Q and A: STAC review of the ANPC/LimnoTech report

This document contains responses to questions that STAC has received about STAC's scientific peer review of the ANPC/LimnoTech report *Comparison of Load Estimates for Cultivated Cropland in the Chesapeake Bay Watershed*.

Question: The STAC review says, "LimnoTech used CBP model predictions for 2009 land use and land management conditions rather than results that are available for 2005, which are more comparable to the 2003-2006 conditions considered by the CB-CEAP model." Can you tell me or share with me which CBP model 2005 data set you all used to generate the corrected CBP numbers in Table 2?

Response: On July 28, the review committee met with the lead developers of both models (Gary Shenk from EPA-CBPO for the CBP model and Lee Norfleet from USDA-NCRS for the CB-CEAP model). We all discussed the two models and the most appropriate comparisons of their results. Gary Shenk then provided the review committee with the numbers from the CBP model run with land use and management conditions from 2005. Here they are:

CB WM Phase 5.3 2005 Scenario (Gary Shenk, USEPA-CBPO, personal communication)										
	Basin	Total	Cultivated Crop	Hay	Pasture	Other Ag	Total Ag	Developed	WWTP	Forest
Nitrogen 1000 pounds										
	Susquehanna	125,012	50,441	8,208	5,338	7,197	71,185	11,759	14,205	27,864
	Upper Chesapeake	39,946	14,615	394	490	441	15,940	7,452	12,437	4,116
	Potomac	59,302	15,501	4,329	4,852	3,620	28,302	8,879	11,472	10,648
	Lower Chesapeake	47,921	6,866	2,343	2,222	1,841	13,271	6,306	18,432	9,912
	Sum of Basins	272,182	87,423	15,274	12,902	13,099	128,699	34,396	56,546	52,540
Phosphorus 1000 pounds										
	Susquehanna	4,606	1,147	228	385	224	1,985	461	1,425	736
	Upper Chesapeake	2,970	1,351	19	51	49	1,469	539	714	248
	Potomac	4,669	1,008	125	1,013	261	2,407	736	940	586
	Lower Chesapeake	5,803	979	65	906	241	2,191	915	1,786	910
	Sum of Basins	18,047	4,486	436	2,355	775	8,051	2,651	4,865	2,480
Sediment 1000 tons										
	Susquehanna	1,430	728	170	68	7	973	148	10	300
	Upper Chesapeake	362	175	16	7	1	199	117	3	43
	Potomac	1,363	422	150	335	9	916	252	15	179
	Lower Chesapeake	1,160	176	139	440	8	762	142	14	242
	Sum of Basins	4,315	1,500	476	850	25	2,850	660	42	763

Question: The STAC review says, "LimnoTech compared controllable nutrient or sediment loads from the CB-CEAP model to total nutrient or sediment loads from the CBP model." Can you tell me how this conclusion was reached? LTI used the CEAP-Bay loads from the 2003-2006 period which reflects the NRCS estimates of the loads from crop fields receiving whatever conservation treatments were found there by the NRI survey. So those definitely are the baseline "treated" loads as the CEAP considered them. Those loads were compared to the CBP model baseline load estimates in the 2009 run – which was the baseline used as the starting point for the load reductions called for in the TMDL. So those CBP model baseline loads should/would also reflect whatever consequences from the conservation practices that were fed to CBP model by Scenario Builder, no? In that sense, both baselines would represent the controlled loads. Is this not correct?

Response: As the review committee noted in the report, "The total load from crop fields can be divided into two components, the background load that would be expected if the fields were in a non-agricultural use (like unmanaged grassland or forest) and the additional load (the controllable load) generated by cropping activities (tillage and nutrient application)." That is,

$T = B + C$,

where T is the total load, B is the background load, and C is the controllable load from tillage and nutrient addition. CB-CEAP describes the concept of the background load on page 12 and the background scenario simulation on page 108.

We'll use the results for sediment to illustrate the problems with LTs calculations, but the same issues apply to the LT interpretations of nitrogen and phosphorus loads (which are reported by CB-CEAP using sets of tables that are analogous to the two sediment tables cited here). Tables 40 and 41 report the cropland sediment loads leaving HUC8 outlets. These are total loads (T) from the APEX output, and the background scenario is *not* involved in calculating these numbers. Table 41 also includes the total loads from other source areas as simulated by SWAT plus the sum of the loads from all sources. Table 42 presents the loads from all sources that are actually delivered to the Bay. These numbers can be different from the loads leaving the HUC8 outlets because sediment can be lost to deposition as it is transported through the river network from the HUC8 outlet to the Bay. Thus the delivered load from all sources for the Susquehanna and Upper Chesapeake (Table 42) are lower than the loads at the HUC8 outlets (Table 41). However, the loads delivered to the Chesapeake from the Potomac and Lower Chesapeake HUCs are actually higher than the loads at the HUC8 outlets, possibly because additional sediments can be mobilized from river banks or floodplains between the HUC8 outlets and the Bay.

