of the largest nonpoint sources of phosphorus in the Great Lakes (the Maumee River), while Lake Ontario has transitioned to oligotrophy and water quality problems are now linked to urban influences (including WPCPs; Higgins et al. 2012). To transfer the focus of phosphorus management for control of Harmful Algal Blooms and hypoxia in Lake Erie to control of nuisance growth of *Cladophora* in Lake Ontario would be entirely inappropriate. Further, the ESR's review of the LEEP report fails to recognize that IJC's recommendation #2 (of 10) that phosphorus management should, "take into account all significant phosphorous sources, and allocate reductions of total phosphorous and DRP [SRP] according to relative loadings." In the case of the Ajax waterfront, significant sources would include the Duffin Creek WPCP which contributes >97% of the SRP load during the period critical to *Cladophora* growth.

Although the issue of phosphorus provenance and the Duffin Creek WPCP is not addressed, the ESR (p. 5-12) does point out that the facility's, "effluent compliance limits are one of the strictest of all WPCPs discharging to the open waters of Lake Ontario." This, the ESR's concluding statement on phosphorus management, is misleading to the extent that,

1) the effluent compliance limits established for the Duffin Creek WPCP seek to address ammonia toxicity and open water trophic state issues and have no basis in protecting the Ajax nearshore from nuisance growth of *Cladophora*; and

2) while the compliance limits for the Duffin Creek WPCP may be the strictest for facilities discharging to the open waters of Lake Ontario, much more efficient technologies for phosphorus removal are being utilized for phosphorus removal at sites across Canada and the U.S., including in the Province of Ontario (e.g. Lake Simcoe basin).

It is the professional opinion of this reviewer that in order to eliminate nuisance growth of *Cladophora* from the Ajax nearshore, it will be necessary to manage the discharge from the Duffin Creek WPCP in a manner consistent with the phosphorus requirements of the alga. The information presented in the ESR focuses on peripheral issues, to the exclusion of the impact of the Duffin Creek WPCP, and does so in a way that leaves the reader with the sense that such management would require technologies and supporting science beyond that presently available. This is far from the truth. The required treatment technologies are now widely applied across Canada and the U.S. (see below) and the body of scientific knowledge relating to *Cladophora* and supporting implementation of those technologies is sophisticated and well advanced beyond that supporting phosphorus management efforts in the 1970s and 80s.

<u>Additional Points</u>

Page	***ESR Statement*** / **Reviewer Response**
5-1	The ESR position on nuisance growth of *Cladophora* at Ajax, Ontario is largely centered on the role played by mussels in the phosphorus-*Cladophora* dynamic. The document sets the stage for this position by suggesting the phosphorus management programs initiated in the 1970s were implemented in response to problems associated with nuisance growth of *Cladophora*. The ESR states that, *The problem [Cladophora blooms] was recognized by a joint commission between Canada and the U.S. and in 1976 a phosphorus program was implemented within the framework of the Great Lakes Water Quality Agreement.* While both of these statements are, at least in part, true, their juxtaposition is inappropriate and misleading. An IJC report published in 1969 recommended that phosphorus from all sources be reduced to their lowest practical level. The Province of Ontario responded in 1970 by calling for reductions in the P-content of detergents and requiring installation of phosphorus removal facilities at municipal and industrial wastewater treatment plants. By the end of 1973, 109 of the 111 facilities required to implement phosphorus removal had done so (Archer 1976). *Cladophora* had yet to appear on the policy and regulatory radar at the time when P-management efforts were implemented. In 1975, IJC sponsored a workshop on *Cladophora* with the proceedings of that meeting (Shear and Konasewich 1975) representing the first major policy statement on the issue.

	***It is incorrect to imply that the phosphorus management efforts initiated starting in 1970 were implemented to address nuisance growth of Cladophora.* As discussed below, those management efforts focused on whole-lake manifestations of eutrophication.**

