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Will animal subjects be used? [ ] Yes [X] No

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Does this application involve any recombinant DNA technology or resea [ ] Yes [X] No

Modeling Nutrient and Organic Carbon Loads and Sources in Central Valley Watersheds: Taking Existing Monitoring Data to the Next Stage

1. Introduction/Question/Objectives

1.1. Introduction

Over the past 50 years, world population, food production, and energy consumption have increased approximately 2.5, 3, and 5-fold, respectively (FAO 2001; United Nations 2002; US Census Bureau 2005). These changes have resulted in a massive mobilization of bioactive nutrients such as nitrogen and phosphorus (N and P) on land. Through activities such as fertilizer production, fossil fuel consumption, and the planting of leguminous crops, humans have more than doubled the rate at which biologically available N enters the terrestrial biosphere (Vitousek and Matson 1993). The global phosphorus (P) cycle has also been greatly altered by human activity. P mining and subsequent use as fertilizer has more than doubled P inputs to the environment over natural, background P from weathering (Mackenzie et al. 1998; Bennett et al., 2001; Fixen and West 2002).

Significant fractions of these mobilized nutrients are washed into flowing surface waters where they have been associated with a number of negative environmental impacts including, drinking water degradation, loss of biodiversity, low dissolved oxygen (DO) conditions leading to fish kills and other stresses, and an increase in frequency and severity of harmful and toxic algae blooms, among other effects (Howarth et al. 1996; Galloway and Cowling 2002; Anderson et al. 2002; Townsend et al., 2004; Carpenter et al., 1998). N and P inputs to surface waters are projected to continue to increase over the next several decades, both globally and regionally (Kroeze and Seitzinger 1998; Harrison et al. 2005).

Over the past century California has paralleled global trends, experiencing large increases in population, food production, energy consumption, and hence nutrient mobilization (USDA-NASS 2004; http://www.nass.usda.gov/ca/indexhist.htm; State of California Department of Finance 2005a and 2005b; EIA 2005). In the San Joaquin River (SJR), this increase in nutrient mobilization (along with increases in the prevalence of subsurface drainage) has been associated with a pronounced (~10-fold) increase in nitrate (NO_3^-) concentrations (Figure 1; Kratzer and Shelton 1998; Dahlgren Pers. Comm.). Over this same time period, P inputs to Central Valley (CV) watersheds have also increased greatly, and a recent study in the Sacramento Basin reported that total phosphorus (TP) concentrations were equal to or greater than national guidelines in almost all tributary streams draining urban and agricultural lands (Domagalski et al. 2000).

High nutrient concentrations in the lower SJR have been associated with an increase in algal standing crop, which in turn has been blamed for low dissolved oxygen (DO) episodes in the lower SJR (R. Dahlgren Unpub. Data). Low DO conditions may act as a barrier to upstream migration of spawning Chinook salmon, and other anadromous fish species (California Regional Water Quality Control Board, 2004). As a result, a major water quality objective of the State's basin plan for the region is to maintain DO levels above 6 mg/L in the SJR between Stockton and Turner Cut during the fall fish runs (September-November) and above 5 mg/L at all other times (California Regional Water Quality Control Board, 2004). Recent investigations suggest that reducing nutrient loads from agriculture and municipalities is one strategy for achieving the DO TMDL in the SJR (Lee and Jones-Lee, 2003).

In addition to the issues associated with increased mobilization of N and P, dissolved organic carbon (DOC) is also of great concern. This is due in part to DOC's role in the formation of potentially carcinogenic and mutagenic compounds (trihalomethanes and haloacetic acids) during drinking water disinfection (U.S. EPA 2000). Concern over the role of DOC in the formation of these compounds has led CALFED to propose an average target concentration of total organic carbon (TOC) of 3 mg/L at drinking water intakes (CalFed 2000). The Sacramento and San Joaquin Rivers, hereafter collectively referred to as the SSJ system, constitute an important source of carbon (270 Mg DOC day^{-1}) to the Bay-Delta region (Jassby et al., 2000; Saleh et al., 2003; Sobczack et al., 2005), the source of drinking water for over 20 million Californians. On average, 75% of the DOC exported to the State Water Project is from upstream watersheds (Sonnerup and Bergamaschi 20002). With nearly 85% of the water exported in the State Water Project coming from the Sacramento River, understanding DOC sources supplying the CV rivers and the factors affecting DOC cycling in the CV is important for planning the use of surface water resources in California's future.

In addition to the health concerns associated with DOC, DOC is also important from ecosystem and biogeochemical perspectives. In the Bay-Delta region, dissolved organic matter (DOM), of which DOC is a constituent, makes up the majority of organic matter inputs (as opposed to particulate organic matter (POM)), and river inputs constitute the largest input of DOM to SF Bay (Sobczak et al. 2005).

Furthermore, DOC has been shown by mass balance to support over 75% of the San Francisco Estuary's net energy demands (Sobczak et al. 2005). In addition to feeding the Bay Delta ecosystem, DOC can control the availability of dissolved nutrients and metals, and affect the optical properties of aquatic systems (Findlay and Sinsibaugh 2001).

There is currently an enormous amount of water quality and discharge information available for the SSJ system (e.g. Kratzer and Shelton 1998; Domagalski and Dileanis 2000). However, these data have not yet been synthesized into models that can predict nutrient export from watersheds as a function of land use and nutrient inputs. Nor have they been used to quantify the relative importance of different land-based nutrient and DOC sources within CV watersheds. With the work outlined in this proposal, we will develop the first spatially explicit, models for predicting DOC, DIN and DIP export, concentrations, and sources for major CV river systems. We will focus on DOC, DIN, and DIP initially because these compounds are the most abundant forms of C, N, and P, respectively (and an even greater proportion of the bioavailable C, N, and P) in much of the SSJ system (Kratzer and Shelton 1998; Alexander et al. 1996).

1.2. Objective and Research Questions:

The objective of the proposed research is to use existing data, in combination with models, to gain a quantitative understanding of current and likely future fluxes, sources and controls of DOC, DIN, and DIP transported through the SSJ system. Specifically, we will address the following research questions:

1. **What are the relative contributions of various land-based sources of DIN, DIP, and DOC to the Sacramento and San Joaquin River systems?**
2. **How can we improve our ability to predict river DOC, DIN, and DIP concentrations, export, and sources?**
3. **How are river DOC, DIN, and DIP concentrations, loads, and sources likely to change as a function of climate, population growth, water demand, and land-use change in the next few decades?**

2. Approach

In the following section we describe the study system, the datasets and models we will use to address our research questions, and how we will use these datasets and models to address each of the questions we have posed. We also outline schedule by which we will accomplish the research we have described.

2.1. The Study System

The Sacramento and San Joaquin rivers basins are the two largest river systems draining California's Central Valley region, and encompass approximately 70,000 and 28,000 km^2, respectively (Figure 2a). The Sacramento River is the largest river in California, and together with the SJR, contributes ~97% of the river freshwater, as well as the majority of organic matter, and river nutrient input to the Bay-Delta system (Jassby and Cloern 2000; Sobczak et al., 2005).

The land use, land cover, climate, and topography are all extremely spatially diverse in both basins (Figure 2b; Gronburg et al., 1998; Saleh et al., 2003). In both basins, there are sub-basins that range from almost entirely un-altered systems, to systems that have been completely altered by human activity and water engineering projects. Land uses in both basins include forestry, rangeland, irrigated agriculture, wildlife refuges, dairies, municipalities, and industry (Figure 2b). Major water uses in the SSJ system include irrigation, municipal and domestic water supply, power, fresh water habitat for wildlife and fish (migration and spawning), recreation and industrial processing (California Regional Water Quality Control Board, 2004). The SJR and Sacramento basins support 4120 and 8090 km^2 of irrigated crops, respectively, including corn, alfalfa, pasture, orchards, vineyards and various other commodities (Kratzer et al., 2004). The hydrology of both systems has been extensively altered by irrigation impoundments and diversions (Ingram 1996; Kratzer and Sheldon 1998). During the irrigation season, up to 50% of the flow in the San Joaquin can originate from irrigation return flows.

We intend to exploit the high degree of landscape, climatic, and land-use diversity within the SSJ system, along with the large amount of existing water quality and discharge data to determine sources and controls on DIN, DIP, and DOC fluxes through these river systems.

2.2. River Nutrient and Discharge Data

Over the past 30 years, at least 6 agencies and organizations (USGS, US-EPA, the Bureau of Reclamation, NWIS, UC-Davis, and the California Department of Water Resources) have carried out extensive and intensive long-term water quality monitoring programs in both the Sacramento and SJR basins. These efforts have resulted in a tremendous amount of publicly available, high-quality nutrient, DOC, and water discharge data for the SSJ system. In the San Joaquin Basin alone between the years of

1972 and 1990, over 13,000 nutrient samples have been analyzed and reported (Kratzer and Shenton 1998). Counting only sites with over 15 samples, there are approximately 10,000 quality assured and quality controlled nitrate measurements available from 41 sites in the SSJ system (C. Kratzer Pers. Comm.). Similar data coverage exists for DIN, DIP, and DOC, and at least 20 (probably more) of these sites are gauged (Saleh et al., 2003), facilitating accurate river nutrient flux estimates at several points throughout the SSJ system. These data are almost entirely available via the web through EPA-STORET (http://www.epa.gov/storet/dw_home.html), USGS-NWIS (http://waterdata.usgs.gov/nwis/qw), and the CDEC (http://cdec.water.ca.gov/) websites.

In addition to these data sources, we will also make extensive use of a dataset collected by Dr. Dahlgren, which contains biweekly data on 28 biogeochemical parameters at 25 sites in the Central Valley since October 1999 and an additional 9 sites in the upper Sacramento River watershed as of October 2002. These sites were chosen specifically to aid in more precisely determining sources of nutrients in the basin ("CALFED Directed Action Proposal For Monitoring and Investigation of the San Joaquin River and Tributaries Related to Dissolved Oxygen." CALFED Ecosystem Restoration Program, Sacramento, CA (Will Stringfellow et al., proposal)). These samples have all been collected using appropriate methods and subject to rigorous quality assurance and quality control procedures, including chain of custody, spikes, blind samples, field blanks, replicates, reference materials, setting of control limits, criteria for rejection, and data validation methods (Kratzer et al., 2004). These data are also being used extensively by many CALFED and state/federal agency programs (e.g. DO TMDL in the San Joaquin Basin and USGS), as they represent the best-available data set for this period of time on water quality for Central Valley Rivers. In addition to the above sources of data, we will also search existing peer-reviewed and gray literature and query water quality monitoring agencies and individuals for additional data.

2.3 Models

Though much nutrient flux data has been collected in the SSJ system, there has not yet been a successful effort to use these data to develop any nutrient or DOC export models for these systems. In other systems, several studies have modeled the dynamics of river DOC, DIN and DIP transport at local to regional scales with mixed success (e.g. Boyer et al., 1996; Weller et al. 2003; HSPF (Bicknell et al., 1997); QUAL2E (Chapra and Pelletier 2003); SWAT (Neitsch et al., 2002); and WASP (Wool et al., 2004); SPARROW (Alexander et al., 2002)). However, these models have generally been developed and highly tuned for specific systems, and are therefore not easily applied to other system types. It is also difficult to use these models to predict system response to hypothetical future conditions because they have been narrowly calibrated to the conditions that exist within a specific watershed or region. Therefore, when run with new input parameters that fall outside of the range to which the models were originally calibrated, these models may act erratically.

Recently, several global models have been developed to predict river export of bioactive elements (N, P, and C) and their respective forms (inorganic/organic, dissolved/particulate; e.g. Dumont et al., In Press; Harrison et al. In Press a and b). Because these models were created as part of a work group called **G**lobal **N**utrient **E**xport from **W**ater**s**heds (Global NEWS), they are referred to as NEWS models, and models for predicting DIN, DIP and DOC export are called NEWS-DIN, NEWS-DIP, and NEWS-DOC, respectively. These models were calibrated and validated using globally distributed rivers, so they are robust over a much broader suite of conditions than models that have been calibrated to a particular system, and they may therefore be more appropriate for making predictions about how a system will respond to novel conditions.

