September 10, 2013
MEMORANDUM
To: RMP Technical Review Committee
From: Jing Wu, Emily Novick, David Senn
RE: Progress on improving stormwater nutrient load estimates

1. Background

Recent estimates presented in a RMP-funded draft report that explores nutrient loads to San Francisco Bay (Novick and Senn 2013) suggest that stormwater loads have the potential to be substantial nutrient sources during the wet season in San Pablo Bay. However, the study acknowledged that the stormwater load estimates were highly uncertain, because they were made with a model (Regional Watershed Spreadsheet Model, RWSM) that had not yet been calibrated with nutrient data. As a result, Novick and Senn (2013) recommended that these estimates be further evaluated, and, to the extent possible, refined.

In June (TRC) and August (SC) 2013, the RMP reviewed and approved a project (Task 3 of the Nutrient and Modeling proposal) that proposed to better constrain stormwater nutrient load estimates from watersheds draining to San Pablo Bays and quantitatively explore uncertainty in load estimates. Task 3.1 of that project involves comparing RWSM estimates to other model-derived or empirical load estimates, and identifying potential next steps. Task 3.2 involves developing improved load estimates and quantitatively exploring uncertainty using a hydrological simulation model.

This memo describes our effort and findings to date on Task 3.1. The goal of this memo is to provide the background for a discussion with the TRC about best next steps on this project.

2. Compare RWSM estimates to other model-derived load estimates

The RWSM output predicted that multiple watersheds draining to San Pablo and Suisun Bays had potentially high nutrient yields. Given the exploratory nature of this project and limited funds, our initial effort in Task 3.1 focused on the Napa River watershed for several reasons:

- Napa was among the watersheds that had relatively high calculated nutrient yields using the RWSM
- At least 2 hydrological/nutrient load models have been developed for Napa River, and there was the possibility that those models could serve as a starting place for Task 3.2.
- Napa River is on the USEPA's 303(d) list for nutrients, and we presumed that work in Task 3.2 would benefit from information gathered as part of the TMDL process, and may in turn inform that effort.

- Nutrient data from Napa River watershed, some of it collected in 2011 and 2012 in support of the TMDL process, was being compiled by the Regional Board and would potentially aid in model calibration.
- An effort focused on a single (and presumably representative) watershed that has the best available data or existing models would allow us to get furthest on quantitatively exploring mechanistic questions and uncertainty.

Effort on Task 3.1 thus far has included online and literature searches for existing hydrological and nutrient load modeling work on Napa River; further literature review into nutrient concentrations in runoff from vineyard landuses; and reviewing nutrient monitoring data in Napa River watershed.

2.1 Comparison of RWSM loads estimates to other model results for Napa River

Some limited hydrological and nutrient load modeling work has been done for the Napa River by UC Santa Barbara (Keller et al. 2004). That study applied two model platforms (SWAT[1] and WARMF[2]) to estimate nutrient loads from Napa River watershed. The RWSM load estimates are considerably higher than both SWAT and WARMF estimates (Table 1). However, the SWAT and WARMF models were calibrated with sparse, dry weather nutrient data. Therefore load estimates from these two models are likely biased low because of lack of storm data to constrain the model estimation.

The RWSM computes runoff volume using spatially-explicit rainfall estimates and landscape/landuse characteristics that influence the fraction of rainfall that leaves a catchment as runoff. The RWSM calculates nutrient loads by multiplying runoff volume from each land use within a subcatchment by landuse-specific nutrient concentrations. While annual runoff can be reasonably well predicted using the RWSM, there exist limited local monitoring data or literature values for specifying (with certainty) representative landuse-specific nutrient concentrations to drive the model. The nitrogen concentrations used for agricultural land uses in the initial load estimates were 1.3 mg L^{-1} NH_4^+-N and 8.9 mg L^{-1} NO_3^-N. These concentrations were based on values presented in three studies (Davis et al., 2000; Ackermann and Schiff, 2003; Willarson 2008), all of which are specific to California and agricultural land uses, but not necessarily specific to the types of agricultural activities in San Pablo and Suisun watersheds. In this round of literature searches, we found only two studies that report nutrient concentrations in runoff from vineyards: wet season average total nitrogen (TN) concentrations from vineyards in Australia and Spain were 4.7-6.0 mg L^{-1} (Cox, et al. 2012) and 2.6-25.5 mg/L (Ramos and Martinez-Casasnovas, 2006), respectively. Since these are TN values, they include both

[1] Soil and Water Assessment Tool
[2] Watershed Analysis Risk Management Framework

inorganic nitrogen (NH_4^+ and NO_3^-) and organic nitrogen. In relatively pristine areas, organic nitrogen is often the predominant form of N observed; however, in developed or anthropogenically-impacted areas, NH_4^+ and NO_3^- often predominate. The combined inorganic nitrogen concentration used in the RWSM (10 mg L^{-1}) is within the range observed in Spain and higher than – but still within a factor of 2 – of the concentrations observed in Australia.

