STATE OF CALIFORNIA
CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD
CENTRAL COAST REGION
895 Aerovista Place Suite 101
San Luis Obispo, CA 93401-7906

SCIENTIFIC PEER REVIEW COMMENTS AND STAFF RESPONSE

FOR

TOTAL MAXIMUM DAILY LOADS FOR NITROGEN COMPOUNDS AND ORTHOPHOSPHATE FOR THE LOWER SALINAS RIVER AND RECLAMATION CANAL BASIN AND THE MORO COJO SLOUGH SUBWATERSHED, MONTEREY COUNTY, CALIFORNIA (DRAFT PROJECT REPORT, MARCH 12, 2012)

PREFACE

California Health and Safety Code Section 57004 requires all California Environmental Protection Agency organizations to submit for external scientific review the scientific basis and scientific portion of all proposed policies, plans and regulations. The peer reviewer's responsibility is to determine whether the scientific findings, conclusions, and assumptions are based upon sound scientific knowledge, methods, and practices.

Two individuals were selected to review this document for scientific adequacy: Dr. Glenn E. Moglen, Professor, Virginia Tech University (Department of Civil and Environmental Engineering); and Dr. Marc W. Beutel, Associate Professor, Washington State University (Department of Civil and Environmental Engineering). These researchers collectively have substantial research experience in water quality, nutrient pollution, hydrology, and aquatic habitat as indicated by their curriculum vitae which are presented in Appendix 1.

Peer reviewer selection was facilitated through the University of California. The detailed step-by-step guidance for setting up and obtaining reviews appears as Exhibit F[1] in an Interagency Agreement between the California Environmental Protection Agency and the University of California. A January 7, 2009 Supplement to the Guidelines[2], in part, provides guidance to ensure confidentiality of the process. No person may serve as an external scientific peer reviewer if that person participated in the development of the scientific basis or scientific portion of the proposed rule, regulation, or policy[3].

The California Health and Safety Code states that if the external scientific peer reviewers find that a State agency failed to demonstrate that the scientific portion of the proposed rule is based upon sound scientific knowledge, methods, and practices, the reviewer's report shall state that finding, and the reasons explaining the finding[4].

Central Coast Regional Water Quality Control Board staff (Water Board staff) asked the reviewers to comment on whether the scientific portions of the Total Maximum Daily Load (TMDLs) project report are based upon sound scientific knowledge, methods, and practices.

[1] Online linkage: http://www.waterboards.ca.gov/water_issues/programs/peer_review/docs/exhibit_f.pdf

[2] http://www.waterboards.ca.gov/water_issues/programs/peer_review/docs/rb1_klamath_river/peer_review_guide_010709.pdf

[3] Health and Safety Code §57004(c)

[4] Health and Safety Code §57004(d)(2)

Specifically, the reviewers were asked to comment on four specific areas related to the document: 1) Water Board staff's approach on the use of USEPA recommended statistical approaches in conjunction with California Nutrient Numeric Endpoints Approach to derive numerical water quality criteria to implement the Central Coast Basin Plan's biostimulatory substances narrative water quality objective, 2) the methodologies, data, and assumptions used, and conclusions made in identifying probable source categories contributing to nutrient loading, 3) the scientific and technical basis of the proposed TMDLs and allocations; and 4) the technical basis of the proposed TMDL implementation and monitoring plan. Reviewers were also asked to contemplate the broader perspective by commenting on any additional scientific issues related to the scientific basis of the TMDL project and to comment on whether - taken as a whole - the proposed TMDL project is based upon sound scientific knowledge, methods, and practices.

The Central Coast Regional Water Quality Control Board appreciates the thorough reviews provided by these referees. T heir comments and insight have prompted us to clarify and improve technical information in TMDL project in several areas.

Note that in the following sections of this document, we reproduce direct transcriptions of the comments from each reviewer and insert staff responses using ***bold, blue italic text*.**

CONTENTS OF THIS DOCUMENT

ACRONYMS-ABBREVIATIONS USED IN THIS DOCUMENT

Basin Plan	Water Quality Control Plan for the Central Coast Basin
CCAMP	Central Coast Ambient Monitoring Program
ESNERR	Elkhorn Slough National Estuarine Research Reserve
NLCD	National Land Cover Dataset
NNE	Nutrient Numeric Endpoints (California Approach)
TN (N)	TN=Total nitrogen N=Nitrogen
TP (P)	TP=Total phosphorus P=Phosphorus
USEPA	U.S. Environmental Protection Agency
Water Board	Central Coast Regional Water Quality Control Board

Scientific Peer Review Comments of

Glenn E. Moglen, Ph.D.

Professor
Virginia Tech University
Department of Civil and Environmental Engineering

Prepared for Central Coast Regional Water Quality Control Board

Comments Received by Water Board Staff April 13, 2012
*Staff responses are inserted in **bold, blue italic text.***

Overall Reaction:

Overall, I found this document to be well-organized and well-written. This comment holds especially true for the early material in the document up to and including most of "Chapter 3: Problem Identification". It is at this point in the document that I found I started to have specific questions or desire for clarification on various topics concerning the calculation of targets, source identification, TMDL allocations and plans for monitoring/implementation. I will be including these questions in the section below "Technical Comments".

While some of these questions might be somewhat pointed, I do not feel that anything I am asking poses a serious challenge to the overall spirit and effort shown by the document's authors. I believe the document is fundamentally sound and certainly hope that the targets and plans outlined in the document are successful at improving water quality in Lower Salinas River, California.*

***** *Emphasis added by Water Board staff.*

Staff response: The reviewer's overall reaction comments are acknowledged.

Technical Comments: (comments will be provided sequentially to the document. More substantial comments will appear in **boldface**)

1. Page 31: The authors write, "At the national scale, natural ambient….in Ecoregion III and subecoregion 6" I don't follow this logic. If nutrients vary at the national scale, why is it important to consider variability at the watershed scale? I don't dispute that there is variability at smaller scales, but I don't see how it follows from the national scale variability assertion.

Staff response: The reference to ecoregional variation is intended to inform the reader that a single, uniform national or state-level regulatory nutrient numeric criterion to address risks of biostimulation is inappropriate because of spatial variability that exists at the ecoregional and watershed-scales. Staff added clarifying narrative to this section of the Project Report.

2. Page 51: The authors write, "…mainstem stream reaches have been substantially altered by human activities". Can the authors elaborate slightly on this alteration? Is the alteration physical

(as in channel widening or other geomorphic changes) or chemical (which I believe is the intention of the authors).

Staff response: Staff added clarifying narrative to this section of the Project Report. In this context (aquatic habitat), alteration of Salinas Valley waterbodies by human activities collectively include hydraulic and physical changes as well as water quality degradation.

3. Page 53: The authors include information about an "inflatable dam". Is this dam still in place today? Is this dam a permanent fixture? Should the TMDL plan have address the removal of this fixture?

Staff response: According to information available to staff, an intent of the inflatable dam is to improve water management, flow conditions and aquatic migratory habitat and to facilitate recovery of steelhead populations. These operations are associated with dam releases from the Nacimiento and San Antonio reservoirs. . The inflatable dam project includes a fishway and habitat monitoring program. Therefore the dam is a net benefit and improvement to aquatic habitat and it is not appropriate for the TMDL to contemplate or recommend any changes to the function of the inflatable dam.

4. Page 95: The "most recent ten years" starts in 1999. Ok, but I have some concerns about the tabulated water quality data. Has there been significant land use change in the study area over this period or since this period? Urbanization can happen quickly and this would have implications on allocations if land use has shifted considerably. Can some indication of the rate of urbanization or other land use change be provided for context?

Staff response: Staff modified the project report to present land use change information as an additional line of evidence supporting the use of the last ten years of monitoring data to assess compliance with water quality standards. Staff considered changes in land cover on the decadal time scale based the NLCD 1992/2001 Retrofit Land Cover Change database[5]. Figure 1 and Figure 2 illustrate land cover change in the TMDL project area from 1992-2001. These figures show that 4.2% of land in the TMDL project area was converted to another type of land use sometime between the years 1992-2001. 4.2% does not reasonably represent a substantial or radical magnitude of change at the project area scale. It is recognized that land use changes at the local scale can be more dramatic and result in variability in local conditions. However, the water quality dataset staff used represented a large geographic scale (e.g., basin and watershed-scale); therefore as a practical matter it is appropriate to assess basin-scale water quality data relative to basin-scale land use changes.

During TMDL development, the most recent NLCD dataset available to staff was the 2001-vintage NLCD Land Use/Land Cover raster, including the 1992/2001 Retrofit Land Cover Change product. Since only 4.2% of land area was converted to another land use between 1992 and 2001, it is therefore presumed that land use change from 1999 to 2010 was not substantially or radically different from the magnitude (4.2%) of land use change observed from the 1992-2001 dataset. Therefore, staff maintains using the most recent ten years of monitoring data (1999-2010) is appropriate to assess compliance with water quality standards because at the project area-scale, land use/land cover likely has not substantially and radically changed more than a few percent during the past decade.

[5] NLCD = National Land Cover Dataset. The NLCD 1992/2001 retrofit land cover change product is available from the Multi-Resolution Land Characteristics Consortium (MRLC), and is a dataset that allows users to conduct change analysis between the 1992 NLCD dataset and the 2001 NLCD dataset.

Figure 1. Map of estimated land cover change, 1992-2001.

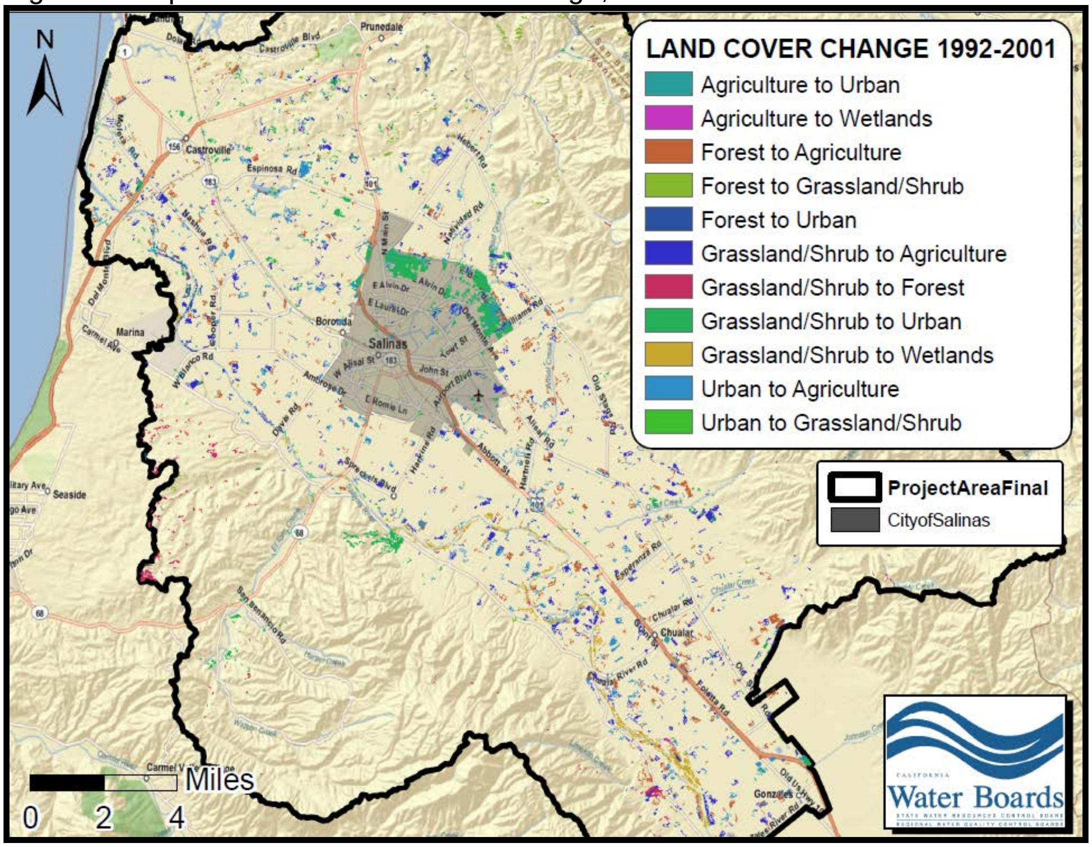
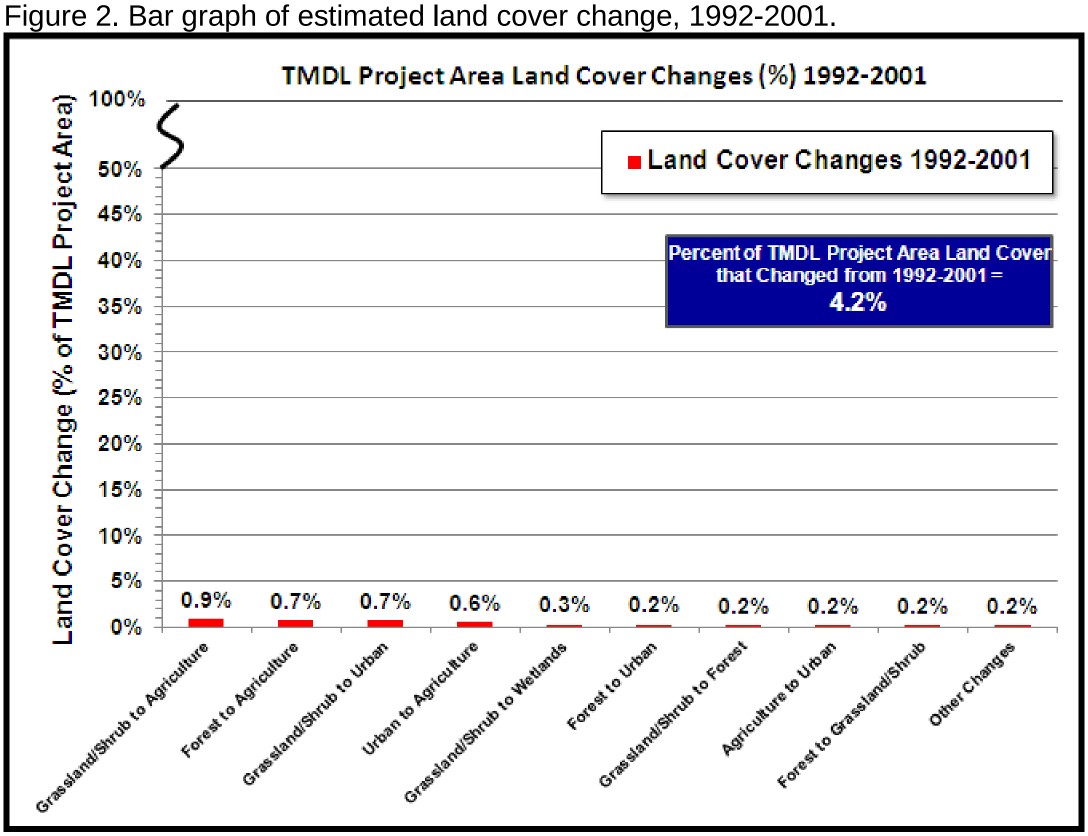


Figure 2. Bar graph of estimated land cover change, 1992-2001.



5. Page 137 (and subsequent to 141): There are targets for the same indicator (e.g. Dissolved Oxygen) that depend on the beneficial use (e.g. Warm vs. Cold). I'm not sure I understand. If we are in a single water body, shouldn't the most stringent beneficial use control the target? In this case, I'd expect a target of 7.0 mg/L throughout even if 5.0 mg/L is identified as acceptable for warm water purposes. I suspect this question shows my lack of understanding of how these targets are written, but it would seem to me that if there are different uses in the same waterbody, if some targets differ, the most severe target would control.

Staff response: The short answer is the TMDL does not address a single waterbody. The reason the most stringent dissolved oxygen water quality standard (COLD beneficial use) was not uniformly applied is because the TMDL addresses multiple waterbodies/reaches located within lower Salinas valley. As such, there is a range of designated beneficial uses that apply to discrete water bodies and reaches within the project area; i.e. some water bodies are designated COLD aquatic habitat, some are designated WARM aquatic habitat (but not designated for COLD).

6. Page 147 (Table 5-1). The input data listed in this table includes some very specific numbers (e.g. 17.78 inches or rain/year, 5.15 mg/L of NO3-N, etc.). Was sensitivity to these numbers in the STEPL program explored? I am concerned that the reported results may accurately present a "best estimate" of loadings, but that uncertainty around that estimate will not be quantified or appropriately considered. Sensitivity analysis is always a good idea, but I'm not seeing any indication of such an analysis in this report, beyond a brief mention of factor of safety later in the document.

Staff response: Staff concurs that from a scientific perspective a sensitivity analyses would add technical value to the TMDL project report. It should be noted that the second peer reviewer (Dr. Beutel) suggested that staff's source estimates, as supplemented by multiple lines of evidence, were reasonably credible:

> ***"The load estimates for nitrogen were well presented, and the convergence of values for total annual loading (~2.9 million pounds per year) estimated via different methods lends credibility to the estimate." – Dr. Marc Beutel, Washington State University.***

Staff maintains that the current source analysis is sufficient to inform the Water Board from a policy and decision-making perspective, and that <u>sensitivity analysis - while technically desirable - will have no regulatory consequences</u>. Nevertheless, time and resources permitting, staff will endeavor to incorporate a sensitivity analysis for the STEPL source characterization input parameters.

7. Page 152: Is the OSDS load really 25 lb/yr for Nitrogen, 10 lb/yr for Phosphorus total? Or is this per septic system? Please be clear. If these are total numbers this category is an absolute throw-away as it is many orders of magnitude smaller than some of the other categories.

Staff response: These numbers represent the total collective nutrient load to surface waters from all OSDS located within a 600 foot buffer of NHDplus flowlines in the project area. Staff added narrative to the project report highlighting that because of the small magnitude of this load, the OSDS category is estimated to be an insignificant source of nutrients to surface waters in the TMDL project area.

8. Page 153: If the atmospheric deposition rate for P is 0.6 kg P/ha/yr then we know this quantity to one (1) significant digit. But the estimate is reported as 211.69 lb/yr. Somehow one

significant digit has become five! This is poor scientific style if nothing else. I'd argue that 200 lb/yr is a more honest characterization of this quantity. For that matter, all reported loadings of N and P show too many significant digits. The report would be more scientifically credible if these were reported to an appropriate number of significant digits (which I would expect to be 2 or 3 significant figures, at most).

Staff response: Staff modified the loading estimates to reflect the reviewer's recommendation regarding the appropriate use of significant digits.

9. **Page 161 (Table 6-1). This is an important and useful table in this document. It would be very helpful to me to see the intersection of this table with the land uses presented earlier in Table 2-4. This would give the reader some sense of which land use categories are going to need to be engaged where reductions are needed. The land use-based loadings were presented earlier, but they were not presented by sub-watershed. That's what I'm asking for here.**

10. **Page 163 (Table 6-2): Same comment as for #9 above.**

Staff response: Based on the reviewer's recommendation, land use-based estimated nutrient loadings at the subwatershed-scale are incorporated into the project report.

11. Page 175: How was a 20% margin of safety determined? It's not clear to me this margin of safety is sufficient. A defensible margin of safety could be determined by considering a sensitivity analysis as described in point#6 above.

Staff response: The 20% margin of safety (MOS) for wet season targets was used because it is consistent with the fact that the U.S. Environmental Protection Agency similarly established a 20% MOS for winter seasonal nutrient target (setting the nitrate numeric target at 8 mg/L instead of 10 mg/L[6]) in the USEPA-approved Malibu Creek watershed of southern California.

A summary of the basis for the 20% MOS is further outlined in Appendix C of the draft Project Report, which is reproduced below – these lines of evidence are similar to the lines of evidence USEPA identified in similarly establishing a 20% MOS for the Malibu Creek watershed.