We propose to scale down NEWS-DIN, NEWS-DIP, and NEWS-DOC models, using higher spatial and temporal resolution datasets than were available for the global application of these models, and apply them to both the entire SJR and Sacramento systems and to sub-basins of those systems. Such an effort will constitute the first time a global nutrient export model has been applied at a sub-basin scale, and will therefore be a significant step forward for the global nutrient export modeling community. This effort will also improve understanding of factors controlling nutrient export from CV basins as it will constitute the first effort to ascribe DIN, DIP, and DOC to land-based sources within CV basins. It will show where knowledge is lacking regarding our understanding of nutrient sources in CV watersheds, and therefore where future research efforts should be directed. It will also lay the groundwork for the scenario analyses we describe below in section 2.7., and provide a basis for comparison with other nutrient export models that are eventually developed for CV basins.

2.3.1 NEWS-DOC

To model DOC fluxes, concentrations, and sources, we will initially rely on a regional application of the NEWS-DOC model (Figure 3a; Harrison et al., In Press a; For more detailed information on NEWS-DOC than is included here, please find a preprint at the following URL: http://marine.rutgers.edu/globalnews/data/NEWS_Papers_Submitted_2005/Harrison_gbc_DOM.pdf ; username: globalnews, password: gl0balnews). NEWS-DOC predicts DOC yield (*DOC*; kg C km^{-2} yr^{-1}) as a function of runoff, wetland area, and consumptive water use. The model's central equation is as follows: $DOC = Q_{act} / Q_{nat} \cdot (R^a \cdot (C_{wet} \cdot W + C_{dry} \cdot (1 - W)))$, where Q_{act}/Q_{nat} is the ratio of present-day discharge (Q_{act}) to pre-dam discharge (Q_{nat}), R is annual runoff (m), W is the fraction of a watershed that is wetland by area, a is a unit-less coefficient describing the shape of the relationship between runoff and DOC yield, and C_{wet} and C_{dry} represent the export coefficients (kg C km^{-2} yr^{-1}) for wetlands and non-wetlands, respectively, calibrated using global datasets. Total DOC export per basin (kg C $basin^{-1}$ y^{-1}) to coastal systems is simply the product of DOC yield and basin area, and DOC concentration can be calculated by dividing DOC load by water discharge. (N.B. The same transformations can be performed for the NEWS-DIN and NEWS-DIP predicted DIN and DIP yields described below.) For the initial applications of NEWS-DOC, we will use area-weighted basin average values as model inputs. However, this may be modified in future, regionally focused, versions of NEWS-DOC (Section 2.5).

NEWS-DOC's formulation is consistent with published regional analyses showing strong relationships between runoff and DOC export (Ludwig et al., 1996) and between basin percent wetland area and DOC export (Dillon and Molot 1997; Gorham et al. 1998; Mulholland 2003; Raymond and Hopkinson 2003; Stepanauskas et al. 2003). In addition to estimating total DOC load and concentration, NEWS-DOC can also be used to calculate the magnitudes of wetland and non-wetland DOC.

When applied at the global level, NEWS-DOC explained 88% of the variability in DOC yield (kg C km^{-2} yr^{-1}) and 93% of the variability in DOC load (Ton C $basin^{-1}$ yr^{-1}) in validation basins (basins not used to calibrate the model), and was free from bias (Harrison et al., In Press a). When preliminarily applied to the SSJ system using low resolution, global datasets, NEWS-DOC did fairly well, with predictions of DOC load falling within the reported values of annual average DOC export from each basin (Saleh et al., 2004; Alexander et al., 1996).

2.3.2 NEWS-DIN

To model fluxes and sources of DIN, we will refine and apply NEWS-DIN (Figure 3b; Dumont et al., In Press) to CV river systems. NEWS-DIN builds on past work by Seitzinger and Kroeze (1998), Kroeze and Seitzinger (1998), Caraco and Cole (1999), and Seitzinger et al. (2002a and 2002b). The NEWS-DIN model includes several N inputs missing from the original N-model (described in Seitzinger and Kroeze, 1998) such as manure N and biological N_2 fixation. NEWS-DIN also includes N retention and loss terms that were absent from the original N-model such as N retention in river networks, N retention in dammed reservoirs, N loss via consumptive water use, and N removed from a watershed via harvesting and grazing (Figure 3). NEWS-DIN also includes a more sophisticated treatment of sewage point sources than was included in the original N-model, incorporating estimates of sewage treatment, sewage connectivity, and variable N-excretion rates.

NEWS-DIN's core equation is: $DINy_{mod} = FE_{riv} \cdot [PS + (FE_{ws} \cdot DS)]$, where $DINy_{mod}$ is modeled DIN yield per river basin (kg N km^{-2} y^{-1}), PS is DIN from sewage point sources (kg N km^{-2} y^{-1}) and DS is N from diffuse sources that is mobilized from the watershed soils and sediments (kg N km^{-2} y^{-1}). FE_{riv} is a river export fraction representing the fraction (0-1) of total point and diffuse DIN inputs to the river that is exported as DIN. FE_{ws} is a watershed export fraction representing the fraction (0-1) of N from diffuse sources in the watershed that leaches to rivers as DIN. Several of the model components (non-point sources, N fixation) and N sinks are modeled, in part, as a function of system hydrology. Because of NEWS-DIN's structure, it is possible to estimate both the total rate of DIN export to coastal regions (Figure 4A) and the relative contribution of DIN to the coastal zone coming from point and non-point sources (Figure 4B). A full description of the model is available on our website: (http://marine.rutgers.edu/globalnews/data/NEWS_Papers_Submitted_2005/NEWS-DIN_mss_17_2_05-1.pdf ; username: globalnews, password: gl0balnews).

NEWS-DIN explains 72-83% of DIN export (kg N $basin^{-1}$ yr^{-1}) in validation basins (basins not used to calibrate NEWS-DIN), depending on the validation dataset used (Dumont et al., In Press). When compared with other DIN export models (Seitzinger and Kroeze, 1998; Smith et al., 2003; Green et al., 2004), NEWS-DIN demonstrated the highest R^2 between measured and modeled DIN export.

2.3.3 NEWS-DIP

We will use our recently developed, global model (NEWS-DIP; Figure 3c) to predict DIP export from Central Valley watersheds (NEWS-DIP; Harrison et al., In Press). This model predicts DIP yield (P) as a function of point source and non-point source P inputs, weathered P, reservoir retention, and consumptive use. The model's central equation is:

$$P = (Q_{act} / Q_{nat}) \cdot (1 - D) \cdot (H \cdot E_{cap} + (1/(1+(R/a)^{-b})) \cdot (W_{max} + L_{max} \cdot (P_{fert} + P_{am})))$$

where P is the area-weighted mean DIP yield (kg P km^{-2} yr^{-1}) for an entire river basin (as opposed to DIP-load (kg P basin^{-1} yr^{-1}) or DIP concentration (mg P-L^{-1})). P is calculated as a function of within-basin P sources and sinks. Source terms include point sources and diffuse sources. Point sources are calculated as a function of population density (H) (individuals km^{-2}) and per-capita DIP yield (E_{cap}) (kg P person^{-1} yr^{-1}). Diffuse sources are calculated as a function of runoff (R) (m yr^{-1}), fertilizer P inputs (P_{fert}) (kg P km^{-2} yr^{-1}), animal manure P inputs (P_{am}) (kg P km^{-2} yr^{-1}), and four calibrated coefficients defining the shape of the runoff response curve for weathering and non-point DIP sources (a, b, W_{max}, and L_{max} ; constrained to observation-based ranges). As with NEWS-DIN, sinks include consumptive water use, calculated as the ratio of contemporary river discharge (Q_{act}) to pre-dam river discharge (Q_{nat}), and within-basin DIP retention due to DIP trapping in reservoirs (D) (0-1). As with NEWS-DOC and NEWS-DIN, input variables for global application consisted mainly of spatially explicit, 0.5º x 0.5º resolution gridded datasets, which were used to compute area-weighted, basin wide means. This approach was applied at the global level because of a lack of higher resolution data. Application to CV watersheds will allow for a higher resolution analysis.

Like NEWS-DOC, and NEWS-DIN, NEWS-DIP can be used to calculate the percent contribution from various land-based sources, including point sources of P, naturally weathered P, fertilizer P, and Manure P. For more detailed information on the NEWS-DIP model, see Harrison et al. (in Press), available at: (http://marine.rutgers.edu/globalnews/data/NEWS_Papers_Submitted_2005/2004GB002357R.pdf ; username: globalnews, password: gl0balnews). When applied at the global scale, NEWS-DIP explains 74% and 61% of the variability in per-basin DIP export (DIP load) in calibration and validation basins respectively.

2.3.4 Accounting for Human Modification of CV Hydrology

The SJR system has at least 25 major reservoirs, 13 major agricultural diversions, and many more minor reservoirs and diversions (Krazer and Sheldon 1998), and the Sacramento system, though somewhat less altered, is still largely a human-regulated system with respect to water. NEWS models currently account for dam and diversion impacts on quantity of water discharged through rivers by correcting for consumptive water use and, in the case of NEWS-DIN and NEWS-DIP, by accounting for DIN and DIP removal in reservoirs as a function of water residence time. We will therefore need to estimate the magnitude of human influence on discharge in each study basin (potential (pre-dam and diversion) discharge minus actual discharge) and reservoir residence time for major reservoirs in each basin). We have already succeeded in attaining information on diversions accounting for approximately 65% of the agricultural diversions in the SJR Basin (Table 1), and will work with the appropriate agencies to attain the necessary data on reservoir inflows and mean water residence times, and additional agricultural diversions.

2.4. Q1. What are the relative contributions of various land-based sources of DIN, DIP, and DOC to nutrient and DOC loads in Sacramento and San Joaquin River systems?

In a recent report Kratzer et al. (2004) used nutrient concentration and isotope data to suggest likely sources of nutrients to land-use types within the SJR system, but did not quantify the relative contribution of different land use types to nutrient and DOC export from the SJR system. To do this would have required the application of a model. However, such models do not currently exist for CV basins. We will take monitoring data to the next step by applying NEWS-DIN, NEWS-DIP, and NEWS-DOC to sub-basins of the San Joaquin and Sacramento rivers where validation data are available. We will also apply these models to the entire Sacramento and SJR basins to estimate total DIN, DIP, and DOC flux and land-based DIN, DIP, and DOC sources to the Bay-Delta. For all of these initial runs, we will use higher spatial resolution input datasets than were used for global model runs. Rather than the 0.5 degree input data (approximately 2500 km^2/grid cell), we will use 30m to 1km resolution input datasets (Table 1). To distinguish region-specific versions of NEWS models from the Global NEWS models, we will hereafter refer to the regional models as CV-NEWS-DIN, CV-NEWS-DIP, and CV-NEWS-DOC. In addition to predicting annual average fluxes and sources, we will explore the possibility of using CV-NEWS models to estimate seasonal DIN, DIP, and DOC fluxes.

After running our models, we will compare model estimates with measured nutrient fluxes. We will also compare model-estimated sources with field-based estimates of DIN, DIP, and DOC leaching to surface waters. Additionally, where possible, we will compare CV-NEWS predictions with source apportionment estimates based on isotope data (e.g. Kratzer et al., 1998).

We will also evaluate seasonal and inter-annual patterns in nutrient fluxes from several "indicator" watersheds in the SSJ system, watersheds that have a dominant land use type (generally urban or agricultural; Domagalski and Dileanis 2000). We will compare these fluxes with temporal patterns in nutrient inputs to the landscape (using data in Table 1), and use the results of this analysis to evaluate a) whether this approach gives additional information about the magnitude of urban and agricultural C, N, and P sources to surface waters and b) whether our models are attributing sources correctly on the landscape. For example, in an agriculture-dominated watershed, it should be possible to use a correlation between increased N or P application over the past 20 years with increases in N and P fluxes to develop a relationship between N and P loading and nutrient loss to surface waters (mass balance analysis). It should also be possible to see pulses of N and P following major irrigation and fertilization periods, whereas urban sources should be relatively constant (e.g. Harrison et al., 2003).

With respect to our analysis of DOC, we will pay particular attention to the role of wetlands, which are thought to be a major source of DOC on the landscape both in the SJR system (Kratzer et al. 2004) and more generally (Mulholland 2003; Harrison et al. In Press a). However, there has not yet been an effort to quantify the amount of DOC coming from wetland sources in either the Sacramento or SJR systems, and therefore how sensitive DOC fluxes are to potential future changes in wetland extent. We will use CV-NEWS-DOM to carry out this analysis.