5-1	The ESR continues with this inappropriate juxtaposition, suggesting that, *This [phosphorus removal] program was deemed successful by the 1980s as nuisance Cladophora blooms were largely eradicated and offshore phosphorus concentrations dropped below the established targets.* There are two problems here. First, the ESR does not provide a reference for its statement that changes in nuisance conditions of *Cladophora* growth were used as a metric for the success of the Great Lakes phosphorus management program. The U.S. EPA (http://www.epa.gov/glindicators/water/trophicb.html) states that its assessment of the impact of phosphorus management on water quality is based on the Trophic State Index of Chapra and Dobson (1981) which considers open water metrics such as chlorophyll concentration, Secchi disk transparency and the hypolimnetic oxygen depletion rate. This reviewer is unaware of any instance where nuisance growth of *Cladophora* was used as a metric of the success of phosphorus management strategies. The second problem is with the extent to which nuisance conditions of *Cladophora* growth were "eradicated" (i.e. to remove completely). The ESR's use of this term (although unreferenced) is likely Higgins et al. (2008) where the term eradicated is used only once and that as part of the paper's abstract. The work of Painter and Kamaitis (1987) provides the only quantitative assessment of *Cladophora* conditions in the Great Lakes for the post P-management and pre-dreissenid period. They reported an average reduction in *Cladophora* standing crop of 58% seven at sites in Lake Ontario. However, the average standing crop following implementation of P-management was 80-86 gDW/m^2, essentially that reported by Higgins et al. (2012, Figure 2) for sites on Lake Ontario experiencing nuisance growth today. ***It is incorrect to imply that conditions of Cladophora growth were used as metrics for the success of P-management programs and, although there were apparently marked reductions in Cladophora standing crop in response to P-management, it is inappropriate to characterize the response as eradication of nuisance conditions.***

5-1	The ESR seeks to make the point that, *Cladophora growth is systemic to Lake Ontario.*

	Illustrating the alga's distribution in Figure 5-2 and meaning that the alga grows everywhere and thus is not particularly associated with urban influences are concluded by Higgins et al. (2012). This statement is true, but misleading. Auer (2014) explains that phosphorus levels in offshore waters are such that will support the presence of *Cladophora* lakewide, but will not result in nuisance conditions except as modified by urban influences. This was the conclusion of Higgins et al. (2012) as well who noted that nuisance conditions did not exist lakewide, but only where discharges from urban areas supplemented whole lake P resources. ***While Cladophora is systemic in its presence in Lake Ontario, nuisance conditions are not. Nuisance conditions are only systemic where urban influences are exerted.***

5-2	The ESR refers to a 'resurgence' of nuisance growth of *Cladophora* in the Great Lakes following colonization by mussels, e.g. *The ecosystem changes brought about by zebra and quagga mussels have coincided with the resurgence of Cladophora growth in Lake Ontario.* Such a reference is not uncommon in the scientific literature, but care must be exercised in its application. A comparison of the standing crop measured in Lake Ontario in the pre-mussel period (Painter and Kamaitis 1987) to that measured in the lake after colonization (Higgins et al. 2012) indicates little change. It is the opinion of this reviewer that what is perceived as a resurgence reflects in large part an expansion of the area available for colonization (a mussel impact) and thus more opportunity to generate algal biomass leading to beach accumulation. ***What is generally perceived as resurgence in Cladophora growth may be more a response to an expanded area of colonization than to mussel-mediated phosphorus cycling.***

5-2	By focusing on peripheral issues and multiple driving forces, the ESR seeks to convey a sense that the problem is not well understood and therefore not amenable to management at present. This intent is made especially clear where the ESR states, *The study of Cladophora is ongoing to better understand how other factors such as mixing, proximity to land-based sources and interannual changes in weather patterns may impact the severity of nuisance Cladophora blooms.* *It is expected that studies like these will help to inform future policies for how nuisance Cladophora growth can be managed lakewide.* Uncertainty has been perceived as a barrier to action in the past, but has been

	effectively addressed. Two decades ago, the Province of Ontario noted that "current scientific evidence is insufficient to develop a firm Numerical Objective at this time", but followed that acknowledgement by establishing the TP-based standard for whole lake trophic state conditions that has been used successfully through to the present time (MOE 1994). ***A robust and diverse body of knowledge exists today with respect to the phosphorus-Cladophora dynamic and its management. Over the past decade, beginning with publications by Higgins (2004; 2005), there has been an unprecedented increase in understanding of the factors mediating Cladophora growth and the need for P-management to reduce or eliminate nuisance conditions. The scientific basis for action and the technologies to implement management decisions are available to the Great Lakes community as never before.***