> At this time, staff proposes a TMDL nitrate target for the wet-season (Nov. 1 to April 30) that is less stringent than the dry-season targets developed previously in this appendix, but more stringent that the Basin Plan numeric objective for nitrate (i.e., the 10 mg/L MUN objective). Staff proposes incorporating a 20% explicit margin of safety to the Basin Plan nitrate MUN numeric objective for the wet-season numeric target to help account for uncertainty concerning biostimulatory problems in the wet season. As such, the proposed wet-season biostimulatory target for nitrate is 8 mg/L. The basis for identifying the 8 mg/L wet-season nitrate-N target is as follows:
>
> 1) Photo documentation, field observations, water quality data, and input provided by researchers (refer back to footnote [see Project Report]) with expertise in eutrophication issues in the central coast region indicate clear evidence of algae problems and biostimulation in the summer months, and that eutrophication is primarily manifested as a summer-time water quality problem in project area waterbodies, and in Elkhorn Slough. In the winter higher flows, cooler temperatures, lower light availability, and scouring evidently limit algal production. There are substantial uncertainties regarding the extent to which winter-time algal biomass problems manifest themselves, and about

[6] 10 mg/L Nitrate-N is an established numeric water quality objective found in the Central Coast Basin plan.

the extent to which winter time loads of nitrogen ultimately contribute to biostimulation problems in the summer.

2) The USEPA similarly established a nutrient TMDL for inland stream in southern California which contained a winter time nitrogen target of 8 mg/L, based on the application of a 20% margin of safety to the Basin Plan's numeric objective of nitrate and to account for uncertainty regarding winter time algae problems[7].
3) Recent research on biostimuation on inland surface waters from an agricultural watershed in the California central coast region indicates that existing nutrient numeric water quality objectives found in the Basin Plan (i.e., the 10 mg/L nitrate-nitrogen MUN objective) is unlikely to reduce benthic algal growth below even the highest water quality benchmarks[8]. Therefore, the 10 mg/L nitrate-nitrogen objective is insufficiently protective against biostimulatory impairments. Consequently, staff concludes that it is necessary to set nutrient wet-season numeric targets more stringent than the existing numeric objectives found for nitrate in the Basin Plan (i.e., the 10 mg/L MUN objective).

Noteworthy is the fact that central coast researchers have reported that the existing Basin Plan nitrate objective (10 mg/L) is unlikely to reduce benthic algal growth, therefore a wet season target more stringent that 10 mg/L is appropriate at this time.

Staff agrees that additional sensitivity and uncertainty analysis on Margins of Safety could ultimately be useful in assuring protection of beneficial uses and communicating to policy makers and the public so that the risks are well understood. Currently, there is no sufficient published national guidance on methodologies from USEPA or from the State Water Resources Control Board to establish explicit Margins of Safety and quantify their uncertainties[9], although limited amounts of informal guidance appear to be available. Staff updated the project report to provide additional justifications and quantifiable estimates of uncertainty for the explicit 20% MOS. However, at this time staff is proposing that the TMDL and load allocations be re-evaluated by the Water Board ten years after TMDL adoption – the proposed TMDL implementation timeline does not envision waterbodies meeting the proposed wet season nitrate concentration of 8 mg/L within ten years. As such, staff proposes that rigorous quantification of uncertainty and sensitivity of the explicit MOS be re-visited as necessary using additional data and potential future national guidance on establishment and quantification of explicit margins of safety. At this time, staff maintains that there is sufficient information to begin making progress towards reducing nutrient loading and getting water column concentrations down to the first interim TMDL waste load and load allocations.

12. Page 176: The authors write, "Additional studies of loadings from nonpoint source categories would be warranted in the future…" If those studies are warranted in the future, why not now? The suggestion of such studies indicates a degree of uncertainty that, again, I am not sure is captured by the 20% margin of safety identified on page 175. **I think there should be a more scientific basis for deciding all margins of safety in all allocations. The report seems singularly focused on setting target numbers with no indication as to the uncertainty surrounding these numbers.**

[7] USEPA. Total Maximum Daily Loads for Nutrients, Malibu Creek Watershed.

[8] University of California, Santa Cruz. 2010. Final Report: Long-term, high resolution nutrient and sediment monitoring and characterizing in-stream primary production. Proposition 40 Agricultural Water Quality Grant Program. Dr. Marc Los Huuertos, Ph.D., project director.

[9] Crumpacker A., Butkus, B, and California North Coast Regional Water Quality Control board. 2009. "*Approaches to Defining TMDL Margins of Safety*". Water Environment Federation (2009).

Staff response: At this time, staff maintains that there is sufficient information to begin making progress towards reducing nutrient loading and getting water column concentrations down to the first interim TMDL waste load and load allocations. Further studies and data collection are not necessary. USEPA TMDL guidance and policy expects TMDLs to be developed on the basis of best available information; USEPA does not require or expect new data and information to be gathered during TMDL development[10]. Further information, data, and additional studies may be conducted during TMDL implementation. With regard to the Margin of Safety, please refer to staff response to comment 11.

13. Page 176: The authors write, "Critical conditions occur when the prescribed load allocation results in achieving the water quality standard by a narrow margin." Please quantify "narrow margin". This is a vague term.

Staff response: Staff agrees that the terminology is vague, and in fact unsubstantiated; staff has eliminated the term "narrow margin" and has re-written the sentence to allow for greater clarity regarding critical conditions. Also, staff has eliminated the reference to "achieving the water quality standard by a narrow margin" as it does not appear to comport with USEPA TMDL guidance[11] nor is this reference found in federal regulations[12]. This was boilerplate language found in some of our older approved TMDLs, but having reviewed USEPA guidance and federal regulation, Staff finds no substantiation or justification for this metric with respect to critical conditions.

14. Page 176 (Critical conditions section). The authors seem to be arguing that because the proposed TMDL is concentration-based, that it is immune to the vulnerability of critical conditions that load-based TMDLs have. I don't agree with this logic. If observed concentrations are "close" to the numeric target then it would seem to me that critical conditions might occur just as they would a load-based context.

Staff response: Please see previous response to Comment 13. Staff have reworded this section so as not to give the impression that concentration-based TMDLs are immune to critical conditions. However, once the relevant concentration-based waste load and load allocations are met over all flow conditions and seasonal conditions, there is no uncertainty from the regulatory perspective that the loading capacities of the waterbodies are being met. Under these conditions, the waterbodies would unequivocally be candidates for de-listing from the CWA Section 303(d) list on the basis of the California 303(d) Listing Policy. Also noteworthy, is that USEPA Region 9 has routinely developed and received final approval of California TMDLs which contain the same project report language pertaining to critical conditions.

15. Page 181 (Table 7-2): A major concern of mine as I read the monitoring section concerns feedbacks. If monitoring suggests that implemented BMP's or other nutrient management measures are not leading to the needed reductions, how will changes be made? There is a little bit of language on this page and over the next few pages, but only weakly so. This concept of feedback/adaptation/revision is central to success of a TMDL plan, but the mechanics of how that feedback would work to make sure that reductions are truly achieved are not enumerated clearly or explicitly. This concept deserves a

[10] Personal communication, Janet Parrish, USEPA Region 9 TMDL Liason, April, 2012.

[11] U.S. Environmental Protection Agency. *Guidelines for Reviewing TMDL Under Existing Regulation Issues in 1992.* http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/final52002.cfm

[12] C.F.R. §130.7(c)(1)

special section unto itself so there is no ambiguity about what will take place if the monitoring should expose a weakness in nutrient reduction achievement.

Staff response: Note that feedback mechanisms, adaptive management, and accountability are already well-established and well-documented in the California Nonpoint Source (NPS) Implementation and Enforcement Policy, the existing Agricultural Order (Order No. R3-2012-0011), and stormwater regulatory permits which staff are relying on to implement the TMDL. Flexibility for how implementing parties can demonstrate progress is built into the regulatory mechanisms; implementing parties can show progress through a variety of methods. Therefore, describing how the feedback and adaptation must occur reduces that flexibility, which is needed for implementing parties to adjust to site-specific conditions.

It is also important to recognize that a TMDL is not a regulatory tool recognized by the California NPS Implementation and Enforcement Policy[13], and a TMDL is therefore not self-executing or self-implementing. Since accountability, flexibility and feedback mechanisms are already well documented in the regulatory tools and policies that will implement the TMDL, staff maintains it is unnecessary - and in fact redundant - to have a more robust enumeration in the report pertaining to feedback mechanisms and revisions during TMDL implementation. Both the California NPS Implementation and Enforcement Policy, the Agriculture Order, and Water Board NPDES permits have conditions requiring sufficient feedback mechanisms, time schedules, milestones, and determinations of whether the implementation program is achieving its stated goals, or whether additional or different management practices or regulatory tools are required.

16. Page 183: The authors cite Davidson et al (2012), "…improved fertilizer management, better education and training of crop advisors, and willingness by farmers to adopt these practices are needed. I'm sure this is true. What is going to be done in the implementation to specifically address this suggestion? It seems like a hollow statement of no value unless the TMDL document speaks directly to this suggestion.

Staff response: This comment refers to a reproduction of assertions published by Davidson et al. (2012). This publication and associated conclusions was noted for their informational value, and represents the view of the researchers and authors of the publication. Staff did not provide our opinion or assertion in this paragraph of the project report, though undoubtedly there is merit to the assertions of Davidson et al. (2012). As these were not staff's assertion, we did not intend to directly address or rebut the opinions of Davidson et al. (2012)

Information available to Staff suggests that a significant number of farmers have, or are currently, implementing improved nutrient and irrigation management practices for a variety of reasons. To the extent that there are farmers whose operations constitute a risk for nutrient pollution and are recalcitrant to implement mitigation measures, the Water Board has the regulatory authority under the existing agricultural regulatory program and under the Porter-Cologne Water Quality Control Act to ensure accountability and that feasible and appropriate management practices are implemented where needed. The Water Board's regulatory tools and authorities to ensure TMDL implementation and compliance with water quality standards are outlined in the implementation section of the project report.

[13] State Water Resources Control Board, May 2004. *Policy for Implementation and Enforcement of the Nonpoint Source Pollution Control Program.*

With regard to the Project Report needing to speak more directly to the issue of increased awareness and acceptance of growers to implement mitigation strategies, it should be noted that staff have met with reputable, local resource professionals who have been working with landowners to implement nutrient pollution control strategies. These resource professionals report that landowners, growers, and stakeholders in the lower Salinas Valley are becoming increasingly more aware of nutrient pollution problems and are increasingly expressing an interest in working collectively on pollution control strategies and business practices. The Water Board anticipates devoting significant staff resources during TMDL implementation to facilitate public outreach and regulatory oversight. Staff will add this information as a footnote to the Davidson et al. (2012) reference in the project report.

17. Page 186 (Table 7-4). Points 7 and 8 speak of monitored data as serving to "validate BMP implementation" plans. Probably this isn't intended, but this language suggests a presumption of success that concerns me. It would be more scientific and more neutral to say the monitored data would be compared against the BMP implementation plans and this would serve to check their validity. If the plans fail, then we're back to my Point#15 above, that there needs to be stronger, clearer, more explicit language explaining how the monitoring that shows lack of success by the current BMP implementation will serve as a feedback and lead to more aggressive BMP efforts.

Staff response: The comment is acknowledged. Points 7 and 8 were draft language referring to implementation actions aimed at addressing nutrient sources from urban stormwater. Staff updated this language that is marginally different from that in the March draft. Stormwater-permitting staff drafted the language that allows flexibility to implementing parties to validate BMP effectiveness based on varying conditions, including the types of BMPs implemented; this flexibility is important to implementing parties as they adjust to local sources and conditions. With regard to feedback mechanisms to ensure success, please refer back to Staff response to Comment 15.

18. Page 197: Figure 7-2 seems to show negative nitrate concentrations. How can this be? Please revise.

Staff response: The figure shows a graph from the Monterey Bay Aquarium Research Institute's (MBARI) LOBO[14] visualization webpage. The data show continuous, real-time data from the LOBO moored sensor in the Old Salinas River. Dr. Ken Johnson (senior scientist with MBARI) explained to staff that the negative values that occasionally plot on the graph are artifacts due to optical interference with the instrumentation, most likely due to periodic presence of air bubbles or zooplankton. As such, the negative values should be considered invalid data. At this time however, Dr. Johnson indicates that MBARI chooses to show all the data on their graphs, including the negative values representing optical interference events. Staff will add a footnote to the MBARI-LOBO graph explaining the significance of the negative concentration values.

19. Page 200: How have the stakeholder meetings changed the planned activities? The EPA strongly supports the stakeholder meeting approach, but I rarely see how some input from one of these meetings actually changes the process. There's nothing in this report to suggest that the process has been influenced by the stakeholder meetings. It would be nice to see that public input has influenced the activity.

[14] LOBO = Land/Ocean Biogeochemical Observatory

Staff response: It is important to recognize that stakeholder outreach was not limited to public meetings, and that additional public review and further input is anticipated during the formal public review comment period. Stakeholder input came in the form of public meetings, correspondence, email, phone, and other informal contacts. Staff will endeavor to include more information of stakeholder contributions to development of the TMDL in the final draft report. In particular, extremely helpful information, feedback, and assistance were provided individuals affiliated with the Elkhorn Slough National Estuarine Research Reserve, the Monterey County Water Resources Agency, the California State University Monterey Bay Watershed Institute, the Central Coast Wetlands Group at Moss Landing Marine Labs, the Monterey Bay Aquarium Research Institute, and the Monterey County Water Quality and Operations Committee.

Editorial Comments: *Dr. Moglen provided brief editorial comments regarding several spelling, grammatical, and formatting errors in the draft TMDL project repot. Dr. Moglen's editorial comments are not directly reproduced here for the for the sake of brevity and since they do not have any regulatory consequences or pertain to the scientific basis of the TMDL.*

Staff response: Staff have endeavored to correct the spelling, grammatical, and formatting errors noted by the reviewer.

SCIENTIFIC PEER REVIEW COMMENTS OF

Marc W. Beutel , Ph.D.

Associate Professor
Washington State University
Department of Civil and Environmental Engineering

Prepared for Central Coast Regional Water Quality Control Board

Comments Received by Water Board Staff May 3, 2012
Staff responses are inserted in ***bold, blue italic text.***

Overall Reaction:

Thank you for this opportunity to review this preliminary version of the Draft TMDL for the Lower Salinas River region. The report represents an enormous level of effort by staff at the Central Coast RWQCB. **While I outline specific critiques of the report below, I found much of the report to have been developed in a scientifically adequate and appropriate way.***

Below I outline some comments and concerns. First I outline general comments on chapters 1-3. Though possibly outside the scope of a strict scientific review, I hope you find these comments useful. Next I comment on the development of numeric targets in Chapter 4 and Appendix C. My main concerns in these sections are the rationale for the focus on orthophosphate instead of total phosphorus, and the use of upper-bound turbidity levels in the NNE modeling effort. After this section I comment on the source analysis in Chapter 5 and Appendix D and E, which could expand its focus to include more analysis of phosphorus loads. Finally, I comment on TMDL Allocations in Chapter 6 and Implementation and Monitoring in Chapter 7. Main concerns relate to the rationale for the implementation time line and the justification for presuming that owners/operators of grazing animals are in compliance with nutrient allocations. The discussions in Chapter 7 regarding the use of constructed treatment wetlands to sustainably control nutrients, especially nitrate, in non-point sources are especially appropriate for the project area.

Do not hesitate to contact me for clarification of any of the discussion below. Good luck to Water Quality Control Board staff and interested stakeholders with revising, finalizing, and implementing this important TMDL effort to protect and enhance water quality in the Salinas River Basin.

Summary Comment on Nutrient Numeric Targets:

On the whole, in my opinion the numeric targets strike a reasonable balance between being over-protective and under-protective*. Nutrient targets in surface waters (1.4-6.4 mg-N/L for nitrate; 0.07- 0.13 mg-P/L for orthophosphate) are around an order of magnitude above ambient background levels (e.g., ~0.15 mg-N/L for nitrate; ~0.07 mg-P/L for orthophosphate), but are around an order of magnitude below current typical levels in surface waters in Project Areas (~3-25 mg-N/L for nitrate; ~0.1-1 mg-P/L for orthophosphate). **This is a reasonable starting point*.**

***** *Emphasis added by Water Board staff.*

Staff response: The reviewer's comments are acknowledged.

A. General Comments Regarding Chapters 1-3

1. In these sections, at times there was a lack of consistency and clarity regarding the units of nitrate, which can be as nitrate (e.g., mg-NO3 -/L) or as nitrate-nitrogen (e.g., mg-N/L). Since nitrate is a cornerstone of the TMDL, the unit of nitrate presented in these chapters should be clearer. It is fine to use either unit (I think both are used), but be clearer in notation of the unit used. It might be informative to explain this issue to the reader, and to note that 4.4 mg-NO3 -/L of nitrate is equivalent to 1 mg-N/L of nitrate-nitrogen.

Staff response: Staff has made the clarifications and corrections as noted by the reviewer.

2. In Table 2-5, the units for mean annual discharge in column 6, and footnote A, are unclear.

Staff response: Staff response: Staff made clarifications to the footnote in Table 2-5

3. Regarding development of mean flows for May-October on p. 28-29, it seems that some simple statistical analysis, such as evaluating standard deviations with means by site, and the means and standard deviations by month, would strengthen the contention that the calculation represent a "plausible approximation of average dry season flows," and that the "instantaneous flow measurements are reasonably representative of the full range of dry season flow conditions." This is particularly important if these flow calculations are used as the basis for loading calculations. If they are not, and are only for informational/illustrative purposes, then perhaps additional analysis is not warranted.

Staff response: The flow estimations are for informational purposes, and have no regulatory consequences. Indeed, the reviewer notes that further analysis may not be warranted if the flow estimates are for informational purposes. As such, staff maintains that as a matter of efficiency it is unnecessary to perform further analysis on flows as the informational value gained will be negligible and inconsequential.

4. I find it odd that in the Nutrient Ecoregions section 2.6, there is no discussion or presentation of the "natural" or "background" estimates of nitrate, total phosphorus, and/or orthophosphate for surface waters in the Project Area based on ecoregion. These values are given for groundwater (0.03 mg-N/L for nitrate and 0.01 mg-P/L for phosphate). They should also be presented for surface waters. Additionally, the relative values of nitrate and phosphorus in "undisturbed" references streams should be introduced in Chapter 2. Perhaps including figures from p. 30 and 35 of Appendix C earlier in the report would be helpful. It is important for the report to avoid the appearance of presenting introductory information that is biased against citing nutrient levels for "background" or "undisturbed", which are going to be much lower than levels in current waters in the Project Area.

Staff response: Staff has made the clarifications and corrections as noted by the reviewer.

5. In Figure 2-12, the median value of 2.7 for the 1950-1985 dataset seems low. Confirm value. Consider dropping standard error since standard deviation is the most appropriate metric to quantify variability of field sampling results. Also consider dropping "mode" from the summary statistics, I do not see it used commonly in this context.

Staff response: The comment is acknowledged. Staff appreciates the recommendations, however note that staff is no longer using the former Figure 2-12 in the project report for the following reason:

The GAMA-Geotracker groundwater nitrate dataset is heavily weighted towards wells that are screened in deeper aquifers (irrigation wells, municipal and industrial supply wells); as

such these data do not constitute a reliable characterization of typical nitrate concentrations in shallow, recently-recharged groundwater. It should be recognized that shallow, recently recharged groundwater is a more relevant consideration in TMDL development. In contrast, precipitation and applied water that is lost to deep percolation are not necessary to consider in the TMDL, since deep aquifers are not contributing to stream baseflow. As such, the informational value of the GAMA-Geotracker dataset and figure used in the March report draft is negligible to TMDL development and is no longer being presented or cited. However, it should be noted that nitrate pollution of groundwater in the lower Salinas Valley is a relevant consideration in TMDL development, as some project area waterbodies are designated for groundwater recharge beneficial use.

