The Department of Ecology's Supplemental Modeling
Report. A Critical Review.
David H. Milne PhD July, 2018

2. GOOD SIMULATION, MISTAKEN INTERPRETATIONS.

2-1. About This Review.

In September 2015, the Washington Department of Ecology (in the following, "Ecology") released a report entitled

Deschutes River, Capitol Lake, and Budd Inlet
Total Maximum Daily Load Study
Supplemental Modeling Scenarios.

Publication No. 15-03-002

This "SM Report" analyzes data obtained from a computer model that simulates hydrographic and chemical/biological processes in Budd Inlet.[1] Its main focus is on Capitol Lake and the dam that separates it from Puget Sound. It presents many modeling scenarios implicating Capitol Lake as the underlying cause of water quality violations (specifically depleted dissolved oxygen) in adjacent Budd Inlet and discounts or fails to mention several other possible causes.

In the following, I discuss and analyze the SM Report. In brief, it is hastily written with many significant and insignificant errors, flaws, and oversights. Significant errors include a mistaken miscalculation of "oxygen depletion" in Capitol Lake. Additional errors include calculations that understate the amounts of total organic carbon (TOC) in the water in a modeled estuary scenario and overstate the comparable amounts of TOC in a modeled lake scenario. A formatting difficulty occurring throughout the Report is that the scales of graphical Figures are numbered in ways that defy easy interpretation. *Most serious of all, the authors appear to assume from the outset that their premise – "Capitol Lake damages Budd Inlet" – is correct, and thus overlook findings in their own Report that strongly suggests the opposite.* This I address in the Review that follows.

I wrote this paper for two groups of readers; the lay public and for persons with scientific backgrounds who may wish to check my reasoning and calculations. On behalf of the former, I use non-technical language wherever possible. This includes using short-cut references in my text instead of the conventional scientific format of documentation, for example saying "SM Report" instead of "Roberts, Pelletier and Ahmed, 2015" whenever I mention that Report as a source. (Likewise mentioning "TMDL Report" instead of "Roberts, Ahmed, Pelletier and Osterberg, 2012" whenever I cite that earlier document.) The References Section gives the full documentation, both in my abbreviated forms and in scientific format. In the following I refer to my own (the present) document as a "Re-

[1] This "Budd Inlet Model" is described in Ecology's report of June 2012. See "TMDL Report 2012" in the References Chapter.

view" to distinguish it from Washington Department of Ecology (Ecology) publications, referred to as "Reports."

On behalf of scientific readers, I have documented *all* of my own calculations in detail enough to enable them to trace my logic. Those are presented in sections labeled "Optional." Readers comfortable with science can trace those (sometimes tedious) calculations, others focused on the content can maintain unbroken continuity of reading by skipping those sections.

My time for analyzing the SM Report was critically limited. It seemed likely that I would have to leave this project unfinished. With that in mind, I wrote this Review by Chapters, each of which could stand alone if my departure was required. My time for research and writing did indeed run out and a draft version of this Review was posted on a CLIPA website during 2016 and 2017. The present Review (2018) replaces that draft, with new information added.

2-2. Introduction.

I believe that the origin of Ecology's SM Report is traceable back to the diagram shown here in Figure 2-1. This image is part of a four-part depiction of simulated conditions in Budd Inlet, with this particular image showing the maximum theoretical oxygen depletion caused mainly by water exiting Capitol Lake and all other (tiny) streams around the shores, excluding any effects by the LOTT (Wastewater Treatment Plant) outfall at the end of the Port peninsula.[2] The brown areas in Budd Inlet are those where not even the tiniest of calculated oxygen depletion violations could be detected by the computer. (That is, almost the whole Inlet.) The few colored patches in East Bay show theoretical violations in a peculiar format. That is, each colored square shows the *maximum* calculated oxygen depletion that occurred there at some depth (not specified) on some date (not specified) during the entire simulation period January 25 – September 15, 1997. The size of the maximum theoretical violation can be read from the colored scale to the right. This Figure, with a few others like it, was presented as all the evidence that anyone needs to see to conclude that Capitol Lake degrades Budd Inlet. My involvement with this topic began with my questions about this Figure in 2013.