5-5	Among the various sources potentially impacting phosphorus levels in the nearshore, the ESR invokes upwelling events, stating that, *Additional mixing processes which may be of importance include coastal upwelling and downwelling events.* *Upwelling events are of particular importance since these periodic events will bring nutrient-rich water from the deeper parts of the offshore into the nearshore.* Although upwellings are common in Lake Ontario, the ESR offers no information supporting assessment of their significance as a phosphorus source. Lean et al. (1987) inferred that deep upwelling water was a source of dissolved nutrients to the coastal zone of Lake Ontario in the early 1970s, but that it ceased being a source by 1983 due to decreases in hypolimnetic dissolved nutrient concentrations. Malkin et al. (2010) surveyed conditions at a suite of stations in the Canadian nearshore of Lake Ontario, including two stations in Halton and Durham regions. They reported that there were no detectable relationships between nutrient concentrations and upwelling events at either the Halton or Durham locations, the latter station being centered on the Pickering Nuclear Generating Station (adjacent to Ajax, ON). Malkin et al. (2010, p. 487) further concluded that "although upwelling may have previously been a source of nutrients to boost *Cladophora* growth, upwelling now likely sets back growth because of the colder temperatures it imposes on stands without any benefit of a nutrient supplement". ***There is no evidence that upwelling events represent a source of phosphorus to the Ajax nearshore.***

5- 6	Figure 2-4 of the ESR presents the relative contributions of phosphorus to Lake Ontario from various sources, *Niagara River >50%, Tributaries ~30% and WPCPs ~10%* This presentation carries with it the implication that WPCPs are a minor contributor to the phosphorus provenance than are the Niagara River and tributaries as relates to nuisance growth of *Cladophora*. This review has already pointed to the work of Higgins et al. (2012) in demonstrating that the loads, as presented in Figure 5-4 of the ESR, result in "strongly P-limited conditions" for *Cladophora* growth in Lake Ontario (Higgins et al. 2012) and that nuisance growth of *Cladophora* is found associated only with sites having significant urban enrichment. Malkin (2010) examined long term Environment Canada monitoring results for Lake Ontario and reported than summer phosphorus levels were higher than those of the offshore, reflecting impacts from catchment derived phosphorus, while north coast levels were comparable to the offshore, indicating little effect by catchment dynamics. ***It is concluded here that while the Niagara River and regional tributary sources have impacts on the lakewide phosphorus budget, they do not play a significant role in supporting nuisance growth of Cladophora.***

5-7	The ESR cautions that phosphorus management has the potential to hurt the ecosystem, *While very low phosphorus concentrations are desirable from the point if view of controlling algal growth (both phytoplankton in the offshore and Cladophora in the nearshore) it can be detrimental for the ecosystem as a whole as minimum phosphorus concentrations are necessary to sustain life. Healthy algae populations are required to sustain ecosystem growth of higher life forms as part of the food chain, including zooplankton and fish.* This is nonsense. First, in the days of early European settlement Lake Ontario hosted a diverse (~150 species) and abundant fish community featuring lake trout and Atlantic salmon (Nantel 1997). Since then, more than 6 million people have been added to the basin's population. We are far from reducing phosphorus levels below those characteristic of that period. Second, target water quality conditions, established under the Great Lakes Water Quality Protocol of 2012 to provide guidance for phosphorus management, take into account a broad range of ecosystem health considerations, including fisheries production requirements. The objectives of the Protocols have not been met for the nearshore waters of Lake Ontario. With phosphorus-driven nuisance algal growth

	present on the lake in areas with urban influence, it makes no sense to claim that we are starving the ecosystem. Hecky et al. (2004, p. 1292) address this issue most directly, *Concerns about food competition have led to calls for relaxing P control in the Great Lakes to ensure adequate primary production to support fish populations. This would likely be a mistake; the nearshore shunt might effectively redirect any increase in nutrient loading into excess benthic algal growth and degradation of ecological and aesthetic conditions along Great Lakes coastlines. The long-term consequences of reengineered nutrient flows in the Great Lakes are uncertain and require focused research before any modification is made to current P control strategies. Rather than relaxing P control to offset some of the consequences of dreissenid invasion, the dreissenid-driven nearshore shunt may require increased regulation of nonpoint sources of P, which are not addressed by existing international conventions, as well as more stringent controls on point sources to maintain beneficial uses of the nearshore where most people interact with the lakes.* ***The ESR's invocation of a need to discharge phosphorus to Lake Ontario to insure support of zooplankton and fish populations is not consistent with either the views of leading scientists or with the position presently taken in binational policy.***

