Capitol Lake and Puget Sound.
An Analysis of the Use and Misuse of the Budd Inlet Model.

3. THE SIMULATED (AND REAL) ROLES OF ORGANIC CARBON.

The SM Report's central claim regarding Capitol Lake's supposed negative effect on Budd Inlet is that the Lake causes depletion of oxygen in the waters (particularly the bottom waters) of Budd Inlet. It happens, say the modelers, because the plants growing in Capitol Lake create "organic matter" (dead stems, particles, etc) that immediately enters Budd Inlet and uses up oxygen in various ways. In this section, I analyze that claim.

I show in the following that the modelers are mistaken. In this section my conclusions are drawn from obvious calculation errors in the SM Report itself. I also hypothesize that the formation of organic carbon in the lake and its entry into the salt water differs from the mode claimed by the modelers in ways that are much more consistent with ecological reality.

For the benefit of readers who are not familiar with the Lake/Estuary conversation, I first present an overview as a reminder of the main facts and issues.

3a. Background.

During summers, Capitol Lake acts as a vast trap for nutrient nitrogen (NN [1] . This has been known since 1977, when the CH2M-Hill consulting firm issued a report describing a year of detailed study of the Lake (CH2M-Hill, 1978). Figure 3-1 shows the NN trap process in action for year 1977 (data from Figure 34 p. 56, CH2M-Hill). The Lake's entrapment of NN can be seen in recent data, as well. Figure 3-2 shows similar uptake of NN by the Lake in 2004.

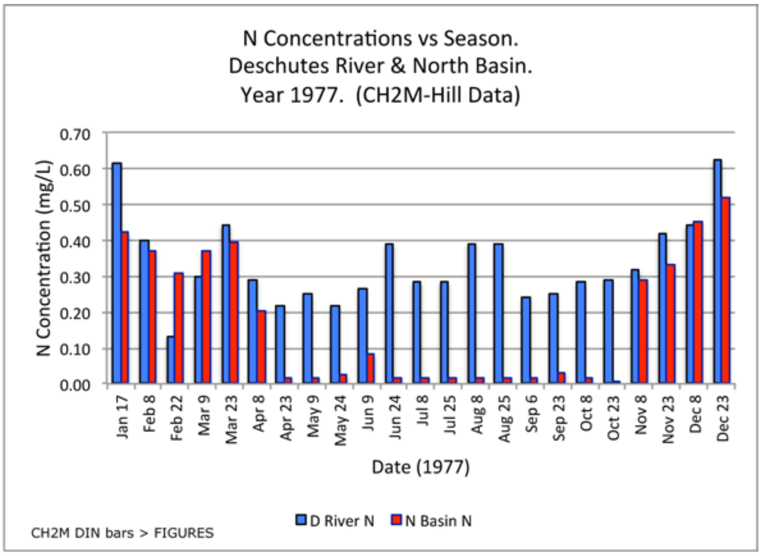

Figure 3-1. Nutrient nitrogen concentrations in the Deschutes River at the south end of Capitol Lake (blue bars) and in water in the North Basin near the dam (red bars), 1977. Differences in bar lengths show the uptake of N by the Lake during almost every time of year, most markedly during summer. (CH2M-Hill data.)

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[1] "Nutrient Nitrogen" is nitrogen in one of three chemical forms; nitrate (NO_3^-), nitrite (NO_2^-) and ammonium (NH_4^+). It is critical to plant growth, very soluble in water, and does not easily become trapped in bottom sediments. Nitrate is usually the most common form in nature, ammonium is usually the scarcest.

How does the Lake trap NN? The plants do it. They take up NN and use it to produce new cells, stems, leaves, flowers, seeds and roots. The mats of algae and rafts of pond lily leaves that we see on the Lake's surface each summer are the reservoirs in which the trapped NN is held.

Nutrient nitrogen is a fertilizer that drives plant growth in all ecosystems – salt water, fresh water, and on land. That plant growth produces oxygen (always "good" in ecosystem dynamics), takes carbon dioxide out of the air or water (*very* good in our modern CO_2-loaded global environment), and produces "food" for the ecosystem's consumers (animals, fungi, bacteria) – all normal and essential ecosystem functions.

There can be a "down side," however. When the newly grown plant material is finally eaten or decays, it uses up exactly as much oxygen as was created when that plant material was first manufactured by photosynthesis. If this oxygen consumption takes place in deep water where O_2 levels are normally low, the oxygen-utilizing animals there - fish, crabs, insect larvae, clams, and the like – run short and may die. *That is the down side that we worry about in Puget Sound.*[2]

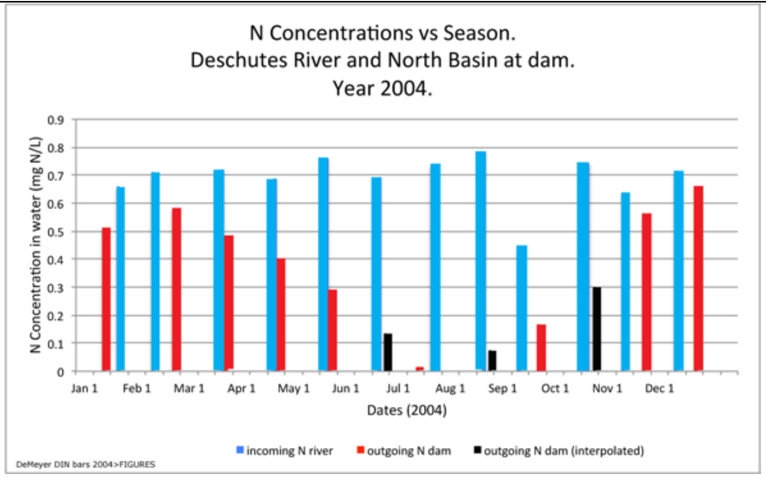

Figure 3-2. Nutrient nitrogen concentrations in the Deschutes River (blue bars) and in water exiting the Lake's North Basin over the dam (red bars), 2004. Same interpretation as Figure 3-1. Black bars are interpolated values for missing data. (DeMeyer data.)

The Deschutes River has a higher concentration of NN in its water than any other major stream entering Puget Sound south of the Narrows. These are compared with the NN contents of other South Sound streams in Table 3-1.

Stream	2006-07	Sept 2007
	mg N/L	kg N/day
Chambers Creek	1.15	112
Deschutes River	0.90	198
Woodland Creek	0.75	57
Moxlie Creek	0.75	15
Mission/Ellis Creek	0.75	0.8
Kennedy Creek	0.45	3.5
McLane Creek	0.25	0.8
Nisqually River	0.20	199

Table 3-1. Average NN concentrations in stream waters 2006-07 (left column) and amount of NN delivered by streams to Capitol Lake (Deschutes) and Puget Sound (all others) each day, Sept. 2007 (right). Sources: SPSDOS, 2011. Fig F-3 p. 124 (left) and Table 7 p. 28 (right) from that source.