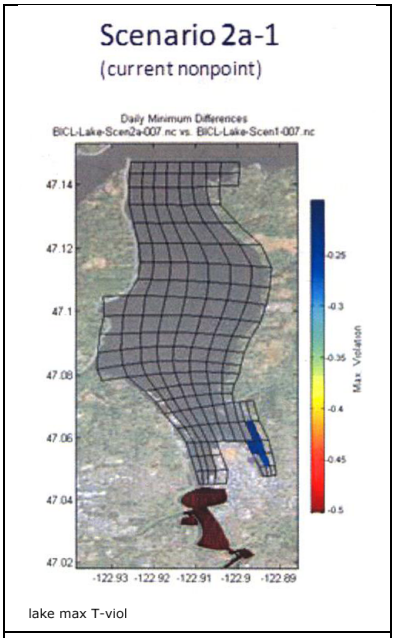

Figure 2-1. Ecology's depiction of the maximum theoretical impact of Capitol Lake and other non-point sources on dissolved oxygen conditions in Budd Inlet (TMDL Report, Figure 90a, p. 206). Fine print in the original at the top of chart reads "Daily Minimum (sic) Differences ECL-Lake-Scen2a-007 nc vs. BCL-Lake-Scen1-007 nc"

[2] The caption of the 4-part figure in The TMDL Report is "Figure 90. Predicted maximum violation of the DO water quality standard under the lake scenarios. The layer with the maximum violation is plotted for each grid cell." (Alternative "estuary scenarios" in which Capitol Lake is replaced by a 'natural' estuary are presented in a separate TMDL Report Figure.)

In encounters with the Ecology staff (described below), I pointed out that these "violations" were so localized and microscopic as to be almost undetectable by a dissolved oxygen (DO) meter in real life and that if this is really the maximum negative effect of Capitol Lake on Budd Inlet, then in reality there is no problem whatsoever. That set off an alarmed scramble (described below) to "prove" that "oops, we've fixed the model and *now* it shows that the Capitol Lake effect is huge." The 2015 SM Report that I review here is the latest result of that "alarmed scramble."

It is worth noting that Figure 2-1 was available to some two dozen representatives of community groups and agencies assembled to advise Ecology on that agency's development of a plan for the Deschutes Watershed and Capitol Lake for two years prior to my joining the discussion. To my knowledge, not a single member noticed or mentioned the feeble depiction of Capitol Lake's purported "effect" on Budd Inlet.

2-3. The Budd Inlet Computer Model.

The Budd Inlet Model was crafted and first used in 1997 by consultants from the Aura-Nova (Seattle) consulting firm (and other firms and entities) for predicting effects on Budd Inlet of proposed changes in Olympia's LOTT wastewater treatment plant. It subdivides Budd Inlet into about 160 "cells" (or "grid squares") that cover the entire surface of the Inlet (seen in Figure 2-1 above).[3] Beneath each grid square, the water is subdivided into a stack of about 19 "grid cubes" that include all of the water from surface to bottom. The total number of cubes that divide up the three-dimensional body of water that is Budd Inlet is therefore about 160 x 19 = 3040. The computer begins on simulated "January 25, 1997." It starts with a vast amount of observed and interpolated data from (or starting from) that date – water salinity, temperature, dissolved oxygen levels, and other water properties in each one of the 3040 "cubes," the 1997 tide table, 1997 weather and stream runoff data, and more. Using the starting data and built-in calculation routines that mimic the transfers of water between adjacent cubes and processes that create and/or use up dissolved oxygen (and change water chemistry in other ways), the computer then calculates the changes in each cube that take place as time goes by – *every six minutes for every depth at every location* – from January 25 to September 15 (TMDL Report, p. 187).[4] A single "run" of the model from start to finish takes 10 full days to complete even at the lightning speed of the computer (SPSDOS Report 2013, p. 38).

If even one of the six minute intervals at even one depth under any of the grid squares is found by the computer to have less dissolved oxygen in it than the legal regulatory water quality standard[5], the whole grid square is colored according to the size of its simulated low oxygen condition and shows up at the end of the simulation flagged, as in the colored East Bay squares in Figure 2-1. The smallest low oxygen condition triggering a "viol-

[3] The number of grid squares is not always the same in Ecology reports. For example, two side-by-side grids on p. 32 of the SM Report (reproduced as Figure 4-3, Chapter 4) show different numbers, 160 and 168. I use 160 throughout this report.