6. A similar attention to unit type and consistency is needed for reporting phosphorus data. For example, is data in the typical unit of mg-P/L on page 35 and elsewhere? And why switch from mg/L to ppb (parts-per-billion) in legend in Figure 2-13B? Also in this discussion on/around p. 35 is "phosphorus" equivalent to total phosphorus or orthophosphate?

Staff response: Staff will make the appropriate clarifications and corrections as noted by the reviewer. With regard to Figure 2-13B from the March peer review draft report, this particular dataset available from the U.S. Geological Survey (USGS) reported phosphorus concentrations in groundwater as ppb. Figure 2-13A was a USGS dataset reporting nitrate-N as mg/L. In these cases, staff simply reproduced the units as reported by USGS.

7. In a number of places, such as Fig. 3-6 and associated text and Figs. 3-10 and 3-11, the units for chlorophyll a are incorrectly listed as mg/L when they should be µg/L. Fig 3-23 needs some help - mg/L in legend and mcg/L on axis. "micrograms/L" is used in Table 3-17 caption. Consistent use of µg/L might be best.

Staff response: Staff has made the appropriate clarifications and corrections as noted by the reviewer.

8. In Chapter 3, there is no discussion for numerical targets or guidelines for "chlorophyll a" or "nutrients" relative to listing water bodies in the Project Area. Yet Table 3-5 and Fig. 3-1 allude to these parameters as resulting in listings. Not until p. 77 is the 40 µg/L listing criteria noted for chlorophyll a. Some context for these two parameters would strengthen this section.

Staff response: Staff has made the appropriate clarifications and corrections as noted by the reviewer.

9. Developing some type of statistical correlations (e.g. linear correlation) between nitrate in surface waters and nitrogen inputs (Fig. 3-4), and between orthophosphate in surface waters and total phosphorus inputs (Fig. 3-5), would strengthen linkage between water pollution and human agricultural activities. Temporal trends in nitrate and orthophosphate in surface water (Fig 3-12), which the report says have "significantly increased," should also be statistically evaluated. In the context of scientific writing, the term significant generally implies a statistical evaluation has been performed. "Qualitative" relationship between fertilizer sales and nitrate in streams (Fig. 3-15) could also be more rigorously evaluated statistically (time delayed linear correlation perhaps) to strengthen linkages.

Staff response: Staff has made the clarifications and corrections as noted by the reviewer. Staff performed statistical correlation tests as recommended, and added the information to the project report.

10. How is Fig. 3-7 (median surface water nitrate) different from Fig. 3-4 (median surface water nitrate)? Also, confirm chlorophyll a levels are mean values in Fig. 3-6; all other parameters appear to be median.

Staff response: Figure 3-7 and Figure 3-4 are the exact same data. The only difference is the map scale. Figure 3-4 is intended to show nitrate surface water concentrations at the regional-scale; Figure 3-7 is intended to show this nitrate data with greater visual resolution at the TMDL project-scale. Chlorophyll a was displayed as a mean value because the data for this constituent appears to be highly non-normally distributed: the data values range over an order of magnitude, and are heavily-weighted towards values at the low end (concentrations well below 10 µg/L – note that spikes of high chlorophyll a at the monitoring site-scale are highly episodic). As such, the mean value for chlorophyll a did a better job as a metric to visually display spatial variation on the bubble map (e.g., the median value – the 50th percentile of data - simply shows what one would expect for an episodic pollutant – the concentrations of the pollutant are typically very low and the median concentration is an inadequate metric to display spatial variation on a bubble map).

11. Some typos worth noting (there were many, as might be expected in a draft report of this magnitude - I presume the report will be reviewed by a copy editor prior to distribution): period after Pose on cover page; NHDPlus vs. NHD Plus; waterbodies in Table 1-1 caption; derive not drive on p. 20; Project Area not consistently capitalized; California EAS or Federal ESA and brackish not backish on p. 47; note repeated paragraph on bottom of p. 123; N03 should be NO3 in Table 3-24.

Staff response: Staff has made the clarifications and corrections as noted by the reviewer.

B. Comments Regarding Numeric Targets (Chapter 4 and Appendix C)

<u>Summary Comment</u>: **On the whole, in my opinion the numeric targets strike a reasonable balance between being over-protective and under-protective***. Nutrient targets in surface waters (1.4-6.4 mg-N/L for nitrate; 0.07- 0.13 mg-P/L for orthophosphate) are around an order of magnitude above ambient background levels (e.g., ~0.15 mg-N/L for nitrate; ~0.07 mg-P/L for orthophosphate), but are around an order of magnitude below current typical levels in surface waters in Project Areas (~3-25 mg-N/L for nitrate; ~0.1-1 mg-P/L for orthophosphate). **This is a reasonable starting point.** Some specific critiques are outlined below.

***** *Emphasis added by Water Board staff.*

Staff response: The reviewer's comment is acknowledged.

1. The rationale for the focus on orthophosphate instead of total phosphorus (TP) presented on p. 142, in my option, is not compelling. The focus on nitrate is reasonable, given the fact that total nitrogen and TKN data are commonly not collected, and that nitrate makes up the vast majority of nitrogen in most surface waters. I do not see compelling facts related to these two themes for orthophosphate. In my experience, TP is collected more often than orthophosphate when evaluating surface water quality. In addition, TP is more commonly used when modeling or evaluating water quality, as was the case for the evaluation of limiting nutrients in the TMDL (p. 113) and the output from the NNE model (Appendix C). While orthophosphate is the biologically available form of phosphorus, it does not account for phosphorus in organic matter or bound to inorganic particulates, which can be biologically available upon decay or release. Water can have low orthophosphate, yet contain substantial algal biomass which has assimilated most of the available orthophosphate. Please clarify the rationale for a focus on orthophosphate. In the water quality data set for the Project Area, what is the relative number of data points for TP versus

orthophosphate? Is there really a substantially lower amount of data for TP? Based on the data set for the Project Area, what fraction of TP is composed of orthophosphate (i.e., what does Fig. 4-1 look like for TP)?

Staff response: Staff concurs that nitrate in inland streams of the lower Salinas Valley are an adequate surrogate to represent total nitrogen. It should be noted that staff also received feedback from our CCAMP data consultant (Dave Paradies – Bay Foundation of Morro Bay) that nitrate is what drives biostimulation in these inland waterbodies and that nitrate accounts for virtually all nitrogen species in the water columns of these inland stream. Further, of all nitrogen sampling events, only about 8% sampled for total nitrogen; the remainder constituted nitrate sampling, underscoring the need to use nitrate as a water quality target in this project area.

Staff concurs that total phosphorus is generally recommended by USEPA for monitoring of nutrients and to assess biostimulation problems, and that total phosphorus is typically the input parameter in models. Staff provided justifications for developing the TMDL on the basis of orthophosphate at this time, in Section 4.3.1 of the March draft report. However, based on the comment, staff provides additional clarifications and justifications below. With regard to the researcher's comment that waterbodies can have low orthophosphate, but high biomass because algae has assimilated the orthophosphate. Staff will also update Figure 4-1 from the March Draft report to show phosphorus as suggested.

Unfortunately, many of the major monitoring programs that are active in the TMDL project area have only been collecting orthophosphate data and have not collected total phosphorus data (e.g., Cooperative Monitoring Program, City of Salinas stormwater program, Elkhorn Slough National Estuary Research Reserve monitoring program etc.). The relatively limited amounts of total phosphorus data that has been collected (Central Coast Ambient Monitoring Program - CCAMP) is episodic and does not have adequate temporal and spatial representation for purposes of TMDL development. Of all forms of phosphorus water column data collected in the TMDL project area since 1999, only about 6% of those samples are for total phosphorus. Also, to the extent there is data for total phosphorus, most of the total phosphorus data was collected in years 2006-2007 which is inadequate for temporal representation.

Staff concur that orthophosphate is only a fraction to total phosphorus in the water column, and that other forms of phosphorus could become biologically available on the basis of phosphorus cycling. It should be noted that estimates by CCAMP and available data suggest that orthophosphate is generally the largest fraction of total water column phosphorus[15] (on average orthophosphate was estimated to be between 79 and 95 percent of total phosphorus in the water column for representative sampling sites).

Also noteworthy is that regional studies, and estuarine researchers suggest that currently, control of nitrogen in this system may be considerably more important than control of phosphorus. TetraTech scientists found that streams in nutrient subecoregion 6 are more often limited by nitrogen than by phosphorus, which may explain by there is a strong water quality correlation between water quality impairment and nitrate levels in subecoregion 6[16]. Further, an estuarine researcher with the Elkhorn Slough National Estuary Research Reserve reported that phosphorus control is not as important as

[15] Based on CCAMP NNE spreadsheet predictor runs developed in 2009.
[16] See TetraTech (2004). *2004 Overview of Nutrient Criteria Development and Relationship to TMDLs.*

nitrogen control with respect to downstream impacts on Elkhorn Slough. The types of ephemeral macroalgae found in Elkhorn Slough thrive readily in high nitrogen conditions but are relatively insensitive to phosphorus inputs[17] (personal communication, Brent Hughes, ESNERR, August 10, 2011). Accordingly, as a practical matter staff maintains that the focus of resources and technical analyses, should be directed with respect to nitrogen.

Finally, as noted in the draft project report, staff is proposing orthophosphate targets on the basis of USEPA guidance. USEPA notes that practical considerations should be balanced against scientific and technical considerations when deciding upon a water quality indicator. This guidance is available in the draft project, but is reproduced here for ease of reference:

> *Various factors will affect the selection of an appropriate TMDL indicator. These factors include issues associated with the indicator's scientific and technical validity, as well as practical management considerations. The importance of these factors will vary for each waterbody, depending, for instance, on the time and resources available to develop the TMDL, <u>the availability of already existing data</u>, and the water's designated uses. Final selection of the indicator should depend on site-specific requirements. The following sections identify some factors to keep in mind during indicator selection.*
>
> *<u>Practical considerations:</u>*
> *Measurement of the indicator should cost as little as possible, while still meeting other requirements. Indicators that can be suitably monitored through volunteer monitoring programs or other cost-effective means should be evaluated for adequate quality control and assurance of sample collection, preservation, laboratory analysis, data entry, and final reporting. Monitoring should introduce as little stress as possible on the designated uses of concern.*
>
> *<u>It is advantageous to select an indicator **consistent with already available data**.</u> Choice of an indicator also should take into account how "obvious" it is to the public that the target value must be met to ensure the desired level of water quality. (For example, the public understands Secchi depth and chlorophyll indicators fairly well.)*
>
> ***<u>Recommendation</u>: Scientific and technical issues should be balanced against practical considerations when deciding upon a water quality indicator.***
>
> *From: USEPA Protocol for Developing Nutrient TMDLs, 1999 (emphasis added)*

Finally, to address this comment in the project report, staff have added further narrative and clarification regarding the selection of water quality targets, which is reproduced from the project report below for ease of reference:

> ***Based on the above information and consistent with USEPA guidance for practical monitoring considerations, staff proposes that nutrient targets for this TMDL project shall be based on nitrate and orthophosphate because (1) nitrate is the overwhelming fraction of total water column nitrogen in Salinas Valley inland streams; (2) because the limited amounts of available total nitrogen data are inadequate to represent spatial and temporal variation (3) because the limited amounts of available total phosphorus data are completely inadequate to represent spatial and temporal variation; and (4) because nitrate and orthophosphate are the generally bioavailable forms of nitrogen and phosphorus in inland surface streams.***

2. As noted in Appendix C, turbidity is a critical and sensitive input to the NNE model. On p. 4 of Appendix C, the report notes that Ecoregion III-6 turbidity reference condition is 2 NTU. The

[17] This information is specific to downstream receiving waters in Elkhorn Slough, and does not definitively indicate that phosphorus control is not important in inland waterbodies of the Salinas Valley.

report then notes that "undisturbed ambient turbidity conditions in some . . . waterbodies may be closer to 20 or 30 NTU." Please support this second statement with a factual presentation of data from the project area for "undisturbed ambient" conditions. While turbidity is shown in the Project Area on p. 4-5 of Appendix C, this is data from currently impacted systems, which are presumably not representative of ambient conditions.

Staff response: Staff updated the project appendix with additional information and justifications regarding turbidity as recommended by the reviewer. Staff changed the word "ambient" to "relatively undisturbed" to be consistent with the USEPA 25^th^ percentile-based approach. For ease of reference, the justifications and supporting information are reproduced below.

The basis for staff's comment about the expectation of higher ambient turbidity levels in agricultural drainages under relatively undisturbed conditions (up to 20 or 30 NTU) are summarized below:

1) ***<u>Peer-reviewed literature:</u> It is recognized in the peer-reviewed literature that the hydraulics and substrates (clay and silt-prone) of agricultural water conveyance structures, such as canals and ditches, are often substantially different than natural streams, and can result in relatively higher levels of turbidity even under undisturbed or lightly-disturbed conditions.***

> ***"The turbidity of irrigation water increases as it travels through delivery ditches, which are bare earth and add suspended solids via erosion"***
>
> ***From: Research Article - "Monitoring helps reduce water-quality impacts in flood-irrigation pasture". Ken Tate, Donald Lancaster, Julie Morrison, David Lile, Yukako Sado, and Betsy Huang, in California Agriculture 59(3):168-175.***

> ***"Partly as a consequence of the hydraulic nature of canals…the water quality and sediment accumulation characteristics of canals also differ greatly from that of river systems. In general, the low flows and incoming land runoff produce a predominance of nutrient-bound clay and silt sediments settling on the channel bed."***
>
> ***From: Swanson, L.A., R.J. Wells, and S.G. Wallis. 2004. Management of canal systems under the Water Framework Directive: determining fundamental properties governing water quality, in Hydrology" science and practice for the 21^st^ century, Volume II. Proceedings of the British Hydrological Society International Conference, Imperial College, London, July 12-16, Vol. 2, pp 160-167.***

2) ***<u>Agricultural drain monitoring data:</u> A large body of monitoring data from 29 agricultural drains in the Central Valley and Salinas Valley of California indicate that an average expected 25^th^ percentile of turbidity data is 21 NTU (representing a relatively undisturbed or unimpacted condition) – see Figure 3 below. This is consistent with staff's comment in the project report about the expectation of relatively higher levels and valley floor agricultural drainages (on the order of 20 to 30 NTU).***

Staff concur that the figure on page 5 of Appendix C of the March draft project report does not represent ambient turbidity conditions (the map illustrates median turbidity), and it is warranted to include some sort of visual representation of relatively undisturbed turbidity conditions in valley floor agricultural drainages. Consequently, as illustrated in Figure 3 below, expected relatively undisturbed conditions in agricultural drainages (25^th^

percentile) could reasonably be approximated to be on average around 21 NTU, which is far higher than undisturbed conditions in natural streams. Note that the USEPA ecoregional turbidity reference criteria for subecoregion is 1.9 NTU (see Figure 4), which is unreasonably low and unrepresentative of an undisturbed state for many agricultural valley floor drainages.

Figure 3. Turbidity data from agricultural drainages in California.

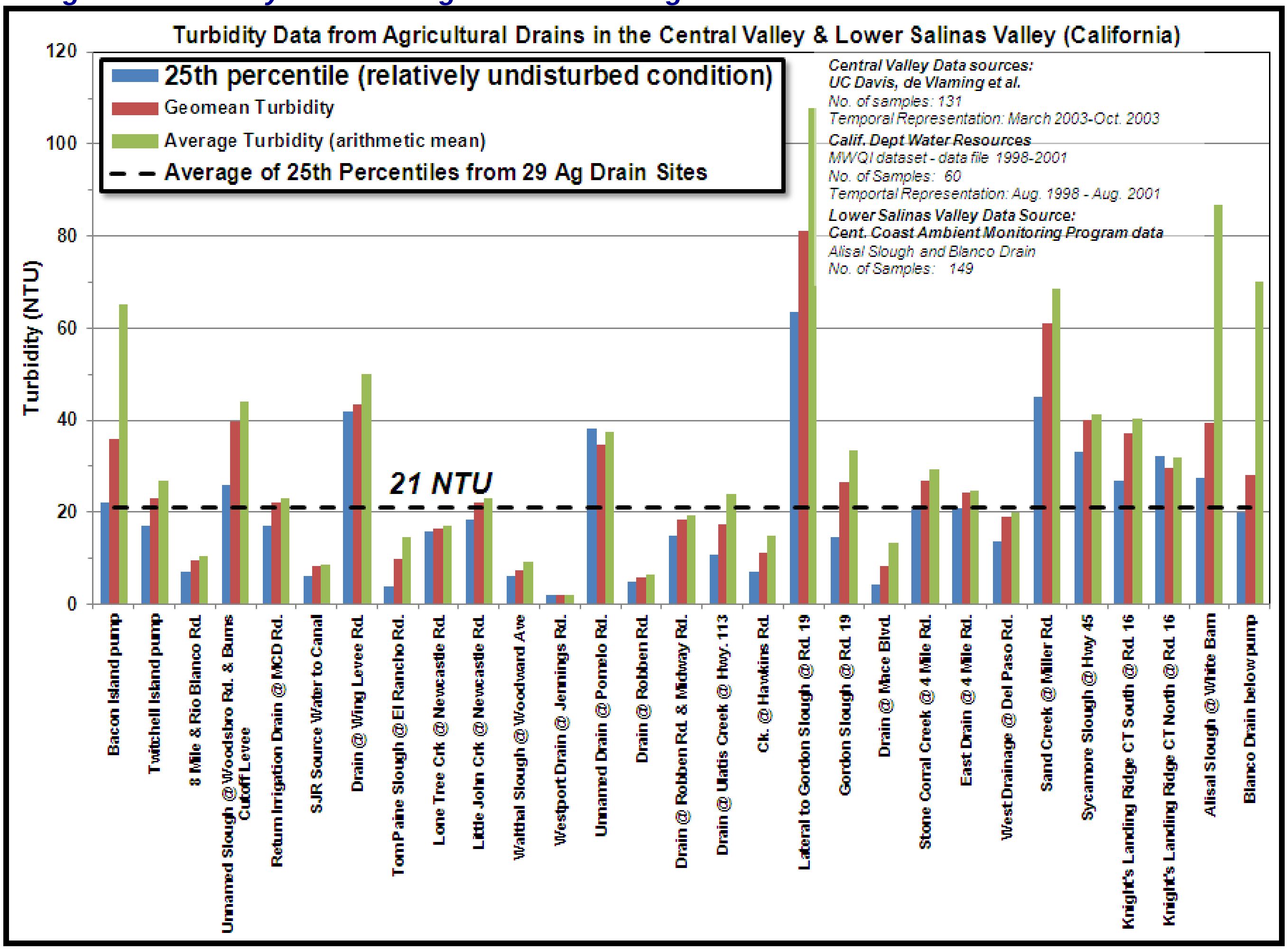
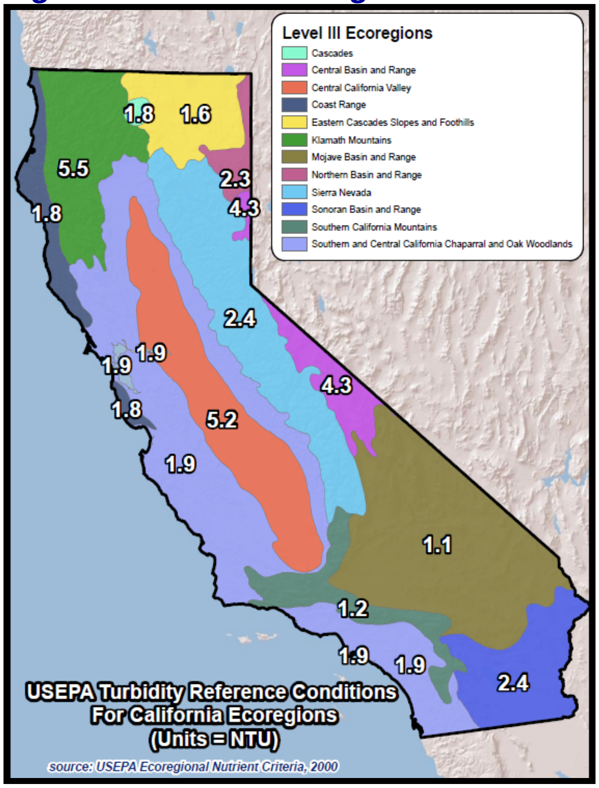


Figure 4. USEPA ecoregional criteria for turbidity.