The RWSM load estimates may also be overestimates because they are essentially the edge-of-stream loads; i.e., they do not take into account nutrient load attenuation or transformation that occurs along the flow path from nutrient source to the Bay. The Napa SWAT model results provide some indication of the potential magnitude of in-stream transformations: that model predicts that 57% of N was lost within the river system. Applying that loss rate to the RWSM estimates reduces loads to 1300 kg N/day.

Table 1 TDN load estimates from SWAT, WARMF and RWSM

Model	Stormwater TDN load (kg N/day)	Total load (kg N/day)	Stormwater % of total
SWAT	562	830	68
WARMF	567	873	65
RWSM	**3060**	**3680**	**83**

Although the magnitude of Napa load estimates differ substantially among the three models (Table 1), they all predict that stormwater N loads comprise a substantial fraction of total N loads (i.e., including wastewater) from Napa River watershed (Table 1). Given the fact that the other two major watersheds draining to San Pablo Bay from the north either have similar land uses (Sonoma) or have the potential for even higher stormwater loads (Petaluma, heavy dairy farms), the observation from the initial loading study (Novick and Senn 2013) that stormwater loads could potentially be substantial nutrient sources during the wet season in certain Bay segments still holds.

2.2 Review of existing monitoring data for model development

Using simulation models to estimate or predict nutrient loads requires the models to be calibrated with both hydrologic data and nutrient data. While both sets of information are needed, in reality it is often the case that there are sufficient data for hydrological calibration but not enough data for water quality calibration. In the case of dynamic watershed models, precipitation and flow process are the dominant forces that drive the generation, fate and transport of pollutants from a watershed, and as a result, load estimates are most sensitive to the hydrologic aspects of the model. Therefore, a hydrological model well calibrated with sufficient precipitation and flow data can largely constrain and reduce the magnitude of uncertainty in load estimation. However, sufficient water quality data is needed to further constrain uncertainty.

Napa River watershed has good quality data for calibrating a hydrological model. Currently, there are two USGS stations in the Napa River with multi-decadal flow records, and three weather stations within the watershed with long-term meteorological data, which are sufficient to develop a full hydrologic model. The SWAT and WARMF platforms (Keller et al., 2004) achieved decent hydrologic calibrations for Napa.

However, nutrient monitoring data in Napa River watershed remains sparse (Table 2). There are 11 sites having 5 or more nutrient samples between 2002 and 2012 within the watershed (SFRWQCB, personal communication, 2013). Furthermore, most samples were collected during the dry season (only one sample was collected in wet season in 2003). The limited nutrient data poses a challenge in terms of developing a calibrated nutrient model and decreasing the uncertainty in load estimates.

Table 2 Number of nutrient sampling for Napa River from 2002 to 2012

Station	Description	No of sampling
N-06	Napa R. @ Zinfandel Lane	8
N-03	Ritchey Ck. nr. Ranger Station	7
N-09	Napa R. @ Yountville Ecopreserve	7
N-02	Mill Ck. @ the old Bale Mill	6
N-11	Tulukay Ck. @ Terrace Court (close to N 44)	6
N-04	Napa Ck. @ Jefferson	5
N-05	Napa R. @ Calistoga Community Center	5
N-13	Murphy Ck. @ "Stone Bridge" on Coombsville Road	5
N-18	Brown Valley Ck. @ "Little Stone Bridge"	5
N-26	Bell Canyon Ck. @ Silverado	5
N-52	Salvadore Channel @ 121 near school	5

3. Next steps

In summary, this first phase of digging more deeply into the current stormwater load estimates to San Pablo Bay and exploring model and data availability included:

- comparing RWSM results with those of other model estimates
- reviewing relevant literature to evaluate RWSM nutrient input data
- considering potential in-stream transformations, and
- evaluating data availability and quality for model calibration

The new information highlights the uncertainty associated with the current load estimates. However, ambiguity remains about whether or not RWSM-calculated loads are substantial overestimates or are realistic. In addition, while there are abundant data to calibrate a Napa hydrological model, there is limited data to support the nutrient calibration.

