6. ECOLOGY'S CENTRAL CLAIM: "THE DAM DEPLETES OXYGEN." WRONG.

Figure 6-1 is from a slide created by Ecology personnel and presented by various speakers to the Olympia City Council, the Thurston County Commissioners, the LOTT governing board, and others who requested a presentation on the Lake/Estuary question. It purports to show that the "Capitol Lake with dam" has a disproportionately large impact on dissolved oxygen levels in a "critical cell" in East Bay, compared with other potential sources of DO depletion. This Figure is the centerpiece of Ecology's present-day claim that the Lake is the principal cause of low oxygen levels in Budd Inlet.

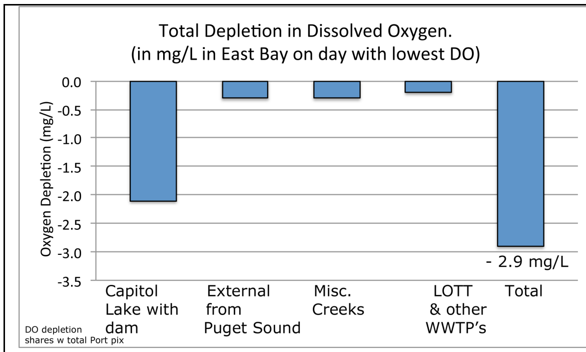

Figure 6-1. Relative sizes of DO depletions in East Bay attributed by Ecology to (L to R) Capitol Lake, External sources outside Budd Inlet, Miscellaneous small creeks entering Budd Inlet, and the LOTT treatment plant. Source: DERT presentation to the Olympia Port Commission November 14, 2016; attributed by DERT to Ecology.

It's wrong. This Chapter shows why. In fact, the "External from Puget Sound" source mentioned in the Figure is almost certainly the main cause of the O2 depletion attributed to the Lake.

6-1. Overview. Why the Claim is Mistaken.

Oxygen depletion is driven by nitrogen enrichment of marine waters. The amount of nutrient nitrogen entering Budd Inlet from Puget Sound is 17x larger than the amount entering from "Capitol Lake with dam." At least 20% of this "external" nitrogen enters West Bay, where it still outweighs nitrogen of Deschutes River (= "Capitol Lake") origin by at least 3 to 1. From there external-source nitrogen moves back outward toward the "critical cell." Because it is coming from the direction of the dam (and mingled with genuine Deschutes nitrogen), the modelers have mistaken it for nitrogen of wholly Deschutes origin, hence assigning the oxygen depletion it causes to "the dam."

There are other errors. The "critical cell" in East Bay persistently shows up in runs of models that simulate the "natural" pre-modern pre-dam estuary. The low late-summer DO level there is a natural estuarine phenomenon, probably including a "null zone" effect,[1] probably aggravated by modern human activities but not caused by them. The modelers do not acknowledge the fact that Capitol Lake plants capture and retain most of the huge nitrogen overload from the Deschutes River, vastly reducing the amount available for phytoplankton growth and oxygen reduction in Budd Inlet.

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[1] The null zone effect is described in Chapter 1: "How Estuaries Work."

6-2. The Availability of Nitrate Nutrients at the East Bay Location.

Oxygen depletion in marine coastal waters ultimately traces back to the availability of nitrogen nutrients (mainly nitrates) that "feed" the phytoplankton, whose cells eventually sink, decompose, and consume oxygen in the process.

Nitrate enters Budd Inlet from four sources distinguished by Ecology; the Deschutes River, other creeks and non-point sources around the shores, the LOTT treatment plant and the "external" South Sound waters north of the mouth of the Inlet. Ecology distinguishes between "natural" nitrate and "anthropogenic" nitrate, the latter created by human activities (Fig. 6-2). Figure 6-3 shows the comparable daily entries of "natural" nutrient nitrogen to Budd Inlet attributable to natural ecosystem processes that are apart from human activities.

