The SAB draft review of the Annex 4 Target P Load Recommendations

Comments by Dr. David Baker, Director Emeritus, NCWQR, Heidelberg University, 10/24/2016

Authors note: As a member of the Annex 4 Objectives and Targets Task Team, I received a copy of the 9/1/16 SAB draft review of our final report -- the Recommended Phosphorus Loading Targets for Lake Erie – and of the associated Ensemble Modeling Report used in the development of those recommendations. Upon reading the SAB review, a set of concerns that I had regarding our report were reinforced. As such, I am taking this opportunity to comment on the SAB report, as well as those concerns regarding our final report.

General Area of Concern: Inadequate emphasis on reductions in bioavailable phosphorus.

The SAB report focused solely on the 40% reduction in TP loading and totally ignored the 40% reduction in DRP loading which was an integral part of our recommendations. This suggests to me that we did not adequately communicate the importance of bioavailable phosphorus loading in our report, even though the 2012 Great Lakes Water Quality Agreement specifically indicated that "the Parties shall take into account the bioavailability of various forms of phosphorus." The issue of phosphorus bioavailability has been a concern in the Great Lakes community since the 1970s. By virtue of the ongoing monitoring of both DRP and TP, coupled with periodic studies of the bioavailability of particulate phosphorus (PP), the Lake Erie Basin is uniquely positioned to incorporate bioavailability into agricultural non-point source control programs aimed at reducing adverse impacts of eutrophication.

In our report, the topic of bioavailability is largely confined to pages 41-42 under "Other Considerations." We note that, for the Maumee River, on average (2002-2013), only about 45% of the TP load is actually bioavailable and that, although DRP makes up only 21% of the average TP load, DRP makes up 46% of the average bioavailable load. This section also states that "Even though a target is established for a TP load, we should attempt to employ load reduction actions that will be most effective at reducing BAP (bioavailable phosphorus), both in DRP and PP." Yet the terms DRP and bioavailable phosphorus do not show up in the executive summary of the SAB report. The only occurrence of the word "bioavailable" in the entire SAB report is on page 12, as follows:

> "The forms of P coming off the landscape are also critical to changes within the Lake Erie system. While TP load has not changed significantly (i.e. there has been no long term trend up or down, even though year to year variation has been high), the fraction of TP that is "bioavailable" has increased significantly over the last 20 years. This appears to be one of the drivers of cyanobacterial growth, although it should be noted that "turning off" SRP (soluble reactive phosphorus) in the models does not result in the elimination of cyanobacteria (i.e., particulate phosphorus also plays a role in cyanobacterial growth)." *(DBaker note: the models say that reducing DRP loading to zero does not reduce cyanobacteria growth enough to reach the maximum allowable cyanobacterial biomass, not that it would eliminate cyanobacteria as stated in the SAB report.)*

My specific concerns are:

1. Ambiguities introduced by calling for a 40% reduction in both TP and DRP loads.

The general relationships among the various forms of phosphorus can be approximated as follows:

TP = DRP + PP; TBAP = DRP + BAPP; BAPP = 0.25 * PP

Where TP = total phosphorus, DRP = dissolved reactive phosphorus, PP = particulate phosphorus, TBAP = total bioavailable phosphorus, and BAPP = bioavailable particulate phosphorus

In calling for 40% reductions in both TP and DRP loading, we are also mathematically calling for, but not directly stating, a 40% reduction in PP loading <u>and a 40% reduction in total bioavailable phosphorus loading</u>. The ambiguity is introduced by the fact that a 40% reduction in TP loading can be achieved by an infinite number of combinations of PP and DRP reductions, all with differing percent reductions in TBAP loading. Only when the DRP reduction is at least 40% will the reduction in TBAP load reach the 40% level (See Sidebar: Ambiguity of a 40% reduction in TP loading relative to reductions in total bioavailable phosphorus loading)

Is it reasonable to tell the agricultural community that they need to reduce both particulate and dissolved P by equal amounts (in this case 40%)? We could have "bitten the bullet" and stated that the target is a 40% reduction in bioavailable P loading, taking into account that DRP is 100% bioavailable and PP is 25% bioavailable. This would have given the agricultural community some flexibility in the development of domestic action plans and also require that they account for any tradeoffs between BMPs targeting particulate or dissolved P reductions.