Now, here's the tricky part--if you estimate cropland loads from Table 42, you get controllable loads only (C), unlike the cropland loads in Table 41, which are total loads (T). The "Percent of load attributed to cultivated cropland" in Table 42 is calculated as

100*(load from all sources– background sources)/load from all sources.

The load from all sources is total cropland load (B+C) plus the load from other sources O. The background load is the cropland background load B plus loads from other sources O. The numerator of the above equation is then ([B+C+O] - [B+O]). The B and O terms cancel, leaving just C. So, the "Percent of load attributed to cultivated cropland" in Table 42 accounts only for the controllable portion of cropland load (C) delivered to the Bay. The background part of cropland load (B) is omitted.

LimnoTech used Table 42 to estimate the cropland loads delivered to the Bay (Crop numbers for NRCS Baseline in LT Appendix B), so their estimates are for the controllable cropland load only (C). There is nothing wrong with reporting the controllable load (C), but it cannot be directly compared to the CBP cropland loads, which are total cropland loads (B+C).

It appears that LT made some additional mistakes in summarizing the loads in Tables 41 and 42. LT took the ratio of cropland load from Table 42 divided by the cropland load in Table 41 as an estimate of the fraction of cropland sediment from the HUC8 outlet that actually reached Chesapeake Bay. Then LT assumed that the same fraction of hay and pasture loads from Table 41 also reached the Bay. This gave the Hay+pasture numbers for NRCS Baseline in LT Appendix B. Finally, LT assigned to the Other category all the remaining load delivered to the Bay from all sources (Table 42) that was not accounted for as Crop or Hay+pasture. This gave the Other numbers for the NRCS Baseline in LT Appendix B.

These further calculations are wrong because the cropland load from Table 41 is a total load (B+C) while the cropland load from Table 42 is the controllable load only (C); so their ratio underestimates the fraction of total HUC8 cropland load delivered to the Chesapeake (a correct delivery ratio would need a total cropland load in both the numerator and the denominator). The sediment delivery ratio is too low, so when it is applied to the hay and pasture numbers of Table 41, it underestimates the load from these agricultural sources actually delivered to the Bay. The final step attributes to the Other category the entire remaining load to the Bay from all sources that was not accounted for by the Crop and Hay+pasture. The Other category is then incorrectly inflated. Besides the load from Other land, it also includes the background load from cropland and some of the load from hay and pasture, which was underestimated by the delivery ratio estimate that was too low.

In short, the cropland load that LT reports from Table 42 is controllable load only and can't be compared to the CBP estimates of total cropland load. Further errors in the calculations mean that LTs reported loads for Hay+pasture underestimate the actual CEAP predictions for delivery from Hay+pasture to the Bay while LTs loads from Other land overestimate the actual CEAP predictions for delivery from Other land to the Bay. The same errors occurred for nitrogen (Tables 46 and 46) and for phosphorus (Tables 49 and 50).

You can see that something is wrong with LTs sediment results if you compare the loads from different sectors in CEAP Table 41 with the loads from the LT method.

		Load in thousand tons					**% of all sources**		
		All sources	Crop	Hay + past	Other		Crop	Hay+ past	Other
Loads at HUC8 outlets (CB-CEAP Table 41)									
	Susquehanna	4246	1429	847	1970		34%	20%	46%
	Upper Chesapeake	1119	218	86	815		19%	8%	73%
	Potomac	2010	196	286	1528		10%	14%	76%
	Lower Chesapeake	1780	127	247	1406		7%	14%	79%
	Sum of Basins	9155	1970	1466	5719		22%	16%	62%
Loads delivered to the Bay (LimnoTech method)									
	Susquehanna	1427	132	78	1217		9%	5%	85%
	Upper Chesapeake	934	139	55	740		15%	6%	79%
	Potomac	2364	108	158	2098		5%	7%	89%
	Lower Chesapeake	2058	65	126	1867		3%	6%	91%
	Sum of Basins	6783	444	417	5922		7%	6%	87%
Loads delivered to the Bay (STAC method)									
	Susquehanna	1427	480	285	662		34%	20%	46%
	Upper Chesapeake	934	182	72	680		19%	8%	73%
	Potomac	2364	231	336	1797		10%	14%	76%
	Lower Chesapeake	2058	147	286	1626		7%	14%	79%
	Sum of Basins	6783	1040	978	4765		15%	14%	70%