Because the Nisqually River has such a large volume of flow, that river delivers more total NN to Puget Sound than any other stream, despite its low NN concentration. (This is especially true when the

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[2] This is *never* a problem in the deep water of Capitol Lake, where the oxygen supply is virtually inexhaustible.

whole year is considered.) But next on the list and far ahead of any other stream is the Deschutes River. All of its NN would go directly into Budd Inlet, were it not intercepted by the Lake (Figures 3-1 and 3-2). That trapped NN – some 20+ tons per summer – is the equivalent of about 80 50-lb bags of conventional fertilizer poured from the Fourth Avenue Bridge into Budd Inlet *every day, all summer long*.[3]

The reason why excess NN is not always a good thing for Budd Inlet is that the water at the bottoms of East Bay and West Bay experience a "low-oxygen" condition every summer, particularly in September. This occurs naturally in almost all northern hemisphere estuaries at this time.[4] By summer's end, a whole season's plant growth, driven by NN, has occurred. Some plant and animal products (leaves, fecal pellets, whole phytoplankton cells, fragments of carcasses, exoskeletons etc) have been sinking to the bottom all summer long, and resident bottom organisms (clams, crustaceans, bacteria, etc) have consumed oxygen by eating or decaying the sunken biomass. When the amount of dead carbon-containing organic material becomes too great, all of this consumption – particularly by bacteria – can drive the deep water oxygen level to zero, with disastrous effects on the organisms that need it.

On the other side of the ledger, the deep water oxygen is continually replenished by a salt water stream coming all the way from Pacific Ocean along the bottom. However, that stream is always naturally low in dissolved oxygen to begin with. The result, during the warm, high-biomass days of September, is that the bottom waters of East and West Bays usually experience their lowest DO's of the year. The net effect of adding NN to the Sound, as the Deschutes River would do, is to ramp up plant growth in the sunlit surface water and, ultimately, to lower DO even further at the bottom.

The Department of Ecology said nothing about the Lake's ability to trap NN in its first TMDL Report. In the months after I brought it to public attention (Spring 2014; Milne, 2014), the modelers began looking for ways in which the Lake could be shown to damage Budd Inlet even though it was preventing NN from reaching the salt water. Their answer was (and still is) the claim stated at the beginning of this Section: "Yes, the Lake traps NN and stores it in plant biomass, but then the biomass itself immediately goes over the dam into Budd Inlet in the form of organic carbon, then decays and releases the trapped NN in the saltwater." Then, of course, marine plant growth would follow with as much consequent deep-water oxygen depletion as if Deschutes water entered Budd Inlet directly with no dam to delay it.

This is a valid scientific hypothesis. It is true that, sooner or later, some, most, or even all of the new plant biomass formed each summer in the Lake must be eaten or break down and decay, consuming oxygen in the process. The critical questions are "Where?" (in the Lake? Budd Inlet? Both?) and "When?" ("sooner," during the summer growing season, or "later," after the growing season?) An alternative to the "sooner" hypothesis is presented and analyzed in Section 6. Here I examine the validity of WDOE's claim that, by this

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[3] 50-lb bags of fertilizer that consists of 10% nutrient nitrogen.

[4] This includes the more-or-less permanent natural estuarine "null zone" introduced in Section 1, but it can be a more widespread phenomenon elsewhere throughout whole late-summer estuaries.

mechanism, the Lake lowers Budd Inlet oxygen more than an undammed estuary would do.

3b. The Production of Organic Carbon by Lake and Estuary.

The modelers support their claim (that Capitol Lake plant matter significantly decreases dissolved oxygen in Budd Inlet all summer) using the graphs shown in Figure 3-3. The upper graph (Fig 3-3a) shows "total organic carbon (= TOC)" levels in Capitol Lake or the estuary that would replace it if the Lake were missing, as calculated by their computer, day by day, from January 25 through September 15, 1997. The lower graph (Fig. 3-3b) shows levels of nutrient nitrogen (NN, called "DIN" by the modelers) in the water, also as calculated for both Lake and estuary for the same time period. The graphs show the Lake trapping more River DIN than would an estuary (Fig. 3-3b) but also releasing more TOC to Budd Inlet than would an estuary (Fig. 3-3a). Pink dots on both graphs show actual observed values of TOC and DIN on various dates.

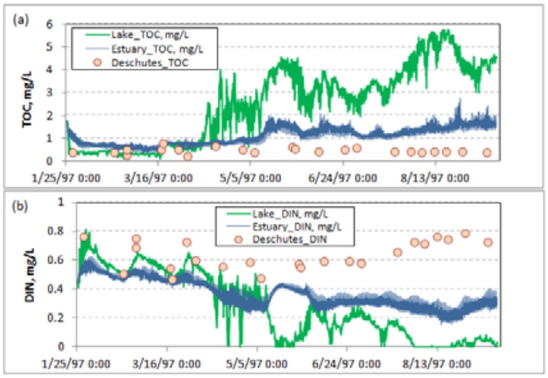

Figure 11. a) Total organic carbon (TOC) and b) dissolved inorganic nitrogen (DIN) concentrations at the location of the Capitol Lake dam under Lake (with the dam) and Estuary (without the dam) scenarios compared with concentrations in the Deschutes River at E Street.

Poster graph Grab2 > Figures

Figure 3-3. Fig.3-3a (Upper). "Total organic carbon" (TOC) in water at the position of the dam if the Lake is present (green graph) or if the Estuary were present (blue graph). Figure 3-3b. (Lower) "Dissolved Inorganic Nitrogen" (DIN) at the dam, same scenarios. Graphs = computer calculations, data points show observations in the Deschutes River, 1997. Source: SM Report Figure 11 p. 36. See also Poster, 2014.

The measurements (pink dots) of observed TOC and DIN were made in the Deschutes River above the Lake. The estimates of TOC and DIN by the computer (blue and green graphs) show their calculated levels in the water at the other end of the Lake basin, near the location of the 5th Avenue Bridge and dam (henceforth, the "Bridge Site").

Both "TOC" and "DIN" as calculated by the modelers are reported in "milligrams per liter (mg/L)." By those units of measurement, the modelers inform us that they are calculating the amount of suspended and dissolved material in each liter of Lake or estuary water – not in solid parts of plants or biomass of animals.