Based on our exploratory effort so far, Table 3 outlines four options for discussion about how to proceed on exploring the stormwater loads.

Table 3 Overview of options for next steps in Task 3.2

Option	Description	Pros	Cons
A	Develop a hydrological and nutrient load model at the appropriate spatial resolution using a mechanistically-based platform (e.g., HSPF) that could be used for future applications in Napa and other watersheds, for nutrients or other contaminants	• Strong hydrological and nutrient/contaminant functionality • Scalable spatial resolution • Use beyond this specific project, in next nutrient step or other contaminant studies, or in other watersheds • Mechanistic simulation of hydrological and nutrient processes will allow for quantitatively exploring uncertainty of multiple parameters and data collection needs to reduce uncertainty • Experience in SFEI with running HSPF • SFEI likely invests heavily in HSPF or similar platforms for other stormwater/LID projects	• Requires effort on the front end for model setup and hydrological calibration, which will carve into time (funding) available for exploring the nutrient goals of the project. • Unknown whether nutrients or other RMP programs will need such a model to inform management decisions in the long run. • While hydrology will be well-calibrated, there will be limited data for nutrient calibration.
B	Use a coarser resolution (whole watershed scale) version of a mechanistic hydrological model that is already calibrated. E.g., Brake Pad Partnership Cu model or Bay Area Hydrological Model, both of which used HSPF	• Faster start-up than Option **A** • Mechanistic simulation of hydrology and nutrients for quantitatively exploring uncertainty. • Fast run time that will allow for large number of simulations to explore uncertainty • Napa and Sonoma both calibrated in this model, so can study two watersheds. • Possibility that such Bay-wide model could be used to develop flow and load estimates for within-Bay modeling effort.	• Unknown if we can get the calibrated model in a form that we can manipulate (proprietary). • Extremely low spatial resolution. All of Napa River watershed treated as a single box. • If the results suggest that we need to dig deeper (i.e., higher resolution), we would eventually need to move to Option **A**. If that happens, starting with Option **A** would have been a more efficient path. • While hydrology is well-calibrated, there will be limited data for nutrient calibration.
C	Refine the existing WARMF model and use it to focus primarily on the nutrient-related uncertainty	• Faster start-up than Option **A** • Like **A** and **B**, mechanistic simulation of hydrology/nutrients • Much higher spatial resolution than Option **B** (but similar resolution as **A**)	• Unlike HSPF, WARMF needs to be run using its graphical user interface which may substantially limit the types of uncertainty analysis that can be conducted (i.e. Monte Carlo simulation may be difficult to implement). • WARMF is not the ideal model we would use for future stormwater /sediment/nutrient load work.
D	Stop, or pause for the time being. Use this memo as the wrap-up for stormwater nutrient load estimate work. Reallocate $50,000 to within-Bay modeling	• If stormwater loads appear unlikely to be a high priority (*and are not needed for within-Bay modeling), this would be a wise reallocation of resources. • The within-Bay modeling work would benefit from the additional funds in year 1.	• No further progress on stormwater load estimates and lingering uncertainty about their potential importance. • Missed opportunity to develop a model platform in-house for RMP that could be used for future applications.

4. Reference

Ackerman, D. and Schiff, K. (2003). Modeling Storm Water Mass Emissions to the Southern California Bight. Journal of the American Society of Civil Engineers 129:308-323

Cox, J.W., Oliver, D.P., Fleming, N.K. Anderson, J.S. (2012) Off-site transport of nutrients and sediment from three main land-uses in the Mt Lofty Ranges, South Australia Lofty Ranges, South Australia. Agricultural Water Management 106 (2012) 50–59.

Davis, J.A., McKee, L.J., Leatherbarrow, J.E., Duam, T.H. (2000). Estimates of Mass Emissions to the San Francisco Bay Region. Appendix B of “Pollutant Mass Emissions to the Coastal Ocean of California”. A technical report of San Francisco Estuary Institute, Richmond, CA.

Novick, E.M., Senn, D.B. (2013) External nutrient loads to San Francisco Bay (Draft). A technical report of San Francisco Estuary Institute, Richmond, CA.

Ramos, M.C., Martinez-Casasnovas, J.A. (2006) Nutrient losses by runoff in vineyards of the Mediterranean Alt Penedes region (NE Spain). Agriculture, Ecosystems and Environment 113 (2006) 356–363

Willarson, B. (2008). Evaluation of BMP Siting Criteria Using EMC, Rainfall, and Runoff. A technical report of the County of Los Angeles Department of Public Works.