3. Are the turbidity levels used in the NNE modeling effort indicative of current presumably higher- turbidity conditions (due to anthropogenic activities in the watershed, some of the same activities that have lead to nutrient enrichment of surface and ground waters), or are they representative of ambient or moderately disturbed conditions? I would argue that the turbidity conditions that drive NNE modeling should be indicative of the ambient or moderately disturbed conditions. While I see a rationale for using the 25th percentile turbidity value for NNE modeling (e.g., 6 NTU for Lowe Salinas River in C.4.2), I do not see a clear rationale for using the turbidity geomean of May-Oct (e.g., 9 NTU for Lowe Salinas River in C.4.2). Why was this upper turbidity value used? Is it valid to term this "typical" dry season turbidity in the context of ambient/moderate impact turbidity levels? With no compelling reason, it should be dropped from the analysis, and nutrient targets should be adjusted accordingly. Was there any consideration of using the 75th percentile turbidity values from headwater and lightly disturbed reaches, thought this may be problematic since they may not be fully representative of lowland ecosystem types?

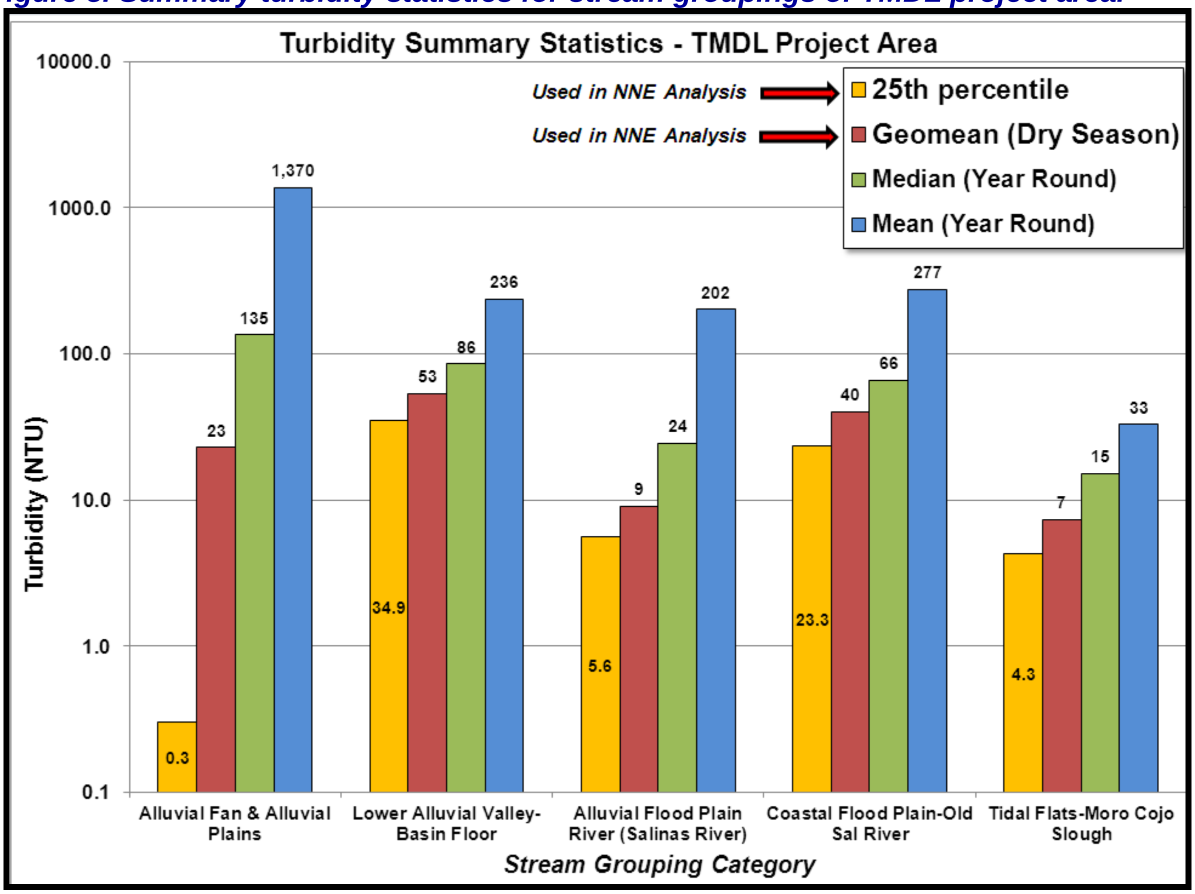
Staff response: Both turbidity values used in the NNE runs (higher sunlight availability scenario and lower sunlight availability scenario) can reasonably be considered colloquially "better than average" or "better than typical", and thus plausibly representative of relatively undisturbed to lightly or moderately disturbed conditions. They are not indicative of higher turbidity conditions that may reflect substantial anthropogenic activities and impacts. As such, staff concur that in Appendix C the colloquial characterizations of "typical turbidity" are imprecise and inaccurate. Staff will endeavor to re-characterize the text in Appendix C to something other than the imprecise colloquialism "typical turbidity".

The reviewer suggests that it would be reasonable to use ambient to "moderately disturbed" turbidity inputs in the NNE runs to represent conditions under which there are

not substantial anthropogenic inputs. Indeed, the upper NNE turbidity value staff used (i.e., dry season geomean) can plausibly be characterized as a lightly-to-moderately disturbed condition. Figure 5 illustrates that for each stream grouping in the TMDL project area, the NNE turbidity dry-season geomean values staff used are generally an order of magnitude <u>lower</u> than a year-round average (arithmetic mean) turbidity for each respective stream grouping. Further, the dry-season geomean turbidity input values even range <u>39% to 83% lower</u> than the median turbidity value for each stream grouping (the median value represent the 50th percentile of the data population). Therefore, staff maintains that the dry-season geomean turbidity value of each stream grouping <u>can fairly be characterized as a lightly-to-moderately disturbed condition;</u> e.g. they are well below average or median metrics. This characterization is indeed consistent with the reviewer's recommendation as reproduced below:

> "I would argue that the turbidity conditions that drive NNE modeling should be indicative of the ambient or moderately disturbed conditions." – Dr. Marc Beutel.

<u>Figure 5. Summary turbidity statistics for stream groupings of TMDL project area.</u>



With regard to the suggestion about using 75th percentile data from headwater and lightly disturbed upland reaches, it is staff's judgment, based on available data for soils, geology, and water quality, that upland reaches are unrepresentative of turbidity conditions that could be expected in agricultural alluvial valley floor reaches. As such, staff did not consider upland turbidity in the context of NNE turbidity input values. In fact, the reviewer similarly noted that lightly-disturbed upland reaches could be problematic because they "may not be fully representative of lowland ecosystem types."

Based on the information provided above, the reviewer's comment is addressed.

4. Please confirm that the USEPA subecoregion III-6 TP "target" (not sure of the meaning of the term target here - isn't it more an "estimate" of pre-disturbed conditions?) of 0.52 mg/L cited on p. 9 of Appendix C is correct. It seems high to me. Please present the values for TP and nitrate for USEPA subecoregion III-6 earlier in the report (see comment 4 in subsection A above).

Staff response: Staff addressed the comment by correcting the typo for value for USEPA criteria for TP to 0.03 mg/L, and staff changed the word "target" to "criteria" in Appendix C of the March peer review draft report. The USEPA phosphorus criteria for Ecoregion III-6 are based on the 25th percentile of the stream population, and therefore represent a relatively undisturbed condition (not "pre-disturbed" or pristine conditions) according to the USEPA methodology. Staff will present USEPA ecoregional nutrient criteria earlier, in Section 2. of the project report, as recommended.

5. Regarding the Old Salinas River-Coastal Flood Plain target development (C.7.2), the 25th percentile for nitrate (4.3 mg-N/L) was appropriately downscaled (3.1 mg-N/L) on the account of its high levels relative to the NEE model. It seems to me that the same rationale should be applied to phosphorus targets for this site. Note that for the river ecotypes, the 25th percentile values for nitrate and orthophosphate covary. Systems with > 4 mg-N/L nitrate have > 0.1 mg/L orthophosphate while systems with < 2 mg-N/L nitrate have < 0.05 mg/L orthophosphate. It seems to me that the 25th percentile value for both nitrate and orthophosphate are not representative of moderately disturbed conditions, as they are both higher than NNE model results under "low" and "typical" turbidity levels (see comment 2-3 above on "typical" turbidity levels). As such, both nitrate and orthophosphate targets should be down scaled. In the current scheme, it seems more appropriate to lower the orthophosphate target to 0.039 mg/L (NEE low light scenario), then default to 0.07 mg/L (lightly disturbed orthophosphate 75th percentile level).

Staff response: Staff concurs with the reviewer's comments and will assign an orthophosphate target of 0.07 mg/L for the Old Salinas River (OSR), which is a value that comports with a lightly disturbed condition that could reasonably be expected in the OSR.

6. What is the justification for a final target which is based on a geomean of dry season samples, as opposed to not exceeding the target value (as was done for the wet season), or using an average or median averaging approach? By using this geomean approach, the TMDL allows for substantial periods when concentrations are above the target concentrations? For example, for the set of values of 5, 10, 50 and 100, the average is around 41 and the median is 30, but the geomean (I assume this means geometric mean) is around 22. This approach, in my opinion, gives the various sources of targeted pollutant too much leeway in meeting TMDL targets, particularly when one considers the long-term nature of the implementation of the TMDL to meet target load allocations (12 years to meet MUN nitrate standard of 10 mg-N/L; 20 years total to meet wet season targets; 30 years total to meet all TMDL targets), as well as the fact that numerical targets were systematically set at levels that were not over-protective. For example, orthophosphate targets in Lower Salinas River and Upper Alluvial Valley Stream were set beyond 25th percentile of the applicable data set (0.04 and 0.05 mg-P/L, respectively), and up to the 75th percentile value of lightly disturbed reaches (0.07 mg-P/L).

Staff response: Staff concurs with the reviewer's rationale. In fact, subsequent to the March 2012 peer review draft of the project report, staff concluded that a geomean metric should not be applied to the final numeric targets. Not only would a geomean criteria

allow "too much leeway" (in the words of the reviewer) for meeting the TMDL targets, but a geomean statistical measure is inconsistent with the California 303(d) Listing Policy[18]. The California 303(d) Listing Policy in fact already specifies a statistical measure (binomial distributions) to account for natural variation, and allow for occasional exceedances of water quality targets in making listing and de-listing decisions. As such, staff will propose that all water quality targets for biostimulatory substances be considered maximum concentrations (allowing for occasional exceedances of water quality targets consistent with the binomial distribution statistical measures provided for in the California 303(d) Listing Policy).

7. Regarding the dry season allowable P concentration for the Moro Cojo Slough, in summary tables (e.g., Table 4-1) should the dry season target include the wording "Geomean of . . ." Also, it is unclear to me the significance of the term orthophosphate versus total phosphate. Is there an analytical difference between these two forms of phosphorus, if they even are different? Please clarify.

Staff response: Consistent with the previous comment, staff will not be proposing numeric targets on the basis of geomeans for any of the waterbodies. Staff will propose that all water quality targets for biostimulatory substances be considered maximum concentrations (allowing for occasional exceedances of water quality targets consistent with the binomial distribution statistical measures provided for in the California 303(d) Listing Policy). Also, staff will change the water quality target for Moro Cojo Slough to "orthophosphate". The March 2012 peer review draft incorrectly stated a phosphorus target for Moro Cojo Slough on the basis of "total phosphate".

C. Comments Regarding Source Analysis (Chapter 5 and Appendix D and E)

1. The load estimates for nitrogen were well presented, and the convergence of values for total annual loading (~2.9 million pounds per year) estimated via different methods lends credibility to the estimate. That said, why was no parallel analysis developed and/or presented for phosphorus? Either more analysis for phosphorus is needed, or the report need to better explain why the STEPL model output for phosphorus (~800,000 pounds per year), with no supporting load estimates, is valid to use in the context of the TMDL effort.

Staff response: Staff will endeavor to add additional analyses and/or information on phosphorus loading as recommended by the reviewer.

As a matter of resource efficiency, Staff's analytical emphasis weighted more towards nitrogen in this project was in large measure due to the fact that regional studies, and estuarine researchers suggest that currently, control of nitrogen in this system may be considerably more important than control of phosphorus. TetraTech scientists found that streams in nutrient subecoregion 6 are more often limited by nitrogen than by phosphorus (refer back to footnote 16), which may explain by there is a strong water quality correlation between water quality impairment and nitrate levels in subecoregion 6. Further, an estuarine researcher with the Elkhorn Slough National Estuary Research Reserve reported that phosphorus control is not as important as nitrogen control with respect to downstream impacts on Elkhorn Slough. The types of ephemeral macroalgae found in Elkhorn Slough thrive readily in high nitrogen conditions but are relatively insensitive to phosphorus inputs (personal communication, Brent Hughes, ESNERR, August 10, 2011). Accordingly, as a practical matter staff concluded that the focus of resources and technical analyses, should

[18] *Water Quality Control Policy for Developing California's Clean Water Act Section 303(d) List.* Adopted by the State Water Resources Control Board (Resolution No. 2004-0063).

be weighted with respect to nitrogen. Finally, supporting loading estimates for phosphorus will not have a regulatory impact, since the targets and TMDLs are not based on existing load estimates.

2. While the data sources for the nitrogen concentrations for farmland for the STEPL analysis were well defined in Table 5-1, those for phosphorus were not. Based on Appendix D, a TP value of 0.64 mg-P/L was used. Please explain source for TP data.

Staff response: Lack of reference to the source of the 0.64 mg/L P concentration in agricultural runoff was an oversight by staff. The literature source of the P concentration value comes from the report: Coastal Water Research Project, Technical Report 335 (Nov. 2000) - Appendix C – Estimates of Mass Emissions to the North and Central Coast Regions from the Southern California. Staff updated the project report to include the referencing.

3. Consider dropping 2 decimal places reporting of loads in Tables 5-2 and 5-4 through 5-10. The estimates do not merit that level of significant figures.

Staff response: Staff made the corrections as noted by the reviewer.

4. Many references noted in the section (e.g., Fig. 5-4) and Appendix E were not cited in the reference section.

Staff response: Staff made the corrections as noted by the reviewer.

5. Note that the load values for the Urban source (Table 5-11; 138,391 lb/yr N and 21,797 lb/yr P) are different from values in summary table at end of Appendix D (77,005 lb/yr N and 11,906 lb/yr P). Please fix or explain this discrepancy.

Staff response: Staff made the corrections as noted by the reviewer. Appendix D contains an older vintage STEPL run, the STEPL results in the project report and in Appendix D will be updated by staff.

D. Comments Regarding TMDL Allocations (Chapter 6) & Implementation and Monitoring (Chapter 7)

1. A stronger rationale is needed on p. 192 regarding the second interim 20-year timeframe and overall 30-year timeline. The first 12-year interim timeframe is reasonable based on the constraints discussed in the report, including the time it will take to develop and implement Farm Water Quality Plans and the time it will take to realize water quality improvements. However, no similar rationale is presented for the second interim timeframe. In addition, the rationale for the 30-year overall time frame, legacy nutrient loads from groundwater and baseflows, seems problematic to me. Figure 2-14 shows that most baseflow groundwaters in the Project Area have mean contact times less than 10 years. And the areas with contact times greater than ten years, mostly located in the western downstream portion of the watershed exhibit relatively low nitrate concentrations (< 10 mg-N/L) based on Figure 2-13A. If the presence of legacy nutrient is the driver for the overall timeline, I think this groundwater data would support a shorter overall implementation timeline than 30 years.

Staff response: Staff added rationale for the 20-year interim milestone, which is justified on the basis that the full effect source control measures (e.g. irrigation and nutrient management) and surface runoff treatment systems will be manifested within 20 years. However, source control and surface treatment are not anticipated to mitigate pollutant contributions from shallow groundwater, which locally moves very slowly through the

hydrogeologic systems, and impacts from legacy pollution in groundwater are anticipated to occur regionally beyond 20 years from the date of potential TMDL adoption.

With regard to contact times, Figure 2-14 from the March draft project report perhaps does not visually illustrate several key issues that we considered in TMDL development. First, it is important to recognize that Contact Time, as defined by the U.S. Geological Survey (USGS) metadata for this dataset represents an "average" amount of time groundwater is in the subsurface before being expressed as stream baseflow; importantly it should not be considered a "maximum" contact time for shallow groundwater. Locally, contact time could be much longer than the mean contact times shown in Figure 2-14 of the March draft project report.

Secondly, it should be noted that the USGS contact time dataset was developed as a national dataset for the conterminous United States on the basis of NHD catchments. As such, this dataset does not necessarily incorporate basin-specific or local information. For the lower Salinas Valley, it is well-established that although groundwater in the East Side Aquifer historically migrated towards the Pressure Subarea of the west side of the valley (e.g., recharging the 180/400 foot Aquifer), pumping overdraft in the East Side Aquifer has caused an apparent reversal of groundwater with groundwater flow now occurring from the Pressure Subarea into the East Side Aquifer Subarea[19] - see Figure 6

The practical effect of this is that locally, shallow groundwater from the west side of the valley (which has high contact times) may flow to the east. Therefore, staff maintains it is reasonable to conclude that very slow moving shallow groundwater (e.g., groundwater from high contact time areas) could potentially locally be manifested as stream baseflow in lower reaches of the eastern creeks.

Further, while the USGS national mean contact time dataset was used in this project report, supplementary information from local water agencies should also be considered. The Monterey County Water Resources Agency (2006) indicates that shallow and perched groundwater zones are widely present in the Salinas Valley, and typically have low to moderate permeabilities. Low permeabilities suggest that a substantial amount of time is required to realize attenuation of nutrient pollution in these shallow hydrogeologic zones:

> *"Recent Alluvium is present in the more established drainages, and typically has low to moderate permeability. Recent Alluvium also includes perched groundwater zones that have not generally been affected by seawater intrusion, but have, in some cases, been impacted by percolation from agriculture."*
>
> *Monterey County Groundwater Management Plan, Salinas Valley Groundwater Basin, May 2006. Prepared for the Monterey County Water Resources Agency.*

It should also be noted that in the southern TMDL area, tributary creeks (Chualar Creek, Quail Creek, Esperanza Creek) are not required to attain the biostimulatory substances allocations, and therefore the proposed 20 and 30 year timeframes are not applicable to these reaches.