These graphs provide a way of checking the computer's calculations. In the lower Figure (3-3b) both Lake and Estuary DIN graphs are positioned lower on the Figure than are the observed data points. The differences in positions show the amounts of DIN removed from the water by the photosynthesizers that create TOC. By calculating those DIN differences and the amounts of TOC created and comparing them with the alleged TOC's presented by the modelers in the upper graph (Figure 3-3a), one finds that *there are serious discrepancies in the modelers' calculations*.

3c. Methods. Estimating TOC from DIN Uptake, using Figures 3-3a and 3-3b.

On both upper and lower graphs, I estimated the values of the observed data points (pink dots) from scale measurements of the graphs. I estimated the date on which each TOC and DIN observation ("pink dot") was made, also by scale measurements. The measurements were made on full-screen images of each graph using the centimeter scale of Photoshop software.[5] My scale-estimated dates and observations of River TOC and DIN values are shown in Table 3-2 (Columns A-D). I used the same technique to estimate the

Basic Data from the Poster Graphs (Figures 3-3a and 3-3b).

A	B	C	D	E	F	G	H
Date of TOC observation RIVER	Amount of TOC observed mg C/L RIVER	Date of DIN observation RIVER	Amount of DIN observed mg N/L RIVER	TOC from green graph, Fig 3-3a date in Column A mg C/L LAKE	DIN from green graph, Fig 3-3b date in Column C mg N/L LAKE	TOC from blue graph, Fig 3-3a date in Column A mg C/L ESTUARY	DIN from blue graph, Fig 3-3b date in Column C mg N/L ESTUARY
Jan 25	-	Jan 25	-	1.85	0.69	1.85	0.53
Jan 29	0.35	Jan 29	0.77	0.35	0.77	0.92	0.57
Feb 19	0.35	*Feb 20*	0.49	0.35	0.46	0.69	0.48
Feb 27	0.52	*Feb 28*	0.75	0.29	0.67	0.69	0.55
Feb 27	0.23	*Feb 28*	0.68	0.29	0.67	0.69	0.55
Mar 19	0.52	*Mar 17*	0.55	0.40	0.52	0.81	0.45
Mar 20	0.75	*Mar 18*	0.46	0.75	0.46	0.75	0.45
Mar 28	0.46	*Mar 27*	0.72	0.92	0.65	0.92	0.52
Apr 1	0.23	*Mar 31*	0.59	0.81	0.59	0.81	0.49
Apr 16	0.63	Apr 16	0.56	2.31	0.44	0.81	0.55
May 1	0.46	May 1	0.59	2.88	0.40	1.04	0.42
May 7	0.35	May 7	0.48	3.12	0.34	1.04	0.34
May 28	0.63	May 28	0.59	4.27	0.08	1.73	0.44
May 29	0.52	May 29	0.56	4.15	0.18	1.50	0.42
Jun 11	0.40	*Jun 10*	0.59	3.92	0.18	2.02	0.34
Jun 26	0.46	*Jun 25*	0.59	2.88	0.22	1.56	0.36
Jul 2	0.58	Jul 2	0.59	3.17	0.20	1.21	0.38
Jul 22	0.40	Jul 22	0.66	3.92	0.20	1.27	0.35
Jul 30	0.40	Jul 30	0.73	4.85	0.00	1.38	0.36
Aug 5	0.35	*Aug 6*	0.72	5.31	0.00	1.56	0.32
Aug 12	0.40	*Aug 13*	0.77	5.42	0.00	1.85	0.33
Aug 18	0.40	*Aug 19*	0.74	5.77	0.05	1.62	0.27
Aug 27	0.40	*Aug 28*	0.79	4.38	0.07	1.85	0.34
Sep 9	0.40	Sep 9	0.73	4.27	0.08	2.42	0.40

Table 3-2. Dates and values of TOC and DIN observations and estimates. River values are observed, Lake and Estuary values are calculated. All values shown in this table were estimated by interpolation from scale measurements of Figures 3-3a (TOC's) and 3-3b (DIN's). Observed River values are from positions of pink data points. Calculated DIN and TOC values are from the tops of the respective green or blue graphs for the dates in Columns A and C. Some (italicized) DIN dates differ by 1 or 2 days from the TOC dates, possibly due to rounding artifacts in the estimate method. For ease of calculation and graphing, hereafter in this Analysis I have used the TOC dates in Column A for both TOC and DIN observations.

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[5] One could in principle try to read the data directly from the graphs themselves, but the results would be crude and in any case the unhelpful date scale provided on the x-axis by the modelers makes this near-impossible.

values of Lake and Estuary TOC's and DIN's calculated by the computer. These measurements were made *from the x-axis to the respective tops of the green and blue graphs* on the same dates as for the River observations. These estimated values are shown in Table 3-2 (Columns E-H).

For the estuary case, I assumed that the uptake of NN (= DIN) by the algae in the estuary is given by the difference between the amount observed in the River and the calculated amount still in the estuary water at the Bridge site *at the end of the same day* (Columns D and H, Table 3-2). These uptake values are shown in Table 3-3 (Column I).

Estuary Case.						
A	B	D	H	I	J	JJ
Date	Amount of TOC observed (mg C/L) RIVER	DIN in River this date* (mg N/L) RIVER	DIN at Bridge this date* (mg N/L)	DIN uptake Col. D-H (mg N/L)	New TOC from DIN uptake Col. I x 7 (mg C/L)	Total TOC DIN-C + River TOC Col. J + Col. B (mg C/L)
Jan 25	-	-	0.53	-		
Jan 29	0.35	0.77	0.57	0.20	1.41	1.76
Feb 19	0.35	0.49	0.48	0.01	0.07	0.42
Feb 27	0.52	0.75	0.55	0.20	1.41	1.93
Feb 27	0.23	0.68	0.55	0.13	0.92	1.15
Mar 19	0.52	0.55	0.45	0.09	0.64	1.16
Mar 20	0.75	0.46	0.45	0.01	0.07	0.82
Mar 28	0.46	0.72	0.52	0.20	1.41	1.87
Apr 1	0.23	0.59	0.49	0.09	0.64	0.87
Apr 16	0.63	0.56	0.55	0.01	0.07	0.70
May 1	0.46	0.59	0.42	0.16	1.13	1.59
May 7	0.35	0.48	0.34	0.14	0.99	1.34
May 28	0.63	0.59	0.44	0.14	0.99	1.62
May 29	0.52	0.56	0.42	0.13	0.92	1.44
Jun 11	0.40	0.59	0.34	0.24	1.70	2.10
Jun 26	0.46	0.59	0.36	0.22	1.56	2.02
Jul 2	0.58	0.59	0.38	0.20	1.41	1.99
Jul 22	0.40	0.66	0.35	0.30	2.12	2.52
Jul 30	0.40	0.73	0.36	0.36	2.55	2.95
Aug 5	0.35	0.72	0.32	0.39	2.76	3.11
Aug 12	0.40	0.77	0.33	0.43	3.04	3.44
Aug 18	0.40	0.74	0.27	0.46	3.25	3.65
Aug 27	0.40	0.79	0.34	0.44	3.11	3.51
Sep 9	0.40	0.73	0.40	0.32	2.26	2.66