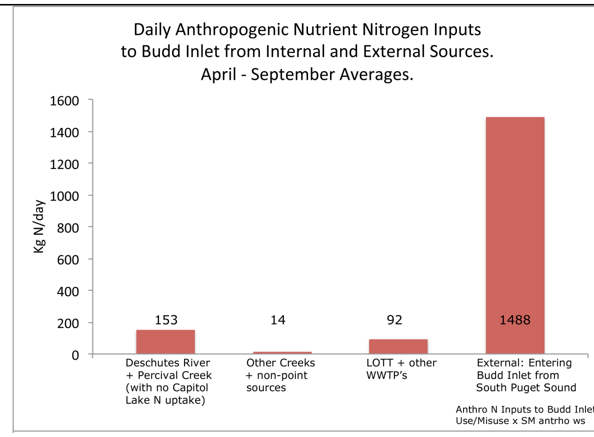

Figure 6-2. Anthropogenic nutrient nitrogen inputs to Budd Inlet from four sources (daily averages for April through September). Source: TMDL Report Table 35, also *SM Report p. 41.*

The grand totals from the N input sources, anthropogenic + natural, are shown in Figure 6-4 (next page).[2] The entry of nutrient nitrogen from Puget Sound vastly outweighs all inputs from all of the sources around the shores of Budd Inlet.

The giant inward flow of N nutrients from the waters beyond Budd Inlet enters by crossing a line from Boston Harbor to Cooper Point. The amount that reaches Priest Point and the vicinity of the "critical cell" in East Bay is much reduced by processes described in the next section.

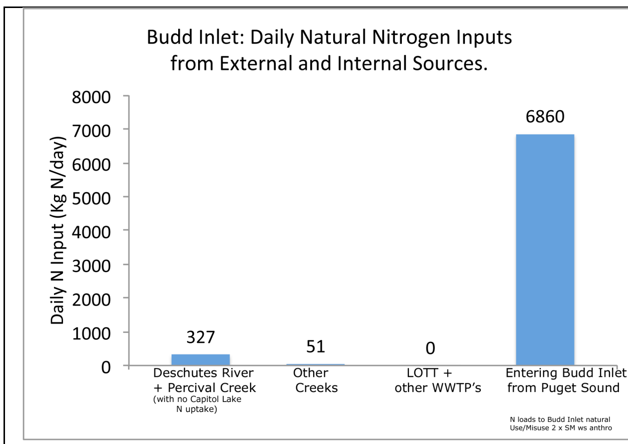

Figure 6-3. Natural nutrient nitrogen inputs to Budd Inlet from three sources. Daily summer averages, April – September. Source: Tables 35 and 36, TMDL Report; External "natural" from external total (Table 35) minus "anthropogenic"(SM Report p. 41).

6-3. The Arrival of Nitrogen Nutrients at Priest Point.

The nutrients entering Budd Inlet from the South Sound are carried by an enormous bottom current, a dominant

[2] Some values of input nitrogen loads used by Ecology in simulation scenarios are somewhat larger than those shown here. No list or source citation is given in the SM Report, readers must infer them from tangential remarks in the SM text. The orders of magnitude are the same as in Fig. 6-4. See Optional – 4, end of this Chapter.

feature of the "estuarine circulation" of every estuary (see Chapter 1). Figure 6-5 shows a diagrammatic view of what's left of that current and a corresponding outgoing surface current in the vicinity of the Port of Olympia.