2. The accuracy of models that indicate a reduction in DRP loading to zero would be insufficient to achieve targeted cyanobacterial bloom reductions.

The WLEEM and Obenour models are cited as indicating that a 100% removal of DRP, the most bioavailable form of P loading, would be insufficient to meet targeted cyanobacterial bloom conditions. Where models call for a 40% reduction in TP loading from the Maumee River and DRP makes up only ~21% of the TP load, obviously reducing DRP, by itself, to zero cannot reduce TP loading by 40%. However, as noted in our report, DRP makes up about 50% of the total bioavailable phosphorus load (page 41). Thus reducing DRP to zero can reduce the loading of bioavailable phosphorus by more than 40%. In the case of the Obenour model, bioavailable phosphorus is calculated as DRP + 50% of PP. By those calculations DRP comprises ~36% of the total bioavailable load rather than the 50% stated in our report. Again, reducing DRP to zero cannot achieve the 40% reduction in bioavailable loading that we have recommended.

Another reason to doubt the models is through comparing the average TP, DRP and PP loading, before and after the re-eutrophication of Lake Erie. If we take the period from 1985 -1995 as reflecting a period of greatly reduced eutrophication problems and the 2000-2015 as a time period during which re-eutrophication problems were evident, we find the following changes in average annual loads for the Maumee River at Waterville: TP loading increased 10% (1,986 MTA to 2,179 MTA); DRP increased by 132% (225 MTA to 523 MTA); and

particulate phosphorus decreased by 6% (1,761 to 1,656 MTA). Assuming DRP is 100% bioavailable and PP is 25% bioavailable, the loading of total bioavailable phosphorus would have increased by 41% (665 to 937 MTA). A return to the bioavailable P loading of 665 MTA (i.e., the average for the 1985-1995 period) could be accomplished by a 52% reduction of the average DRP loading of 2000-2015. Yet the models say we can't get to acceptable cyanobacterial conditions even if we were to reduce DRP loading to zero. We certainly did not have zero DRP loading prior to re-eutrophication. Since PP loading decreased between the two periods, it is difficult to link PP loading as a cause of re-eutrophication or to argue that a 40% reduction in PP loading below current levels is needed to achieve sufficient cyanobacterial reductions.

It is stated in the modelling report (Ensemble Modeling Report, page 20) that the process models (e.g., WLEEM) internally account for the bioavailability of TP. According to the report, "WLEEM is driven by actual measured particulate and dissolved phosphorus forms, so it explicitly accounts for bioavailable phosphorus and the kinetic conversions of one phosphorus form to another within the model domain (e.g. mineralization of organic phosphorus to orthophosphate , gradient-driven desorption of orthophosphate from inorganic particulate phosphorus)." However, in the modeling section of our report (page 41), the mineralization of organic phosphorus to orthophosphate is noted as a pathway to bioavailability for part of the nonreactive phosphorus component of total dissolved phosphorus. Since most of the total dissolved phosphorus measured at Waterville is DRP, the conversion of dissolved organic phosphorus to orthophosphate adds little to the bioavailable P loads entering the lake (Baker et al, 2014a).

Gradient driven desorption of orthophosphate from particulate phosphorus does provide a pathway to bioavailability for particulate phosphorus. The rate of this process relative to the settling rate of the sediments that bear the particulate phosphorus is relevant to the issue of "positional bioavailability." The portion of the particulate phosphorus that is chemically or physically bioavailable (i.e. about 25%) may not support algal growth if that sediment is deposited or buried prior to orthophosphate release to the water column. In this regard it is noteworthy that in the calibration/confirmation portion of the WLEEM model (starting on page B7-10) it is noted that when the calibrated model was applied to 2008 data, the changes in particulate phosphorus load between Waterville and the mouth of the river were underestimated (B7-22). In other words, there was more deposition of particulate P (and sediment) than the model predicts. Lagrangian sampling of storm water movement through the lower Maumee River and Maumee Bay does show substantial deposition of sediment between the Waterville sampling station and Maumee Bay (Baker et al, 2014b). Given the high DRP concentrations in the storm water surrounding the sediment, gradient driven desorption of orthophosphate from BAPP would be small. These observations indicate that positional bioavailability reduces the biological significance of particulate phosphorus loading, as measured at Waterville, beyond the 25% chemical and physical bioavailability. Thus, the DRP loading becomes even more significant as a driver of cyanobacterial blooms.