*Table 3-3. Amounts and uptakes of DIN and resultant total TOC at Bridge Site. Columns A, B, D and H are the same as those of Table 3-2 for ease of visualization. Column I; amount of estuary DIN taken up by algae. Column J; the amount of new TOC that would be created by the DIN uptakes shown in Column I (= Column I values x 7). Column JJ; total TOC at Bridge site (Col. J + Col. B). (Rounding of products alters some 2nd place decimals). *See note on dates, Columns A and C, Table 3-2.*

Plants and algae remove DIN/NN from the water and use it (via photosynthesis) to build new organic matter. I estimated the amount of carbon in the new organic matter created by the Estuary's uptake of NN using the modelers' formula, namely the amount of Carbon in new organic stuff is the amount of Nutrient Nitrogen taken up multiplied by 7

(Ahmed and Pelletier, 2014). In the following, “new TOC calculated from DIN uptake” (as in Column J, Table 3-3) is abbreviated as “DIN-C.”

For example, on February 19 algae in the water of the imagined estuary removed 0.01 mg of N from every liter of water (Column I Table 3-3, row Feb. 19). The amount of carbon built into new organic matter by this uptake would be 7 x 0.01 = 0.07 (mg C/L). If *all* of this new carbon-containing organic material ended up suspended or dissolved in the water, the newly manufactured carbon present as TOC (= “DIN-C”) on that day would be 0.07 mg C/L (Column J Table 3-3, row Feb. 19).

Proceeding in this way, the new TOC that would be created by the uptake of NN from the estuary water each day is shown in Column J of Table 3-3. The total TOC to be expected at the Bridge site is the new “DIN-C” plus the existing “River TOC” (Columns B+J, Table 3-3). These totals are shown in Column JJ, Table 3-3.

It is likely that River water would pass through an estuary in a single day if there were no dam to retard its flow. Because it takes 15 days for river water to pass through the Lake however (TMDL Report p. 13), a different procedure was used for the Lake case. For each observation date (Column A Table 3-2) I calculated a “lag date” 15 days after the observation date (Column K Table 3-4). I estimated from scale measurements in Figure 3-3b (x-axis to top of green graph) the amount of DIN in the Lake water at the Bridge site on each lag date (Column L Table 3-4). For each DIN measurement, that is the amount of DIN still left in the water 15 days after the River water entered the other end of the Lake. To determine the uptake of DIN by plants during those 15 days, I subtracted the amount of DIN calculated to be present at the Bridge site on each lag date from the amount of DIN observed in the River 15 days earlier. (This subtraction is Column D minus Column L, Table 3-4.) The 15-day uptake values are shown in Column M, Table 3-4.

As in the Estuary case, the amount of carbon that would be incorporated into new organic biomass via DIN uptake was found from “New Carbon = 7 x DIN uptake.” If *all* of this new carbon manufactured from DIN uptake became suspended as particles or dissolved as molecules in the water during the 15-day uptake period, this would be the amount of newly manufactured TOC predicted to appear at the Bridge site on each lag date. If some of the new “DIN-Carbon” remained in storage in the biomass of large plants, the TOC’s appearing at the Bridge would be smaller – *much* smaller -- than these values.

The final step of the lake calculation requires estimating the amounts of TOC of River origin expected to be present on the lag dates. These values were found by interpolating between the River TOC values observed (Table 3-2 Column B) on the observation dates (Column A, Tables 3-2 and -4) just before and just after each lag date. These interpolated values are shown in Column O Table 3-4. The total TOC expected at the Bridge Site is shown in Column P, Table 3-4 (= Col. N + Col. O values).

I also calculated data estimates for the Lake scenario to see what would result if there were no 15-day lag between the entry of DIN from the river and the appearance of new

TOC at the Bridge site. This calculation (not shown here) uses exactly the same procedure as for the Estuary case except using Lake data from Columns D and F, Table 3-2.

Lake Case.							
A	D	K	L	M	N	O	P
Date of Observation	DIN observed River mg N/L	*Lag Date 15 days later*	*DIN in Lake on lag date (mg N/L)*	*DIN uptake (15 days; Cols. D-L) (mg N/L)*	*New TOC from DIN uptake (Col M x 7) mg C/L*	*River TOC interpolated values for lag dates mg C/L*	*Total TOC DIN-C + River TOC Cols. N + O*
Jan 25	-	*Feb 9*				*0.35*	
Jan 29	0.77	*Feb 13*	*0.58*	*0.19*	*1.32*	*0.35*	*1.67*
Feb 19	0.49	*Mar 6*	*0.62*	*-0.13*	*-0.88*	*0.33*	*-0.55*
Feb 27	0.75	*Mar 14*	*0.57*	*0.18*	*1.27*	*0.46*	*1.73*
Feb 27	0.68	*Mar 14*	*0.57*	*0.11*	*0.78*	*0.46*	*1.24*
Mar 19	0.55	*Apr 3*	*0.60*	*-0.05*	*-0.38*	*0.28*	*-0.10*
Mar 20	0.46	*Apr 4*	*0.57*	*-0.11*	*-0.75*	*0.31*	*-0.44*
Mar 28	0.72	*Apr 12*	*0.50*	*0.22*	*1.54*	*0.52*	*2.06*
Apr 1	0.59	*Apr 16*	*0.54*	*0.04*	*0.29*	*0.63*	*0.92*
Apr 16	0.56	*May 1*	*0.41*	*0.14*	*0.99*	*0.46*	*1.45*
May 1	0.59	*May 16*	*0.07*	*0.52*	*3.62*	*0.47*	*4.09*
May 7	0.48	*May 22*	*0.07*	*0.42*	*2.91*	*0.55*	*3.46*
May 28	0.59	*Jun 12*	*0.21*	*0.37*	*2.60*	*0.41*	*3.01*
May 29	0.56	*Jun 13*	*0.29*	*0.27*	*1.86*	*0.41*	*2.27*
Jun 11	0.59	*Jun 26*	*0.24*	*0.34*	*2.41*	*0.47*	*2.88*
Jun 26	0.59	*Jul 11*	*0.19*	*0.39*	*2.75*	*0.50*	*3.25*
Jul 2	0.59	*Jul 17*	*0.20*	*0.39*	*2.70*	*0.45*	*3.15*
Jul 22	0.66	*Aug 6*	*-0.01*	*0.66*	*4.64*	*0.35*	*4.99*
Jul 30	0.73	*Aug 14*	*0.00*	*0.73*	*5.09*	*0.40*	*5.49*
Aug 5	0.72	*Aug 20*	*0.00*	*0.72*	*5.02*	*0.40*	*5.42*
Aug 12	0.77	*Aug 27*	*0.06*	*0.71*	*4.94*	*0.40*	*5.34*
Aug 18	0.74	*Sep 2*	*0.03*	*0.70*	*4.92*	*0.40*	*5.32*
Aug 27	0.79	*Sep 11*	*0.06*	*0.73*	*5.08*		
Sep 9	0.73	*Sep 24*					