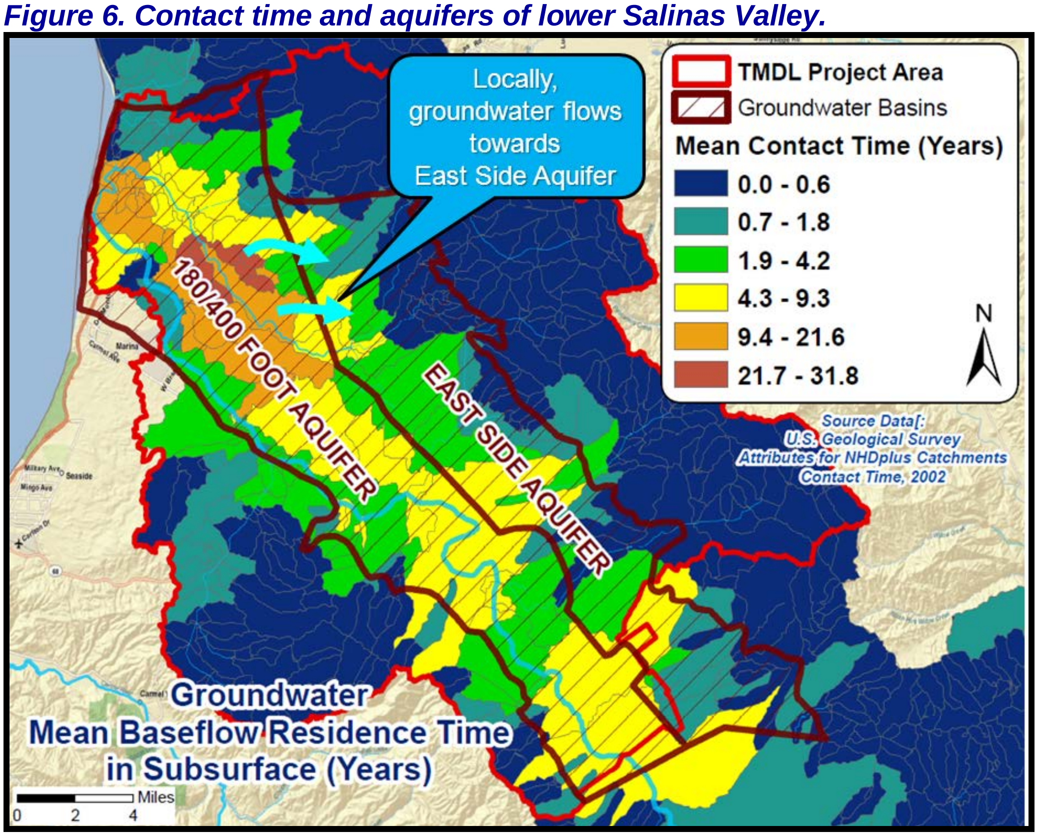
With regard to the comment about low concentrations of nitrate in shallow groundwater of the downstream, lower alluvial basin floor reaches, the color gradation and scale of Figure 2-14 of the March draft peer review document perhaps did not visually convey sufficient

[19] See "Final Report: Hydrostratigraphic Analysis of the Northern Salinas Valley. 2004. Kennedy and Jenks Consultants. Prepared for Monterey County Water Resources Agency.

information. While predicted shallow groundwater concentrations are indeed relatively lower in the "western, downstream portion of the watershed", it should be recognized that average nitrate concentrations in shallow groundwater in these areas are still predicted to be above 6.4 mg/L (see Figure 7). As such, nitrate in these groundwaters are anticipated to higher than the dry season biostimulatory targets for lower alluvial basin floor stream reaches. Accordingly, at this time staff anticipates that legacy nitrate pollution from shallow groundwater baseflow will continue to contribute to exceedances of the dry season biostimulatory substances target for decades.

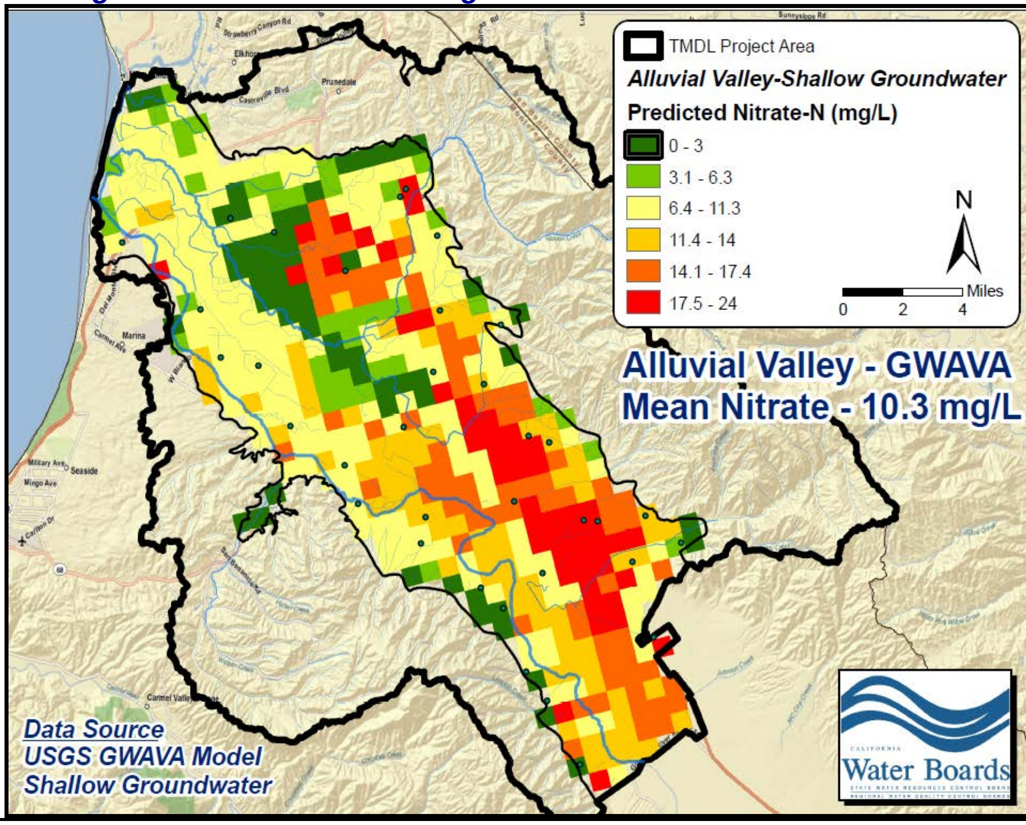
Finally, with respect to timeframes and legacy pollution of shallow groundwater, staff took into consideration an additional line of evidence from a scientific source. While not directly analogous to the Salinas Valley, the U.S. Geological Survey (USGS) reports that in spite of many years of efforts to reduce nitrate levels in the Mississippi River Basin, concentrations have not consistently declined during the past two decades. USGS concludes that elevated nitrate in groundwater are a substantial source contributing to nitrate concentrations in river water. Because nitrate moves slowly through groundwater systems to rivers, the full effect of management strategies designed to reduce loading to surface waters and groundwaters may not be seen in these rivers for decades. (see: "No Consistent Declines in Nitrate Levels in Large Rivers of the Mississippi River Basin" USGS News Release dated 08/09/2011)[20].

Figure 6. Contact time and aquifers of lower Salinas Valley.



[20] USGS online linkage @ http://www.usgs.gov/newsroom/article.asp?ID=2874

Figure 7. Estimated shallow groundwater nitrate-N concentrations.



Map color gradation summary:

Green shades < biostimulatory water quality target @ 6.4 mg/L nitrate
Yellow-Orange-Red shades > biostimulatory water quality target @ 6.4 mg/L nitrate

2. The scientific justification for statements related to the owners/operators of grazing animals already being in compliance with their nutrient allocations, discussed in part on p. 161 and 187, needs to be presented in more detail. Note 63 on p. 187 cites examples of waterbodies that are dominated by inflow drainage from grazing lands that are apparently low in nutrients including Towne Creek Tributary, Gabilan Creek (at Old Stage Road), and Chualar Creek. But I could find no water quality data Towne Creek, and based on Table 3-25, Gabilan Creek in impaired for nitrate (MUN) and Biostimulatory Substances while Chualar Creek is impaired for un-ionized ammonia and nitrate (MUN). What specific water quality information supports the contention that grazing areas are in compliance?

Staff response: The water quality data indicating attainment of water quality standards for biostimulatory substances on the basis of the California 303(d) Listing Policy in upland monitoring sites are shown in the water quality data tables from Section 3.5.7.2 of the March 2012 peer review draft report, and are as follows: Gabilan Creek at Old Stage Road and Crazy Horse Road (sites GAB-OSR and GAB-CRA), Towne Creek and tributary Big Oak Creek (sites TOW-OSR and BOC-OSR, respectively) and upper Chualar Creek (site CHU-CCR). Additionally, staff reviewed regional data from rangeland subwatersheds elsewhere in Monterey and San Benito counties which capture drainage largely from grazing lands. These subwatersheds (Tularcitos Creek, upper San Benito River, and Arroyo Seco River) show low levels of nutrients in surface water, constituting an additional line of evidence that upland creeks draining rangeland can be expected to have relatively low levels of nutrients in this region.

Further, staff added an additional supporting line of independent evidence to the project report. Staff's conclusions regarding grazing lands are supported by an independent line of research available from scientists at the Watershed Institute at California State University-Monterey Bay; these researchers concluded that data from southern Monterey Bay watersheds indicate that grazed lands are not significant nitrate or phosphate sources (Anderson et al., 2003)[21].

It is also noteworthy that most reaches of these upland-rangeland streams in the TMDL project area are dry throughout the summer and early fall (because of our Mediterranean climatic conditions) and therefore compliance with the dry season biostimulatory water quality targets is a moot point. The major concern for these stream reaches would be compliance with the proposed wet season biostimulatory substances targets (8 mg/L nitrate, 0.3 mg/L orthophosphate) – based on available data, these wet season targets are easily being achieved in project area upland watershed reaches.

3. Is it valid to call the TMDLs "maximum concentrations" on p. 160? Note that the dry season concentrations are geomeans not maximums.

Staff response: Comment noted. Staff is no longer proposing the geomean water quality targets for biostimulatory substances; as such the comment is addressed.

4. While this may be outside the scope or responsibility of the TMDL report, I found there to be a lack of clarity regarding who will pay for and conduct the long-term watershed water quality monitoring proposed on p. 182, as well as the beginning of Section 7.7. Are owners/operators of irrigated lands responsible for water quality monitoring of their water quality impacts in the Project Area?

Staff response: Water quality monitoring is currently being conducted on behalf of growers by the Cooperative Monitoring Program (CMP). This monitoring program works on behalf of growers and has been collecting a large body of data for at least seven years. At this time, the TMDL is not proposing nor anticipates additional monitoring above and beyond what growers are already paying for, or are required to do pursuant to the adopted Agricultural Order. To limit the burden of monitoring, we are proposing at this time a limited number to TMDL compliance monitoring sites, and that current monitoring programs, including CMP, ESNERR, and CCAMP are already collecting sufficient data at these sites.

5. I would like to commend the report for including the many examples of constructed treatment wetlands to control nutrients in non-point sources in Chapter 7. Treatment wetlands are especially effective at converting nitrate to harmless dinitrogen gas via biological denitrification. This biotechnology is sustainable and very economical, and should be considered for mitigation of nutrient pollution from irrigated lands, and even partial diversion of creeks and streams, throughout the project area. Note that wetlands, while losing some water via evapotranspiration, also cool water during warm months, which can benefit aquatic biota. Wetlands also provide wildlife habitat and opportunities for educational outreach in areas where human activity has dramatically decreased the area of natural wetlands. California has lost on the order of 90% of its natural wetlands. The use of treatment wetlands

[21] Anderson, T., F. Watson, W. Newman, J. Hager, D. Kozlowski, J. Casagrande, and J. Larson. 2003. Nutrients in surface waters of southern Monterey Bay watersheds. The Watershed Institute, California State University-Monterey Bay. Publication No. WI-2003-11.

can enhance water quality while synergistically enhancing the broader ecological value of the area.

Staff response: The comment is acknowledged and staff appreciates the additional information on mitigation measures.

APPENDIX 1

Curriculum Vitae

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Education:

- Ph.D. in Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, 1995.
- M.S. in Civil Engineering, Colorado State University, Fort Collins, Colorado, 1989.
- B.S. in Civil Engineering, University of Maryland, College Park, Maryland, 1987. Degree awarded Cum Laude with Honors in Engineering.

Professional Experience:

- Professor, Department of Civil and Environmental Engineering, Virginia Tech, Falls Church, VA. August 2008-present.
- Assistant and Associate Professor, Department of Civil and Environmental Engineering, University of Maryland, College Park, Maryland. August 1996-August 2008.
- Associate Researcher, National Center for Smart Growth Research and Education, August 2005-2008.
- Visiting Hydrologist, U.S. Geological Survey, Office of Surface Water, Department of the Interior, Reston, Virginia. September 2003-July 2004. (Sabbatical Leave)
- Research Scientist, National Weather Service, NOAA, Department of Commerce, Silver Spring, Maryland. September 1995-August 1996.
- Post-doctoral Associate, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts, September 1994-August 1995.

Publications:

Book Editor:

Moglen, G.E. (2005). *Managing Watersheds for Human and Natural Impacts: Engineering, Ecological, and Economic Challenges*. Proceedings of the 2005 Watershed Management Conference. Environmental and Water Resources Institute of the American Society of Civil Engineers. ISBN 0-7844-0763-0.

Chapters in Books:

1. Pizzuto, J.E., **G.E. Moglen**, M.A. Palmer, K.C. Nelson, and Moglen (2007). "Two model scenarios illustrating the effects of land use and climate change on gravel riverbeds of suburban Maryland" in M. Rinaldi, P. Ergenzinger, H. Habersack, T. Hoey, and H. Piegay (eds.) *Gravel Bed Rivers VI - From Process Understanding to River Restoration*. Elsevier. ISSN: 0928-2025 DOI: 10.1016/S0928-2025(07)11133-0
2. **Moglen, G.E.** and D.R. Maidment, (2005). "Chapter 15: Digital Elevation Model Analysis and Geographic Information Systems" in M.G. Anderson (ed.) *Encyclopedia of Hydrological Sciences*. Wiley. ISBN: 0-471-49103-9.
3. **Moglen, G.E.**, K.C. Nelson, M.A. Palmer, J.E. Pizzuto, C.E. Rogers, and M.I. Hejazi, (2004). "Hydro-Ecologic Responses to Land Use in Small Urbanizing Watersheds Witihin the Chesapeake Bay Watershed" in R. DeFries, G. Asner, and R. Houghton (eds.) *Ecosystems and Land Use Change*. Geophysical Monograph Series, American Geophysical Union, Washington, D.C. 153: 41-60.
4. **Moglen, G.E.**, (2002). "Frequency Analysis under Non-Stationary Land Use Conditions" Chapter 13 of *Modeling Hydrologic Change* (with R.H. McCuen). CRC Press, Boca Raton, Florida, pp. 367-385.
5. Palmer, M.A., **G.E. Moglen**, N.E. Bockstael, S. Brooks, J.E. Pizzuto, C. Weigand, and K. VanNess, (2002). "The Ecological Consequences of Changing Land Use for Running Waters: the Suburban Maryland Case" in K. Krchnak (ed.) *Human Population and Freshwater: Bulletin Series – Yale School of Forestry and Environmental Studies*, Yale University Press, 107: 85-114.

Articles in Refereed Journals:

1. McCuen, R.H. and **G.E. Moglen** (1988). "Multicriterion Stormwater Management Methods." *Journal of Water Resources Planning and Management Division*, ASCE, 114(4):414-431.
2. **Moglen, G.E.** and R.H. McCuen (1988). "Effects of Detention Basins on In-Stream Sediment Movement." *Journal of Hydrology*, 104: 129-139.
3. **Moglen, G.E.** and R.H. McCuen (1990). "Economic Framework for Flood and Sediment Control with Detention Basins." *Water Resources Bulletin*, 26(1): 145-156.
4. Julien, P.Y. and **G.E. Moglen** (1990). "Similarity and Length Scale for Spatially Varied Overland Flow." *Water Resources Research*, 26(8): 1819-1832.
5. Ijjasz-Vasquez, E.J., R.L. Bras and **G.E. Moglen** (1992). "Sensitivity of a Basin Evolution Model to the Nature of Runoff Production and Initial Conditions*." Water Resources Research*, 28(10): 2733-2742.
6. **Moglen, G.E.** and R.L. Bras (1995). "The Importance of Spatially Heterogeneous Erosivity and the Cumulative Area Distribution." *Geomorphology*, 12(3): 173-185.
7. Veneziano, D., **G.E. Moglen**, and R.L. Bras (1995). "Multifractal Analysis: Pitfalls of Standard Procedures and Alternatives." *Physical Review E*, 52(2): 1387-1398.
8. **Moglen, G.E.** and R.L. Bras (1995). "Effect of Spatial Heterogeneities on Geomorphic Expression in a Model of Basin Evolution." *Water Resources Research*, 31(10): 2613-2623.
9. McCuen, R.H., L.C. Conley, and **G.E. Moglen** (1996). "A Multicriterion Philosophy for Storm-Water Infrastructure." *Infrastructure*, 1(2): 42-49.