It appears that there is no place in the model where the portion of the particulate phosphorus that could participate in "gradient driven" desorption is entered as input to the model (i.e. the chemical/physical bioavailability of the particulate P). If there is, it is not stated in any of the modeling descriptions available in the modeling report. While portions of the deposited particulate phosphorus may subsequently contribute to internal loading, such loading is calculated independently in the model. Internal loading of bioavailable phosphorus should not be superimposed on assumptions that 100% of the chemically and

physically available particulate phosphorus moving past the Waterville monitoring station is released to the water column of Maumee Bay and the Western Basin.

In the development of the load-response curves that serve as the basis for target load recommendation, TP loads were reduced by 25%, 50% 75% and 100% (zero load) and increased by 25%. For the WLEEM model this would have involved changing the concentrations of both particulate and dissolved phosphorus forms. At the same time, other forcing factors, such as flows, temperature, wind and external loads (including sediment and nitrogen loads) were held constant (page B7-28). How realistic is it to lower particulate P loads without changing sediment loads? The primary way to reduce particulate P concentrations is to lower suspended sediment loads and concentrations. Did retaining sediment loads and concentrations as constants affect model outputs?

Statements from the modelers that reducing DRP to zero is insufficient to meet cyanobacteria load targets likely contributed to the SAB focus on TP and their near absence of comments on DRP reductions and bioavailability issues. At this time, shouldn't the x-axis of the load response curves used to set phosphorus target loads for Lake Erie be in the units of total bioavailable phosphorus rather than TP?

3. Needed: A Strong starting place for our Adaptive Management approaches.

   The environmental and agricultural communities need to start our adaptive management programs off on the strongest scientific basis currently available. In my view, this requires that in the development of our domestic action plans, the issues associated with the differing bioavailability of dissolved and particulate phosphorus from agricultural sources must be taken into account. In calling for a 40% reduction in both TP and DRP we are also calling for a 40% reduction in particulate phosphorus reduction. For the Maumee River, this translates into a 449 MTA reduction in particulate P and a 124 MTA reduction in DRP. In view of those reductions, it is quite possible that domestic action plans could put more focus on reductions of particulate phosphorus through erosion control than on dissolved phosphorus. Unfortunately, the major BMPs for erosion control include no-till, mulch till, and winter cover crops, all of which have been known to increase DRP runoff. In fact, many researchers believe that the increases in DRP loading during re-eutrophication were due, in part, to the adoption of no-till and mulch till in the 1990s. The erosion control programs did reduce particulate P loading, even in the face of increased riverine discharge. However, the increased DRP loads overwhelmed the decreased PP loads in terms of effects on bioavailable phosphorus loading and on cyanobacterial growth.

   I believe the initial focus of domestic action plans should be on the reduction of DRP loading and that this should have been emphasized in our report. If and when edge-of-field studies confirm that erosion control programs can be developed that do not simultaneously increase DRP loading, they can be added to the tool box for bioavailable phosphorus reduction for Lake Erie. We do not want to start down the wrong path relative to reducing cyanobacterial blooms in the Western Basin.

References:

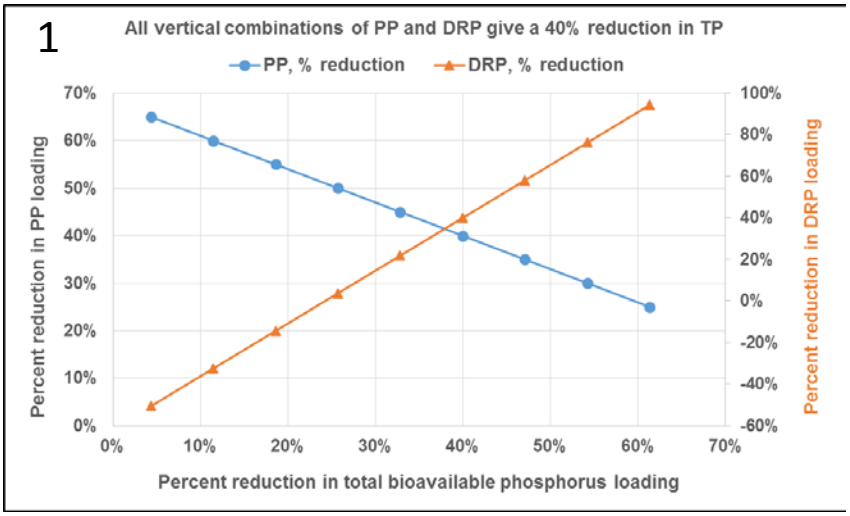
Baker, D.B., R. Confesor, D.E. Ewing, L.T. Johnson, J.W. Kramer, and B.J. Merryfield. 2014a. Phosphorus loading to Lake Erie from the Maumee, Sandusky and Cuyahoga rivers: The importance of bioavailability. J. Great Lakes Res. 40:502-517.

Baker, D.B., D.E. Ewing, L.T. Johnson, J.W. Kramer, B.J. Merryfield, R.B. Confesor, Jr., R. P. Richards, A.A. Roerdink. 2014 b. Lagrangian analysis of the transport of processing of agricultural runoff in the lower Maumee River and Maumee Bay. J. Great Lakes Res. 40:479-495.

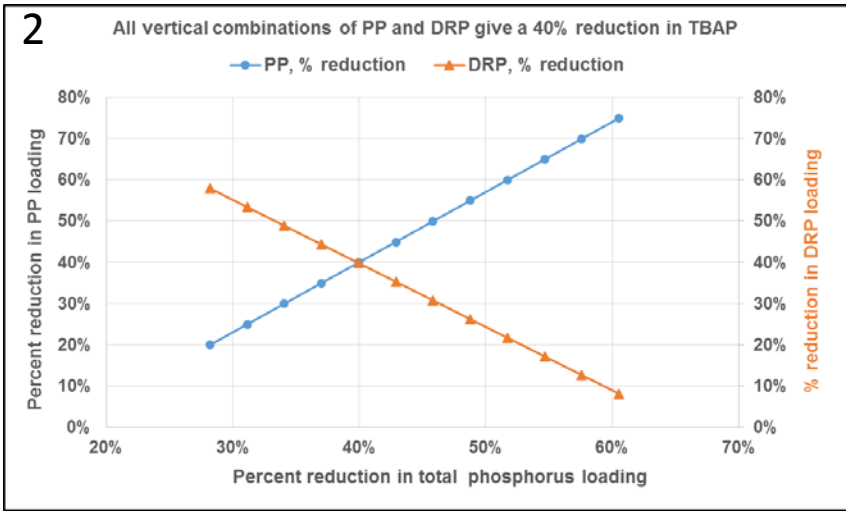
Sidebar: Ambiguity of a 40% reduction in TP loading relative to reductions in total bioavailable phosphorus loading

A 40% reduction in spring total phosphorus (TP) loading, relative to 2008 loads, can be achieved by various combinations of percent reductions in dissolved reactive phosphorus (DRP) and particulate phosphorus (PP) (Graph #1). The associated reduction in total bioavailable phosphorus (TBAP) will vary depending on the proportions of reductions of DRP, which is 100% bioavailable, and PP, which is ~25% bioavailable, that are combined to achieve the 40% reduction in TP loading. Only when the DRP loading is reduced by at least 40% will the TBAP loading be reduced by 40%. By recommending a 40% reduction in both TP and DRP, the Task Team insured a 40% reduction in TBAP loading, but also stipulated equal reductions in both DRP and PP. Without specification of the DRP reduction, a 40% TP reduction is ambiguous relative to the accompanying reduction in TBAP.