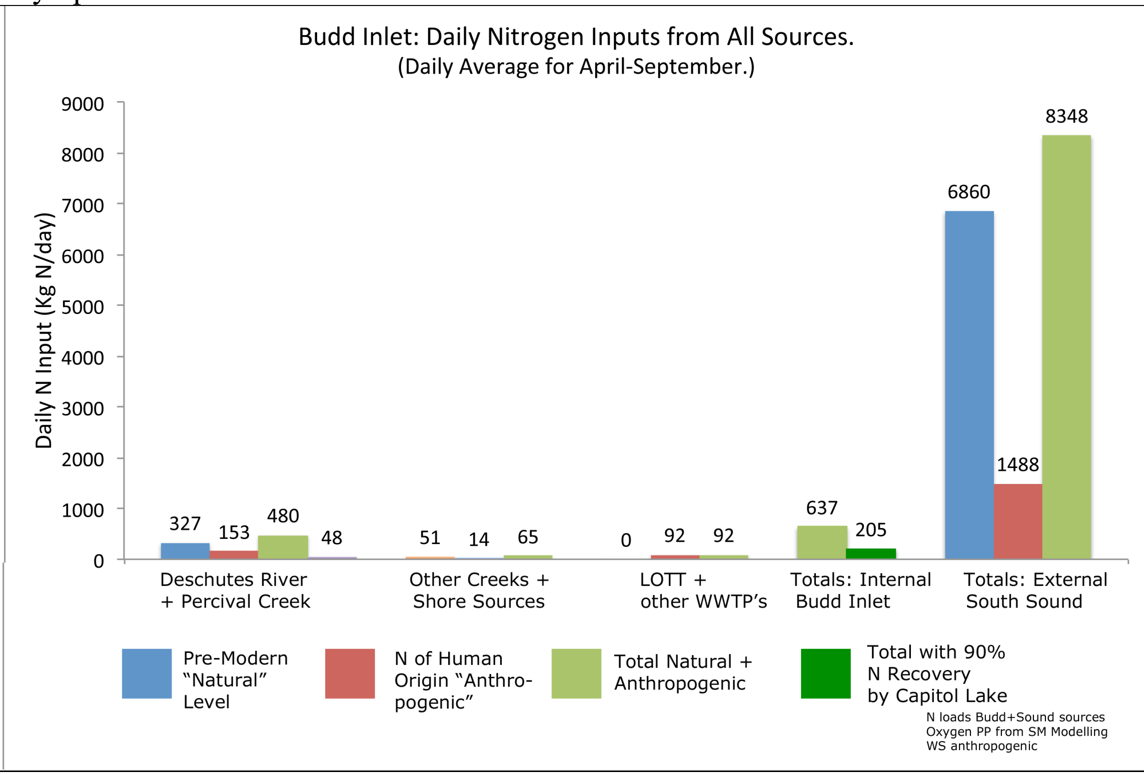

Figure 6-4. Nutrient nitrogen inputs to Budd Inlet from all sources, internal and external. Sources: See Captions, Figs. 6-2 and 6-3. [For visualization, I have included Capitol Lake's effect (removal of about 90% of incoming nitrate from the Deschutes River water), not mentioned by Ecology. CH2M-Hill, 1978.]

As the bottom current moves inward, it loses parts of its nutrient nitrogen load by mixing upward with the outgoing waters at the surface. By the time it reaches Priest Point, the huge initial load of nitrogen has dwindled away to about 20% of its original value (that is to about 1670 kg N/day; TMDL Appendix G p. 49). The nutrient load from the Deschutes River, on the other hand, has only a short distance to go to reach the East Bay area and most (or all) of it actually gets to Priest Point.[3]

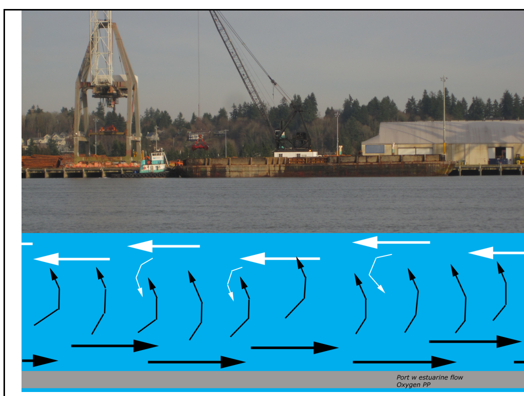

Figure 6-5. Estuarine flow in West Bay. An incoming bottom current flows all the way to the dam, mixing upward with outgoing water from the Deschutes River as it goes. The bottom current carries Nitrogen nutrients from points of

The amounts of nutrient nitrogen available from various sources to ultimately cause oxygen depletion in the East Bay critical cell are

[3] Some of the Deschutes water mixes downward into the incoming external water, but all of that water rises back to the surface and moves seaward, eventually carrying all Deschutes-origin nitrogen with it.

origin outside Budd Inlet.

shown in Figure 6-6a. Each amount is juxtaposed over the amount of oxygen depletion said by Ecology to be caused by that source in the critical East Bay cell (Figure 6-7).

The sizes of the sources are wildly incongruent with the claimed oxygen depletions. *The Deschutes source delivering only a third as much nitrogen (at most) as the South Sound source is said by Ecology to create fully eight times as much oxygen depletion as the larger source.*

The SM Report never identifies the "critical cell" in East Bay explicitly, but one can infer from the text (p. 40) that it is the red cell identified in Figure 6-7. That cell is adjacent to observation station BI-1 of the BISS field study (see Fig. 2-2, Chapter 2 of this Review.)