For any HUC8 basin, the difference between the outlet load and load delivered to the Bay should only reflect the sediment lost (or gained) in moving loads through major rivers from the HUC8 outlet to the Bay. The individual basin results from the LT method would imply that somehow the agricultural contribution went way down in that transport process while the contribution from Other sources went up. SWAT doesn't model river transport of sediment from different sources separately, so that's not possible. The changes in source attribution between a HUC8 outlet and the Bay that are seen with the LT method result from the errors described above. In contrast, with the STAC method, the loads delivered to the Bay from each HUC have the same source attribution as the loads at the HUC8 outlet.

Question: I should add, relative to the preceding question…what is the nature of the correction that was applied to the load figures in Table 2 to deal with the controlled vs uncontrolled load issue as the STAC review team saw it? I can't tell from the write up what was done, mathematically, to arrive at and apply the correction.

Response: We used the numbers from the "all sources" column in the upper parts of tables 41, 45, and 49 of the final CB-CEAP report as estimates of total sediment, N, and P loads delivered to the HUC8 watershed outlets from all sources. From tables 42, 46, and 50; we took the numbers from the "load from all sources" column as loads delivered to the Bay. For each material and each HUC, we calculated a delivery ratio to the Bay as the ratio of the delivered to the Bay load divided by the delivered to HUC8 outlet load. We applied those delivery ratios to the individual source loads in tables 41, 45, and 49. This estimated the delivered to the Bay load from each source. Those estimates were used to construct Tables 2, 3, and 4 of the STAC review. This method was discussed during the July 28 review committee meeting with Gary Shenk of EPA-CBPO and Lee Norfleet of USDA-NRCS, and we all agreed that it was a valid way to estimate total loads from the CB-CEAP model that could be compared with the CBP total load estimates.

	Average annual loads at HUC8 watershed outlets							Average Annual Loads Delivered to Chesapeake Bay							
Basin	All sources	Cultivated cropland	Hayland	Pasture & Grazing	Urban NPS	Point sources	Forest & other	All sources	Delivery ratio	Cultivated cropland	Hayland	Pasture & Grazing	Urban NPS	Point sources	Forest & other
Nitrogen CB-CEAP Tables 45 and 46 in thousand pounds															
Susquehanna	140,802	58,939	13,891	15,822	9,335	24,760	18,046	125,260	0.89	52,433	12,358	14,076	8,305	22,027	16,054
Upper Chesapeake	53,112	22,592	543	4,111	5,047	16,419	4,397	46,634	0.88	19,836	477	3,610	4,431	14,416	3,861
Potomac	78,256	12,761	4,457	12,601	9,743	28,250	10,441	80,365	1.03	13,105	4,577	12,941	10,006	29,011	10,722
Lower Chesapeake	57,326	7,319	1,856	6,302	6,840	23,916	11,091	55,977	0.98	7,147	1,812	6,154	6,679	23,353	10,830
Sum of Basins	329,496	101,611	20,747	38,836	30,965	93,345	43,974	308,236		92,521	19,224	36,779	29,421	88,808	41,467
Phosphorus CB-CEAP Tables 49 and 50 in thousand pounds															
Susquehanna	10,599	3702	1316	554	580	3885	562	3,815	0.36	1,332	474	199	209	1,398	202
Upper Chesapeake	2,726	1152	15	132	198	1015	214	2,362	0.87	998	13	114	172	879	185
Potomac	4,717	1077	270	602	531	1895	341	4,000	0.85	913	229	510	450	1,607	289
Lower Chesapeake	4,714	499	87	406	417	2870	436	4,636	0.98	491	86	399	410	2,823	429
Sum of Basins	22,756	6430	1689	1693	1726	9664	1552	14,813		3,735	801	1,224	1,241	6,707	1,106
Sediment CB-CEAP Tables 41 and 42 in thousand tons															
Susquehanna	4,246	1429	708	139	1274	0	696	1,427	0.34	480	238	47	428	0	234
Upper Chesapeake	1,119	218	7	79	473	0	342	934	0.83	182	6	66	395	0	285
Potomac	2,010	196	139	147	1083	0	445	2,364	1.18	231	163	173	1,274	0	523
Lower Chesapeake	1,780	127	69	178	787	0	619	2,058	1.16	147	80	206	910	0	716
Sum of Basins	9,155	1970	924	543	3617	0	2102	6,783		1,040	487	491	3,007	0	1,758

Question: On October 8, the President of the American Farm Bureau wrote a letter to the editor of the Washington Post in which he stated that STAC's review of the LimnoTech report "noted that the EPA's modeling has a margin of error of up to 30 percent." I cannot find any reference to this determination of margin of error in the STAC review. Did the STAC review committee conclude that the CBP model has a margin of error of up to 30 percent?