With respect to DIN, past work suggests that a recent increase in subsurface drainage from agricultural fields (tile drainage) is largely responsible for the observed increase in river-borne DIN (Kratzer and Sheldon 1998), but other factors could be contributing as well. For example, manure production, N-deposition, and human population density have all increased substantially over the period of observed increase in DIN. We will use CV-NEWS-DIN to evaluate the potential contribution from each of these sources to SJR and Sacramento River DIN fluxes.

Though phosphorus concentrations in the SJR have declined since the onset of widespread sewage treatment in the late 1960s, loading of non-point P to basin land surface has continued to increase (e.g. from 17,900 ton P/yr in 1970 to 24,200 kg P/yr in 1990; Kratzer and Sheldon 1998), suggesting that P concentrations may soon begin to rise again as non-point sources increasingly contribute P to CV river systems. This change could play an essential role in SJR ecosystem function, as preliminary analysis of SJR N:P ratios suggests that algal productivity is limited by P availability (median TN:TP at Maze Rd. = 38; Fig 2a; Dahlgren Unpublished data). We will use CV-NEWS-DIP to evaluate the relative importance of non-point P sources in contributing to river-borne DIP in CV river systems.

2.5. Q2. How can we improve our ability to predict river DOC, DIN, and DIP export and sources?

The work outlined in the previous section will constitute the first step in what will be an iterative process of model application and model refinement. After each model run, we will compare model predictions with measured annual and seasonal fluxes at each gauging station for which there is sufficient measurement data. We will evaluate outliers on these plots for consistent traits, and will consider accounting for those traits in subsequent versions of CV-NEWS models.

We will not initially recalibrate the original Global NEWS models to CV fluxes for the reasons outlined in section 2.3. However, if concerns over model accuracy dictate that we re-calibrate CV-NEWS models specifically for Central Valley Regions, then we will re-validate CV-NEWS models as well. To accomplish this, we will reserve at least 25% of the basins for which we have nutrient flux data, and not use them in model calibration. We will then test the ability of CV-NEWS models to predict DIN, DIP, and DOC export in the basins that were not used for model calibration. We will also evaluate the ability of both un-calibrated and calibrated CV-NEWS models to predict nutrient and organic matter fluxes from basins with newly collected data. Throughout first two years of our proposed three-year project, collection of additional data will be occurring. We will not initially use these data in our model runs, but will reserve them as a model validation dataset. At beginning of third year, we will test CV-NEWS models against the newly-collected validation data.

Eventually, it is our aim to incorporate higher temporal resolution, within sub-basin dynamic interactions of elements and water, and estimates of DOC quality as well as bulk quantity in CV-NEWS-models. We have recently developed the capacity to simulate within-basin nutrient transformation for global models (Wolheim et al., Submitted). However, even without these refinements, the work that we

have proposed represents a significant advance over the state of nutrient export modeling in the CV region. Nonetheless, as time permits, we will also work to incorporate the aforementioned improvements. With respect to the incorporation of a DOC quality component, we will work with Dr. Brian Bergamaschi to incorporate growing understanding of DOC sources and composition (gained through intensive study of the Willow Slough watershed) into future versions of our DOC model. We will also explore opportunities for collaboration with the group at the California Department of Water Resources that is developing the Delta Simulation Model II (DSMII; http://modeling.water.ca.gov/delta/models/dsm2/), to see whether there is a potential to combine the biogeochemical sophistication of the NEWS models with the high spatial and temporal resolution and computing power associated with DSMII.

2.5.1 Error, Efficiency, and Sensitivity Analyses

In addition to attempting to reduce model error by exploring other potential controlling variables and higher resolution input datasets, we will also explicitly quantify model uncertainty. Three aspects of uncertainty will be explored: 1) uncertainties associated with river nutrient export observations (sampling approach: tools and techniques, sampling locations, and sampling rate) leading to quantification of uncertainties associated with interpolation and extrapolation both in space and in time; 2) uncertainties associated with model boundary conditions (upscaling and downscaling issues associated with climate data, digital elevation models, nutrient inputs, and other parameters as noted above); and 3) uncertainties associated with models (parameterization of processes, propagation of errors through uncertainties in boundary conditions). Every effort will be made to ensure that the best available data is used for model validation or model input.

Once we are satisfied with model performance, we will evaluate the contribution of individual model components to model predictive capacity as in Harrison et al. (In Press a). To accomplish this, we will evaluate change in model efficiency (a measure of deviation from the 1:1 line of measured vs. modeled nutrient export; Nash and Sutcliffe 1970) upon removal of model components (e.g. in the case of the DIP model point sources, non-point sources, weathering sources, consumptive use, and reservoir DIP retention).

We will also subject the CV-NEWS models to sensitivity analyses in which we vary each model input and coefficient and each combination of inputs and coefficients and quantify model response to these variations. This analysis will indicate how sensitive our models are to errors in input data or parameter estimation. Together, these analyses will suggest how accurate CV-NEWS-based estimates are likely to be, and where our understanding of DOC, DIN, and DIP transport is lacking and must be improved as in (Harrison et al., In Press a and b).

2.7. Q3. How are river DOC, DIN, and DIP loads and sources likely to change as a function of climate, population growth, and land-use change in the next few decades?

To this point there has not been an effort to forecast how river nutrient or DOC fluxes the SSJ system will respond to likely future changes in climate, water consumption, fertilizer application, or population growth. The understanding we gain by addressing questions 1 & 2 will poise us to make the first quantitative, spatially explicit predictions as to how nutrient fluxes and sources in CV river basins are likely to change as a function of these potential anthropogenic perturbations.

We will use the models developed to address Q1 and Q2, in conjunction with estimates of water availability (due to climate change), population growth, water-use, and fertilizer use to estimate likely future rates and sources of DOC, DIN, and DIP transport through the CV rivers.

Before running future projections, we will first test model response to multiple simultaneous changes in model inputs by using 1975 input data (Table 1) to hind-cast to 1975. We will then test model performance in basins for which sufficient validation data is available (at least 20 sub-basins; C. Kratzer Pers. Comm.).

We will then apply our CV-NEWS models to several possible future scenarios, including: 1) a business as usual (BAU) projection of 2030 land-use, population-density, and fertilizer inputs (e.g. Bouwman et al., 2004), 2) a projection with current nutrient inputs and hydrology consistent with global warming predicted reductions in snow-pack and water availability, and 3) a projection incorporating both the BAU projection of nutrient loading to the landscape and projected climate change and resultant reduced snow-pack. We already have datasets required for a coarse-scale (0.5 degree) land-use change projection, but will use finer resolution data as available (e.g. 30 m resolution land-use data from NLCD-USGS and county-level population projections; Table 1). Data for climate projection will be similar to that presented in Miller et al. (2003) and Snyder et al. (2004).

2.8. Schedule of Tasks and Feasibility

We will spend the first six months of the project gathering, collating, and quality controlling nutrient concentration and water discharge data, delineating watersheds at the appropriate scale (or attaining existing watershed delineations from the USGS, as shown in Kratzer and Shelton 1998; Domagalski and Dileanis 2000), associating land-uses with sub-basin watersheds, and gathering as much information as possible regarding the amounts and timing of nutrient and water dynamics in the CV river systems.

Over the subsequent year of the project (5/2006-5/2007), we will use data collected during the initial six months, along with CV-NEWS models, to develop estimates of current DIN, DIP, and DOC fluxes through the SJR and Sacramento River systems, as well as the relative importance of various land-based sources of those nutrients. We will also use this time to refine, validate, and evaluate model uncertainty, model efficiency, and model sensitivity. In addition, we will be gathering (or creating based on past trends) additional input data necessary to run model projections, and preparing a manuscript reporting the results of our data-mining exercise (Section 2.4), quantifying patterns and controls of DIN, DIP, and DOC export in the Sacramento and SJR systems.

From June 2007-June 2008, we will focus our efforts on developing and running model forecasts for DIN, DIP, and DOC export and sources. We will simultaneously be preparing a paper on our efforts at present-day source estimates, with a planned submission date of December 2007. Finally, from June 2008-August 2008, we will prepare the future projection manuscript(s) for submission. Throughout the duration of the project, R. Dahlgren will continue to collect additional bi-weekly water quality samples that can be used in model validation.

We anticipate that the work we have proposed is feasible given that it includes no fieldwork or laboratory-based experiments and the majority of the required datasets are either publicly available or already in our possession (Table 1). In addition, Harrison has recently carried out an analysis of similar scope at the global scale in a similar time frame.

3. Anticipated Products and Benefits

3.1. Benefits to CALFED

The research we have proposed specifically addresses two of CALFED's main objectives: 1) improving ecosystem quality, and 2) improving water quality. Nutrients and DOC affect both water and ecosystem quality in fundamental ways. By increasing our understanding of the land-based controls of nutrient and DOC inputs to the Bay Delta system, this work will contribute to CalFed's ability to manage water quality and ecosystem function effectively. This work also directly addresses CALFED's three priority topic areas by: 1) improving the understanding the relationship between water operations and biological resources (e.g. dam releases and management of irrigation waters likely have a huge impact on nutrient and organic matter transport, which in turn affects downstream ecosystems), 2) improving understanding of ecological processes and their relationship to water management and key species (e.g. the relationship between nutrient loading and DO in the lower SJR), and 3) developing an analytical framework (i.e. models) to improve understanding of the implications of future changes.

The work outlined above will also lead to: 1) an updated and consolidated water quality and discharge database for Sacramento and San Joaquin systems 2) models relating land-use to nutrient and DOC loads to CV rivers and to the Bay Delta; 3) estimates of current and future (2030) DIN, DIP, and DOC loading as well as estimates of the major land-based sources contributing to this loading; 4) scholarly articles published in peer-reviewed journals; and 5) training for at least one postdoctoral scholar and one undergraduate researcher.

The quality of California's surface waters is essential to the health and well-being of CA's citizens. The Sacramento and San Joaquin systems provide drinking water to over 22 million Californians and habitat for multiple threatened fish species. However, DIN, DIP, and DOC loading brought on, in part, by CA's intensive land-use and urbanization, and rapid economic development threaten both. The nutrient export models we propose to develop and apply to the SSJ system will constitute a step towards a system of models that can contribute to the protection of CA's rivers and Bay-Delta region while still allowing for continued economic growth. Specifically, the models we are proposing to develop will provide managers with initial insight into what land-uses sources in specific watersheds are most important in contributing to water quality degradation. As such, these models will eventually grant insight into potential eutrophication-mitigating activities that managers and policy makers can encourage or enforce. This insight will likely be applicable to the agricultural water quality waiver currently in force in California (California Regional Water Quality Control Board, 2004). In addition to contributing tools that can help direct the reduction of N, P, and C loading to coastal systems, these models will also likely provide managers and policy-makers with a tool to forecast how different development scenarios are likely to affect

river and delta water quality. Such information may help managers and policy makers set priorities. Finally, as there is no field-work associated with the work we have proposed, it presents a cost-effective project that utilizes historic datasets and ties together multiple existing CALFED-funded projects.

3.2. Benefits to Fellow

The proposed research will benefit the fellow in several ways, including: 1) career development by providing resources required for peer-reviewed publications; 2) continued training and experience working with regional scale nutrient transport modeling; 3) development of professional relationships between fellow and CV/CALFED scientists and policy-makers; and 4) providing the fellow with experience administering a grant.

3.3. Benefits to Research Mentor

The proposed research will benefit the research mentor (Dr. R. Dahlgren) in several ways, including 1) adding value to R. Dahlgren's current research efforts by providing a way to extrapolate from water quality monitoring data (collected as part of a CALFED grant to monitor SJR water quality) to basin-wide patterns of nutrient and DOC transport; 2) contributing experience and expertise on aquatic biogeochemical processes and modeling to R. Dahlgren's lab group; 3) co-authorship with fellow on peer-reviewed publications that substantially utilize the aforementioned water quality monitoring dataset or to which R. Dahlgren makes a substantive intellectual contribution; 4) contact with a likely future collaborator; and 5) an additional link to the CALFED community.