Table 3-4. Values of DIN in Lake water at the Bridge site (Column L) on the "lag" dates shown (Column K), estimated from green graphs calculated by computer (in Figure 3-3b). Column M; estimated uptake of DIN during the 15 days in which the water flows from the River to the Bridge site (= Columns D – L). Column N; new carbon created by this uptake (= 7 x Column M). Column O; estimated River TOC values for the lag dates found by interpolation using values in Column B Table 3-2. Column P; total TOC to be expected at the Bridge site on each lag date (=Cols. N+O). Columns A and D are replicated from Table 3-2 for ease of visualization. See note in caption of Table 3-2 regarding dates of DIN observations (Column A). All italicized values are for the lag dates. *Values calculated by the Excel spreadsheet show 2nd decimal place numbers that differ slightly in some cases from those shown in Column N.*

<u>3d. Results. Estimating TOC from DIN Uptake.</u>

The following graphs show data from these calculations.

For the estuary case, Figure 3-4 shows the amounts of NN observed in the river on the observation dates, the estimated levels of NN in the estuary as calculated by the computer, and the amounts of NN removed daily. Figure 3-5 shows how the levels of TOC that must be created by the daily uptakes of NN (that is, "DIN-TOC") compare with the TOC values presented directly by the modelers in their graph (Figure 3-3a). For the Lake case, Figure 3-6 shows how the levels of organic carbon created by 15-day uptakes of DIN compare with the TOC values presented by the modelers in their graph (Figure 3-3a). Figure 3-7 compares the modelers' graph with new organic carbon from DIN uptakes in the Lake with no 15-day lag.

In Figure 3-6 the upper line representing total TOC (DIN-C + River TOC) is the sum of values in Columns N and O, Table 3-4, for each lag date.

3e. Discussion. TOC from DIN Uptake.

The modelers have presented computer calculations of the nutrient N levels that would be present in the water at the Bridge Site for a Lake scenario and for an Estuary scenario (green and blue graphs respectively, Figure 3-3b). From that nutrient data I have estimated the amounts of NN taken up by the plants in each ecosystem and hence the amount of carbon converted to new plant biomass for each scenario. In the estuary, the "plants" are either single-celled phytoplankton organisms or the cells of an alga mat

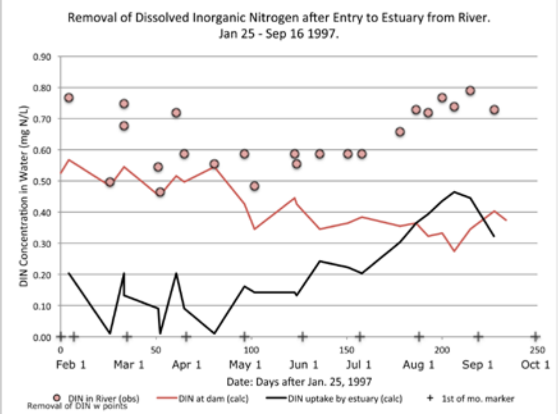

Figure 3-4. Estuary Case. Changes in Dissolved Inorganic Nitrogen, January 25 – September 9 1997. Data points are observed DIN values in the River (same as in Fig. 3-3b). Upper line is DIN in the estuary at the Bridge Site as calculated by computer (fits the blue graph in Figure 3-3b). Lower line is DIN removed from estuary on each date, found by subtracting the upper line value from the value of the data point directly above it. The lower line is DIN uptake, used to calculate DIN-C production.

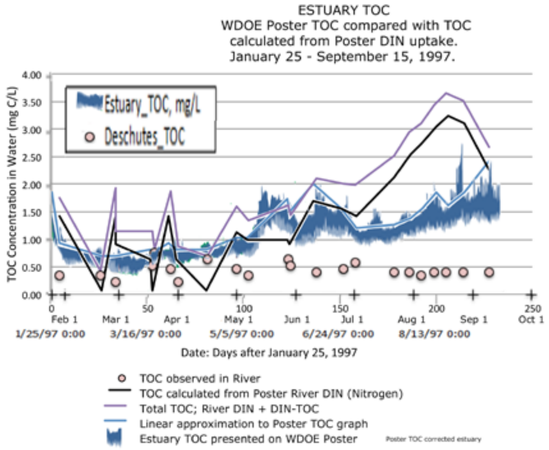

Figure 3-5. Estuary Case. Comparison of TOC created by DIN uptake with TOC presented by modelers. Data points show TOC observed in River (as in Figure 3-3a). Black line: DIN-TOC calculated from DIN uptakes (from Col. I Table 3-3, shown in Figure 3-4). Uppermost line; Total TOC in estuary (DIN-TOC + River TOC) at Bridge site. Background blue graph: modelers' calculation of Estuary TOC at Bridge site (as in Figure 3-3a).

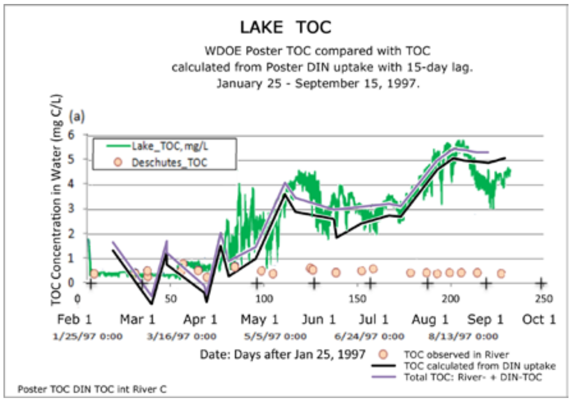

Figure 3-6. Lake Case. Comparison of TOC created by 15-day DIN uptakes with TOC presented by modelers. Data points show TOC observed in River (as in Figure 3-3a). Black line: DIN-TOC calculated from DIN uptakes (Col. N, Table 3-4). Uppermost line: Total TOC in lake (DIN-TOC + River TOC) at Bridge site. Background green graph: modelers' calculation of Lake TOC at Bridge site (as in Figure 3-3a).

on the intertidal mud. There is not much capacity there for carbon “storage.” In those communities, cells are eaten and recycled almost as fast as they grow and there can be no huge buildup of immobile new carbon-containing biomass. In the lake, the plants are mostly big rooted floating entities that can store the new carbon they create for a whole summer – or even for years. Here, there is a huge capacity for carbon storage.