10. Finnerty, B., M. Smith, D.J. Seo, V. Koren, and **G.E. Moglen** (1997). "Space-Time Scale Sensitivity of the Sacramento Model to Radar-Gage Precipitation Inputs." *Journal of Hydrology*, 203(1-4): 21-38.
11. **Moglen, G.E.**, E.A.B. Eltahir, and R.L. Bras (1998). "On the Sensitivity of Drainage Density to Climate Change." *Water Resources Research*, 34(4): 855-862.
12. **Moglen, G.E.** and M.J. Casey (1998). "A Perspective on the Use of GIS in Hydrologic and Environmental Analysis in Maryland." *Infrastructure*, 3(4): 15-25.
13. **Moglen, G.E.** and R.E. Beighley (2000). "Using Geographical Information Systems (GIS) to determine the extent of gaged streams in a region." *Journal of Hydrologic Engineering,* ASCE, 5(2): 190-196.
14. Veneziano, D., **G.E. Moglen**, P. Furcolo, and V. Iacobellis (2000). "Stochastic Model of the Width Function." *Water Resources Research*, 36(4): 1143-1157.
15. **Moglen, G.E.** (2000). "Effect of Orientation of Spatially Distributed Curve Numbers in Runoff Calculations." *Journal of the American Water Resources Association*, 36(6): 1391-1400.
16. **Moglen, G.E.** and G.L. Hartman (2001). "Examination of GIS Data Resolution on Hydrologic Modeling Parameters and Peak Discharge." *Journal of Hydrologic Engineering*, ASCE, 6(6): 490-497.
17. Beighley, R.E., and **G.E. Moglen** (2002). "Trend Assessment in Rainfall-Runoff Behavior in Urbanizing Watersheds." *Journal of Hydrologic Engineering,* ASCE, 7(1): 27-34.
18. **Moglen, G.E.**, and R.E. Beighley (2002). "Spatially Explicit Hydrologic Modeling of Land Use Change." *Journal of the American Water Resources Association,* 38(1): 241-253.
19. Benda, L., N. L. Poff, M.A. Palmer, C. Tague, N.E. Bockstael, J.E. Pizzuto, E.H. Stanley, **G.E. Moglen**, S. Cooper (2002). "How to Avoid Train Wrecks when Using Science in Environmental Problem Solving" *BioScience*, 52(12): 1127-1136.
20. Nilsson, C., J.E. Pizzuto, **G.E. Moglen**, M.A. Palmer, E.H. Stanley, N.E. Bockstael, and L.C. Thompson, (2003). "Ecological Forecasting and Urbanizing Streams: Challenges for Economists, Hydrologists, Geomorphologists, and Ecologists." *Ecosystems*, 2003(6): 659-674, doi:10.1007/s10021-002-0217-2.
21. Beighley, R.E., and **G.E. Moglen** (2003). "Adjusting Measured Peak Discharges from an Urbanizing Watershed to Reflect a Stationary Land Use Signal." *Water Resources Research, 39*(4), 1093, DOI: 10.1029/2002WR001846.
22. **Moglen, G.E.**, S.A. Gabriel, J.A. Faria, (2003). "A Framework for Quantitative Smart Growth in Land Development." *Journal of the American Water Resources Association,* 39(4): 947-959.
23. Gabriel, S.A., J. Faria, and **G.E. Moglen**, (2006). "A Multiobjective Optimization Approach to Smart Growth in Land Development." *Socio-Economic Planning Sciences*, 40: 212-248.
24. Hejazi, M.I., and **G.E. Moglen**, (2006). "Regression-Based Approach to Low flow Prediction in the Mid-Atlantic Region of the U.S. under Joint Climate and Land Use Change." *Hydrological Processes,* DOI: 10.1002/hyp.6374.
25. **Moglen, G.E.** and S. Kim, (2007). "Limiting imperviousness: Are threshold-based policies a good idea?" *Journal of the American Planning Association*, 73(2): 161-171.
26. Allmendinger, N.E., J.E. Pizzuto, **G.E. Moglen**, and M. Lewicki, (2007). "A Sediment Budget for an Urbanizing Watershed." *Journal of the American Water Resources Association*, 43(6):1483-1498. DOI: 10.1111/j.1752-1688.2007.00122.x

27. Lewicki, M, J.E. Pizzuto, **G.E. Moglen**, N.E. Allmendinger, (2007) "A Watershed Scale Numerical Model of the Impact of Land Use Change on Bed Material Transport in Suburban Maryland" *Water Resources Research* 43, W07424, doi:10.1029/2006WR004959.
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29. Pavlovic, S.A. and **G.E. Moglen**, (2008). "Discretization Issues in Travel Time Calculation." *Journal of Hydrologic Engineering*, ASCE, 13(2): 71-79.
30. Shivers, D.E. and **G.E. Moglen,** (2008). "Spurious Correlation in the USEPA Rating Curve Method for Estimating Pollutant Loads." *Journal of Environmental Engineering*, ASCE, 134(8): 610-618. August, 2008.
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32. Nelson, K.C., M.A. Palmer, J.E. Pizzuto, **G.E. Moglen**, P.L. Angermeier, R.H. Hilderbrand, M. Dettinger, and K. Hayhoe, (2009). "Forecasting the combined effects of urbanization and climate change on stream ecosystems: from impacts to management options." *Journal of Applied Ecology*, 46:154-163, doi: 10.1111/j.1365-2664.2008.01599.x. February 2009.
33. Mejia, A.I. and **G.E. Moglen**, (2009). "Spatial Patterns of Urban Development from Optimization of Flood Peaks and Imperviousness-Based Measures." *Journal of Hydrologic Engineering*, ASCE, 14(4): 416-424. April 2009.
34. **Moglen, G.E.,** (2009). "Hydrology and Impervious Areas." *Journal of Hydrologic Engineering*, ASCE, 14(4): 303-304.
35. **Moglen, G.E., (**2009). Discussion of "Is Denser Greener? An evaluation of higher density development as an urban stormwater-quality best management practice." *Journal of the American Water Resources Association*, 45(6): 1536-1538, DOI: 10.1111/j.1752-1688.2009.00381.x.
36. Pavlovic, S.A. and **G.E. Moglen,** (2010). Authors' Response to T.S.W. Wong's Discussion of "Discretization Issues in Travel Time Calculation." *Journal of Hydrologic Engineering,* ASCE, 15(4): 320-321.
37. Mejia, A.I. and **G.E. Moglen,** (2010). "Impact of the Spatial Distribution of Imperviousness on the Hydrologic Response of an Urbanizing Basin." *Hydrological Processes.* doi: 10.1002/hyp.7755.
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39. Tsang, Y.-P., G.K. Felton, **G.E. Moglen**, and M. Paul, (in press). "Region of influence method improves macroinvertebrate predictive models in Maryland." *Ecological Modeling.*
40. Ciavola, S.J., C.A. Jantz, J. Reilly, and **G.E. Moglen**, (in review). "Forecast Changes in Runoff Quality and Quantity in the DelMarVa peninsula." Submitted to the *Journal of Hydrologic Engineering*, ASCE, (submitted May 24, 2011)
41. Casey, M.J., J.H. Stagge, **G.E. Moglen**, and R.H. McCuen, (in review). "The Effects of Watershed Subdivision in Rainfall-Runoff Modeling." Submitted to the *Journal of the American Water Resources Association*. (submitted August 4, 2011)

42. Maldonado, P.P., and G.E. Moglen, (in review). "Low Flow Variations in Source Water Supply for the Occoquan Reservoir System Based on a 100-Year Climate Forecast." Submitted to the Journal of Hydrologic Engineering, ASCE, (submitted September 28, 2011)
43. Blass, J.B. and **G.E. Moglen**, (in preparation). "GIS-Based BMP Optimization for Nutrient Removal in Maryland." To be submitted to the *Journal of Hydrologic Engineering*, ASCE. (planned submission December 2011).

Peer Reviewed Professional Papers:

1. **Moglen, G.E.** and D.E. Shivers, (2006). "Methods for Adjusting U.S. Geological Survey Rural Regression Peak Discharges in an Urban Setting." Scientific Investigations Report, U.S. Geological Survey, SIR 2006-5270.

Other Articles:

1. **Moglen, G.E.** (2000). "Urbanization, Stream Buffers, and Stewardship in Maryland." *Watershed Protection Techniques*, 3(2): 676-680. (reprinted in: *The Practice of Watershed Protection*, 2000. T.R. Schueler and H.K. Holland, (eds.), The Center for Watershed Protection, Ellicott City, Maryland.)
2. **Moglen, G.E.** and A. Kosicki (2000). "GISHydro2000: Performing Automated Hydrologic Analyses in Maryland." *TR News*, 210: 18-19. Transportation Research Board, National Academy of Sciences. Washington, DC.
3. **Moglen, G.E.** (2010). "One Educator's Experience with Distance Instruction in Hydrology and Water Resources." *Water Resources Impact*, 12(6): 10-12, American Water Resources Association.
4. Stagge, J.H. and **G.E. Moglen** (2011). "Regional Effects of Land Use Change on Water Supply in the Potomac River Basin." *Watershed Science Bulletin*, Fall 2010: 52-53.
5. Maldonado, P.P. and **G.E. Moglen** (in review). "Water System Management in a Changing World: Local Effects of Climate and Land Use Change in the Occoquan Reservoir Watershed." Submitted to Watershed Science Bulletin (submitted September 28, 2011).

Book Reviews:

1. **Moglen, G.E.** (1996). Review of, Kinematic Wave Modeling in Water Resources, by V. Singh, in *Water Resources Bulletin*, 32(3): 637-638.
2. **Moglen, G.E.** (1997). Review of, Distributed Hydrological Modeling, by M.B. Abbott and J.C. Refsgaard (eds.), in *Water Resources Bulletin*, 33(4): 920-921.
3. **Moglen, G.E.** (2002). Review of, Fractal River Basins: Chance and Self-Organization, by I. Rodriguez-Iturbe and A. Rinaldo, in *Hydrological Processes*, 16: 3097-3098.

Original Designs:

I have developed a GIS-based program for the Maryland State Highway Administration and the Maryland Department of the Environment called GISHydro2000 to serve their needs in automating hydrologic analysis in and around the state. This software includes automated basin delineation, detection of stream gages, and stream cross-section generation and interfaces to USGS Regression Equations, the Natural Resources Conservation TR-20 program, and the U.S.

Army Corps of Engineers HEC-1 program. My software was featured in Fall 2000 in the *TR News*, a bi-monthly publication of the Transportation Research Board of the National Academy of Sciences and has been recognized as an "Outstanding Contribution to GIS in Maryland" by the 14th Annual Towson University GIS Conference for the State of Maryland, 2001. This software can be downloaded at: http://www.gishydro.umd.edu.

Contracts and Grants:

1. Principal Investigator, "Watershed Erosion and Siltation Agreement." Howard County Department of Public Works, $37,500, October 1, 1996 to January 31, 1998.
2. Principal Investigator, "Development of Data Handling Tools for the Hydrologic Analysis of Small Watersheds." Maryland State Highway Administration, $49,140, February 14, 1997 to June 30, 1998.
3. Principal Investigator, "Development of a Systematic Approach for Stream Restoration." U.S. Geological Survey, $32,970, September 1, 1997 to January 31, 1999.
4. Co-Principal Investigator (with Robert M. Ragan), "Updating and Enhancing the Functionality of GISHYDRO Including Digital Terrain and Digital Line Data. (Phase I)", Federal Highway Administration, $49,920 (Moglen fraction: $29,508, September 30, 1997 to April 30, 1998.
5. Principal Investigator, "Investigation of Extent of Gage Coverage of Maryland." Maryland State Highway Administration, $14,729, February 18, 1998 to May 31, 1999.
6. Principal Investigator, "Refinements and Additions to the Maryland Hydrologic Geographic Information System to Accommodate NPDES Watershed Assessment." Federal Highway Administration, $68,974, July 1, 1998 to August 31, 1999.
7. Co-Principal Investigator (with Robert M. Ragan), "Updating and Enhancing the Functionality of GISHYDRO Including Digital Terrain and Digital Line Data (Phase II)." Federal Highway Administration, $145,593 (Moglen fraction: $111,951), July 1, 1998 to June 30, 2000.
8. Principal Investigator, "Evaluation of Alternative Statistical Methods for Estimating Frequency of Peak Flows in Maryland", Maryland State Highway Administration, $99,937, October 1, 1999 to May 15, 2002.
9. Principal Investigator, "Implementing GISHydro Installation, Customized Enhancements and Support", Maryland State Highway Administration, $91,468, February 24, 2000 to February 28, 2002.
10. Co-Principal Investigator (with Margaret Palmer [Biology], Nancy Bockstael [Agricultural Economics], and James Pizzuto [Univ. of Delaware]), "Spatial Patterning of Land Use Conversion: Linking Economics, Hydrology, and Ecology to evaluate the Effects of Alternative Future Growth Scenarios on Stream Ecosystems", U.S. Environmental Protection Agency, $879,942 (Moglen fraction: $170,054), June 1, 2000 – May 31, 2003.
11. Principal Investigator, "Interfacing GISHydro2000 with HEC-1", Maryland State Highway Administration, $35,067, July 11, 2000 – July 10, 2001.
12. Co-Principal Investigator (with Margaret Palmer [Biology]), "Hydro-Ecologic Impacts of Climate Change in DC region", U.S. Environmental Protection Agency, $77,000. (Moglen fraction: $27,249), January 30, 2001 – July 31, 2002.
13. Principal Investigator, "Continued Enhancements to GISHydro2000", Maryland State Highway Administration, $99,902, June 1, 2002 – April 30, 2004.

14. Co-Principal Investigator (with Margaret Palmer [Biology], Nancy Bockstael [Agricultural Economics], and James Pizzuto [Univ. of Delaware]), "Jointly Changing Climate and Land Use in the Mid-Atlantic: Modeling Drivers and Consequences in Economics, Hydrology, Geomorphology, and Ecology", U.S. Environmental Protection Agency, $299,744 (Moglen fraction: $55,684), July 1, 2002 – December 31, 2005.
15. Principal Investigator, "Service on the Maryland State Highway Hydrology Panel", Maryland State Highway Administration, $28,969 July 26, 2002 – June 1, 2005.
16. Principal Investigator, "Moglen Sabbatical Leave at U.S. Geological Survey", U.S. Geological Survey, $48,405, September 2, 2003 – June 4, 2004.
17. Principal Investigator, GISHydro2005, Maryland State Highway Administration, $64,985, June 1, 2004 – May 31, 2006.
18. Principal Investigator, "Generation and Incorporation of Precipitation Database for GISHydro", Maryland State Highway Administration, $15,671, September 1, 2004 – August 31, 2005.
19. Principal Investigator, "Development of Travel Time Calculation Tools for GISHydro", Maryland State Highway Administration, $14,999, February 15, 2005 – February 14, 2007.
20. Principal Investigator, "Development of Preservation Strategies to Preserve Water Resources – Coastal Zone Demonstration", Maryland Department of Natural Resources, $53,179 (Moglen fraction: $33,179), July 1, 2005 – September 30, 2005.
21. Principal Investigator, "Hydrologic Predictions in Support of FEMA Flood Mapping", Maryland Department of the Environment, $39,992, August 15, 2005 – August 14, 2006.
22. Principal Investigator, "GISHydro: Next-Generation Geospatial Environment for Hydrologic Analysis", Maryland State Highway Administration, $149,853 (Moglen fraction: $90,238), February 2, 2006 – September 30, 2006.
23. Principal Investigator, "GISHydro Nutrient Loading Interpolator for the Chesapeake Bay Program Model", Maryland Department of the Environment, $25,000, April 15, 2006 – June 30, 2007.
24. Principal Investigator, "Hydrologic Predictions in Support of FEMA Flood Mapping – Phase II", Maryland Department of the Environment, $59,922, July 1, 2006 – June 30, 2007.
25. Principal Investigator, "Development of Preservation Strategies to Preserve Water Resources - Coastal Zone Demonstration – Phase II", Maryland Department of Natural Resources, $15,000, April 1, 2006 – September 30, 2006.
26. Principal Investigator, "Developing GISHydro for the State of Delaware", Delaware Department of Transportation, $10,000, May 1, 2006 – June 30, 2007.
27. Principal Investigator, "Developing a Decision Support System for the DelMarVa Peninsula – A Tool to Integrate Alternative Growth…", Maryland Sea Grant $144,823, February 1, 2007 – January 31, 2011. Subcontracts to Claire Jantz, (Shippensburg University) and James Reilly, (private subcontractor) (Moglen fraction: 57,067)
28. Co-Principal Investigator, "Reality Check Plus - Envisioning a Sustainable Maryland", U.S. Environmental Protection Agency, $272,074 (Moglen fraction: $71,378), October 1, 2006 – September 30, 2009.
29. Principal Investigator, "GISHydro: Next-Generation Geospatial Environment for Hydrologic Analysis – Phase II", Maryland State Highway Administration, $174,732 (Moglen fraction: $104,049), November 30, 2006 – September 30, 2007.

30. Principal Investigator, "GISHydro Nutrient Loading Interpolator for the Chesapeake Bay Program Model – Phase II", Maryland Department of the Environment, $49,973, July 1, 2007 – June 30, 2008.
31. Principal Investigator, "Hydrologic Predictions in Support of FEMA Flood Mapping – Phase III", Maryland Department of the Environment, $103,426, July 1, 2006 – June 30, 2007.
32. Principal Investigator, "Developing GISHydro for the State of Delaware – Phase II", Delaware Department of Natural Resources and Environmental Protection, $4,510, October 1, 2007 – September 30, 2008.
33. Principal Investigator, "Calibration of Western Coastal Plain Peak Flow Equations and Future GIS Directions", Maryland State Highway Administration, $35,641 (Moglen fraction $28,141), July 1, 2008 – June 30, 2009.
34. Lead Principal Investigator, "Climate Change and Urban Growth: Development of a Sustainable and Resilient Water Management System Portfolio for the Greater Washington, DC Metropolitan Area", Institute for Critical Technology and Applied Science, ~$300,000 (Moglen Fraction: ~$70,000), July 1, 2009 – June 30, 2012.
35. Principal Investigator, "Hydrologic Predictions in Support of FEMA Flood Mapping – Phase IV" Maryland Department of the Environment, $65,000, August 1, 2009 – May 31, 2010.
36. Principal Investigator, "GISHydro Development in ArcGIS" Maryland State Highway Administration, $90,000, July 1, 2009 – June 30, 2010.
37. Principal Investigator, "GISHydro Development in ArcGIS – Phase II" Maryland State Highway Administration, $75,000, July 1, 2010 – June 30, 2011.

Moglen Contracts and Grants Summary

Year	**Total Funding($)**	**Moglen Share($)**	**Funding Organization***
1996	37,500	37,500	Howard Co. MD
1997	132,030	111,618	FHA, MSHA, USGS
1998	229,296	195,654	FHA, MSHA
1999	99,937	99,937	MSHA
2000	1,006,477	296,589	USEPA, MSHA
2001	77,000	27,249	USEPA
2002	428,615	184,555	USEPA, MSHA
2003	48,405	48,405	USGS
2004	80,656	80,656	MSHA
2005	108,170	88,170	MSHA, MD-DNR, MDE/FEMA
2006	706,581	435,202	USEPA, MSHA, MD-DNR, MDE, DELDOT
2007	302,732	214,976	NOAA/SeaGrant, MDE, MDE/FEMA, DNREC
2008	35,641	28,141	MSHA
2009	455,000	225,000	MSHA, ICTAS, MDE/FEMA
2010	75,000	75,000	MSHA
Totals:	**$3,823,040**	**$2,148,652**	

***Funding Organizations Key:**

- Howard Co. MD: Howard County, Maryland Department of Public Works
- FHA: Federal Highway Administration

- USGS: US Geological Survey
- MSHA: Maryland State Highway Administration
- USEPA: US Environmental Protection Agency
- MD-DNR: Maryland Department of Natural Resources
- MDE: Maryland Department of the Environment
- MDE/FEMA: Maryland Department of the Environment/Federal Emergency Management Administration
- DELDOT: Delaware Department of Transportation
- DNREC: Delaware Department of Natural Resources and Environmental Conservation
- ICTAS: Institute for Critical Technology and Applied Science (internal Virginia Tech organization)

Research Awards

I received the Outstanding GIS Award "…in recognition of my contributions to GIS in Maryland" from the 14th Annual Towson University GIS Conference for the State of Maryland, 2001.

Editorships

- Associate Editor, *Water Resources Research*, January 2001-December 2002.
- Associate Editor, *ASCE Journal of Hydrologic Engineering*, February 2008 – present.
- Guest Editor, *Journal of Hydrologic Engineering, ASCE*. Served as editor of special issue of *ASCE Journal of Hydrologic Engineering* (April 2009 issue) on the topic of imperviousness in hydrologic modeling. This was related to my service on the ASCE Watershed Management Technical Committee in which I chaired a task committee on this same topic.

<u>Teaching and Advising:</u>

Courses Taught:

- University of Maryland: ENES 100G - Introduction to Engineering Design, Fall 1998. (approximate enrollment – 20)
- University of Maryland: ENCE 100 – Introduction to Civil and Environmental Engineering, Spring 2003 (approximate enrollment – 20, first time course was ever taught)
- University of Maryland: ENCE 301 – Geo-metrics and GIS in Civil Engineering, Spring 2004-present (approximate enrollment 35-40)
- University of Maryland: ENCE 430 - Flow in Open Channels and Conveyance Structures, Spring semesters, 1997-2002. (approximate enrollment – 20)
- University of Maryland: ENCE 465 - Geographic Information Systems for Planning and Design Models, Fall semesters, 1997-2002. (approximate enrollment – 30)
- University of Maryland: ENCE 489 – Hydrologic Measurements (co-taught with Kaye Brubaker). Winter 2006. (enrollment – 5)
- University of Maryland: ENCE 634 (Formerly 688R) - River Engineering, Fall semesters, 1996-present (except Fall 1998, 2000). (approximate enrollment

- University of Maryland: ENCE 635 (Formerly 688Z) - Geographic Information Systems for Watershed Analysis, Spring semesters, 1999-present. (approximate enrollment 10)
- Virginia Tech: CEE 5324 – Advanced Hydrology, Fall 2008 (approximate enrollment 10)
- Virginia Tech: CEE 5734 – Urban Hydrology and Stormwater Management, Spring 2009 (approximate enrollment 10)
- Virginia Tech: CEE 4304 – Hydrology, Fall 2009 (approximate enrollment 45)
- Virginia Tech: CEE 5324 – Advanced Hydrology, Spring 2010 (approximate enrollment 10)
- Virginia Tech: CEE 4324/5984 – Open Channel Flow, Fall 2010 (approximate enrollment 20)
- Virginia Tech: CEE 5734 – Urban Hydrology and Stormwater Management, Spring 2011 (approximate enrollment 27)

Teaching Awards:

- Lilly-Center for Teaching Excellence Fellow, 1997-1998 academic year.
- Department of Civil and Environmental Engineering Teaching Award for excellence in teaching during the 1999-2000 academic year.
- "Outstanding Educator of the Year – 2001", awarded by American Society of Civil Engineers, Maryland Section.
- E. Robert Kent Teaching Award, awarded by the A. James Clark School of Engineering, University of Maryland, December 2002.
- Department of Civil and Environmental Engineering Teaching Award for excellence in teaching during the 2004-2005 academic year.
- Member of University of Maryland, Academy for Excellence in Teaching and Learning, 2007-2008.