3.4. Benefits to Community Mentor

The proposed research will benefit the CALFED community mentor in several ways, including: 1) adding value added to B. Bergamaschi's current research efforts by providing a tool to explore regional-scale implications of CALFED-funded, catchment-scale Willow Slough experiment; 2) contributing expertise and experience to B. Bergamaschi's group; 3) co-authorship with fellow on peer-reviewed publications to which B. Bergamaschi makes a substantive intellectual contribution peer-reviewed publications; and 4) contact with a likely future collaborator.

Table 1. A subset of the datasets (currently in our possession) that will be employed in analysis of land-use-river DOC, DIN, and DIP-loading relationships, current, historical, and future estimates of DOC, DIN, and DIP export and concentrations.

Dataset	***Brief Description and Source***
River nutrient and water discharge data	US Geological Survey WQN (Alexander et al., 1996), US Geological Survey NAWQA (http://water.usgs.gov/nawqa/), National Water Information System (NWIS), US-EPA Storage and Retrieval (STORET), UC-Davis water quality dataset (R. Dahlgren Pers. Comm.)
30 m land use	Land use in 24 classifications, including wetlands, irrigated and dryland agriculture, forest, pasture, and urban classifications (National Land Cover Characterization 1992-USGS)
County-level N and P fertilizer use	Fertilizer use by county for the years 1945-1991 (http://spo.nos.noaa.gov/projects/cads/description.html)
County-level manure N and P production	Agricultural census data (http://spo.nos.noaa.gov/projects/cads/description.html)
1 km basin delineations	Hydro 1k (Verdin et al., 1996)
Water Diversion Data	http://esd.lbl.gov/people/nwquinn/Grassland_website/sanjoaquin/agdiversion/index.htm
County-level historic and projected population data	http://www.dof.ca.gov/HTML/DEMOGRAP/DRU_Publications/Projections/P3/P3.htm
0.5º gridded N-fixation	N-Fixation estimate (Cleveland et al., 1999)
0.5º gridded N fertilizer application	Fertilizer application by crop type for 1975, 1995, and 2030
0.5º gridded N manure	Manure application by land-use type for 1975, 1995, and 2030
1º gridded NHx and NO_y deposition	NHx and NOy deposition by decade (1860-2000) and projected N deposition (2025 and 2050) (Fig. 3)
Sewage treatment plant discharge	Discharge for major wastewater treatment plants (Kratzer and Sheldon 1998)

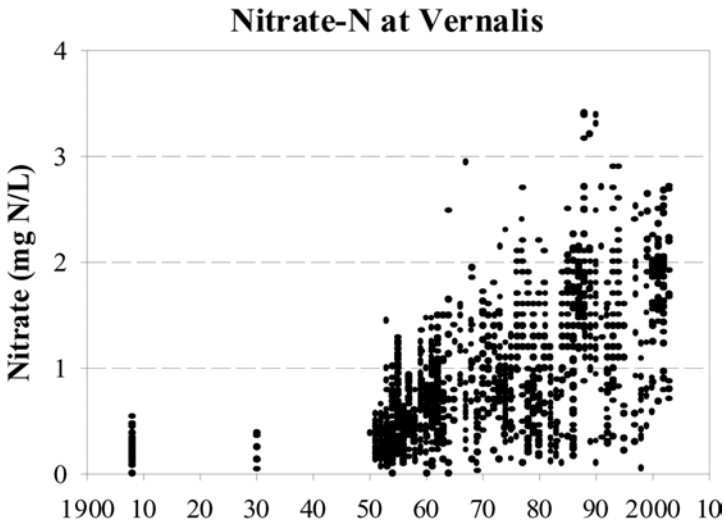

Figure 1. Nitrate (NO_3^-) concentrations (mg N/L) as measured near Vernalis (one of the most downstream water quality monitoring sites on the San Joaquin River; Figure 2a), showing an order of magnitude increase in recent years over pre-industrial levels (Data from R. Dahlgren).

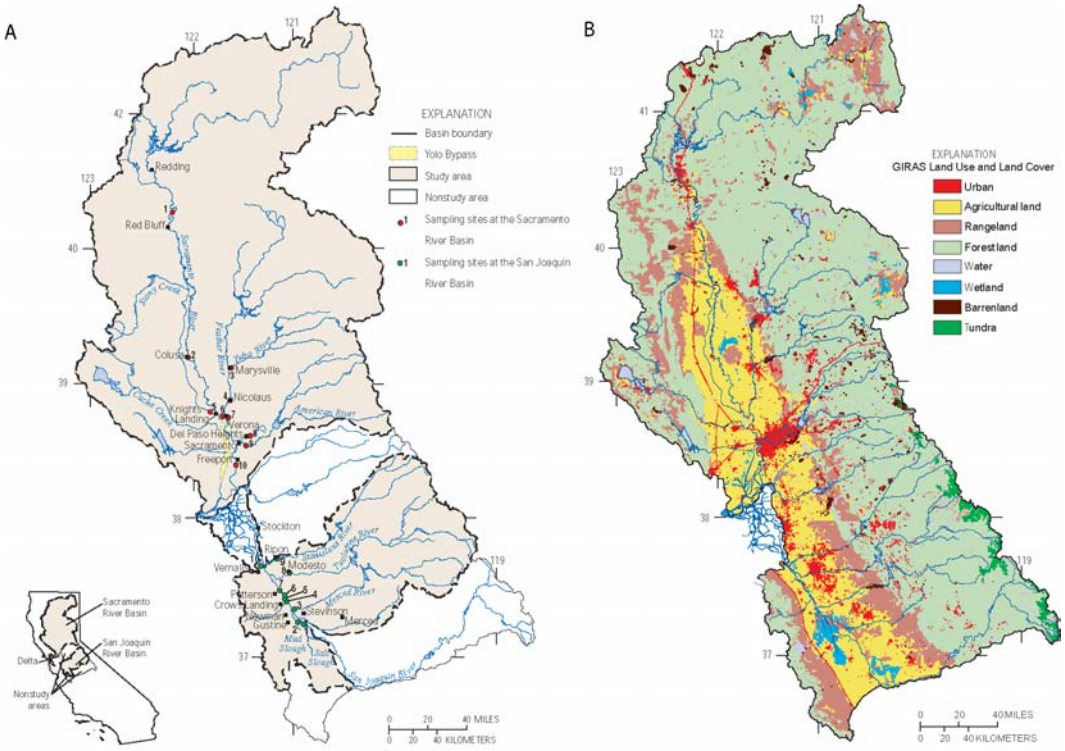

Figure 2. A) Study basins and a small fraction of the sampling sites that will be included in the study, and B) Land use in California's Central Valley from EPA GIRAS (Redrawn from Saleh et al. 2003).

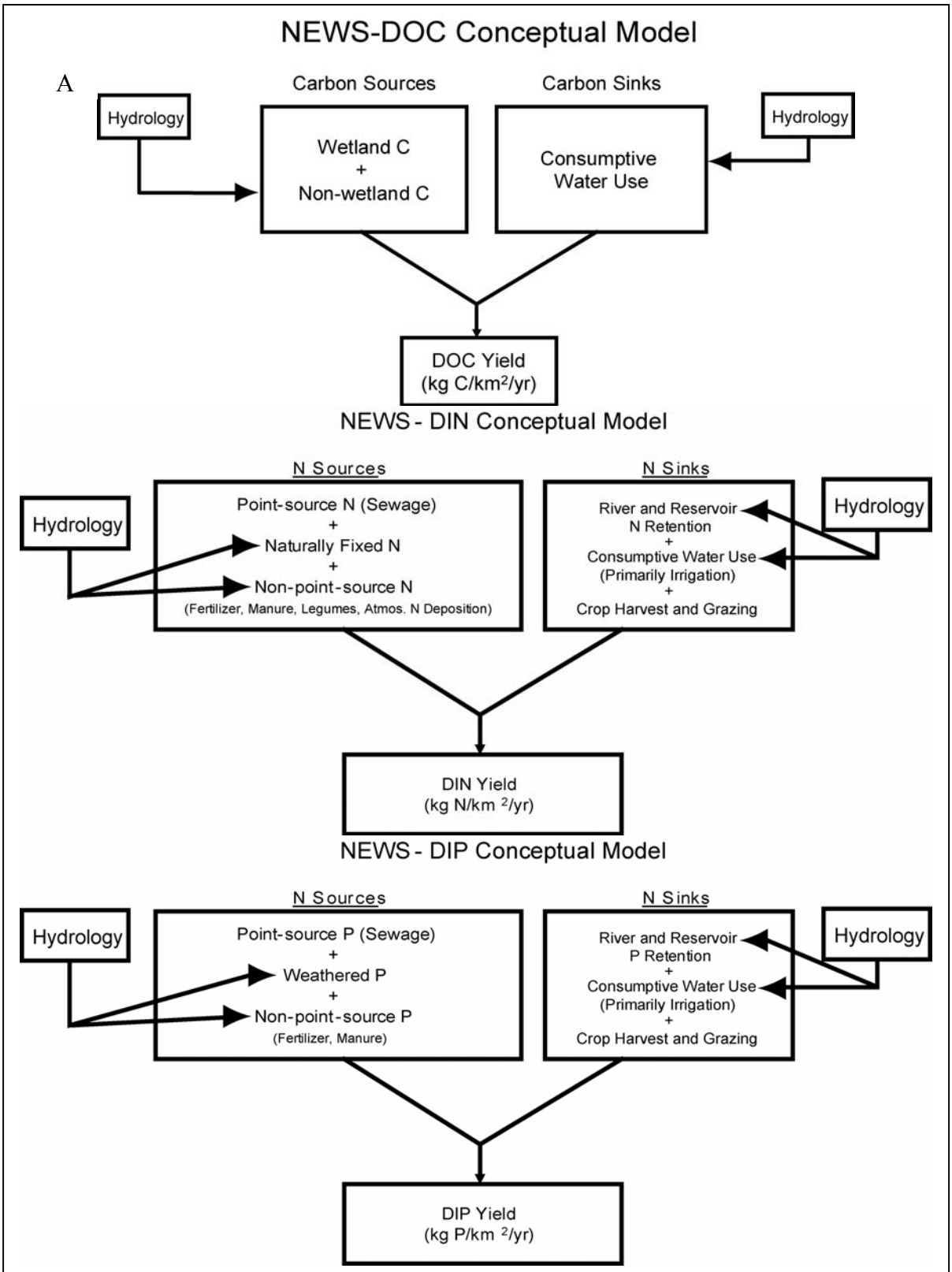

Figure 3. Conceptual models for A) NEWS-DOC, B) NEWS-DIN, and C) NEWS-DIP

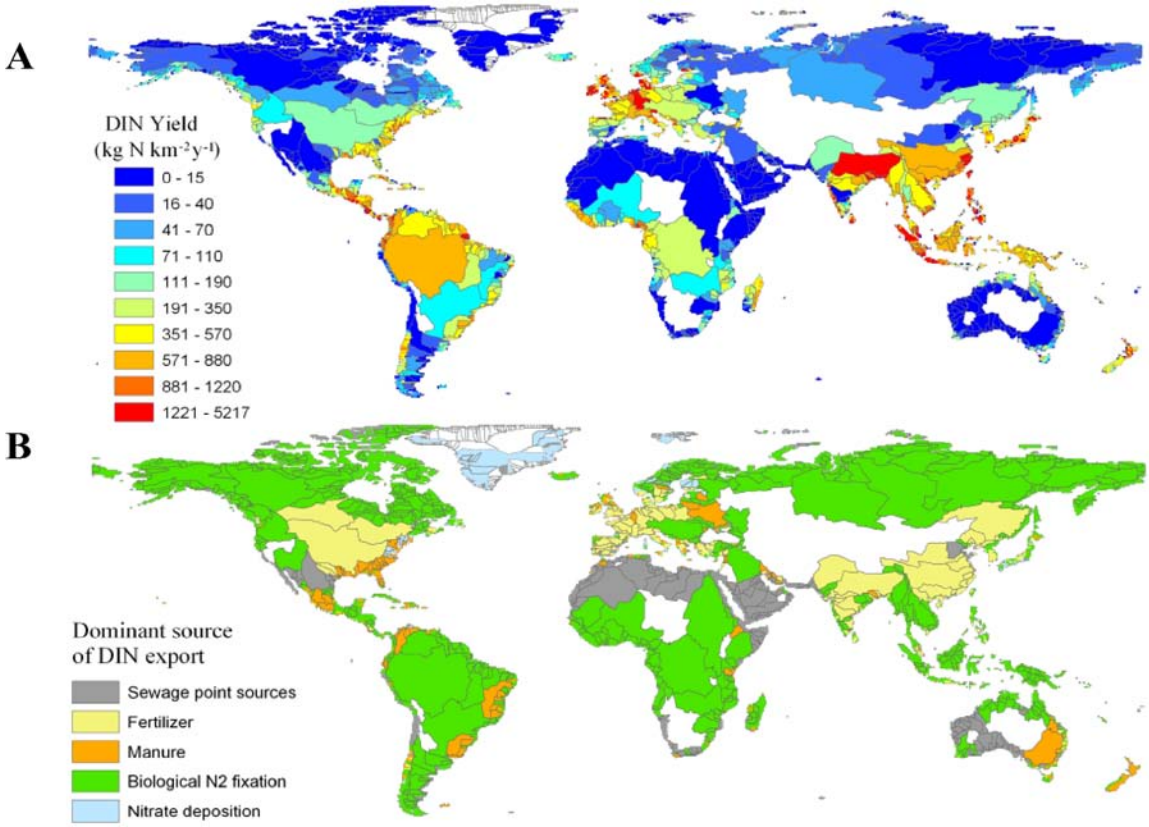

Figure 4. A) NEWS-DIN predicted DIN yield from watersheds globally, and B) NEWS-DIN predicted dominant sources of DIN to the coastal zone. Dominant sources are shown here, but NEWS-DIN can also be used to estimate percent contribution of DIN from specific land-based DIN sources. White areas flow to inland seas and were not included in this analysis. NEWS-DIP and NEWS-DOC are capable of producing similar output (Harrison et al., In Press, and Dumont et al., In Press)