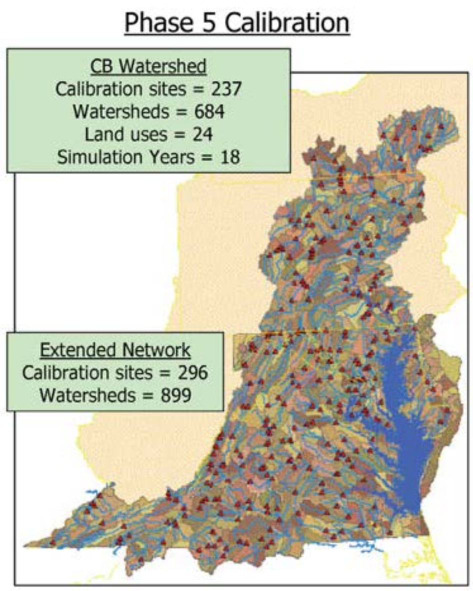
Response: No. STAC did not estimate margins of error for CBP model predictions or for CB-CEAP model predictions. The review committee did report that the total agricultural loads from the two models differed by 15% for nitrogen, 28% for phosphorus, and 29% for sediment. The differences for phosphorus and sediment are near 30%, but it would not be legitimate to interpret one of these percentage differences as a margin of error for either model. STAC offered no such interpretation. The review committee did recommend that, in the future, the CBP and CB-CEAP modeling teams could both attempt to estimate uncertainties in key predictions in order to more objectively assess the significance of differences between the two models.

Chesapeake Bay Commission Follow-up Questions

The Chesapeake Bay Commission (http://www.chesbay.us/) invited STAC to present a summary of the STAC scientific peer review of the ANPC/LimnoTech report *Comparison of Load Estimates for Cultivated Cropland in the Chesapeake Bay Watershed*. STAC made that presentation to the November 10 meeting of the Commission in York, PA (http://www.chesbay.us/Agendas/Nov2011agenda.pdf); and the STAC presentation was followed by an update on the implementation of the Chesapeake Bay TMDL presented by Shawn Garvin, Regional Administrator of EPA Region 3 (http://www.epa.gov/aboutepa/region3ra.html). After that meeting, members of the Commission submitted five follow up questions about the STAC presentation. Below are their questions (in italics) and the STAC responses (in plain type).

1. How many stream monitoring points are used to calibrate the Chesapeake Bay model? What percentage of the 64,000 square mile Bay watershed can these monitoring points accurately represent? Do you concur with RA Garvin's assessment that the model has limitations at the finer scale? What causes the limitations at the finer scale? Has STAC previously reviewed the model's precision at the local scale?

RESPONSE: The CBP model uses 237 calibration/validation sites within the Chesapeake watershed for flow, 215 for total phosphorus, 200 for suspended sediment, and 115 for total nitrogen (Table 1, STAC 2011 and Table 11-1, USEPA-2010a). There are also additional calibration sites outside the Chesapeake Bay watershed (see map below). These non-Chesapeake sites are available because the states supported expanding the model to cover all of Virginia, Maryland, and Delaware. The expanded coverage was intended to facilitate statewide consistency in water quality analysis and regulation, and consistency of local efforts with regional Chesapeake Bay activities (USEPA 2010b).



Map of CBP model calibration sites (Figure 1-7a in USEPA 2010b).