[4] In scientific parlance, six minutes is the "iteration interval" of the model.

[5] The regulatory water quality standard is complex. It is described in detail in Chapter 3.

ation" color is a DO level 0.2 mg/L below the standard – the blue top end of the scale in Figure 2-1. As can be seen, the simulation that produced that Figure subjected Budd Inlet to a gargantuan dragnet search of staggering size – colloquially, a search with a fine-tooth comb -- and, even so, failed to find any theoretical violations even this small over almost all of the Inlet.

2-4. Data Sources.

The consulting firm that devised the Budd Inlet Model, in partnership with others, also conducted a year-long field study of Budd Inlet. Beginning in September 1996 and finishing in September 1997, measurements were made regularly at some stations and less frequently at others on some 34 different occasions throughout the study year.[6] The scientists involved measured water quality properties at depths ranging from the surface to the bottom at the locations shown in Figure 2-2. To date, this "Budd Inlet Scientific Study" (= BISS in the following) is the most detailed and reliable study of Budd Inlet ever made.

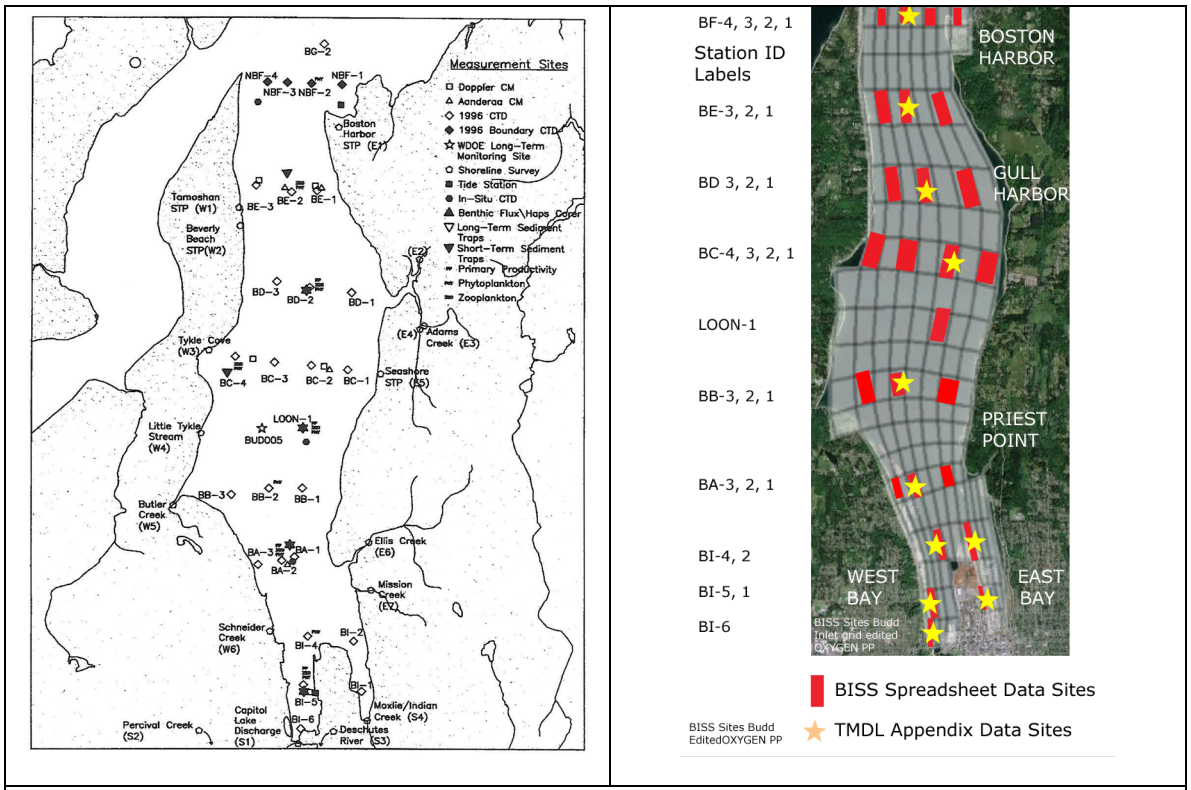

Figure 2-2. (Left) All BISS sample sites in Budd Inlet with a key to observations made at each site. Source: BISS Vol. 1 p. 59, 1998. Figure 2-2. (Right) Sites for which the 1996-1997 BISS data are available in Budd Inlet. Red bars; locations of BISS data in the spreadsheet. Stars; BISS data also shown in the TMDL Appendix. The BISS spreadsheet also has data for a station BG-2 outside the mouth of Budd Inlet shown in the leftmost but not the rightmost figure.