5-8	Citing the work of Howell (2012) and Howell et al. (2012), the ESR refers to the regular MOE monitoring programs in demonstrating that, *Theories about the nearshore shunt notwithstanding, concentrations in the water column of total phosphorus, soluble reactive phosphorus, dissolved inorganic nitrogen, and silicate, when averaged over the entire nearshore, were typically similar to the open lake.* This is exactly the point made by Malkin et al. (2010), Auer (2011), Higgins et al. (2012) and Auer (2014), that much of the north coast of Lake Ontario exhibits water quality conditions similar to those of offshore waters. At these levels of phosphorus, the offshore waters can support the presence, but not nuisance growth of *Cladophora*. ***Lost in the averaging of phosphorus levels across the entire nearshore is the fact that, in areas such as Ajax, urban influences increase phosphorus concentrations to levels capable of stimulating nuisance growth.***
5-8	The ESR (p. 5-8) notes that the Toronto and Region Conservation Authority (TRCA) has been studying water quality along the Ajax Waterfront, with a particular focus on phosphorus, since 2007. The ESR abstracts selected findings from the TRCA studies, but provides no supporting data or a citation directing the reader to the results of

	those studies. In particular, Chapter 5 of the ESR makes no mention of the 93-page peer review of the TRCA monitoring program (Auer 2011). In that peer review (p. 40), it was noted that TRCA phosphorus *"detection limits (4 $\mu gP \cdot L^{-1}$ in 2007 and 2 $\mu gP \cdot L^{-1}$ in 2008 and 2009) lie above the range of concentrations meaningful to Cladophora management."* The peer-review noted that detection limits of 0.3 $\mu gP \cdot L^{-1}$ were achievable and recommended that TRCA seek to achieve that standard. A review of subsequent TRCA phosphorus data indicates that this recommendation was not accepted by TRCA. In addition, the peer review (p. 34) concluded that the TRCA monitoring program was less than successful in resolving the issue of phosphorus provenance relative to nuisance growth of *Cladophora* and recommended that attention be given to this topic. The ESR fails to acknowledge the role of the Duffin Creek WPCP in phosphorus provenance despite the fact that the peer-review determined that the plant accounts for 98-99% of the SRP load to the region and that a Region-supported study by Leon et al. (2008, p. 57) concluded that, *"Of the local influences examined … only DCWPCP had an appreciable effect on seasonal accumulation of algal biomass."* ***In preparing this ESR, the Regions have looked to the TRCA and its network of scientists for the water quality information used to support proposed activities at the Duffin Creek WPCP, however, key issues and key findings from that work have gone unrecognized.***

5-8	The ESR states, (p. ES10, ES11) that the preferred solution, *Meets all federal and provincial regulations and therefore no net effects are anticipated.* and that, *TP [concentrations] are well below PWQOs in all areas except the shoreline.* The ESR can make this statement because current federal and provincial regulations do not address phosphorus concentrations in a manner that is germane to the issue of nuisance growth of *Cladophora*. A total phosphorus-based standard has never been

proposed as a metric to control nuisance growth of *Cladophora* because it fails to address the issue of bioavailability. That a TP-based standard simply doesn't work is made clear by the fact that TP levels in the Ajax nearshore regularly meet PWQOs, while nearshore water quality is severely degraded by nuisance growth of *Cladophora*.

Although there are presently no federal or provincial regulations dealing directly with *Cladophora*, it is expected that policies and regulations will be in place soon as,

- the body of knowledge regarding the phosphorus – *Cladophora* dynamic has expanded rapidly in the last decade and scientists and engineers in Canada and the U.S. are well positioned to support establishment of a standard aimed at controlling nuisance growth of *Cladophora*.
- with respect to Objectives, the Great Lakes Water Quality Protocol of 2012,
    - has established a Lake Ecosystem Objective to maintain the levels of algal biomass below the level constituting a nuisance condition;
    - has called for development of Substance Objectives for phosphorous concentrations for nearshore waters, including embayments and tributary discharge for each Great Lake and
    - has issued a mandate for establishment of load reduction targets for priority watersheds that have a significant localized impact on the Waters of the Great Lakes, taking into account the bioavailability of various forms of phosphorus.
- with respect to programs, the Great Lakes Water Quality Protocol of 2012 has directed Canada and the U.S. to assess and, where necessary, develop and implement regulatory and non-regulatory programs to reduce phosphorus loading from urban sources including,
    - programs to prevent further degradation of the Waters of the Great Lakes from wastewater treatment plants located in the Great Lakes basin;
    - programs to optimize existing wastewater treatment facilities;
    - programs to ensure that construction and operation of municipal