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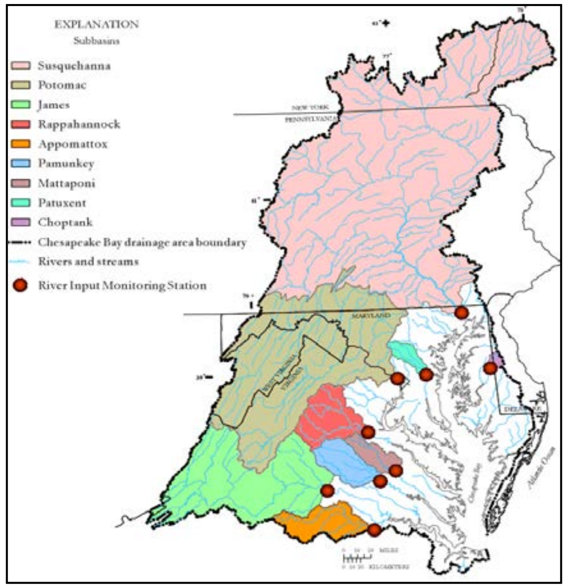
The CBP model calibration stations include the nine major "River Input" monitoring stations (see map below). Just those nine stations together measure the discharges from about 80% of the watershed. The hundreds of other calibration stations include sites that represent the area downstream of the nine river input stations and sites that provide much additional information on the major river basins (see map above).



Nine river input monitoring sites (red circles). The upstream area draining to each site is shaded (USGS 2010).

A 2008 STAC review panel considered the limitations of the CBP model at finer scales (page 5, Band et al. 2008). Like R.A. Garvin, the committee concluded that the CBP model does have limitations at finer scales. The STAC review committee wrote that the current CBP model implementation is not appropriate for development and implementation of TMDLs at the local watershed scale. The committee defined local watersheds as watersheds smaller than the segments of the CBP model, which translates roughly to watersheds smaller than 66 square miles in area and producing a mean annual flow rate less than 100 cubic feet per second (cfs) at the watershed outlet. The limitation arises because the CBP model is built on county level data and a river network that accounts for streams with mean annual flow larger than 100 cfs. The review committee wrote that this resolution is suitable for full watershed or major tributary scale analysis. The STAC review suggested one possible solution--the CBP model framework could be implemented for smaller watersheds using information from local sampling and measurement, and spatial data from higher-resolution local sources.

2. You mention that the 5.2.3 model was calibrated with stream monitoring points. Has the 5.3.2 model been validated? Should it be validated before being used to predict water quality improvements?

RESPONSE: The CBP model *has* been validated. In this context, "calibration" refers to adjusting model parameters to achieve the best match of model predictions with monitored data on water discharge and nutrient concentrations. In "validation," model predictions are compared to monitored data that were *not* already used in model development or calibration. This provides an independent test of model skill in predicting water and nutrient loads. The CBP model was calibrated to data collected during the years 1985-95, and validated with data from the same stations for a separate time period (1995-2005). This strategy was recommended by STAC (Band et al. 2008) and implemented by the CBP modeling team.

3. On page 5 of the STAC review committee's report, the committee concluded "It is unclear where LimnoTech obtained the notion that the EPA expects TMDLs to be accurate to a single pound because no TMDL has or will ever likely obtain such accuracy, and most watershed modelers would concur that such a goal is folly." But in Appendix Q, EPA has assigned very specific N, P and sediment loads, sometimes expressed to the billionth of a pound. How literally will these load reductions be interpreted when measuring sufficient progress?

RESPONSE: Appendix Q, which is titled "Detailed Annual Chesapeake Bay TMDL WLAs and LAs," is a supplement to the TMDL documentation (USEPA 2010c).

Appendix Q is a spreadsheet that presents CBP model output summarized with some additional mathematical formulas, and the numbers have the full precision offered by computer calculations (Gary Shenk, USEPA-CBPO, personal communication). As an example of computer precision, entering the simple division problem "=5/7" into a spreadsheet cell generates the fraction 0.714285714285714. The high level of precision that computers automatically produce should never be interpreted as an indication that real-world quantities are known to that high level of accuracy or precision.

The heart of your question seems to be "How far above the TMDL assignments would loads need to be for EPA to make a judgment of insufficient progress?" This is a policy question, not a science question, and it is really an issue that should be discussed by EPA and the states.

4. One of the core corrections the STAC made in its review of the LimnoTech report was to add into LimnoTech's cropland load figures the additional load that NRCS calls "Background" in the CEAP. LimnoTech agreed that this was an error and corrected it in the update they issued earlier this week. Why is the background load so large? The now corrected number that results from adding in the "Background" load goes up to slightly more than 2 million tons (Table 3, Page 3 of the LimnoTech November Update). Wouldn't that make the background load larger than the load from a cultivated acre? Can you work with the CEAP team at NRCS to help us to understand this issue?