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Budget Justification

Dr. J. Harrison and Dr. R. Dahlgren will be responsible for managing all aspects of the proposed work. A stipend of 45,000/yr is requested to cover J. Harrison's participation (12 mo/y). In addition, a fringe benefit rate of 30% is requested. Supply costs are required for computing equipment (desktop, laptop, printer, and other peripherals), software, including GIS license and extensions, statistical packages, Matlab and required Matlab extensions, and graphics software, and costs for acquisition of some proprietary databases (e.g. water use data). Funds to support communication, conference registration, and publication of research results are budgeted. Domestic and international travel funds are budgeted to support travel costs to one national and one international scientific meeting (1 person/yr). Funds are also requested to support a full-time undergraduate research assistant at a rate of $13/hour for 21 weeks during the first year of the project, and for 30 weeks during the second two years of the project. This undergraduate will primarily assist with data processing, but will also have an opportunity to be involved in additional aspects of the project. The indirect cost rate for the University of California, Davis on this project is 25% of direct costs, the rate set by the California Bay-Delta Authority Science Fellows Program.

FISCAL YEAR: All Years

PROJECT NUMBER	Randy Dahlgren **NAME OF MENTOR**
University of California-Davis **INSTITUTION**	John Harrison **NAME OF FELLOW**

			CALFED FUNDS
A.	**EXPENDABLE SUPPLIES AND EQUIPMENT**		
	1. Desktop computer/Laptop computer /Printer		4,500
	2. Software		2,000
	3. Proprietary datasets		8,000
	4. Office Supplies/phone/mail		3,000
	5.		
		TOTAL SUPPLIES	17,500
B.	**PERMANENT EQUIPMENT**		
	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL EQUIPMENT	0
C.	**TRAVEL**		
	1. DOMESTIC-U.S. AND ITS POSSESSIONS		
	2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		
		TOTAL TRAVEL	9,000
D.	**PUBLICATION AND DOCUMENTATION COSTS**	0 TOTAL PUB COSTS	6,500
E.	**OTHER COSTS**		
	1. Fellowship Stipend		135,000
	2. Fringe for postdoctoral stipend at UC-Davis(30%)		40,500
	3. Undergraduate research assistant		42,000
	4.		
	5.		
	6.		
	7.		
	8.		
		TOTAL OTHER COSTS	217,500
F.	**TOTAL DIRECT COSTS** *(A THROUGH E)*	TOTAL DIRECT COSTS	250,500
G.	**INDIRECT COSTS**		
	ON CAMPUS 25.0% OF 75,000		18,750
	OFF CAMPUS OF		0
		TOTAL INDIRECT COSTS	18,750
H.	**TOTAL COSTS**	TOTAL COSTS	269,250

DATE: _____

Prepared by: John Harrison
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Administrative Contact: Mary McNally
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E-mail: mmmcnally@ucdavis.edu

FISCAL YEAR: 9/1/05-8/31/06

PROJECT NUMBER	Randy Dahlgren **NAME OF MENTOR**
University of California-Davis **INSTITUTION**	John Harrison **NAME OF FELLOW**

			CALFED FUNDS
A.	**EXPENDABLE SUPPLIES AND EQUIPMENT**		
	1. Desktop computer/Laptop computer /Printer		4,500
	2. Software		2,000
	3. Proprietary datasets		2,000
	4. Office Supplies/phone/mail		1,000
	5.		
		TOTAL SUPPLIES	9,500
B.	**PERMANENT EQUIPMENT**		
	1.		
	2.		
	3.		
	4.		
	5.		
		TOTAL EQUIPMENT	0
C.	**TRAVEL**		
	1. DOMESTIC-U.S. AND ITS POSSESSIONS		1,500
	2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		1,500
		TOTAL TRAVEL	3,000
D.	**PUBLICATION AND DOCUMENTATION COSTS**	0 TOTAL PUB COSTS	1,500
E.	**OTHER COSTS**		
	1. Fellowship Stipend		45,000
	2. Fringe for postdoctoral stipend at UC-Davis(30%)		13,500
	3. Undergraduate research assistant		11,000
	4.		
	5.		
	6.		
	7.		
	8.		
		TOTAL OTHER COSTS	69,500
F.	**TOTAL DIRECT COSTS** *(A THROUGH E)*	TOTAL DIRECT COSTS	83,500
G.	**INDIRECT COSTS**		
	ON CAMPUS 25.0% OF 25,000		6,250
	OFF CAMPUS OF		0
		TOTAL INDIRECT COSTS	6,250
H.	**TOTAL COSTS**	TOTAL COSTS	89,750

DATE: _____

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FISCAL YEAR: 9/1/06-8/31/07

PROJECT NUMBER	Randy Dahlgren **NAME OF MENTOR**
University of California-Davis **INSTITUTION**	John Harrison **NAME OF FELLOW**

		CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT		
1. Proprietary Datasets		3,000
2. Office Supplies/phone/mail		1,000
3.		
4.		
5.		
	TOTAL SUPPLIES	4,000
B. PERMANENT EQUIPMENT		
1.		
2.		
3.		
4.		
5.		
	TOTAL EQUIPMENT	0
C. TRAVEL		
1. DOMESTIC-U.S. AND ITS POSSESSIONS		1,500
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		1,500
	TOTAL TRAVEL	3,000
D. PUBLICATION AND DOCUMENTATION COSTS	0 ˜AL PUB COSTS	2,500
E. OTHER COSTS		
1. Fellowship Stipend		45,000
2. Fringe for postdoctoral stipend at UC-Davis(30%)		13,500
3. Undergraduate research assistant		15,500
4.		
5.		
6.		
7.		
8.		
	TOTAL OTHER COSTS	74,000
F. TOTAL DIRECT COSTS *(A THROUGH E)*	TOTAL DIRECT COSTS	83,500
G. INDIRECT COSTS		
ON CAMPUS 25.0% OF 25,000		6,250
OFF CAMPUS OF		0
	TOTAL INDIRECT COSTS	6,250
H. TOTAL COSTS	TOTAL COSTS	89,750

DATE: _____

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FISCAL YEAR: 9/1/07-8/31/08

PROJECT NUMBER	Randy Dahlgren **NAME OF MENTOR**
University of California-Davis **INSTITUTION**	John Harrison **NAME OF FELLOW**

		CALFED FUNDS
A. EXPENDABLE SUPPLIES AND EQUIPMENT		
1. Proprietary Datasets		3,000
2. Office Supplies/phone/mail		1,000
3.		
4.		
5.		
	TOTAL SUPPLIES	4,000
B. PERMANENT EQUIPMENT		
1.		
2.		
3.		
4.		
5.		
	TOTAL EQUIPMENT	
C. TRAVEL		
1. DOMESTIC-U.S. AND ITS POSSESSIONS		1,500
2. INTERNATIONAL (INCLUDING CANADA AND MEXICO)		1,500
	TOTAL TRAVEL	3,000
D. PUBLICATION AND DOCUMENTATION COSTS	˜AL PUB COSTS	2,500
E. OTHER COSTS		
1. Fellowship Stipend		45,000
2. Fringe for postdoctoral stipend at UC-Davis(30%)		13,500
3. Undergraduate research assistant		15,500
4.		
5.		
6.		
7.		
8.		
	TOTAL OTHER COSTS	74,000
F. TOTAL DIRECT COSTS *(A THROUGH E)*	TOTAL DIRECT COSTS	83,500
G. INDIRECT COSTS		
ON CAMPUS 25.0% OF 25,000		6,250
OFF CAMPUS OF		
	TOTAL INDIRECT COSTS	6,250
H. TOTAL COSTS	TOTAL COSTS	89,750

DATE:

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Links to the CALFED Program

The quality of California's surface waters is essential to the health and well-being of CA's citizens. The Sacramento and San Joaquin systems provide drinking water to over 22 million Californians and habitat for multiple threatened fish species. However, dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), and dissolved organic carbon (DOC) loading brought on, in part, by CA's intensive land-use and urbanization, and rapid economic development threaten both. By providing guidance for land-use planners and information to citizen groups, the models we propose to refine and apply will help protect CA's rivers and Bay-Delta region while allowing for continued economic growth. Specifically, the models we are proposing to develop will provide managers with initial insight into what land-uses/N sources in specific watersheds are most important in contributing to water quality degradation. As such, these models will grant insight into potential eutrophication-mitigating activities that managers and policy makers can encourage or enforce. This insight will be directly applicable to the agricultural water quality waiver currently in force in California (California Regional Water Quality Control Board, 2004). In addition to contributing tools that can help direct the reduction of N, P, and C loading to coastal systems, these models will also provide managers and policy-makers with a tool to forecast how different development scenarios are likely to affect river and delta water quality. Such information may eventually help managers and policy makers set priorities in terms of environmental protection and mitigation.

The research program I have proposed has direct implications for four key elements of the California Bay-Delta Plan: drinking water quality, watershed management, ecosystem restoration, and science. Furthermore, the proposed research specifically addresses two of CALFED's main objectives: 1) improving ecosystem quality, and 2) improving water quality. By increasing our understanding of the land-based controls of DIN, DIP, and DOC inputs through CV river systems and to the Bay Delta system, this work will contribute to CalFed's ability to manage water quality and ecosystem function effectively. This work also directly addresses CALFED's at least three priority topic areas as stated in Appendix E of the CBDA Science Fellows Program Request for Applications by: 1) improving the understanding the relationship between water operations and biological resources (e.g. dam releases and management of irrigation waters likely have a huge impact on nutrient and organic matter transport, which in turn affects downstream ecosystems), 2) improving understanding of ecological processes and their relationship to water management and key species (e.g. the relationship between nutrient loading and DO in the lower SJR), and 3) developing an analytical framework (i.e. models) to improve understanding of the implications of future changes.