All of the new carbon created can be estimated from the uptake of DIN from the water in either ecosystem, no matter which types of plants are using it, from data taken from Figure 3-3b. When comparing that carbon creation with the values reported by the modelers in their separate calculation of TOC, strange discrepancies emerge. Those are, a huge amount of new carbon seems to be stored out of circulation in the estuary case (where one would expect none), and *none* of the newly created carbon seems to be stored in the lake case (where one would expect huge storage) throughout most of the summer. The following explores these findings.

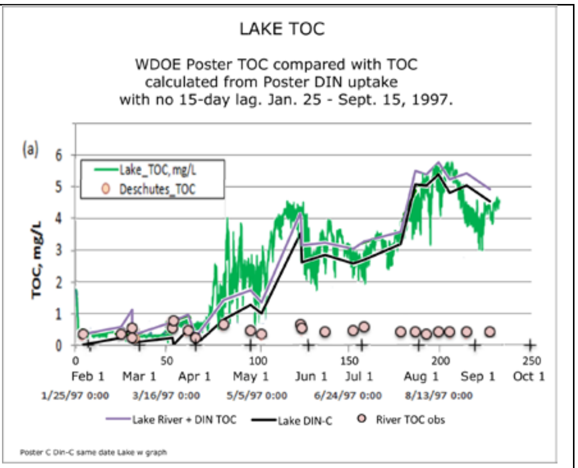

Figure 3-7. Lake case with no time lag. Comparison of TOC’s created by DIN uptakes with TOC’s presented by modelers. Same as Fig. 3-6 except that in this example there is no 15-day time lag between entry of DIN from the River and its appearance in the form of TOC at the Bridge site. The Total TOC line (upper, purple) differs in detail and position from its counterpart in Figure 3-6 because the two lines are calculated for different dates.

<u>1). Lake Case.</u> In Figure 3-6, the total amount of TOC that the uptake of nitrogen is capable of creating (black line) is less than the amounts shown by the modelers (green graph) during April and part of May. After that, the black line follows the green graph closely and the total TOC (purple line) fits the green graph even more closely. During the months of close fit, there is *no* storage of the newly created carbon compounds in the Lake. *All* of it shows up in the water as TOC.

Where the green graph is higher than the total (purple) line (mainly April and late May), the modelers’ calculation shows more waterborne carbon-containing biomass (TOC) than capture of the waterborne nutrient nitrogen is capable of producing.

How can these fits and mis-fits be interpreted?

During the times when DIN-C + River TOC match the modelers’ TOC graph (early May and again in June – August), *all* of the newly manufactured carbon that the captured DIN can produce ends up suspended or dissolved in the Lake water. There is none left over for long-term storage in large plants. To make that happen the modelers would have to assume that *all* uptake of NN in the Lake during that time is by phytoplankton, none is by large plants. In other words, the big plants simply don’t grow during the summer. If their storage uptake were properly modeled and subtracted from the DIN-created amount of carbon that ends up as TOC, the “Lake TOC” in Figure 3-3a would be smaller – *much* smaller – than that shown by the modelers.

During April and part of May and also when the DIN-C values go briefly negative (parts of March, Fig. 3-6), the modelers’ graph shows more TOC in the water than could be produced from the nutrient nitrogen consumed. Could this be TOC released from the early and late spring decay of overwintered material from large plants, produced and stored the year before? If so, one would expect, by way of compensation, less free-drifting TOC than could be created from the consumed nutrient nitrogen at some other time in the graph, when carbon storage occurs. In Figure 3-6 a hint of that “some other time” is seen in late August/early September, where the green graph drops below the black DIN-TOC line for the first time. Does the Lake begin to store new carbon-containing biomass at this time? (In a realistic scenario, storage would begin much sooner, probably before June 1.)

Unfortunately, the computer simulation stops at September 15. Nutrient nitrogen uptake, manufacture of carbon-containing plant material, and probably carbon storage certainly continue through September into October (as in Figure 3-1) but the model can tell us nothing about this. In any event, *if the departures of the green graph from the calculated DIN-TOC line really reflect release of TOC or storage of carbon, then they emphasize the positive effect of Capitol Lake on Budd Inlet.* That is, by the modelers’ own calculations, storage of newly manufactured plant material (thus prevention of its entry to Budd Inlet) begins at precisely the time in late summer when the Inlet is most vulnerable to degradation by TOC. Similarly release of stored organic carbon from the Lake in the form of TOC in April and May is shown early enough in the growing season as to have no significant effect on Inlet water quality at that or any other time.

The “fit” of calculated DIN-C to the modelers’ calculated values of TOC appears to be even better if one assumes that river NN is taken up and converted to new plant biomass immediately, which biomass then travels to the Bridge site in the lake all in the same day (Figure 3-7). This could only happen if all of the growing plants involved – phytoplankton and/or larger plants -- were to move down the Lake at water-ski speed as they grow, break up, then die and decay, arriving at the Bridge site in one day rather than making a leisurely 15-day drift. That appears to be an unlikely scenario, at best.

2). Estuary Case. The estuary case presents an opposite puzzle. At the heads of estuaries, almost all photosynthesis is carried on by single-celled phytoplankton organisms and by thin layers of algae on intertidal mud. Larger plants – green seaweed, kelps, brown rockweeds, eelgrass – are scarce or absent here. There is almost no capacity for carbon storage, since the phytoplankters and algal cells are eaten almost as fast as they grow, immediately recycling almost all of the NN they took up and the new organic carbon they created back into the water.

Yet Figure 3-5, comparing DIN-C with the TOC calculated by the modelers, shows much more organic carbon must be produced via DIN uptake than is shown by the modelers TOC graph from July 1 through September 15. There is so much “stored carbon” that, if it were all in the form of TOC *and shown in Fig. 3-3a*, the “estuary TOC” would be nearly as large as the “lake TOC” shown there during the summer.

3) Summary of Both Cases. Figure 3-8 summarizes the above discussion. As before, the green and blue graphs show levels of “Lake TOC” and “Estuary TOC” as calculated and presented by the modelers (Figure 3-3a above). The dark green- and blue- lines in Fig. 3.8 are the “Lake Corrected TOC” and “Estuary Corrected TOC” (purple) “Total TOC lines” in Figures 3-5 and 3-6 above, calculated by me.