RESPONSE: The STAC calculations (STAC 2011) were later endorsed by LimnoTech in its correction (LimnoTech 2011b). Those calculations indicate that the CB-CEAP model estimates a load of 2,018 tons of sediment delivered to Chesapeake Bay from all agricultural sources, of which 1,040 tons come from cropland. Let's focus on the cropland load because the CB-CEAP model (USDS-NRCS 2011) estimated "background loads" only for cropland, (not for other agricultural or non-agricultural sources). Correctly including the cropland background load raised the total cropland delivered load from LimnoTech's original underestimate of 448 thousand tons (Table 3, LimnoTech 2011a) to the corrected estimate of 1040 thousand tons (STAC 2011; Table 3, LimnoTech 2011b). LimnoTech's original underestimate accounted for only 43% of the delivered cropland load, and LimnoTech's original underestimate of loads per cultivated acre (204.1 pounds/acre; Table 3, LimnoTech 2011a) also accounted for only 43% of the corrected estimate (474 pounds/acre; STAC 2011; Table 3, LimnoTech 2011b).

The CEAP team reported information that can be used to estimate the load from cultivated cropland due to "background," which is the load that would be expected if the cropland were converted to a grass/tree mix with no tillage or nutrient addition (USDA-NRCS 2011). Those calculations show that across the entire watershed, most of the nutrient load delivered to the Bay from cropland (97% of the delivered crop nitrogen and 93% of the delivered crop phosphorus) came from crop activities (tillage and nutrient addition). Only a small amount of the nutrients came from background (4% of the delivered crop nitrogen and 7% of the delivered crop phosphorus). In contrast, 57% of the cropland sediment delivered to the Bay (596 thousand tons) comes from background. As you point out, the background component of the cropland sediment load *is* larger than the 43% attributed to cultivation (444 thousand tons).

It does make sense that the background load is a higher percentage of the cropland load for sediment than it is for nitrogen and phosphorus. The scarcity of nitrogen and phosphorus often limits plant growth (that's why we must add fertilizer to improve crop production). Ecological processes in natural ecosystems (like forests and grasslands) are very effective at holding on to scarce nitrogen and phosphorus. Much of the nitrogen and phosphorus in natural ecosystems is incorporated into living and dead vegetation or tightly bound to subsurface soil particles. The nitrogen and phosphorus are not available to cause water pollution, so background loads from forest and grassland are very low. The situation for sediment is very different. All ecosystems (forest and grasslands as well as croplands) contain vast amounts of soil. Forest and grasslands are typically better at holding soil in place than croplands, but forests and grasslands still contain huge amounts of soil that can be eroded to deliver sediments to streams and so contribute to background sediment loads. Current sediment delivery also depends on historical land use activities. Erosion from land clearing and agriculture has deposited huge amounts of sediment in floodplains, streams, and river channels. Even if the erosion due to cropland tillage were stopped completely (as in the hypothetical USDA-NRCS "background" scenario), those legacy sediments in and near streams from past agricultural activities would still be available to contribute to high background sediment loads.

5. If an individual model is really only useful for its designed purpose, at its designed scale, is there any way for different models to relate to each other at all for decision-making purposes? For example, the current Chesapeake Bay Watershed Model appears to be accurate for planning purposes only at the basin scale, but other models exist that have been designed for farm-level planning. Are there any protocols by which these different models can be integrated or bridged? What would be required to do so?

RESPONSE: First, let's rephrase your initial premise. STAC did not conclude that a "model is really only useful for its designed purpose." STAC said that models have different purposes, and those different purposes inevitably lead to differences in model assumptions, input data, model frameworks, and model results. STAC would also say that a model would be expected to perform best when applied for its designed purpose, but might still provide useful information when applied in other ways. For example, the CBP model may perform best for basin scale planning and have limitations for setting local TMDL allocations (see response to question one on page 6). Even so, the CBP model can still provide information that is useful to local planners.

The Chesapeake Bay partnership already uses a suite of models to accomplish its objectives. In trying to understand the sources and fates of nutrients and sediments in the watershed, the partnership has used the USGS SPARROW model to address some questions where that model is more effective than the CBP model. STAC believes that USDA's CB-CEAP model may provide better field-level understanding of some questions than does the CBP model, and STAC has recommended some analyses that would use the CB-CEAP model independently of the CBP model (STAC 2011). STAC has also recommended that some of the underlying data and knowledge gained from the CEAP studies could be assimilated into future versions of the CBP model. USDA and EPA had already thought of that idea and are actively working to accomplish it. Developing better ways to more effectively apply multiple models in Chesapeake Bay management is an area of current interest and active interaction between STAC and the Chesapeake Bay partnership.

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