The proposed work will also lead to several products useful to the CALFED program, including: 1) an updated and consolidated water quality and discharge database for Sacramento and San Joaquin systems 2) models relating land-use to DIN, DIP, and DOC fluxes through CV rivers and to the Bay Delta; 3) estimates of current and future (2030) DIN, DIP, and DOC loads, concentrations, and major sources; and 4) several scholarly articles published in peer-reviewed journals. I will communicate results to the CALFED program in several ways. In addition to presenting my work at the annual CALFED Science Meeting, in an annual seminar, and through papers, I will collaborate with members of the CALFED and academic communities (e.g. Randy Dahlgren, Brian Bergamaschi, Charlie Kratzer, James Cloern, Carol Kendall, Beth Boyer, Toby O'Geen, Tamara Kraus, Brian Pelerin, and others). I will also interact directly with several existing CALFED-funded projects, including the Willow Slough study (PI-B. Bergamaschi), a monitoring and investigation of the San Joaquin River and tributaries related to dissolved oxygen (Co-PI-Randy Dahlgren), a study of flow-paths in oak woodlands (PI-Toby O'Geen – PIN no. 726), a study of the effects of constructed wetlands on nutrient and organic matter transport (Agricultural Water Quality Grant Program, Water Resource Control Board—PIN no. 2260, and a study of organic C transport and dynamics in the California Aqueduct (B. Bergamaschi and T. Kraus- USGS). In addition, I hope to interact with E. Boyer (UC Berkeley) on an inter-model comparison between NEWS models and a scheduled (but not yet initiated) application of the USGS **SPA**tially **R**eferenced **R**egressions **O**n **W**atershed **A**ttributes (SPARROW) model to the Central Valley. I will also make an effort to coordinate my modeling work with the Computational Assessments of Scenarios of Chage for the Delta Ecosystem (CASCaDE: PI-J. Cloern) project recently recommended for CALFED funding, making sure we use consistent scenario input datasets and about the potential to link NEWS models to their system of models. I will also contact and explore the possibility of collaborating with the hydrodynamic modeling groups at the California Department of Water Resources (DSMII and CALSIM II), to incorporate some of the insights from our modeling effort into these highly spatially and temporally resolved hydrodynamic and electroconductivity models for the Bay Delta and CV region.

Personal Statement

As I plan to pursue a career focused on research, teaching, and the communication of policy-relevant science to non-scientists, the CBDA Fellowship presents an ideal career development opportunity for me. I intend to continue developing a research program focused (in part) on the sources, transport and transformation of bio-active nutrients in surface waters. As such, the research program I have proposed would give me invaluable experience and skills. Carrying out the research I have proposed would allow me to strengthen my background in modeling surface water nutrient dynamics at the regional scale, an area that would nicely connect some of the regional-scale field and laboratory-based experiments I did for my thesis research with some of the global modeling work I have done more recently. I also have a long-standing interest in pursuing policy-relevant science and in communicating this science to management and policy communities. Given CALFED's strong commitment to strengthening communication between researchers, mangers, and policy-makers, it seems that working with the CALFED community through a CBDA fellowship would provide me with an excellent opportunity to continue to develop this interest. I also foresee a continued involvement with California-based water quality and ecosystems research beyond the three-year scope of this postdoctoral opportunity, and view the CBDA Fellowship as a launch pad for working in that capacity.

I am well prepared to carry out the research task that I have proposed. Both my doctoral and postdoctoral research efforts have focused on links between human activities and nutrient biogeochemistry of flowing surface waters (rivers and streams). In studying this topic, I have used field and laboratory-based experiments as well as modeling approaches to improve understanding of the biogeochemistry of bioactive nutrients at local, regional, and global scales.

For my thesis research, with Dr. Pamela Matson at Stanford University, I examined nitrogen dynamics and greenhouse gas production in streams and canals draining the Yaqui Valley, a rapidly developing Mexican agricultural valley (not unlike California's Central Valley). I used differences between land-use in eight Yaqui Valley catchments to examine the relationship between land-use, biogeochemical cycling, and greenhouse gas (carbon dioxide (CO_2), methane (CH_4), and N_2O) production in surface waters at the regional scale. Different land-use regimes led to striking differences in forms, temporal patterns, and overall amounts of nitrogen, phosphorus, and carbon export from land to sea. Nutrient over-enrichment in surface freshwater and coastal marine systems is important to understand because it can lead to problems such as increased algal growth, alteration and loss of seagrass habitats, increase in extent and duration of anoxic and hypoxic water, harmful algal blooms, and coral reef degradation, among others. Since the completion of my thesis, follow-up work has shown massive phytoplankton blooms in Gulf of California waters resulting from land-based N additions from the Yaqui Valley.

In the course of this project, I carried out an intensive observational program, employing state-of-the-art sampling, gas chromatographic, and mass spectrometric methods to examine denitrification rates, greenhouse gas production, and nitrogen transfer in Yaqui Valley surface drainage waters, their underlying sediments, and their receiving estuaries. In doing this work, I found some of the highest nitrous oxide fluxes ever reported from freshwater systems. I also discovered and characterized an in-stream day-night redox cycle, which resulted in rapid and pronounced changes in water chemistry, nutrient transfer, and trace-gas production/consumption. This was the first time such a rapid and complete diel redox oscillation has been characterized and quantified in a flowing freshwater system. It has important implications for downstream nutrient transfer in the Yaqui Valley, and perhaps in other biologically productive systems as well.

My thesis research experience prepared me to carry out my proposed research in many ways. It familiarized me with water quality monitoring and nutrient analysis techniques, carbon, nitrogen, and phosphorus biogeochemistry, and the workings of an intensive agricultural production system. I would likely draw upon each of these pieces of knowledge as I carry out the research I have proposed.

Also, as part of the larger, interdisciplinary Yaqui Valley project, I developed strong collaborations with researchers at Stanford University, the Carnegie Institute, UC Berkeley, the International Center for Improvement of Wheat and Maize (CIMMYT), Tec de Monterrey (Mexico's largest private university), and many others. These contacts (particularly at Stanford, Berkeley, and Carnegie) could prove quite useful as I pursue the research I have proposed.

As a postdoctoral associate working with Dr. Sybil Seitzinger at Rutgers University's Institute of Marine and Coastal Sciences, I currently co-chair an international, interdisciplinary, UNESCO-IOC/UNEP/NSF/NOAA-funded effort to develop a spatially explicit model of global nutrient (carbon, nitrogen, and phosphorus) export to the coastal zone. As the sole postdoc on this Global NEWS (**N**utrient **E**xport from **W**ater**s**heds) project, I am responsible for managing, coordinating, and synthesizing the diverse work of the 20+ project participants (For a more complete description of Global NEWS see http://marine.rutgers.edu/globalnews/). As part of this larger project, I have taken the lead on the development of spatially explicit, GIS-based, predictive global models for export of dissolved inorganic phosphorus (DIP) and dissolved organic matter (DOC, DON, and DOP) (See Harrison et al., In Press a and b referenced in the accompanying proposal.). I have also been integrally involved in the development of similar dissolved inorganic nitrogen (DIN) and particulate carbon, nitrogen, and phosphorus (PC, PN, and PP) export models (See Dumont et al., In Press and Beusen et al., In Press referenced in the accompanying proposal.). Additionally, with a subset of the Global NEWS group, I am exploring how climate change, year-to-year climate variability, land-use change, and dam construction have affected river nutrient exports at regional to global scales, and are likely to affect river nutrient export in the future. This work has given me extensive experience with the formulation, application, and evaluation of river nutrient export models. As such, it has given me many of the tools I will need to successfully carry out the research I have proposed to do if granted a CBDA Science Fellowship.

Other research experiences that have molded my interest, contributed to my research abilities, and may prove relevant to my ability to function effectively as a CBDA Science Fellow include: a year-long, Brown University-Funded investigation of the interaction between scientific research and environmental policy communities in Costa Rica, Taiwan, and England; research on nutrient-ecosystem interactions in Massachusetts estuaries and Northern Alaskan streams; oceanographic research in Antarctica; research on East Asian acid deposition and North American forest policy at Environmental Defense; and salmon research on the lower Snake River in Washington State.

In summary, I believe that a California Bay-Delta Authority Science Fellowship represents an ideal career opportunity for me, that the proposed research would be a valuable contribution to areas of importance to CALFED, and that my cumulative experience makes me uniquely qualified to carry out the research I have proposed. I can only hope you agree. In the mean time, thank you for your time and consideration.

Sincerely,

John Harrison

John Harrison

Institute of Marine and Coastal Sciences
Rutgers University
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New Brunswick, NJ 08901

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EDUCATION

2003 Ph.D., Geological & Environmental Sciences, Stanford University,
Dissertation: *Nitrogen Dynamics and Greenhouse Gas Production in Yaqui Valley Surface Drainage Waters*
Doctoral Committee: Pamela Matson (advisor), Peter Vitousek, Scott Fendorf, Robert Dunbar

1995 Sc.B. (Honors), Biology, Brown University

PROFESSIONAL EXPERIENCE

2003 - Present Postdoctoral Associate, Institute of Marine and Coastal Sciences; Co-Chair **Global N**utrient **E**xport from **W**ater**s**heds (Global NEWS) research group, Rutgers University, New Brunswick, NJ, Postdoctoral Advisor: Sybil Seitzinger

1995 - 1997 Samuel T. Arnold Fellow: Costa Rica, Taiwan, and England

1995 Research Associate: Environmental Defense, New York, NY

1994 - 1995 Research Assistant: Palmer Station, Antarctica and Scripps Institute of Oceanography

1993 - 1994 Writing and Rhetoric Fellow: Brown University, Providence, RI

1992 - 1994 (3 Summers) Research Assistant: Marine Biological Laboratory, Ecosystems Center, Woods Hole, MA and Toolik Lake, AK

1993 Creative writing teacher: Hope High School, Providence, RI

1991 Experimental Biologist's Aide: Oregon Department of Fish and Wildlife: Snake River Gorge, WA

SELECTED GRANTS AND AWARDS
(Proposals written by Harrison)*

2001 - 2003	*National Science Foundation (NSF) Dissertation Enhancement Award
1999 - 2002	*NASA Earth System Science Graduate Fellowship
1997 - 2000	*NSF Pre-doctoral Fellowship
1998 - 2000	*McGee Fellowships, Stanford University
1995 - 1997	*Samuel T. Arnold Fellowship, Brown University
1993 & 1994	NSF Research Experience for Undergraduates Grants
1992	*Woods Hole Marine Research Consortium Fellowship

PUBLICATIONS

Seitzinger, S. P., **J. A. Harrison,** B. J. Peterson, R. Lowrance, A. F. Bouwman, J. K. Bohlke, and C. Tobias (In Review) Denitrification across landscapes and waterscapes: a synthesis, *Ecological Applications*.

Harrison, J. A., N. F. Caraco and S. P. Seitzinger (In Press) Global distribution and sources of dissolved organic matter export by rivers: results from a spatially explicit, global model (NEWS-DOM), *Global Biogeochemical Cycles.*

Harrison, J. A., S. P. Seitzinger, A. F. Bouwman, N. F. Caraco, A. H. W. Beusen and C. Vörösmarty (In Press) Dissolved inorganic phosphorus export to the coastal zone: results from a spatially explicit, global model (NEWS-DIP), *Global Biogeochemical Cycles.*

Dumont, E., **J. A. Harrison**, C. Kroeze, E. J. Bakker and S. P. Seitzinger (In Press) Dissolved inorganic nitrogen export to the coastal zone: results from a spatially explicit, global model (NEWS-DIN), *Global Biogeochemical Cycles.*

Beusen, A. H. W., A. L. M. Dekkers, A. F. Bouwman, W. Ludwig and **J. A. Harrison** (In Press) Estimation of global river transport of sediments and associated particulate carbon, nitrogen, and phosphorus, *Global Biogeochemical Cycles.*

Glibert, P. M., **J. A. Harrison**, C. Heil and S. P. Seitzinger (In Press) Escalating worldwide use of urea: a global change contributing to coastal eutrophication, *Biogeochemistry.*

Harrison, J. A., P. A. Matson and S. Fendorf (In Press) Effects of a diel oxygen cycle on nitrogen transformations and greenhouse gas emission in a eutrophied, subtropical stream, *Aquatic Sciences*.

Harrison, J. A. and P. A. Matson (2003) Patterns and controls of nitrous oxide (N_2O) emissions from drainage waters of the Yaqui Valley, Sonora, Mexico. *Global Biogeochemical Cycles, 17,* (3), 1080.

Harrison, J. A. (2003) The carbon cycle (what goes around comes around), (www.visionlearning.com) - Online Textbook Module.

Harrison, J. A. (2003) The nitrogen cycle (of microbes and men), (www.visionlearning.com) - Online Textbook Module.

Deegan, L. A., A. Wright, S. G. Avayzian, J. T. Finn, H. Golden, R. R. Merson and **J. A. Harrison** (2002) Nitrogen loading alters seagrass ecosystem structure and support of higher trophic levels. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *12*:193-212.