Two additional lines are shown. The “50% Storage” line illustrates the following scenario. Suppose that roughly half of the new biomass created by all photosynthesizers during each 15-day interval (and therefore the carbon contained in it) remains in the large plants as new living stems, leaves, roots and flowers until after September 15. This would be “stored carbon,” manufactured from DIN uptake but never appearing in the water as TOC. What would appear in the water would be the leftovers, whatever TOC is produced by all photosynthesizers during each 15-day interval less the 50% stored in plants. That is shown by the “50% Storage” line. Likewise the “90% Storage” scenario line shows the situation that would result if large plants stored 90% of all carbon in newly manufactured biomass.

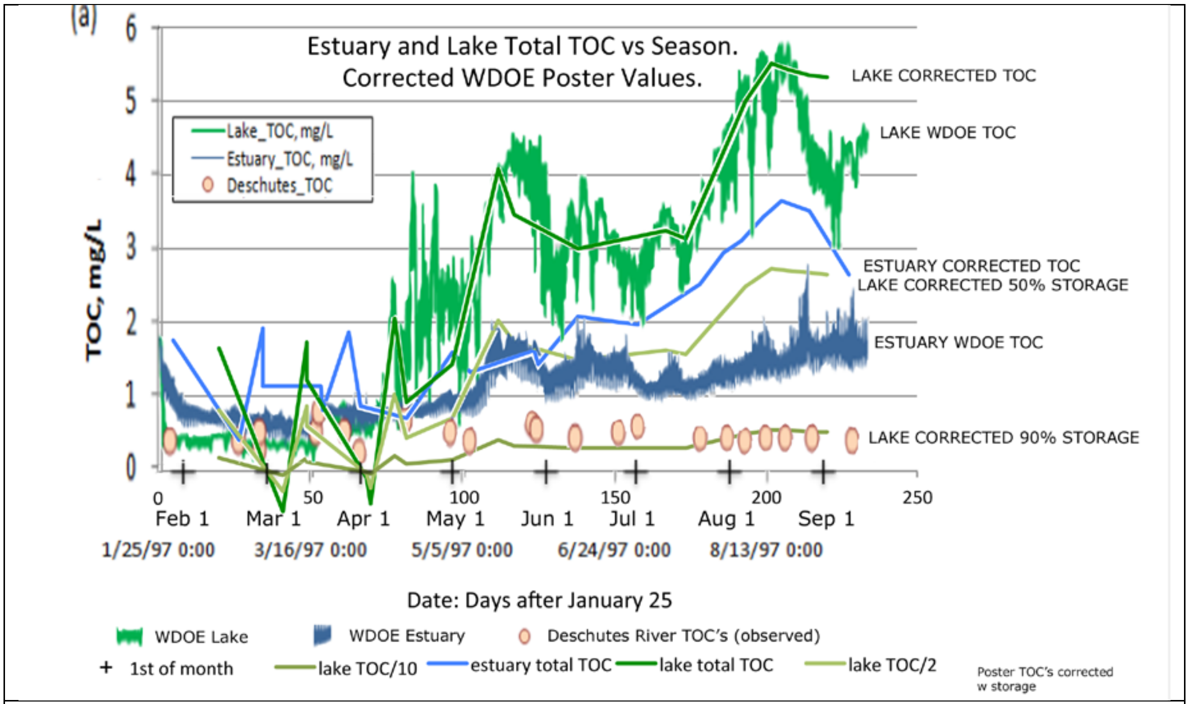

Figure 3-8. Summary. WDOE Poster TOC’s compared with (my) corrected calculations. Data points for all Lake Corrected TOC’s (points not shown but occurring at breaks in the dark- and light- green linear graphs) are for dates 15 days after the observed River data dates, reflecting the 15-day passage of water through Capitol Lake. Data points for Estuary Corrected TOC’s (blue line) are for the same dates as the observed River values, reflecting the one-day passage of water from the River through the estuary. Estuary and Lake corrected TOC’s show the carbon calculated from DIN uptake (“DIN-C” in the text) with the river TOC’s added (uppermost purple lines in Figures 3-5 and 3-6), present at the Bridge site.

As can be seen, *if the large plants succeeded at storing even as little as 50% of all new carbon-containing biomass manufactured by photosynthesizers, the amount of TOC escaping from the Lake would be less than the amount of TOC in the (corrected) Estuary scenario.* My expectation is that the large plants would succeed at storing as much as 90% of all carbon in newly manufactured biomass (the 90% scenario).

It appears that the modelers ignored the large plants in their simulation of the Lake case and assumed that all of the NN uptake and carbon-producing photosynthesis was due to phytoplankton, most of the time. That would be a serious oversight. It also appears that something in their calculation "hides" a lot of the organic carbon created by NN uptake in the estuary case. That, too, would be at odds with what aquatic ecologists would expect to see in a head-of-estuary ecosystem. Absent a plausible explanation of these apparent flaws, the findings presented in their Figures 3-3a and -3b can't be taken at face value. *Nor can any other findings dependent upon accurate simulation of the Lake and Estuary scenarios (see below).* Lacking (and needed) are plausible presentations of the model's calculations of the new carbon stored by large plants *and animals* in the lake, the carbon present each day in phytoplankton, and for the estuary case, the carbon stored in the algal mat *and its animals* (mussels, barnacles) each day.

Phytoplankton cells are not much different from chemicals in a physical model of the movements of water. The water takes them wherever it goes, they interact with other chemicals (producing O_2 and consuming nutrients and CO_2, for example), interact with small swimming or drifting animals that can themselves be accommodated by a physical model, and differ from chemicals mainly in that they reproduce (and sink). The plants of a shallow freshwater ecosystem, on the other hand, are in a separate simulation universe that a physical model can't be tweaked to accommodate. They require a complex separate model that recognizes trophic levels, long lifetimes with little or no movement, many species with different ecological roles, competition, predation, and other complex features of their existences, all in addition to the chemistry and hydrology so familiar to physical modelers. In Budd Inlet, focus on the phytoplankton is the way to go; in a rich shallow lake filled with plants and animals, that is not enough. Unless the Budd Inlet model was grafted onto a whole different complex ecosystem model – which I expect it was not – there is no hope of it giving trustworthy insights into Lake processes.