[6] Most of the "occasions" were separate dates, however several sets of measurements were made during the same day on a few dates.

Some of the data from this study are stored in a gigantic Excel spreadsheet file, which LOTT personnel graciously made available to me. This awesome compilation consists of some 29,000 rows of data spanning the study period, arranged in 14 columns. A sample is shown in Table 2-1. The spreadsheet shows these data at every depth from the surface to the bottom (whose actual depth varies from date to date due to tidal changes) in increments of 0.5 meters.

The Budd Inlet computer model used by the Ecology staff was updated and calibrated by comparing its predictions with the values actually observed by the BISS scientists. These comparisons, made after the calibrated model was judged to be as accurate as it could be,

A	B	C	D	E	F	G	H	I	J	K	L	M	N
I	2	BI-1	1/22/97	17:53	7.5	3.9	-3.9	8.12	27.38	21.2789	7.14	1.10082	0.001896
R		BI-1	2/11/97	7:25	7.5	3.0	-3.0	7.93	26.68	20.7563	7.59	3.51059	0.0799
I	3	BI-1	5/29/97	22:08	7.5	3.5	-3.5	11.89	27.34	20.6641	8.00	-999	0.001595
I	4	BI-1	8/21/97	5:29	7.5	3.9	-3.9	15.54	28.31	20.7081	5.02	-999	0.2617
R		BI-1	9/24/97	13:26	7.5	3.5	-3.5	14.73	28.48	21.0101	2.85	9.40895	33.33

Table 2-1. Example of BISS spreadsheet data. Column labels are A Cruise type; B Sweep number; C Site ID; D Date; E Time of Day; F Depth below surface (m); G Depth relative to MLLW; H (see below); I Water Temperature ^{o}C; J Water Salinity ppt; K Water Density (σ_T); L Dissolved Oxygen Concentration (mg/L); M Chlorophyll Concentration μg/L); N Light level. This example shows bottom water at station BI-1 (head of East Bay, includes the colored squares of Figure 1-1) on various dates (Jan. 22 – Sep. 24, 1997), depth 7.5 m below the surface, water temperatures ranging from 8+ to 15+ ^{o}C, salinities ranging from 26+ to 28+ parts per thousand, and DO's ranging from 8.00 to 5.02 mg/L over these dates. "-999" indicates that data were lost or not taken on some occasions. A separate BISS worksheet lists "Errors;" measurements discovered to be flawed when the data were compiled. The colored value in this sample is one of those.

The lines of data shown here are not contiguous in the spreadsheet; they are assembled here for illustrative purposes. Some spreadsheet data are rounded here to two decimal places. Data under shaded headings are also replicated in the TMDL Appendix graphs. The label on Column H says "Elev." I'm not sure what it refers to. I did not use data from this Column, nor from A, B, and N.

are shown in an Ecology Report that accompanies the 2012 TMDL Report – namely, the "TMDL Appendix." In the Appendix the calibration data are mostly reported as graphs of the computer's calculations with observed BISS data points superimposed. Readers must calculate the computer's numbers by measurement of the graph scales and interpolation. Table 2-1 shows which data are presented in both the Appendix and in the spreadsheet. The Appendix also includes graphs for variables (for example nitrate levels, biological oxygen demand levels, etc.) that are not in the BISS spreadsheet in my possession.

The Spreadsheet and the TMDL Appendix were my major sources (referenced here as "TMDL Appendix" and "BISS 1998.") of dissolved oxygen data. I found that these two sources are identical in most cases, but also that each has data not shown by the other (see Chapter 3).