Harrison, J. A. and P.A. Matson (2000) The Atmosphere as Global Commons, Chapter 10 in *Protecting the Commons*, Burger, J., R. Norgaard, E. Ostrom, D. Policansky, and B.D. Goldstein (eds.), Island Press, Washington D.C..

L. Harris et al. (1995) *A Moment of Truth*, **J.A. Harrison** (contributor) Environmental Defense Fund Press, New York.

THESES

Harrison, J. A. (2003) *Nitrogen Dynamics and Greenhouse Gas Production in Yaqui Valley Surface Drainage Waters*, Doctoral Thesis, Stanford University.

Harrison, J. A. (1995) Young-of-the-Year Arctic Grayling (*Thymallus arcticus*) Metabolism, Swimming Ability, and Temperature, Undergraduate Honors Thesis, Brown University.

IN PREPARATION

Harrison, J. A., A.F. Bouwman and S.P. Seitzinger. Global dissolved inorganic phosphorus (DIP) export to the coastal zone: 1970-2030. For *Global Biogeochemical Cycles.*

Seitzinger, S.P., **J. A. Harrison** A.F. Bouwman, N.F. Caraco, W. Ludwig, A. Beusen, C. Vörösmarty, and others. Sources and delivery of carbon, nitrogen, and phosphorus to the coastal zone, a synthesis of Global NEWS models. For *Global Biogeochemical Cycles.*

Seitzinger, S.P. and **J. A. Harrison**. Sources and Delivery of Nitrogen to Coastal Systems, Chapter 8 in *Nitrogen in the Marine Environment, 2nd edition*. D. Capone, D.A. Bronk, M. R. Mullholland, E. Carpenter Eds., Academic Press, New York.

Wollheim, W. M., C. J. Vörösmarty, A. F. Bouwman, P. Green, **J. A. Harrison**, M. Meybeck, B. J. Peterson, S. P. Seitzinger and J. P. Syvitski (In Review) A spatially distributed framework for aquatic modeling of the earth system (FrAMES), *Global Biogeochemical Cycles*.

Caraco, N.F., **Harrison, J. A.** and S.P. Seitzinger. Natural and anthropogenic controls on river borne dissolved organic carbon, nitrogen and phosphorus in the US. For *Ecosystems.*

Ludwig, W., **J. A. Harrison**, S.P. Seitzinger and W.H. Chang. Patterns of N and P export and coastal productivity in the Mediterranean: a regional application of global nutrient export models. For *Global Biogeochemical Cycles.*

SELECTED PRESENTATIONS AND INVITED LECTURES (* invited lecture)

***Harrison, J. A.**, Human impacts on watershed biogeochemistry: insights from modeling and field-based approaches, University of California-Davis, Davis, CA: April 2005.

***Harrison, J. A.**, Dissolved Inorganic Phosphorus Export to the Coastal Zone: Results from a Spatially-explicit, Global Model, University of California-Davis, Davis, CA: April 2005.

***Harrison, J. A.**, Rivers, Nutrients, and Greenhouse Gases: Insights from a Case Study and a Global Model, Purdue University, West Lafayette, IN: March 2005.

***Harrison, J. A.**, Human impacts on watershed biogeochemistry: insights from modeling and field-based approaches, Indiana University, Bloomington, IN: January 2005.

***Harrison, J. A.**, Global-NEWS models and global dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach, Institute of Ecosystem Studies, Millbrook, NY: January 2005.

Harrison, J. A., S.P. Seitzinger, N. Caraco, A.F. Bouwman, A. Beusen, and C.J. Vörösmarty. Dissolved inorganic phosphorus export to the coastal zone: results from NEWS-DIP, Ecological Society of America, Portland, OR: August 2004.

Harrison, J. A. Rapporteur, International Conference on Denitrification, Woods Hole, MA: May 2004.

***Harrison, J. A.**, S.P. Seitzinger, N.F Caraco, A.F. Bouwman, A. Beussen, and C.J. Vörösmarty. Global NEWS models and global dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach. UNESCO, Paris, France: May 2004.

Harrison, J. A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach at the regional scale, American Geophysical Union-Ocean Sciences, Portland, OR: January 2004.

***Harrison, J. A.**, Global NEWS models and global dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach. RIVM, Bilthoven, Netherlands: December 2003.

Harrison, J. A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach at the regional scale, Estuarine Research Federation, Seattle, WA: September 2003.

Harrison, J. A., S.P. Seitzinger, C. Kroeze, N.F Caraco, and E. Dumont. Dissolved nitrogen and phosphorus export to the coastal zone: early results from a multi-element, multi-form approach, Gordon Conference, New London, NH: July 2003.

***Harrison, J. A.** Spatially explicit models for river export of dissolved organic nitrogen and soluble reactive phosphorus: successes and challenges. UNESCO, Paris, France: March 2003.

Harrison, J. A. Nitrogen dynamics and greenhouse gas production In Yaqui Valley surface drainage waters, Thesis Defense, Stanford University, Stanford, CA: December 2002.

Harrison, J. A., and P.A. Matson. Rapid-onset anoxia, greenhouse gas production, and nitrogen transfer in a Mexican stream: National meeting of the Ecological Society of America, Tucson, AZ: August 2002.

***Harrison, J. A.** Nitrogen dynamics and nitrous oxide (N_2O) production in drainage waters and estuaries of an intensively farmed, subtropical valley, Department of Environmental Science, Policy, and Management, UC Berkeley, CA: January 2002.

Harrison, J. A., and P.A. Matson. Nitrogen dynamics and nitrous oxide (N_2O) in coastal streams of an intensively farmed, subtropical valley, Estuarine Research Federation, St. Petersburg, FL: October 2001.

Harrison, J. A. Nitrogen dynamics in Yaqui Valley drainage waters, Annual meeting of the Yaqui Valley research group, San Carlos, Mexico: October 2001.

***Harrison, J. A.** Nitrogen dynamics and nitrous oxide (N_2O) production in drainage waters and estuaries of an intensively farmed, subtropical valley, Water Resources Group at USGS, Menlo Park, CA: December 2001.

Harrison, J. A., and P.A. Matson. Nitrogen dynamics and nitrous oxide (N_2O) in coastal streams of an intensively farmed, subtropical valley, National meeting of the Estuarine Research Federation, St. Petersburg, FL: November 2001.

Harrison, J. A., Nitrogen dynamics and nitrous oxide (N_2O) in the drainage waters of the Yaqui Valley, Annual meeting of the Yaqui Valley research group, Stanford University, CA: October 2001.

Harrison, J. A., and P.A. Matson. Nitrous oxide (N_2O) emissions from drainage waters in an intensively farmed, subtropical valley: National meeting of the Ecological Society of America, Madison, WI: August 2001.

Harrison, J. A., and P.A. Matson. Nitrous oxide (N_2O) emissions from drainage waters in an intensively farmed, subtropical valley, Open Science Conference, Amsterdam, ND: July 2001.

Harrison, J. A., and P.A. Matson. Nitrous Oxide (N_2O) emissions from drainage waters in an intensively farmed, subtropical valley, National meeting of The American Geophysical Union, San Francisco, CA: December 2000.

* **Harrison, J. A.** Climate change: Is it real? Portland chapter of the World Affairs Council: November 2000.

Harrison, J. A., and P.A. Matson. Greenhouse gas emissions from drainage waters in an intensively farmed, subtropical valley, Snowbird, UT: August 2000.

Harrison, J. A., P.A. Matson. Greenhouse gas emissions from drainage waters in an intensively farmed, subtropical valley, National meeting of the Ecological Society of America: August 2000.

* **Harrison, J. A.** The role of natural scientists in Taiwanese and Costa Rican environmental policy formulation: successes and challenges: Presentation of Arnold Fellowship research results: Taiwan Forestry Research Institute; Taipei, Taiwan: July 1996.

* **Harrison, J. A.** The role of tropical ecologists in Costa Rican environmental policy: La Selva Tropical Research Station, Costa Rica: March 1996.

Harrison, J. A. Honors thesis presentation I – "Young-of-the-Year Arctic Grayling (*Thymallus arcticus*) Metabolism, Swimming Ability, and Temperature," Ecosystems Center, The Marine Biological Laboratory, Woods Hole, MA: December 1995.

Harrison, J. A. Honors thesis presentation II- *Ibid.* Brown University, Providence, RI: December 1995.

Harrison, J. A. "Food web dynamics in Waquoit Bay's Hamblin Pond, a ^{15}N tracer study."- Woods Hole, Summer Research Symposium: August 1992.

PROFESSIONAL SERVICE
President Rutgers-IMCS Postdoctoral Association; postdoctoral representative to faculty
Original Organizer of the Stanford Biogeochemistry Seminar 1999-2000
Reviewer for: *Biogeochemistry, Environmental Science and Technology, Ecological Applications, Global Biogeochemical Cycles, Journal of Contamination Hydrology, Journal of Environmental Quality, Limnology and Oceanography, and Water, Air, and Soil Pollution*

PROFESSIONAL MEMBERSHIPS
American Association for the Advancement of Science
American Geophysical Union
American Society of Limnology and Oceanography
Ecological Society of America
Estuarine Research Federation
Sigma Xi

WORKSHOPS
Stable Isotope Ecology Course: University of Utah, 1999
Integrating Research in a Teaching Environment Program: Stanford I-RITE course for communicating research to public, 2001
Nitrate Stable Isotopes Workshop: USGS, Menlo Park, 2002

OTHER
Proficient in Spanish; Some Chinese; Eagle Scout, 20+ years of violin and bluegrass fiddle; writer, editor, and special agent for Open Spaces Magazine, Portland, OR 1997-present

Plan for collaborating with community mentor

As someone who is both integrally involved with the CALFED effort and focused on water quality research, Dr. Brian Bergamaschi is a natural choice to be my CALFED community mentor. B. Bergamaschi's specific interest in DOC characterization and water quality is directly applicable to the project I have proposed. Furthermore, the additional expertise available through USGS in Sacramento will be invaluable as I carry out this project. In addition to B. Bergamaschi, I also anticipate interacting with a number of his colleagues at USGS (e.g. Charlie Kratzer, James Cloern, Noah Knowles, and Carol Kendall) and collaborators at UC Davis (e.g. Randy Dahlgren, Peter Hernes, Willy Horwath, and Toby O'Geen), UC Berkeley (Elizabeth Boyer), and others.

B. Bergamaschi has been involved with the CALFED community since 1997, and during that time has worked extensively in the area of water quality research, and served in numerous technical advisory capacities for CALFED. For example, as a member of the CALFED Bay Delta Program Water Quality Technical Committee he was coauthor of a report identifying local activities which may improve drinking source water quality. As a technical advisor to the CALFED Comprehensive Monitoring and Assessment Program, he assisted in the development of a monitoring and assessment plan for drinking water quality issues. He was a participant in an expert panel convened to identify important water quality research objectives in Sacramento-San Joaquin Delta (composed of representatives from academia, consultants, members of the California Department of Water Resources).

This background in research and technical oversight of CALFED Water Quality activities has provided B. Bergamaschi a solid understanding of both the science and policy associated with CALFED projects. He is also familiar with the workings of the CALFED process and will be able to advise me as to how best to communicate the results of my work to stakeholders. He has already put me in touch with a number of key players in the CALFED community and pointed me to useful sources of information regarding nutrient and water discharge data.

I plan to stay in close contact with B. Bergamaschi through frequent email exchanges, phone calls, and quarterly meetings and visits to Sacramento USGS (merely 30 minutes by car from Davis). I also intend to give occasional seminars (~ 1/yr) updating B. Bergamaschi and the rest of the community as to the status of my research. These seminars will present an opportunity to obtain feedback from the scientific community and to identify potential positive interactions that might be developed with members of the CALFED community. These seminars will be held either at UC Davis or USGS-Sacramento, and Dr. Bergamaschi and his lab will be invited to these.

Once model results from the Central Valley application of Global NEWS models have been accepted for publication in peer-reviewed journals, I will facilitate the sharing of model source code with anyone who is interested in using them. Additionally, I will provide any useful information that I derive from data mining effort to B. Bergamaschi and the rest of the CALFED community. Furthermore, I hope to work collaboratively on research articles and future research proposals with Dr. Bergamaschi and members of his group. Specifically, I hope to collaborate with postdoctoral fellows in Brian's lab who are working on different aspects of DOC transport and fate in California's rivers, streams, and aqueducts (e.g. Drs. Brian Pellerin, Tamara Kraus).