A 40% reduction in TBAP loading can also be achieved by various combinations of reductions in DRP and PP loading (Graph 2). The associated reductions in TP loading will vary greatly depending on the combination of DRP and PP reductions used to achieve the 40% reduction in TBAP loading. By stipulating a 40% reduction in TBAP loading rather than a 40% reduction in TP loading, the agricultural community would have been given options regarding their choice of DRP and PP reductions deemed most achievable/appropriate for meeting a targeted 40% reduction TBAP loading. Graph 2 should be the starting place for the development of domestic action plans. It should also be emphasized that reductions in DRP are more important than reductions in PBAP, because DRP is delivered more efficiently than PBAP to waters where cyanobacterial blooms develop.



In Graph 1, all vertical combinations of percent reductions in DRP and PP give a 40% reduction in TP loading. Note the wide variation in percent reductions of TBAP loading (X-axis) associated with the various combinations of PP and DRP reductions. Only when the DRP reduction reaches 40% does the TBAP reduction reach 40%. (See excel files on the next page that were used to print these graphs.)



In Graph 2, all vertical combinations of percent reductions in DRP and PP give a 40% reduction in TBAP loading. Note the wide variation in percent reductions of TP (X-axis) associated with the various combinations of PP and DRP reductions. Only when both DRP and PP load reductions equal 40% does the TP reduction equal 40%. Shouldn't the farming community be given options in how to achieve a 40% reduction in TBAP loading?

Prepared by Dr. David Baker, Director Emeritus, NCWQR, Heidelberg University, 10/24/2016. This sidebar accompanies comments submitted to the SAB revue panel by Dr. Baker on 10/25/2016.

Relationships used in these tables: TP = DRP + PP; TBAP = DRP + BAPP; BAPP = 0.25*PP

	TP		DRP		PP		TBAP		DRP		BAPP	
Graph 1 file	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008
2008	1433	0%	310	0%	1123	0%	591	0%	310	0%	281	0%
	860	**40%**	-38	112%	898	**20%**	186	68%	-38	112%	225	**20%**
	860	**40%**	18	94%	842	**25%**	228	61%	18	94%	211	**25%**
	860	**40%**	74	76%	786	**30%**	270	54%	74	76%	197	**30%**
	860	**40%**	130	58%	730	**35%**	313	47%	130	58%	182	**35%**
Target	**860**	**40%**	**186**	**40%**	**674**	**40%**	**355**	**40%**	**186**	**40%**	**168**	**40%**
	860	**40%**	242	22%	618	**45%**	397	33%	242	22%	154	**45%**
	860	**40%**	299	4%	562	**50%**	439	26%	299	4%	140	**50%**
	860	**40%**	355	-14%	505	**55%**	481	19%	355	-14%	126	**55%**
	860	**40%**	411	-33%	449	**60%**	523	11%	411	-33%	112	**60%**
	860	**40%**	467	-51%	393	**65%**	565	4%	467	-51%	98	**65%**
	860	**40%**	523	-69%	337	**70%**	607	-3%	523	-69%	84	**70%**

	TP		DRP		PP		TBAP		DRP		BAPP	
Graph 2 file	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008	Spring Load, MTA	% reduction from 2008
2008	1433	0%	310	0%	1123	0%	591	0%	310	0%	281	0%
	1029	28%	130	58%	899	20%	**355**	**40%**	130	58%	225	**20%**
	987	31%	144	53%	843	25%	**355**	**40%**	144	53%	211	**25%**
	945	34%	158	49%	786	30%	**355**	**40%**	158	49%	197	**30%**
	903	37%	172	44%	730	35%	**355**	**40%**	172	44%	183	**35%**
Target	**861**	**40%**	**187**	**40%**	**674**	**40%**	**355**	**40%**	**187**	**40%**	**169**	**40%**
	818	43%	201	35%	618	45%	**355**	**40%**	201	35%	154	**45%**
	776	46%	215	31%	562	50%	**355**	**40%**	215	31%	140	**50%**
	734	49%	229	26%	506	55%	**355**	**40%**	229	26%	126	**55%**
	692	52%	243	22%	449	60%	**355**	**40%**	243	22%	112	**60%**
	650	55%	257	17%	393	65%	**355**	**40%**	257	17%	98	**65%**
	608	58%	271	13%	337	70%	**355**	**40%**	271	13%	84	**70%**