I also consulted data from five additional sources. These are:

1) Dissolved Oxygen (DO) and other measurements at the +1.0 foot tide level in Eld Inlet made by a probe fixed to the bottom; growing seasons 1998, 1999, and 2000;

2) DO measurements by the LOTT Wastewater Treatment Plant staff at five locations in lower Budd Inlet, surface to bottom, from September 2009 through September 2011;

3) DO's vs. depths presented by an Ecology website for two Budd Inlet stations (Olympia Shoal and Port of Olympia) for 1996, 2002, and 2014;

4) DO's and other measurements made by the University of Washington's Oceanography Department at Gull Harbor and Buoy 12, Budd Inlet, in 1957 and 1958;

5) DO's and other measurements made by me with colleagues at five locations in West Bay, lower Budd Inlet, and Capitol Lake, September 19, 2013.

These are listed in the References chapter at the end of this Review and cited where mentioned in this text.

2-5. Encounters with the Department of Ecology.

In Autumn 2012 I was invited to examine the claim that Capitol Lake degrades water quality in Budd Inlet by the members of the Capitol Lake Improvement and Protection Association (CLIPA). At that time I knew that there was discussion of the possible removal of the Lake and conversion of its basin back to the estuarine condition that prevailed before the dam at 5th Avenue was built, but this had been remote from my daily concerns and I had no opinion one way or the other on that proposition. I began by obtaining and reading copies of the TMDL Report and TMDL Appendices and attending monthly meetings of Ecology's "TMDL Advisory Group," a group of professionals, agency representatives, and members of various organizations that met monthly to advise Ecology on restoration of the Deschutes River. This group's agenda included the Lake/ Estuary question.

I quickly realized (from Figure 2-1 from the TMDL Report and others like it – Figure 2-3 shown here, for example) that the computer modeling staff were unfamiliar with aquatic ecology and were missing important interpretations of the model's outputs. It was also clear that no mention was made of Capitol Lake's removal of nitrogen nutrients from the Deschutes River water – an immense benefit to water quality in Puget Sound. These and other oversights were driving the impression that the Lake degrades Budd Inlet.

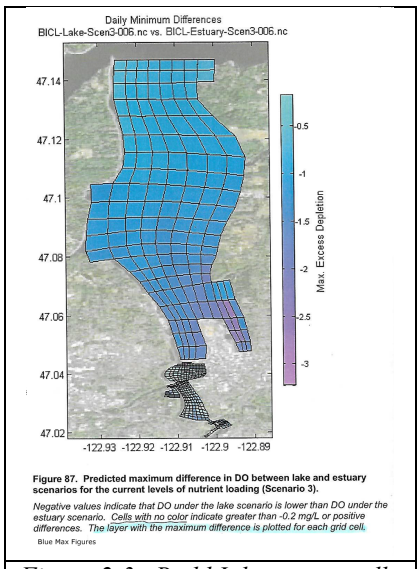

Figure 2-3. Budd Inlet purportedly with less dissolved oxygen everywhere "caused" by the Lake, compared with DO levels if an estuary were present. Source: Figure 87, TMDL Report. [7]

In early 2014, I requested an opportunity to share my views with the TMDL Advisory Group as a speaker at one of the meetings. The Ecology staff members overseeing the TMDL effort requested a preliminary private briefing to familiarize themselves with what I would say. A colleague and I met with two staffers in March 2014.

Following that briefing, TMDL meetings for the next three months were cancelled. When they finally resumed, the topic was a TMDL effort at Chesapeake Bay featuring a speaker working there.

During the interim "waiting period," I compiled a written report of my findings (Milne, 2014). In it I described and analyzed many shortcomings of the TMDL Report'schapter on Capitol Lake and presented it to the CLIPA group that I was advising. The report was posted on the CLIPA website, distributed in printed form to various interested parties, and made available to the Ecology modeling staff members.

Also during the interim "waiting period," it was announced by the Ecology staff that a "poster" describing an "improvement" in the Budd Inlet Model had been released (Poster 2014 in References). The modelers had changed the way in which the simulated sediment exchange with the water takes place, and also presented a graph that showed, for the first time, the Lake water removing nitrogen nutrients from Deschutes River water. (This is discussed in detail in Chapter 7.) The effect of this change was to make Budd Inlet appear to be far more degraded by Capitol Lake than is shown in Figure 2-1 and elsewhere in the TMDL Report.