      wastewater treatment facilities that discharge one million liquid gallons or more per day achieve a maximum effluent concentration of 0.5 milligram per litre total phosphorus for plants in the basins of Lakes Ontario and Erie;
    - and that more stringent restrictions on phosphorus discharges from wastewater treatments plants may be considered as action plans are developed and implemented.

- nuisance growth of *Cladophora* is a widely recognized as a water quality issue

	of importance in the Great Lakes and has been cited as a major stakeholder concern in public meetings regarding the proposed Duffin Creek WPCP activities. **Nuisance growth of Cladophora, recognized as a major stakeholder concern in this ESR, occurs because no regulatory framework is in place to address its cause – excessive phosphorus discharge. To say that no net effects of the proposed solution are anticipated because the Duffin Creek WPCP meets all present federal and provincial regulations is incorrect and misleading.**

Bioavailable Phosphorus Removal

The Great Lakes Water Quality Protocol of 2012 requires that the U.S. and Canada take into account bioavailability in establishing objectives for phosphorus in nearshore waters. In order to meet such these objectives, at levels meaningful to the *Cladophora* problem, technologies capable of achieving exceptional removal efficiencies will be required. Such technologies are now in widespread use in Canada and the U.S. The material below describes the implementation and operational success of one such plant.

The Metropolitan Syracuse Wastewater Treatment Plant (Metro) provides full secondary and tertiary treatment to a service population of 270,000, discharging ~3 m^3/s (260 million liters per day) to Onondaga Lake (Syracuse, New York). In 2005, Metro implemented advanced tertiary treatment (high rate flocculated settling, HRFS) utilizing the Actiflo® process at a cost of $15 million (2002 dollars). Actiflo® is a micro-sand ballasted approach where the sand serves as a seed for floc formation after coagulant (alum, ferric chloride) addition. The micro-sand / coagulant flocs provide a large surface area for bonding of suspended solids and thus promote rapid settling. Settled solids are passed through a hydrocyclone where the lighter Al- or Fe-enriched chemical sludge is separated from the ballast (Effler et al. 2012).

In the Metro application, HRFS (Actiflo®) was installed as part of a $130 million (2002 dollars) tertiary treatment system upgrade which also included a secondary effluent pump station, a biological aerated filter for ammonia removal, a UV disinfection system and a new effluent flume for flow monitoring. Operations at Metro were unaffected by construction as the tertiary treatment system was a complete new addition and not a retro-fit. Once the whole tertiary treatment upgrade was completed, flow was directed to the system and a new increased level of treatment was thus attained. Construction began in the summer of 2001 and the HRFS system went on line in February 2005.

Operationally, implementation of HRFS (Actiflo®) has increased the demand for ferric chloride from 1000 gallons per day to 3000-4000 gallons per day. The use of ferric chloride as the coagulant has led to increased maintenance and equipment costs (e.g. fouling of the sleeves of UV disinfection lamps and corrosion of RAS lines and HRFS (Actiflo®) ferric /sand slurry hoppers. The lamella tubes in the HRFS (Actiflo®) settling tanks were replaced with tubes of a larger diameter to reduce clogging. An ongoing optimization project seeks to assess and improve performance, operation, reliability and maintenance of the Actiflo HRFS system and has led to relocation of the coagulant feed, flow distribution optimization, mixer improvements, and a reduction in the micro sand diameter used. Seasonal use of PAC as a coagulant is also being investigated. It has been demonstrated (Auer et al. 2014) that changing to alum as the coagulant would not degrade the phosphorus removal capabilities of the process. The HRFS (Actiflo®) system generates ~500,000 gallons of sludge per day. Several benefits have been associated with the characteristics of this sludge including enhanced settling in the sludge gravity thickeners and reduced hydrogen sulfide in anaerobic digester gas.