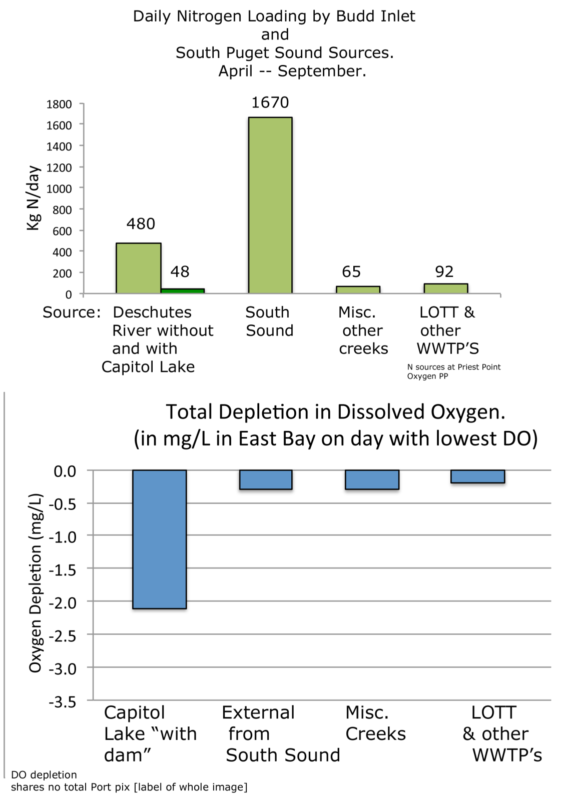

Figure 6-6. Upper. Daily loads of N nutrients delivered by four sources to the Priest Point area. Lower. Oxygen depletion in East Bay attributed by Ecology to each source. (The N value shown for the South Sound source is the amount present at Priest Point.)

<u>6-4. The Movement of Nitrogen Nutrients Into and Out of West Bay.</u>

The bottom current is driven by the flow of the Deschutes River. Under the river's influence, it continues past Priest Point and *almost all of it enters West Bay*. (A small fraction, perhaps 1 %, is drawn in by tiny Moxlie Creek and moves directly toward the "critical cell" area.) In West Bay, the nutrients carried in the bottom water are mixed upward into the outgoing surface water (as shown in Figure 6-5) where they move back toward the Priest

Point area, either incorporated in phytoplankton or still unassimilated. *Almost all* of the nutrients from South Sound that get as far as Priest Point end up returning seaward, mixed and carried by Deschutes River water from the direction of "the dam."

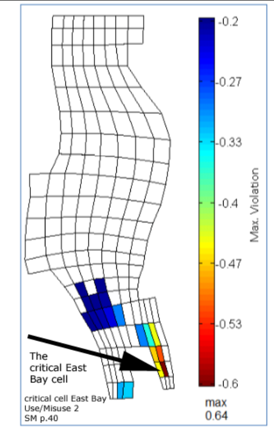

Figure 6-7. The critical East Bay cell said by Ecology to be impacted by "the dam." Source: Fig. 17 and text on page 40, SM Report.

Water in prolonged contact with the surface becomes 100% saturated with atmospheric oxygen via absorption from the air.[4] Phytoplankton photosynthesis drives the DO % saturation even higher, at and just below the surface. Water below the sunlit surface zone is almost always unsaturated with oxygen due to the respiration of organisms and bacteria and the absence of processes that can replenish the depleted oxygen. The hallmark feature of upwelling water is that it is less than100% saturated right at the surface itself.

The water in West Bay shows exactly this expected pattern, all the way from Priest Point to the dam (Figure 6-8).

Figure 6-8 shows the % DO saturation of Budd Inlet waters from the surface to the bottom along a transect from opposite Priest Point (opposite "WB Marina" in the Figure) to "Bayview" near the dam, measured September 19, 2013 by me and colleagues. Each cluster of bars shows one observation location (of five total). In each group, the leftmost and rightmost bars show the surface and bottom % DO saturations, respectively. A blue line shows the 100% saturation level.