I met with the Ecology staff on two other significant occasions. The first was a dual presentation by the modelers and by me to the Alliance for a Healthy South Sound on

[7] My detailed response to the Ecology modelers regarding this Figure is contained in my Report (Milne, 2014) and also in Power Point slides presented to them on July 17, 2014. The Figure actually shows a flush of surface water oxygen production by Inlet phytoplankton caused by the ongoing flood of nutrients from the Deschutes River – accurately detected by the computer -- while overlooking the near-inevitable detrimental consequence of that, namely DO depletion at the bottom. Ecology never acknowledged their mistaken interpretation but also never used this Figure again (to my knowledge).

July 17, 2014 (AHSS, 2014). At that time I gave a Power Point presentation correcting dubious interpretations of Figures in the TMDL Report and suggested alternative hypotheses addressing the conspicuous late-summer low DO levels in East Bay. Two members of the modeling staff gave a complementary presentation in which they advanced an important hypothesis explaining how Capitol Lake might degrade Budd Inlet in spite of the fact that the Lake removes nutrient nitrogen from the Deschutes River. This was a cordial, informative exchange that advanced the thinking of all of us on new ways to explore the Lake/Inlet interaction. I left a copy of my presentation with the modelers at this time (Power Point "OK," 2014.)

After the OK presentation, I left a telephone message with one of the modelers suggesting we all get together over coffee and continue our conversation about the model. This turned into something far different. The TMDL overseers worried that "estuary advocates" would demand to know why they hadn't been included and scheduled a meeting of people said to be knowledgeable about simulation modeling and aquatic ecology. The meeting, which included mostly people with little such knowledge, was held on November 3, 2014. Again the modelers and I gave presentations. Mine included a printed list of ways in which I thought the model could be improved for greater accuracy, which with a copy of the Power Point presentation (Power Point OK2, 2014), I left with the modelers. This meeting was somewhat confrontational. The "estuary advocates" brought an expert on freshwater ecology, Dr. Jonathan Frodge, who had critiqued my earlier report (Frodge, 2014). To their chagrin, he and I had an agreeable and informative discussion of aquatic ecology, all overshadowed by our growing realization that this meeting was political, not scientific.

Following this meeting, I turned my attention to addressing the public's widespread negative perception of Capitol Lake. To this end I wrote a report that presents the Lake as a truly remarkable positive feature of Washington's ecological landscape (Milne, 2015). Whether or not Ecology has a copy I don't know; it is available on the CLIPA website.

As a result of our encounters, the modelers appear to have adopted some of my suggestions. The new SM Report (2015) includes a discussion of how the Budd Inlet model has been grafted onto their model of Capitol Lake (SM Figure 6, p. 31), moves away from the earlier preoccupation with the "depth of maximum dissolved oxygen difference" by addressing instead the bottom water in one case (SM Figure 15, p. 38), and gives a nod to statistical confidence limits. None of this is acknowledged by Ecology; the SM Report's References section makes no mention of any of my written or presented contributions.

2-6. The Review That Follows.

In the following Chapters of this Review I address errors, mistaken assumptions, and mistaken interpretations presented by the modelers (Roberts, Pelletier and Ahmed) in the SM Report. Central to all of it is the Budd Inlet Model – an impressive (even "remarkable") tool for examining broad scale changes in Budd Inlet. I believe that the Model, as originally designed for marine water, has been poorly adapted to mimic the ecology of Capitol Lake by the modelers. I also have reason to believe (and have never been cor-

rected on this by the modelers) that the Ecology staff consider every single one of the model's thousands of calculations of dissolved oxygen levels throughout simulated "1997" to be dead-on accurate, close enough to the real levels that prevailed during that year for certainty in every case where the model shows low DO and therefore a real-world water quality standards violation. All such calculated violations are invariably regarded by them as "real."

Wherever possible throughout this Review, I compare the outputs of the computer model and the modelers' interpretations with real, observed data. Where real-life observations show water quality standards violations, that can be trusted. Where the computer calculates water quality standards violations, that is suggestive and instructive – but not conclusive evidence of real-world violations.