HRFS (Actiflo®) has been exceptional successful in removing phosphorus. From 2008-2010, the effluent summer (mid-May to mid-Sep) average total (TP) and soluble reactive (SRP) levels were 103 and 5 µgP/L (Effler et al. 2012). These effluent P levels are considerably lower than those for the Duffin WPCP: 303 and 158 µgP/L for TP and SRP, respectively.

The Great Lakes Water Quality Protocol of 2012 calls for consideration of phosphorus bioavailability in developing phosphorus management plans for the nearshore waters of the Great Lakes. Bioavailability refers to the fraction of a particular TP component (e.g. soluble reactive P, dissolved organic P and particulate P) which can be utilized by algae. Quantification of P bioavailability is determined by performing bottle test (for SRP and DOP; Miller et al. 1978) and dual culture diffusion apparatus (PP; DePinto 1982) algal assays. Samples for use in the assays were collected in 2012 at the entry to and exit from the HRFS (Actiflo®) system (Figure 1). These samples thus reflected the phosphorus characteristics of the plant effluent prior to (pre-Actiflo®) and following (post- Actiflo®) implementation of advanced tertiary treatment. As presented in Table 1, utilization of HRFS (Actiflo®) at Metro led to a reduction in TP of 88% and in bioavailable P of more than 98% compared with the final effluent for traditional tertiary treatment. Effluent SRP levels under the HRFS (Actiflo®) regime were 2 µgP/L (compared to 158 µgP/L for the Duffin WPCP).

Figure 1. Implementation of advanced tertiary treatment at Metro included biological aerated filters (BAF) for ammonia removal and high rate flocculated settling (HRFS Actiflo®) for phosphorus removal. These two processes followed the activated sludge unit operation in the process train, i.e. the point immediately prior to disinfection prior to modification. Samples for phosphorus and bioavailable phosphorus analysis were collected before and after HRFS Actiflo®, providing characterization of the effluent without and with advanced tertiary treatment.

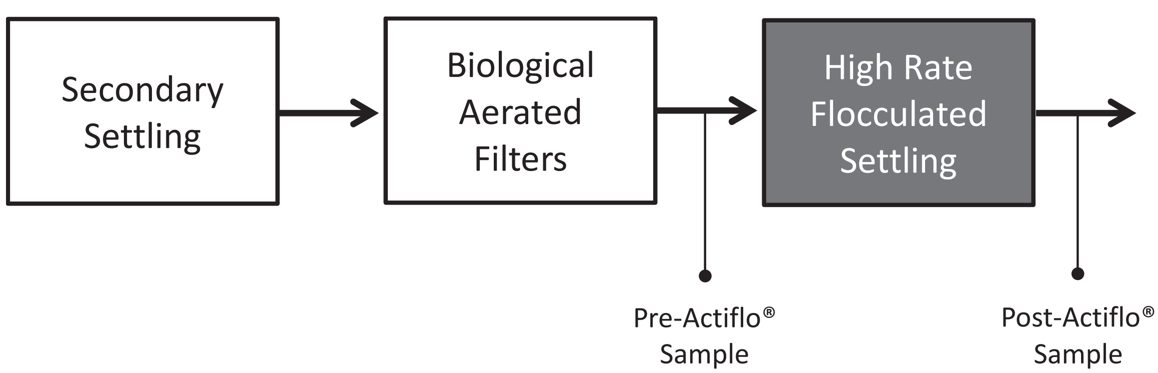

Table 1. Waste stream phosphorus concentrations and removal efficiencies.

	SRP	DOP	PP	TP
P				
Pre-Actiflo (μgP/L)	293	63	138	494
Post-Actiflo (μgP/L)	2	26	31	60
Removal (%)	99+	59	78	***88***
Bioavailability	fraction of P analyte that is bioavailable			
Pre-Actiflo	1.00	0.79	0.21	-
Post-Actiflo	1.00	0.18	0.015	-
Bioavailable-P				
Pre-Actiflo (μgP/L)	293	50	29	372
Post-Actiflo (μgP/L)	2	5	<1	7
Removal (%)	99+	90	98	**98+**

In summary, the HRFS (Actiflo®) process as implemented at the Syracuse Metropolitan Treatment Plant,

- was easily accommodated within the plant footprint;
- was considerably cheaper than other technologies explored to attain permit limits; and
- is highly effective in reducing the phosphorus which may stimulate nuisance algal growth.

This and similar applications are in place at wastewater treatment plants across Canada and the U.S.

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