Graduate Advising:

Master of Science:

1. Seth Brown, "Prediction of Stream Geometry in the Maryland Piedmont Based on Land Use and Urbanization" (1997-1999). (Employer: Parsons-Brinkerhoff, Baltimore, Maryland)
2. Michael Casey, "The Effect of Watershed Subdivision on Simulated Hydrologic Response Using the NRCS TR-20 Model" (1997-1999). (Employer: University of Maryland, Department of Civil and Environmental Engineering)
3. Ginger Hartman, "Effect of GIS Data Resolution on Hydrologic Modeling" (1998-2000). (Employer: Camp, Dresser, & McKee, Boston, Massachusetts)
4. Sally Magee, "Using a Geographic Information System for Flood Hazard Analysis: A Case Study on Quail Creek, Colorado" (1999-2001). (Employer: Federal Emergency Management Agency)
5. Eric Gross, "Using GIS Methods and the HEC-1 Model to Assess the Effect of Dams on Streamflow in the State of Maryland" (2000-2002). (Employer: Federal Energy Regulatory Commission)
6. William Medina, "Modeling Water Quantity and Water Quality with the SWMM Continuous Flow Model Under Non-Stationary Land-use Conditions Using GIS" (2001-2004). (Employer: KCI Technologies, Inc.)

7. Mohamad Hejazi, "The Joint Effects of Climate Change and Urbanization on the Distribution of Streamflow Magnitudes in the Maryland Piedmont Region" (2002-2004). (Employer: University of Illinois, Department of Civil Engineering)
8. Sung-Hee Kim, "The Characteristics and Impact of Imperviousness from a GIS-Based Hydrological Perspective" (2002-2005). (Employer: University of Maryland, Department of Geography).
9. Ian Stack, "Sensitivity of Peak Discharge Calculation to GIS-Derived Hydrologic Routing Parameters in the TR-20 Rainfall-Runoff Model" (1999-2006). (Employer: Indus Corporation).
10. Sandra Pavlovic, "Estimation of the Time of Concentration with High-Resolution GIS Data: Limitations of Existing Methods and Analysis of New Methods."(2005 – 2007). (Employer: Black and Veatch).
11. Dorianne Shivers, "Examination of a GIS-Based Water Quality Model Using USGS Gaged Watersheds in Maryland." (2006 – 2007). (Employer: unknown)
12. Karthik Ravirajan, "Development and Application of a Stream Flashiness Index Based on Imperviousness and Climate Using GIS." (2006 – 2007). (Employer: Patton, Harris, Rust, & Associates – an engineering consulting firm)
13. Jeffrey Blass, "Optimization of Best Management Practices for Watershed Planning in the State of Maryland." (2006-2007). (Employer: Charles P. Johnson & Associates – an engineering consulting firm)
14. Sarah Ahmed, "Evaluation of Nutrient and Sediment Nonpoint Source Loadings using High Resolution Land Use Data in GIS: A Multiple Watershed Study for the State of Maryland." (2007 – 2008). (Employer: Interstate Commission for the Potomac River Basin)
15. Philip Maldonado, "Modeling Drought Frequency and Severity in the Occoquan Reservoir Water Supply System (approximate title). (2009 – present).
16. Suzanne Ciavola, "Modeling Changes in Nutrient Loading in the DelMarVa Peninsula (approximate title). (2009 – 2011).

Doctor of Philosophy:

1. Kambiz Agazi, "A Reliability Analysis of Stream Restoration." (1988-1990, 1994-1997). (Employer: Office of the County Executive, Fairfax County, Virginia)
2. Edward Beighley, "GIS Adjustment of Measured Streamflow Data from Urbanized Watersheds." (1998-2001). (Employer: Associated Professor and Associate Chair, San Diego State University)
3. Alfonso Mejia, "The Spatial Distribution of Imperviousness in Watershed Hydrology. (2006 – 2009). (Employer: National Weather Service – NOAA, Silver Spring, Maryland)
4. James Stagge, "Using Kalman Filtering techniques for Optimal Dam Management in the Potomac River Basin under Joint Land Use and Climate Change (approximate title). (2009 – present).

Professional Committee Memberships

- Member, American Society of Civil Engineers, Watershed Management Technical Committee, 2003-present. Secretary (2005-2006), Vice-chair (2006-2008), Chair (2008-2010, Past-Chair (2010-present).

    - Conference Chairman, Watershed Management 2005: Managing Watersheds for Human and Natural Impacts: Engineering, Ecological, and Economic Challenges. Williamsburg, Virginia, July 19-22, 2005.
    - Chairman, Impervious Surface Task Committee, Watershed Management Technical Committee, American Society of Civil Engineers (2005-2009).
- Member, American Geophysical Union Surface Water Hydrology technical committee, 2000-present.
    - Chair, American Geophysical Union Special Session at Spring, 2001 meeting in Boston, MA. "Hydrology and Water Quality of Urbanizing Systems".
- Chairman, American Water Resources Association, GIS and Remote Sensing Technical Committee, 2001-2003 (member since 2000).

Respectfully submitted: October 4, 2011

Glenn E. Moglen
Professor

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EDUCATION

- Ph.D., University of California, Berkeley, Civil and Environmental Engineering, 2000
- M.S., University of California, Berkeley, Civil and Environmental Engineering, 1994
- B.S., University of California, Los Angeles, *Cum Laude*, Civil Engineering, 1990

EXPERIENCE

- Associate Professor, Department of Civil and Environmental Engineering, Washington State University, 2011-Present
- Assistant Professor, Department of Civil and Environmental Engineering, Washington State University, 2004-2011
- Principal Water Resources Engineer, Brown and Caldwell, Walnut Creek, CA, 2001-04
- Fulbright Post-Doctoral Researcher, Kastanienbaum Limnological Institute, Switzerland, 2000-01
- Junior/Assistant Engineer, East Bay Municipal Utility District, Oakland, CA, 1990-93

AWARDS

- 2009 NSF CAREER Grant: *Mercury Cycling in Lakes on the Colville Indian Reservation*
- 2009 WSU College of Engineering and Architecture Merit Grant
- 2005 WSU Faculty Seed Grant
- 2000 Fulbright Post-Doctoral Fellowship

RESEARCH ACTIVITIES

Funded Research Activities (~$1.3 million as PI)

Colville Confederated Tribes. 2011-12. $52,500. Beutel (PI). *Effects of Lake Oxygenation on Mercury Accumulation in Zooplankton and Fish - third renewal.*

WSU Nitrogen Systems: Policy-oriented Integrated and Policy in Research (NSPIRE) IGERT Fellowship. 2011-13. Lamb (PI Civil Eng/LAR). $80,000. Beutel and Duvil (PhD student). *Two-year PhD Fellowship and three-month policy internship.*

NSF Research Experience for Undergraduates. 2010-11. $5,700. Supplemental to 2009 CAREER Grant. Beutel and Adam (Civil Eng).

USDA Cooperative State Research, Education and Extension Service. University of Idaho and Washington State University Aquaculture Initiative. 2010-12. $23,700. Beutel (PI) and Liou (University of Idaho). *Enhancing Aquaculture Water Usage and Fish Production using Oxygenation*.

Colville Confederated Tribes. 2010-11. $161,000. Beutel (PI) and Moore (Natural Res). *Lake Oxygenation to Improve Trout Habitat and Water Quality in Twin Lakes - second renewal.*

WSU College of Engineering and Architecture Merit Grant. 2009. $6,000. Beutel. *Discretionary funds via the Dean to support 2009 CAREER research efforts.*

Washington State Department of Ecology. 2009-10. $150,000. Barber (PI Civil Eng), Beutel and Orr (Earth Env Sci). *Lake Osoyoos Drought Study*.

Washington State Omnibus Equipment Allocation. 2009-11 Biennium. $65,000. Beutel. *Funds to Acquire Brooks Rand MERX Automated Methylmercury Analytical System.*

Washington State Centennial Clean Water Program. 2010-13. $250,000. Hummel (PI Extension), Beutel, Erwin (Extension) and Ullman (Biosys Eng). *Clarks Creek Water Quality Science, Restoration and Education Implementation Program.*

NFS 2009 CAREER Grant Program. 2009-14. $400,200 (#0846446). Beutel (PI). *CAREER: Fundamental Understanding of Mercury Cycling in Lakes and Use of Reservation-Based Research to Recruit American Indians into Environmental Engineering and Science.*

Colville Confederated Tribes. 2009-10. $167,400. Beutel (PI) and Moore (Natural Res). *Lake Oxygenation to Improve Trout Habitat and Water Quality in Twin Lakes - first renewal.*

Agouron Institute Grant in Microbial Ecology. 2008-12. $158,000. Beutel (PI) and Call (Vet Med). *Microbial Ecology of Mercury Cycling in Freshwater Lakes.*

Strategic Environmental Research and Development Program. FY 2008. $149,300. Watts (PI Civil Eng), Beutel and Rentz (Civil Eng). *Pretreated Starch Suspensions for Low Environmental Impact Aircraft Deicing.*

Northwest Power & Conservation Council FY 2007-09 Fish and Wildlife Program Innovative Project Solicitation. $150,000. Funded by Colville Confederated Tribes. Beutel (PI) and Moore (Natural Res). *Lake Oxygenation to Improve Trout Habitat and Water Quality in Twin Lake.*

Dow AgroSciences. 2007. Pro Bono Supply of ^{14}C-Ring-Labled Chlorpyrifos valued at $30,000. Beutel. *Fate and transport of Chlorpyrifos in treatment aquatic sediments.*

Inland Northwest Research Alliance Research Fellowship. 2007-09. $60,000. Beutel and Gebremariam (PhD student). *Two-year PhD Fellowship.*

USGS Section 104(B) Grant. FY2007. $23,000. Beutel (PI), Watts (Civil Eng) and Peters (Biosys Eng). *Quantifying and Enhancing Nitrogen Removal in Constructed Wetlands.*

Murdock Charitable Trust 2007 Award Competition. $500,000. Ullman (PI Biosys Eng) and multiple co-PIs. *Support of Research in Metal Contaminated Sediments.*

USGS Section 104(B) Grant. FY2006. $23,000. Beutel (PI). *Effects of Sediment Oxygenation on Methylmercury Bioaccumulation in Benthic Biota.*

Metropolitan Water District of Southern California. 2006-07. $25,000. Beutel (PI). *Lake Perris Sediment-Water Interface Study.*

WSU 2005 Faculty Seed Grant. $19,900. Beutel (PI). *Effects of Wet-Dry Cycling on Chlorpyrifos removal in Wetland Sediments.*

WSU College of Engineering and Architecture 2006 Interdisciplinary Research Fellowship. $24,000. Beutel and Gebremariam (PhD student). *One-year PhD Fellowship.*

USGS Section 104(B) Grant. FY2005. $27,500. Beutel (PI) and Moore (Natural Res). *Oxygenation for the Management of Sediment Mercury Release from Aquatic Sediments.*

Fulbright Postdoctoral Grant. 2000-01. $30,000. Beutel (PI). Swiss Federal Institute for Environmental Science and Technology, Kastanienbaum Limnological Institute, Lucerne.

Recent Research Funding Efforts in Review

Colville Confederated Tribes. 2012-14. $50,000. Beutel. Effects of *Lake Oxygenation on Mercury Cycling in Twin Lakes.*

NSF Research Experience for Undergraduates. 2012-13. $6,000. *Supplemental to 2009 CAREER Grant.* Beutel (PI).

USAID Partnership for Enhanced Engagement in Grant Application Form Research. 2012-15. $150,000. Utomo (PI, Brawijaya University, Indonesia), Beutel, Anderson (Massey University, New Zealand). *Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara Province.*

Mercury Laboratory Capabilities

- Brooks Rand MERX Automated Methylmercury Analytical System
- Tekran 2600 Mercury Analysis System

- Milestone Direct Mercury Analyzer 80 with micro-balance
- Envirco Mac-10 Positive Pressure Work Area
- AirClean Systems Class 100 Horizontal Laminar Flow Work Station
- Clean Hands/Dirty Hands trace metal sampling training, Frontier Geosciences
- Methylmercury Analytical Method Training, Battelle Marine Sciences Trace Metals Laboratory

Radioisotopes Laboratory Capabilities

- Beckman Coulter LS6500 System Plus liquid scintillation counter
- Ludlum Measurements Inc. Model 44-9 Geiger counter
- 3 mCi of ^{14}C -ring-labeled chlorpyrifos for fate and transfer experiments
- 28 mCi of ^{35}S-labeled-sulfate for sulfate reduction assays in sediments and water

Applied Research/Consulting

JUB Engineering, Boise, ID. 2010-Present. *Evaluation of constructed treatment wetlands to cool secondary effluent from Moscow, ID wastewater treatment plant.*

Lake Tahoe Environmental Research Center, Davis, CA. 2010-Present. *Informal advisor regarding efforts to assess future anoxia-induced internal nutrient loading from profundal sediments and control measures for current Asian clam infestation in littoral sediments of Lake Tahoe, CA/NV.*

Brown and Caldwell Consulting Engineers, Walnut Creek, CA. 2009-Present. *Expert review of efforts to implement monitoring program to evaluate mercury bioaccumulation in Soulajule Reservoir, a back-up raw water reservoir in Marin, CA.*

Parsons Engineering, Syracuse, NY. 2006-Present. *Expert review of efforts to develop lake management strategies to impede mercury bioaccumulation in aquatic biota of Onondaga Lake, a heavily polluted urban lake in NY.*

Water Quality Engineering, Wenatchee and Washington State Department of Ecology. 2007-08. *Feasibility study of lake management strategies including lake alum treatment, alum treatment of tributary inflows, and lake aeration or oxygenation for Jameson Lake, WA.*

Montgomery Watson and Metropolitan Water District of Southern California. 2006. *Evaluation of proposed lake oxygenation on sediment biogeochemistry in Lake Perris, a eutrophic drinking water reservoir in Southern California.*

PUBLICATIONS AND PRESENTATIONS

Peer Reviewed Journal Articles (24 with ~120 citations)

(*Graduate or **undergraduate student advised by Beutel; ***other graduate student)

Gebremariam, S.Y.*, M.W. Beutel, M. Flury, J.B. Harsh, D.R. Yonge. 2011. Non-singular adsorption/desorption of chlorpyrifos in soils and sediments: Experimental results and modeling. *Environmental Science & Technology*. DOI: 10.1021/es203341b.

Lancaster, C.***, M.W. Beutel. 2011. Fate and transport of metals and particulates within the roadside environment - A review. *Water Research and Management*. 1(3):37-46.

Gebremariam, S.Y.*, M.W. Beutel, D.R. Yonge, M. Flury, J.B. Harsh. 2011. Sorption and desorption of chlorpyrifos. *Reviews of Environmental Contamination and Toxicology*. 215:123-175.

Plahuta, J.M.***, A.L. Teel, M. Ahmad, M.W. Beutel, J.A. Rentz, R.J. Watts. 2011. Oxidized starch solutions for environmentally friendly aircraft deicers. *Water Environment Research*. 83:826-833.

Gebremariam, S.Y.*, M.W. Beutel, T.F. Hess, D. Christian. 2011. Research advances and challenges in the microbiology of enhanced biological phosphorus removal - A review. *Water Environment Research*. 83:195-219.

Betancourt, C.***, F. Jorge, R. Suárez, M.W. Beutel, S.Y. Gebremariam*. 2010. Manganese sources and cycling in a tropical eutrophic water supply reservoir, Paso Bonito Reservoir, Cuba. *Lake and Reservoir Management*. 26:217-226.

Gebremariam, S.Y.*, M.W. Beutel. 2010. Effects of drain-fill cycling on chlorpyrifos mineralization in microcosms containing wetland sediment. *Chemosphere*. 78:1337-1341.

Allen, J.G.*, M.W. Beutel, D.R. Call, A.M. Fischer. 2010. Effects of oxygenation on ammonia oxidation potential and microbial diversity in sediment from surface-flow wetland mesocosms. *Bioresource Technology*. 101:1389-1392.

Palmer, H.R.*, M.W. Beutel, S.Y. Gebremariam*. 2009. High rates of ammonia removal in experimental oxygen-activated nitrification wetland mesocosms. *ASCE Journal of Environmental Engineering*. 135:972-979.

Al-Houri, Z.M.***, M.E. Barber, D.R. Yonge, J.L. Ullman, M.W. Beutel. 2009. Impacts of frozen soils on the performance of infiltration treatment facilities. *Cold Regions Science and Technology*. 59:51-57.

Beutel, M.W., C.D. Newton*, E.S. Brouillard, R.J. Watts. 2009. Nitrate removal in surface-flow constructed wetlands treating dilute agricultural runoff in the lower Yakima Basin, Washington. *Ecological Engineering*. 35:1538-1546.

Churchill, J.J.*, M.W. Beutel, P. Burgoon. 2009. Evaluation of the optimal dose and mixing regime for alum treatment of Matthiesen Creek inflow to Jameson Lake, WA. *Lake and Reservoir Management*. 25:102-110.

Lancaster, C.***, M.W. Beutel, D.R. Yonge. 2009. Evaluation of roadside infiltration to manage stormwater runoff in semi-arid eastern WA. *Environmental Engineering Science*. 26:935-940.

Gebremariam, S.Y.*, M.W. Beutel. 2008. Nitrate removal and DO levels in batch wetland mesocosms: Cattail (*Typha* spp.) versus bulrush (*Scirpus* spp.). *Ecological Engineering*. 34:1-6.

Beutel, M.W., N.R. Burley**, S.R. Dent*. 2008. Nitrate uptake rate in anoxic profundal sediments from a eutrophic reservoir. *Hydrobiologia*. 610(1):297-306.

Beutel, M.W., T.M. Leonard*, S.R. Dent*, B.C. Moore. 2008. Effects of aerobic and anaerobic conditions on P, N, Fe, Mn and Hg accumulation in waters overlaying profundal sediments of an oligo-mesotrophic lake. *Water Research*. 42:1953-1962.

Beutel, M.W., A.J. Horne, W.D. Taylor, R.F. Losee, R.D. Whitney. 2008. Effects of oxygen and nitrate on nutrient release from profundal sediments from a large, mesotrophic reservoir, Lake Mathews, California. *Lake and Reservoir Management*. 24:18-29.

Beutel, M.W., I. Hannoun, J. Pasek, K. Bowman Kavanagh. 2007. Hypolimnetic oxygenation pre-design study for a large eutrophic raw water reservoir, San Vicente Reservoir, CA. *ASCE Journal of Environmental Engineering*. 133:130-138.

Beutel, M.W. 2006. Inhibition of ammonia release from anoxic profundal sediments in lakes using hypolimnetic oxygenation. *Ecological Engineering*. 28:271-279.