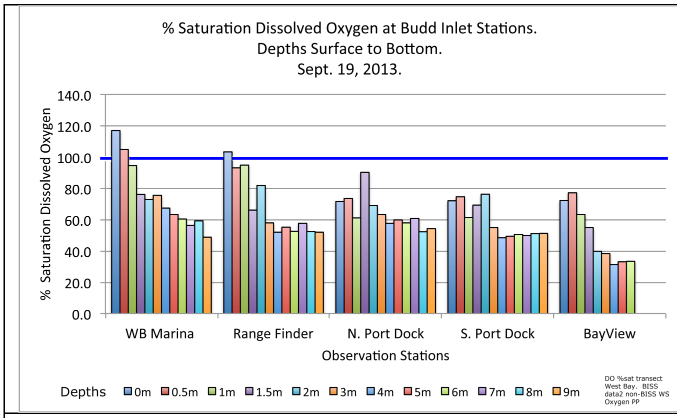

Figure 6-8. Percent oxygen saturation of West Bay waters increasingly distant from the 5th Ave. dam. September 19, 2013. Blue line shows the 100% saturation level. (Observations by the author and CLIPA colleagues.)

Moving from Bayview to WB Marina (the direction in which the Deschutes River net surface flow moves, right to left in Figure 6-8), the surface water becomes progressively more saturated, then supersaturated as more and more time elapses after its upwelling. This is due to oxygen absorption from the air and phytoplankton photosynthesis. That upwelled bottom water is from the external source outside Budd Inlet. By the time the total surface flow reaches Priest Point, the flow is already10 times larger than the flow of the Deschutes River itself by inclusion of the upwelled external water (Source: TMDL Appendix G p. 49). Some 75% of the surface flow nutrients moving outward are now from the external source (97% if Capitol Lake is credited with removing 90% of the natural + anthropogenic inputs by the Deschutes River).

[4] This topic (saturation) and its relationship to vertical water motion is described and illustrated in Chapter 1.

What do the modelers see in the waters near the entrance to East Bay? A large flow loaded with external source nutrients coming from the direction of "the dam." They may be mistakenly assigning that whole nutrient load to "the dam" itself (Figures 6-1 and 6-6b).

6-5. Dissolved Oxygen Depletion in East Bay Caused by "The Dam" – *Zero*?

Percent oxygen saturation values shown in Figures 6-9a and 6-9b for the entrance and head of East Bay, respectively, resemble the pattern in West Bay. The surface water at the head of East Bay (Fig. 6-9b) is slightly unsaturated, as are the subsurface waters, suggesting that this water is upwelling from the bottom.[5] When the outflowing surface water reaches the East Bay entrance, it has had time to acquire additional oxygen from the air and photosynthesis to become supersaturated (Fig. 6-9a). As in West Bay, this suggests bottom water flowing into East Bay toward the head of the inlet, rising to the surface, then (propelled by Moxlie Creek) flowing out at the surface.

The question is, "bottom water from where?" The fresh Deschutes River water entering West Bay at "the dam" begins its journey outward at the surface. Bottom water moving headward in East Bay can only be that entering from the external source water outside the estuary. *It is likely that "the dam" has no effect on dissolved oxygen in East Bay whatsoever. Zero. None.*

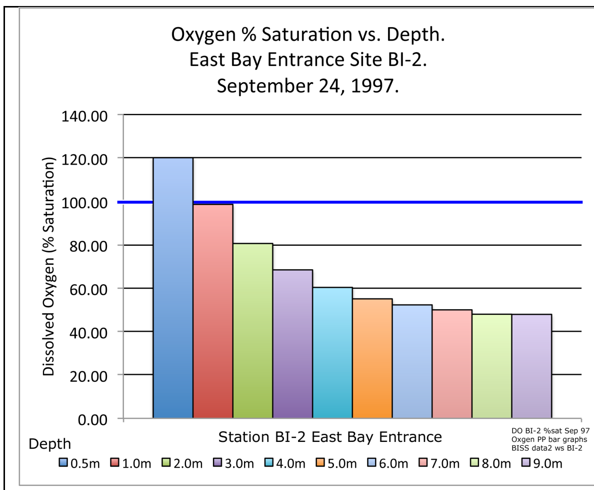

Figure 6-9a. Per cent dissolved oxygen saturation of water from surface to bottom at the entrance to East Bay (BISS station BI-2), Sept. 24 1997. Source: BISS spreadsheet with % DO's calculated using USGS "DOTABLES" tool; see USGS, DO Tables in References.