If macroscopic plants were periodically harvested and removed from Capitol Lake, the effect would almost certainly be to strengthen the Lake's ability to capture NN and for that harvest to physically remove some nutrients from the Lake and Budd Inlet aquatic systems once and for all. A harvest program would almost certainly strengthen the Lake's ability to protect Puget Sound. Perhaps the most aggravating omission from the entire SM Report is the deliberate omission of simulation of a harvesting program. Blithely assuming the role of harvesting experts, the modelers tell us essentially that they already know that such a simulation would be unhelpful and, based on their guesses about phosphorus, phytoplankton, the tonnage required, and the like, they declined to do it (p. 69, SM Report).

I expect that their guesswork is not the real reason why they didn’t attempt such a simulation. The real reason, I expect, is that their Lake model is much too rudimentary to allow any meaningful simulation of a plant harvest. A Lake model like that mentioned in the previous paragraph would be needed – and they know it.

In a meeting on November 12, 2013 one of the modelers was asked whether harvesting the plants in Capitol Lake could be an effective way of preventing nutrient nitrogen from reaching Budd Inlet. Her reply – “It is unrealistic to harvest the phytoplankton because it is microscopic.” -- an anecdotal incident that suggests that the modelers are not fully cognizant of the giant presence of macrophyte plants in the Lake (Havens pers. comm., 2015).

3f. How Would These Errors Affect Our View of Dissolved Oxygen in Budd Inlet?

The preceding section ends with a precaution that, due to seeming unrealistic features of the lake model scenario and unreported TOC in the estuary scenario, the TOC present in the Lake at the Bridge site during the growing season would probably be less than the TOC that would be present at that time and place if an estuary replaced the lake. That would translate as follows. Less TOC at the Bridge site from the Lake would mean less nutrient nitrogen release as that TOC material decayed in the salt water and less uptake of dissolved oxygen in the salt water by the decaying material itself. *The Lake, in other words, would have less adverse impact on Budd Inlet than would the Estuary*.

Figure 3-9 shows a Figure from the SM Report that might be regarded as the centerpiece of WDOE’s entire effort to incriminate Capitol Lake (SM Report Fig. 16, p.39). This Figure shows calculated DO levels in the bottom water at six sites changing as the summer progresses, all dropping to lower levels if a Lake were present than they would if an Estuary were present. The physical basis for this would be the depletion of DO by decaying organic TOC material entering Budd Inlet at the Bridge site, and the release of nutrient nitrogen (with consequent phytoplankton growth and decay) from that same material, with the least effect caused by the scenario that delivers the lowest level of TOC to Budd Inlet.

In WDOE’s Figure, the Lake gets the blame. But WDOE’s calculations assumed no meaningful carbon storage in the Lake scenario and neglected to report all of the TOC formed in the estuary scenario (Figure 3-8). That almost certainly means that their Figure 16 (here, Figure 3-9) has got it backward; namely that the Lake’s effects would result in higher DO’s in Budd Inlet’s bottom water than would an Estuary’s effects (as suggested by the corrected key to Figure 3-9).

More is said about the movement of organic carbon between the Lake and Budd Inlet in another section. Here we have found reason to believe that the DIN graphs created by WDOE’s version of the Budd Inlet Model reveal information about the TOC graphs (Figure 3-3 above) that invalidates the credibility of the agency’s allegation that Capitol Lake degrades oxygen levels in Budd Inlet.

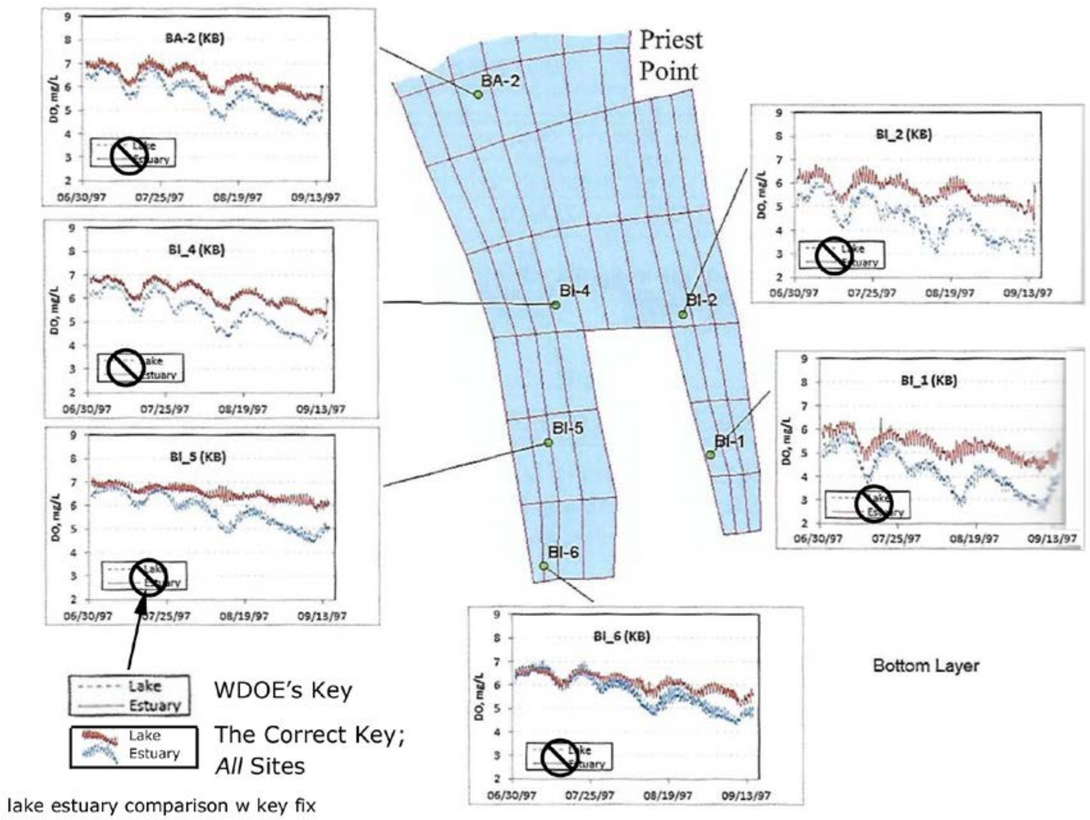

Figure 3-9. WDOE's computer calculations for six locations alleging that DO levels with the Lake in place (blue graphs) start dropping below DO levels that would occur if an estuary was in place (red graphs) at about the end of June. Lake case DO's everywhere are alleged to be about 1-2 mg/L lower than estuary case DO's by September (Modelers' Figure 16, p. 39 SM Report). The corrected key in the lower left corner suggests the positions of the Lake and Estuary graphs that would have been displayed in this Figure had WDOE used a simulation that reports all of the Estuary TOC and also a realistic simulation of carbon storage of Lake TOC (as in Figure 3-8, this Analysis).