Beutel, M.W., N. Burley**, K.M. Culmer**. 2006. Quantifying the effects of water velocity and oxygen on sediment oxygen demand. *Hydrological Sciences & Technology*. 22:15-28.

Beutel, M.W. 2003. Hypolimnetic anoxia and sediment oxygen demand in California drinking water reservoirs. *Lake and Reservoir Management*. 19:208-221. *Second Place, Best Paper of the Year, North American Lake Management Society*.

Beutel, M.W., A.J. Horne, J.C. Roth, N.J. Barratt. 2001. Limnological effects of anthropogenic desiccation in a large, saline lake, Walker Lake, Nevada. *Hydrobiologia*. 466:91-105.

Beutel, M.W. 2001. Oxygen consumption and ammonia accumulation in the hypolimnion of Walker Lake, Nevada. *Hydrobiologia*. 466:107-117.

Beutel, M.W., A.J. Horne. 1999. A review of the effects of hypolimnetic oxygenation on lake and reservoir water quality. *Lake and Reservoir Management*. 15:285-297.

Manuscripts in Review

Beutel, M.W., J. Erlenmeyer*, E.S. Brouillard. Phosphorus removal in a sedimentation basin/surface-flow wetland system treating irrigation runoff in the lower Yakima Basin, Washington. *Ecological Engineering*.

Dent, S.R.*, M.W. Beutel. Targeted outreach to enhance diversity in university-sponsored technology competitions. *J. Applications Practices Engineering Education*.

Debroux J., M.W. Beutel, C.M. Thompson, S. Mulligan. A novel hypolimnetic oxygenation system using off-gas from an ozone contactor. *Lake and Reservoir Management.*

Gebremariam, S.Y.*, M.W. Beutel, D. Christian, T.F. Hess. Effects of glucose on the performance of enhanced biological phosphorus removal in activated sludge. *ASCE Journal of Environmental Engineering*.

Dent, S.R.*, M.W. Beutel, P. Gantzer, B.C. Moore, E. Shallenberger. Response of iron, manganese and mercury in an anoxic water column to hypolimnetic oxygenation. *Water Research*.

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Conference Proceedings

Nelson, S.S.***, D.R. Yonge, M.E. Barber, M.W. Beutel, Z.M. Al-Houri***. 2007. Performance evaluation of cold weather flow control and runoff treatment BMPs. Proceedings of the 13th International Conference on Cold Region Engineering, Oromo, ME.

Beutel, M.W. 2005. Improving quality of salmonid habitat in lakes using hypolimnetic oxygenation. Proceedings of the Universities Council on Water Resources/National Institute for Water Resources Annual Conference, Portland, ME.

Beutel, M.W., D. Wilson. 2005. Targeted oxygen addition to Hood Canal: A potential management strategy to ameliorate the impacts of hypoxia. Proceedings of the 2005 Puget Sound Georgia Basin Research Conference, Seattle, WA.

Barber, M.E., M.W. Beutel, B. Lamb, R. Watts. Understanding hydrologic processes in semi-arid cold climates. American Geophysical Union Fall Conference, San Francisco, CA.

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Magazine Articles

Beutel, M.W. 2011. Letter to the Editor - The Dam and the Reservoir. *Civil Engineering - ASCE Magazine*. December, 2011.

Beutel, M.W., B.C. Moore, P. Gantzer, E. Shallenberger. 2011. Ease the Squeeze in Twin Lakes - The Colville Confederated Tribes Work to Enhance a Trout Fishery and Improve Water Quality in Reservation Lakes. *Lakeline - North America Lake Management Society Magazine*. 30(4):31-37.

Technical Reports

Beutel, M.W., S.R. Dent*. 2011. Summary of 2010 Monitoring Efforts at Twin Lakes. Report to the Colville Confederated Tribes. 9 p.

Moore, B.C., B. Lanouette***, A. Martin***, S. Mead***, E. Preece***, B. Cross***, M.W. Beutel, S.R. Dent*. 2011. Fish Habitat Utilization in Twin Lakes, Washington Following Hypolimnetic Oxygenation. Report to the Colville Confederated Tribes. 48 p.

Beutel, M.W. 2010. Use of the Moscow Constructed Treatment Wetlands to Cool Wastewater Effluent. Technical Memorandum to JUB Engineering and the City of Moscow, Idaho. 5 p.

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Beutel, M.W., L. Tran***, M.E. Barber, C. Orr., K. Rajagopalan***, W. Helander***. 2010. Effects of Zosel Dam Water Regulation on Osoyoos Lake Water Quality (Study 4). Report to the Washington State Department of Ecology. 38 p.

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Beutel, M.W. 2008. Jameson Lake Technical Memoranda: (1) Preliminary Sizing and Cost of Aeration and Oxygenation System; (2) Sediment Oxygen Demand; (3) Sediment Phosphorus Release; (4) Effects of Alum Addition on pH and Phosphorus in Lake Water and Lake Inflow. Reports to Water Quality Engineering and Washington State Department of Ecology. 40 p.

Beutel, M.W., H.R. Palmer*, C.D. Newton*. 2008. Quantifying and Enhancing Nitrogen Removal in Constructed Wetlands. Project Completion Report to State of Washington Water Research Center and USGS. Project 2007WA196B. 5 p.

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Newspaper Articles, Blogs and Interviews

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The Enterprise. Cape Cod, MA. June 25, 2010."For alum, support from scientists, despite unknown effects on mercury"

Moscow-Pullman Daily News. Pullman, WA. June 21, 2010. "Taking advantage of the lull - Faculty, students use summer months to focus on research projects"

The Olympian. Olympia, WA. July 9, 2005. "Hood canal fixes proposed - Water quality panel scrutinizes oxygen-injection idea"

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Invited Presentations

Beutel, M.W. 2011. Effects of Lake Oxygenation on Mercury cycling in Twin Lakes, Washington. University of Vermont, Rubenstein Ecosystem Science Laboratory and Rubenstein School of Environment and Natural Resources, Burlington, VT.

Beutel, M.W. 2011. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. University of Arkansas, Department of Civil Engineering, Fayetteville, AR.

Beutel, M.W. 2011. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. University of Waterloo, Department of Civil and Environmental Engineering, Waterloo, Ontario, Canada.

Beutel, M.W. 2011. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. University of Western Ontario, Department of Civil and Environmental Engineering, London, Ontario, Canada.

Beutel, M.W. 2011. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. McMaster University, Department of Civil Engineering, Hamilton, Ontario, Canada.

Beutel, M.W. 2010. Effects of lake oxygenation on mercury cycling in Twin Lakes, Washington. IWA Lake and Reservoir Management Workshop. Montreal, Canada, September 2010.

Beutel, M.W. 2010. Mercury cycling in lakes: A graphical overview. University of Idaho. Moscow, ID.

Beutel, M.W. 2010. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. San Diego State University, Department of Civil, Environmental and Construction Engineering, San Diego, CA.

Beutel, M.W. 2008. Novel research avenues related to oxygenation: Mercury cycling in lakes and ammonia removal in wetlands. University of Florida, Environmental Engineering Sciences Department, Gainesville, FL.

Beutel, M.W. 2005. The use of oxygenation to improve water quality in Hood Canal. Testimony to the Washington State Legislature Select Committee on Hood Canal, Olympia, WA.

National and International Presentations

Marshall, P.*, M.W. Beutel, others. 2011. Mercury biomagnification in Twin Lakes in 2011 under oxygenated and non-oxygenated conditions. North American Lake Management Society Conference, Spokane, WA.

DeSilva, L.*, M.W. Beutel, B. Lamb, E. Shallenberger. 2011. Field measurements of mercury deposition in Pullman and Puyallup, Washington. North American Lake Management Society Conference, Spokane, WA.

Cox, S.*, M.W. Beutel, S.R. Dent*. 2011. Influence of macrobenthos on the cycling of mercury at the sediment-water interface of lakes. North American Lake Management Society Conference, Spokane, WA. *Finalist for Outstanding Student Paper*.

S.R. Dent*, M.W. Beutel, others. 2011. Important consideration for managing mercury accumulation in aquatic food webs when implementing a hypolimnetic oxygenation treatment. North American Lake Management Society Conference, Spokane, WA.

Gebremariam, S.Y.*, M.W. Beutel. 2011. Enhancing trout production and health in aquaculture and hatcheries facilities using oxygenation. North American Lake Management Society Conference, Spokane, WA.

Beutel, M.W., M.E. Barber, L. Tran. 2011. Effects of Zosel Dam water regulation on Osoyoos Lake water quality. Osoyoos Lake Water Science Forum. Osoyoos, BC, Canada.

Moore, B.C., B. Lanouette***, M.W. Beutel, S.R. Dent*, A. Martin***, E. Preece***, E. Shallenberger. 2011. Short-term response to hypolimnetic oxygenation in North Twin Lake on the Colville Reservation. American Fisheries Society, Seattle, WA.

Dent, S.R.*, M.W. Beutel, B.C. Moore, E. Shallenberger. 2011. An evaluation of the impacts of hypolimnetic oxygenation on water quality and mercury in Twin Lake, Washington. Tenth International Conference on Mercury as a Global Pollutant, Halifax, Nova Scotia, Canada.

Beutel, M.W., S.R. Dent*, B.C. Moore, E. Shallenberger. 2011. Impacts of lake oxygenation on mercury cycling in Twin Lake, Washington. Second IWA Symposium on Lake and Reservoir Management, Granada, Spain.

Mobley, M., R. Ruane, P. Gantzer, E. Shallenberger, F.H. Dunlap, M.W. Beutel, J.A. Sykes. 2011. Oxygen diffusers to enhance water quality and fish habitat in natural lakes, water supply reservoirs and hydropower reservoirs. Second IWA Symposium on Lake and Reservoir Management, Granada, Spain.

Beutel, M.W., B. Reed*, S.R. Dent*, B.C. Moore, E. Shallenberger. 2011. Effects of biodilution and lake oxygenation on mercury bioaccumulation in zooplankton in Twin Lake, Washington. American Ecological Engineering Society Conference, Ashville, NC.

Beutel, M.W., S.R. Dent*, B. Reed*, B.C. Moore, D.R. Yonge, E. Shallenberger. 2010. Effects of hypolimnetic oxygenation on mercury cycling in Twin Lake, Washington. Poster. American Geophysical Union Fall Meeting, San Francisco, CA.

Gebremariam, S.Y.*, M.W. Beutel, D.R. Yonge, M. Flury, J. Harsh. 2010. Retention and migration of chlorpyrifos in aquatic sediments and soils. American Geophysical Union Fall Meeting, San Francisco, CA.

Betancourt, C.***, F. Jorge, R. Suárez, M.W. Beutel, S.Y. Gebremariam*. 2010. Evaluation of manganese sources and cycling in a eutrophic water supply reservoir. XV International Scientific Congress, Cuban National Center for Scientific Research, Havana, Cuba.

Beutel, M.W., L. Tran***, M.E. Barber, C. Orr., K. Rajagopalan***, W. Helander***. 2010. Effects of Zosel Dam on Osoyoos Lake water quality. International Osoyoos Lake Board of Control Annual Meeting, Oroville, WA.

Black, B. (high school student), K. Picollo (high school student), R. Rise(high school teacher), M.W. Beutel. 2010. A simple solar-powered water disinfection kit for developing countries. Poster, American Indian Science and Engineering Society Annual Conference, Albuquerque, NM.

Clegg, E.***, B.C. Moore, M.W. Beutel, S.R. Dent. 2010. Movements and distribution of trout following hypolimnetic oxygenation in North Twin Lake, Washington. North American Lake Management Society Conference, Oklahoma City, OK.

Beutel, M.W., S.R. Dent *, B.C. Moore. 2010. Use of oxygenation technology to enhance surface water resources. UCOWR/NIWR Conference, Seattle, WA.

Dent, S.R.*, M.W. Beutel, B.C. Moore. 2010. Effect of hypolimnetic oxygenation on the mercury cycle in the water column of Twin Lakes, WA. UCOWR/NIWR Conference, Seattle, WA.

Moore, B.C., M.W. Beutel, S.R. Dent*. 2010. Habitat improvement and internal load reduction with hypolimnetic oxygenation at Twin Lakes. UCOWR/NIWR Conference, Seattle, WA.

Mobley, M., M.W. Beutel, P. Gantzer, B.C. Moore, E. Shallenberger. 2009. Oxygenation diffusion for fish habitat enhancement at Colville Confederated Tribe's North Twin Lake. North American Lake Management Society Conference, Hartford, CT.

Dent, S.R.*, M.W. Beutel. 2009. Effect of transient oxygenation on methylmercury in the hypolimnetic waters of a eutrophic freshwater lake. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR. *Awarded Best Student Presentation.*

Whritenour, V.A.*, M.W. Beutel, J.R. Foltz***. 2009. Effectiveness of surface-flow constructed wetlands receiving agricultural runoff in mitigating pathogens and turbidity. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR.

Reed, B.**, M.W. Beutel, B.C. Moore, others. 2009. Comprehensive limnological evaluation of water quality and trout habitat in Twin Lakes, Colville Indian Reservation. Poster. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR.

Erlenmeyer, J.J.*, M.W. Beutel. 2009. Phosphorus removal in constructed treatment wetlands polishing agricultural return flows in the Yakima Valley, Washington. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR.

Allen, J.G.*, M.W. Beutel. 2009. Microbial activity, composition and abundance in bench-scale oxygen-activated nitrification wetlands. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR.

Gebremariam, S.Y.*, M.W. Beutel. 2009. Effects of drain/fill cycling on chlorpyrifos mineralization in constructed treatment wetlands. American Ecological Engineering Society Conference, Oregon State University, Corvallis, OR.

Beutel, M.W., H.R. Palmer*. 2008. Almost beyond wetlands: Enhancing ammonia removal in constructed treatment wetlands using oxygenation. American Ecological Engineering Society Conference, Virginia Technical University, Blacksburg, VA.

Beutel, M.W., S.Y. Gebremariam*. 2007. Environmental properties and biochemical transformations of permethrin in aquatic ecosystems – A role for constructed wetlands? American Ecological Engineering Society Conference, Kansas State University, Manhattan, KS.

Beutel, M.W., N. Burley** and K. Culmer**. 2007. Induced sediment oxygen demand and nitrate demand. American Society of Limnology and Oceanography Conference, Santa Fe, NM.

Dent, S.R.*, M.W. Beutel. 2007. The use of oxygenation treatments for reducing methylmercury flux from sediments in controlled incubations. American Society of Limnology and Oceanography Conference, Santa Fe, NM.

Dent, S.R.*, M.W. Beutel. 2006. Effects of lake oxygenation on bioaccumulation of mercury in benthic organisms. 8th International Conference on Mercury as a Global Pollutant, Madison, WI.

Leonard, T.M.*, M.W. Beutel. 2006. Control of mercury release from lake sediments using oxygenation. American Ecological Engineering Society Conference, Berkeley, CA.

Dent, S.R.*, M.W. Beutel. 2006. Methylmercury accumulation in fish tissue as a function of lake trophic status. American Ecological Engineering Society Conference, Berkeley, CA.

Beutel, M.W. 2005. Improving quality of salmonid habitat in lakes using hypolimnetic oxygenation. American Ecological Engineering Society Conference, Columbus, OH.

Beutel, M.W. 2004. Effects of aeration/oxygenation on nitrogen dynamics at the sediment-water interface of lakes. North American Lake Management Society Conference, Victoria, Canada.

Select Regional Presentations

DeSilva, L.*, M.W. Beutel, B. Lamb, E. Shallenberger. 2011. Field measurements of mercury deposition in Pullman and Puyallup, Washington. PNWIS Annual Conference, BC, Canada.

Beutel, M.W., E. Shallenberger. 2011. Lake oxygenation and mercury cycling in Twin Lakes, Washington. Water in the Columbia Basin Conference. Stevenson, WA.

Beutel, M.W., M. Barber. 2011. Effects of Zosel Dam Water Regulation on Osoyoos Lake Water Quality Water in the Columbia Basin Conference. Stevenson, WA.

Mena, E. (high school student), M.W. Beutel, P. Marshall*, L. DeSilva*. 2011. Impacts of Lake Oxygenation on Mercury in Fish in Twin Lakes, Washington. WSU Upward Bound/USDA High School Outreach Program. Pullman, WA.

Reed, B.*, M.W. Beutel. 2010. Effects of oxygenation on mercury bioaccumulation in zooplankton in Twin Lakes, Washington. PNWIS Annual Conference, Missoula, MT.

Marshall, P.*, M.W. Beutel. 2010. A review of colloid-facilitated transport of pesticides in soils. PNWIS Annual Conference, Missoula, MT.

DeSilva, L.*, M.W. Beutel. 2010. Greenhouse gas emissions from constructed treatment wetlands: An overview. PNWIS Annual Conference, Missoula, MT.

Cox, S.*, M.W. Beutel. 2010. An introduction to the effects of macrobenthos on the efflux of pollutants from aquatic sediments. PNWIS Annual Conference, Missoula, MT.

Gebremariam, S.Y.*, M.W. Beutel, D.R. Yonge, M. Flurry, J. Harsh. 2010. Dual-component sorption of chlorpyrifos in aquatic sediments and soils at environmentally relevant concentrations. PNWIS Annual Conference, Missoula, MT.

Moore, B.C., M.W. Beutel, E. Shallenberger. 2010. Reduced internal phosphorus, organic mercury loading, and improved fish habitat in North Twin Lake after hypolimnetic oxygenation. Poster, WSU Showcase, Pullman, WA.

Beutel, M.W., J. Liou. 2010. Enhancing aquaculture water usage and fish production using oxygenation. University of Idaho/WSU Aquaculture Meeting, Moscow, ID.

Whritenour, V.A.*, M.W. Beutel, J.R. Foltz***. 2009. Effectiveness of surface-flow constructed wetlands receiving agricultural runoff in mitigating pathogens and turbidity, Lower Yakima Basin, WA. Poster, WSU Showcase, Pullman, WA.

Beutel, M.W, B.C. Moore, others. 2009. Comprehensive limnological evaluation of water quality and trout habitat in Twin Lakes, Colville Indian Reservation. Poster, WSU Native American Research EXPO, Pullman, WA.

Dent, S.R.*, M.W. Beutel. 2008. Reducing the formation of methylmercury in freshwater lakes: From theory to practice. PNWIS Annual Conference, Anchorage, AK.

Beutel, M.W., H.R. Palmer*. 2008. A mesocosm study evaluating effects of pure oxygen addition on ammonia removal in constructed treatment wetlands. Inland Northwest Aquatic, Riparian and Wetland Symposium, Spokane, WA.

Gebremariam, S.Y.*, M.W. Beutel. 2007. Enhanced remediation of organic pesticides using reciprocating surface-water constructed wetlands. PNWIS Annual Conference, Boise, ID.

Palmer, H.R.*, M.W. Beutel. 2007. Effects of pure oxygen gas on ammonia removal in surface flow treatment wetlands. PNWIS Annual Conference, Boise, ID.

Churchill, J.J.*, M.W. Beutel. 2007. Evaluation of alum treatments for Jameson Lake inflows. PNWIS Annual Conference, Boise, ID.

Dent, S.R.*, M.W. Beutel. 2007. Reducing the formation of methylmercury at the sediment-water interface in freshwater lakes. PNWIS Annual Conference, Boise, ID. *Best Student Presentation.*

Beutel, M.W. 2006. Experimental determination and modeling of the effects of mixing and concentration gradient on sediment oxygen demand and sediment nitrate demand in lakes. Pacific Northwest Regional Conference, Oregon Lakes Association/Washington State Lake Protection Association, Portland, OR.

Beutel, M.W. 2005. Air is free but oxygen is cheaper - Using pure oxygen to aerate small lakes. Washington State Lake Protection Association Annual Meeting, Spokane, WA.