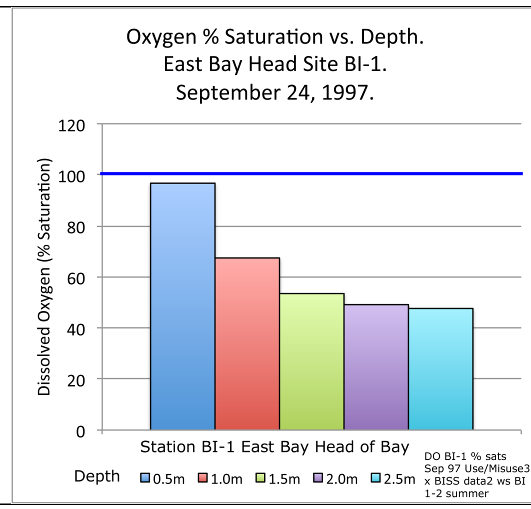

Figure 6-9b. Per cent dissolved oxygen saturation of water from surface to 2.5 meters depth near the head of East Bay (BISS station BI-1), Sept. 24 1997. (This station is adjacent to Ecology's "critical cell," SM Report.) Sources: as in Figure 6-9a.

[5] Figure 6-9b shows only the DO % saturations from the surface to 2.5 meters. Measurements made at BI-1 were all in error below that depth (BISS spreadsheet error worksheet); the error values are not shown here. Only the leftmost four bars in Fig. 6-9a are strictly comparable with the whole of Figure 6-9b. The bottom at BI-1 on this occasion (September 24, 1997) was actually 7.5 meters deep.

6-6. Summary. Likely Causes of Low DO Conditions in East Bay.

As shown in Chapter 5 (pp. 5-10 ff), the shallow waters of East Bay can have astonishingly high photosynthesis (hence DO production) right at the bottom (as on Sept. 10, 1997; see Figures 5-8 and 5-9, this Review). More often, the Bay in September is the site of the lowest calculated DO's in all of Budd Inlet, both in its "natural" (pre-modern) condition and at present. If "the dam" isn't causing the present-day low DO's, then what is?

Ecology's "critical cell" is near the dead-end head of East Bay where several local factors cause low DO conditions. One is the high nutrient concentration of Moxlie Creek. Another is the restriction of the Bay entrance (seaward of the "critical cell") by a breakwater that extends about halfway to the opposite shore. Yet another is the blockage from oxygen replenishment from the air by boat bottoms and docks at the East Bay marinas (occluding some 15% of the low-tide Bay surface, by my estimate). The boats and structures also shade the water beneath them, possibly inhibiting algal photosynthesis and oxygen production. It is possible that the rising fresh water from the LOTT outfall outside the Bay entrance creates a "curtain" of sorts that further isolates the Bay. The feeble flow of Moxlie Creek draws in a small amount of nutrient-laden bottom water from the external source current entering Budd Inlet. Finally a phenomenon never mentioned by Ecology – the estuarine null zone – is probably at work in East Bay (see Chapter 1).

Given the flow pattern of Budd Inlet as a whole and the abundance of alternative causes of low DO in East Bay, the idea that "the dam" is causing the problems there is mistaken.

6-7. Conclusions and a Recommendation.

The nutrients entering Budd Inlet from the external South Sound source move headward in West Bay and back out again in a way that invites the mistaken interpretation that their source is Capitol Lake. Many factors other than "the dam" could explain low DO conditions in the East Bay "critical cell."

Outside the modeling realm, I have a recommendation.

Namely, do real-world real-time oxygen measurements in the water of the "critical cell" in East Bay.

This pivotal place in Budd Inlet that has been made central to a community decision on whether or not to spend $400 million removing the dam (Curry, pers. comm. 2018) is not currently being observed. Ecology regularly samples a site in West Bay (see Chapter 2), but has not seen fit to acquire any data from East Bay.

To my knowledge, no one has actually measured DO levels there since the end of the BISS research in September 1997. All of Ecology's posturing on water quality there is based on computer calculations. The computer routinely gets wrong answers (Chapter 3, this Review), there are myriad possible alternative explanations of low-DO occurrences there (preceding Section), a Budd Inlet model component that should have added oxygen to the bottom water failed catastrophically there on September 10, 1997 (the "Benthic Algae subroutine," see Chapter 5), and Ecology's claims that "hydrodynamics" are to blame are unsupported (see Chapter 5).

Given all that, there are many reasons to question Ecology's central claim, that Capitol Lake (aka "the dam") is responsible for the low DO levels seen in the isolated backwater that is East Bay.