This Review is divided into 10 Chapters. Their titles and the main thesis of each one follow.

Chapter 1. Background. Estuaries and Dissolved Oxygen.

This introductory chapter describes the non-tidal water movements in estuaries and how they relate to the forces that deplete and replenish critical dissolved oxygen in estuary ecosystems.

Chapter 2. Good Simulation, Mistaken Interpretations.

This introduction describes Ecology's Budd Inlet computer Model, my early involvement with the lake/estuary controversy, Ecology's bias against Capitol Lake, and an overview of the chapters that follow.

Chapter 3. The Computer Gets Many Wrong Answers.

At least half of the calculations by the model don't agree with data obtained by the BISS field research. At its worst, the day with the highest DO level of the whole season was the day for which the model predicted the lowest DO level of the whole season -- at three sites. One was Ecology's single most important site; the "critical cell" in East Bay.

Chapter 4. The Budd Inlet Estuary; "Natural" and Modern.

"Natural" Budd Inlet before modern times was loaded with DO standards violations. The model shows that modern Budd Inlet with the dam is only marginally worse. Modern Budd Inlet without the dam, however -- with all modern human activities – is "shown" to be stupendously better than it was in pre-modern "natural" days – an unlikely proposition. Ecology's presentation obscures this absurd contradiction and the high-violation levels discovered in the "natural" estuary.

Chapter 5. Ecology's Budd Inlet Simulations: Flawed Science.

Ecology has avoided simulations that would show beneficial effects of Capitol Lake, downplayed simulations that show possible improvements without removing the dam, and made calculation errors and statements about hydrodynamics not supported by model outputs, all slanted toward forcing the conclusion that removal of the dam is the only way to improve Budd Inlet's water quality. This Chapter questions those claims.

Chapter 6. Ecology's Central Claim: "The Dam Depletes Oxygen." Wrong.

The load of nitrogen entering Budd Inlet from beyond Boston Harbor is 16 times larger than the load entering from Capitol Lake. Yet Ecology insists that Capitol Lake causes eight times as much dissolved oxygen depletion in Budd Inlet's East Bay as does the external source. They've got it backward; this Chapter shows why.

Chapter 7. Organic Carbon Claims: Misleading, Mistaken, Not Credible.

Calculations claimed to show that Capitol Lake releases more oxygen-depleting organic carbon to Budd Inlet during the growing season than would be released if the dam were removed actually show the opposite; an estuary in that basin would release more organic carbon *during the growing season*.

Chapter 8. The Late-Season Departure of Organic Carbon from Capitol Lake.

This Chapter presents real-world observations and ecological explanations of why most organic carbon formed by plants in Capitol Lake can't deplete dissolved oxygen in Budd Inlet during the growing season.

Chapter 9. Capitol Lake: Errors and False Claims.

Ecology's most grotesque calculation error has created a widespread public perception that Capitol Lake itself is "deficient in oxygen." The Lake actually has higher DO levels than any other lake (or estuary) in the county, year round. Ecology's calculation error and the real-world facts are described in this Chapter.

Chapter 10. Low Dissolved Oxygen in Natural Estuaries.

Widespread violations of modern dissolved oxygen standards are calculated by the model for pre-modern Budd Inlet before the dam was built. This unwelcome feature of the "natural" inlet complicates efforts to show that "the dam" is responsible for modern low oxygen episodes there. Ecology's response; to "update" the model to eliminate low "natural" DO's. This Chapter presents evidence (from Eld Inlet) that natural DO's are to be expected.

Chapter 11. References.

2-7. Good Science …

The SM Report has a page at its beginning citing the need for "good science" as essential to deciding whether Capitol Lake should remain or be removed. Repeated mention is made of the number of reviews of the model itself – as is proper. There is never any mention of reviews or editing of the Reports that present (or omit) model findings and interpretations.

As the author of a textbook whose three drafts were critiqued by some 52 peer reviewers, I am familiar with what reviewed text material looks like (Milne, 1995). The SM Report has no resemblance to peer reviewed work. The ultimate test of its credibility (and that of other Ecology publications) would be to submit the present draft for publication in a peer-reviewed journal. My expectation is that editorial reviewers would suggest many, many revisions like those in the Review that follows.