I also hope to interact directly with B. Bergamaschi through his recently funded CALFED project studying the Willow Slough watershed. The Willow Slough project aims to "1) Quantify the dominant chemical and physical processes affecting watershed export of DOC, nutrients, sediments, and salts by focusing on key locations on the hydrologic flowpath, and use this data to identify the land use types and characteristics related to high export of drinking water constituents of concern (DWCC), using a typical environment (Willow Slough) as a model environment, 2) Quantitatively assess the potential contribution of agricultural, natural and stream channel settings to DWCC in water exported from CV watersheds, and 3) Identify and characterize natural setting and practical land management practices useful for mitigating DWCC

export and assess the stakeholder support and costs of implementing them as part of an extensive outreach to farms and watershed groups and agencies."

The models I have proposed to develop would likely add substantial value to the Willow Slough project by providing a tool to use to scale up insights gained through intensive study of the Willow Slough watershed. They may also help focus Willow Slough measurements by suggesting which small-scale processes are likely to have important implications at regional scales. The regional modeling effort I have proposed would also benefit greatly from the insight and data gathered as part of this intensive study. For example, land-use and nutrient-specific leaching rates are going to be quantified as part of the Willow Slough project. These data would be particularly useful as a way to test whether model source apportionment predictions are reasonable.

In addition Dr. Randy Dahlgren, though technically my research mentor rather than my CALFED community mentor, will also serve as an effective link to the CALFED community. Dr. Dahlgren is involved with several CALFED-funded projects, including one project entitled "CALFED Directed Action Proposal For Monitoring and Investigation of the San Joaquin River and Tributaries Related to Dissolved Oxygen," supported by the CALFED Ecosystem Restoration Program.

In summary, sustained interactions with Drs. Bergamaschi and Dahlgren, combined with the inherently interdisciplinary nature of the work I have proposed, will assure a strong and lasting link to the larger CALFED community.

United States Department of the Interior

U. S. GEOLOGICAL SURVEY
Brian A. Bergamaschi, Ph.D.
California Water Science Center
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California State University
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IN REPLY REFER TO:

California Sea Grant College Program
Scripps Institution of Oceanography
8602 La Jolla Shores Drive, Building T-16
La Jolla, CA 92037
(858) 534-4440
CALFEDfellow@seamail.ucsd.edu

Monday, May 16, 2005

Dear Sir or Madame,

I have been asked to serve as CALFED mentor on John Harrison's proposal for the CALFED Postdoctoral program, entitled "Modeling Nutrient and Organic Carbon Loads and Sources in Central Valley Watersheds: Taking Existing Monitoring Data to the Next Stage."

The proposed work synthesizes existing disparate monitoring data into a cohesive analysis of the status and trends of water quality constituents of concern using existing validated modeling approaches. John's background and the work outlined in the proposal suggest a high probability that significant new findings will result from this research.

I highly recommend that this proposal be funded and pledge to cooperate in whatever way necessary to facilitate this important work.

Please call if you have any questions or need further information.

Sincerely,

Brian Bergamaschi

CALFED SCIENCE FELLOWS PROGRAM In cooperation with the California Sea Grant College Program	
PROJECT SUMMARY FORM	
Project Number:	**Revision Date:**
Project Title: **Modeling Nutrient and Organic Matter Export and Sources in Central Valley Watersheds: Taking Existing Monitoring Data to the Next Stage**	**Initiation Date:** 9/1/05
	Completion Date: 8/31/08
Mentor/Principal Investigator: Randy Dahlgren	
Affiliation: UC Davis	
Fellow: John Harrison	
Affiliation: UC Davis	
CALFED Funds:	**Last Year's CALFED Funds:**

OBJECTIVE:

The objective of the proposed research is to use existing data, in combination with models, to gain a quantitative understanding of current and likely future fluxes, sources and controls of DOC, DIN, and DIP transported through the Sacramento and San Joaquin River systems. Specifically, we will address the following research questions:

1. What are the relative contributions of various land-based sources of DIN, DIP, and DOC to the Sacramento and San Joaquin River systems?

2. How can we improve our ability to predict river DOC, DIN, and DIP concentrations, export, and sources?

3. How are river DOC, DIN, and DIP concentrations, loads, and sources likely to change as a function of climate, population growth, water demand, and land-use change in the next few decades?

RATIONALE:

High nitrogen and phosphorus (N and P) concentrations in the lower San Joaquin River (SJR) have been associated with episodes of low dissolved oxygen (DO) San Joaquin River that may act as a barrier to upstream migration of spawning Chinook salmon, and other anadromous fish species. DOC plays a role in the formation of potentially carcinogenic and mutagenic compounds (trihalomethane and haloacetic acids) during drinking water disinfection, and the Sacramento and San Joaquin Rivers (SSJ systems) constitute a dominant source of carbon to the Bay-Delta region, the source of drinking water for over 20 million Californians. In addition to its associated human health concerns, DOC is also important from ecosystem and biogeochemical perspectives. DOC constitutes an important source of organic matter, support over 75% of the San Francisco Estuary's net energy demands. In addition to feeding the Bay Delta ecosystem, DOC can control the availability of dissolved nutrients and metals, and affect the optical properties of aquatic systems. Clearly understanding N, P, and DOC sources and fluxes in CV rivers is important for planning the use of surface water resources in California's future.

There is currently an enormous amount of water quality and discharge information available for SSJ systems. However, these data have not yet been synthesized into models that can predict nutrient export from watersheds as a function of land use and nutrient inputs. Nor have they been used to quantify the relative importance of land-based nutrient sources within watersheds. We propose to refine and apply recently published global nutrient export models to the SSJ systems, thereby creating the first spatially explicit, models for predicting dissolved organic carbon, dissolved inorganic nitrogen, and dissolved inorganic phosphorus (DOC, DIN and DIP, respectively) export and sources for major Central Valley (CV) river systems. We will focus on DOC, DIN, and DIP initially because these compounds are the most abundant forms of bio-available C, N, and P, respectively in both the Sacramento and SJR systems. The formulation of models that can predict river nutrient fluxes as a function of land-based activities constitutes a critical step toward wise management of freshwater resources.

PROJECT SUMMARY FORM (continued)

Mentor/Principal Investigator: Dr. Randy Dahlgren

Fellow: Dr. John Harrison

METHODOLOGY:

We will use high-resolution land-use, nutrient loading, and water quality data to scale down recently formulated and published global models for the prediction of river dissolved inorganic nitrogen (DIN), dissolved inorganic phosphorus (DIP), and dissolved organic carbon (DOC) export. We will then apply these models to both the entire SSJ system and to sub-basins of those systems to estimate loads, concentrations, and sources of DIN, DIP, and DOC in Central Valley (CV) rivers.

After running our models, we will compare model estimates with measured nutrient fluxes. We will also compare model-estimated sources with field-based estimates of DIN, DIP, and DOC leaching to surface waters. Additionally, where possible, we will compare nutrient export model predictions with predictions based on isotope data.

We will iteratively refine NEWS models and will also work toward incorporating higher temporal resolution, within sub-basin dynamic interactions of elements and water, and estimates of DOC quality as well as bulk quantity in CV-NEWS-models. However, even without these refinements, the work that we have proposed represents a significant advance over the state of nutrient export modeling in the CV region. With respect to the incorporation of a DOC quality component, we will work with Dr. Brian Bergamaschi to incorporate growing understanding of DOC sources and composition (gained through intensive study of the Willow Slough watershed) into future versions of our DOC model. We will also explore opportunities for collaboration with the group at the California Department of Water Resources that is developing the Delta Simulation Model II (DSMII), to see whether there is a potential to combine the biogeochemical sophistication of the NEWS models with the high spatial and temporal resolution and computing power associated with DSMII.

We will also explicitly quantify model uncertainty. Three aspects of uncertainty will be explored: 1) uncertainties associated with river nutrient export observations (sampling approach: tools and techniques, sampling locations, sampling rate) leading to quantification of uncertainties associated with interpolation and extrapolation both in space and in time; 2) uncertainties associated with model boundary conditions (upscaling and downscaling issues associated with climate data, digital elevation models, nutrient inputs, and other parameters as noted above); and 3) uncertainties associated with models (parameterization of processes, propagation of errors through uncertainties in boundary conditions).

In addition, we will evaluate the contribution of individual model components to model predictive capacity. To accomplish this, we will evaluate change in model efficiency upon removal of model components. We will also subject the CV-NEWS models to sensitivity analyses in which we vary each model input and coefficient and each combination of inputs and coefficients and quantify model response to these variations. This analysis will indicate how sensitive our models are to errors in input data or parameter estimation. Together, these analyses will suggest how accurate CV-NEWS-based estimates are likely to be, and where our understanding of DOC, DIN, and DIP transport is lacking and must be improved.

Finally, we will use the models we develop, in conjunction with estimates of water availability (due to climate change), population growth, water-use, and fertilizer use to estimate likely future fluxes, concentrations, and sources of DOC, DIN, and DIP in the SSJ system. We will also apply our nutrient export models to several possible future scenarios, including: 1) a business as usual (BAU) projection of 2030 conditions, 2) a projection using current nutrient inputs and hydrology consistent with global warming predicted reductions in snow-pack and water availability, and 3) a projection incorporating both the BAU projection of nutrient loading to the landscape and projected climate change and resultant reduced snow-pack.

ACCOMPLISHMENTS: (New Project)

UNIVERSITY OF CALIFORNIA, DAVIS

BERKELEY DAVIS IRVINE LOS ANGELES RIVERSIDE SAN DIEGO SAN FRANCISCO SANTA BARBARA SANTA CRUZ

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May 18, 2005

California Sea Grant College Program
Scripps Institution of Oceanography
8602 La Jolla Shores Drive, Building T-16
La Jolla, CA 92037

Dear Fellowship Committee:

I am writing to enthusiastically support the application of **Dr. John Harrison** who has applied for a CalFed Postdoctoral Fellowship. I agree to serve as Dr. Harrison's research mentor and provide institutional support through the University of California – Davis for his proposed scope of work. At UCD, Dr. Harrison will be able to collaborate with scientists with a wide range of expertise in watershed sciences. My research team is involved in TMDL investigations in the Sacramento-San Joaquin River watersheds and in the "CalFed Directed Action Project for Monitoring and Investigation of the San Joaquin River and Tributaries Related to Dissolved Oxygen" (Will Stringfellow, PI). As a result, Dr. Harrison will be able to easily network with many of the key research groups involved in these activities. As part of these efforts, I am already collaborating on projects with Dr. Bergamaschi (USGS), who will serve as his community mentor. The demonstrated collaborations between my research team and several CALFED agency scientists will provide an excellent opportunity for synergism and cross-fertilization of ideas with respect to Dr. Harrison's proposed modeling activities. I expect that Dr. Harrison will foster these interactions and truly build upon the synergies of collaboration.

A number of visions for the future of Central Valley aquatic ecosystems include actions that could significantly affect the supply, transport and fate of nutrients, algae, dissolved and particulate organic matter, dissolved oxygen and other food web resources. To provide information on these water quality parameters, my research team has collected a wide range of water quality data over the past 6 years from the Sacramento and San Joaquin River watersheds (up to 35 sites). These data will provide critical information for model development and validation. Dr. Harrison's proposed modeling activities will provide the first critical synthesis of dissolved nutrient patterns at the scale of the Central Valley. More importantly, by examining water quality in a land-use framework, he will be able to provide critical information that can be applied to watershed management. He comes well prepared with state-of-the-art modeling experience and the ability to integrate California water quality patterns into a global context. While the proposed research may appear extremely ambitious, Dr. Harrison's previous experience with these models will allow him to quickly adapt his previous models without having to climb a steep learning curve of model development. Water quality data from several sources have already been compiled by several existing projects, which will greatly reduce the time required to compile the necessary data. Thus, the proposed research is very feasible for the given timeframe.

Dr. Harrison is a highly regarded young scientist with excellent academic and research records. Through the proposed project, he has the potential to make a very strong impact as his proposed modeling activities will provide the synthesis necessary to understand water quality parameters at the large watershed scale. I would also expect that Dr. Harrison will contribute to several of the ongoing process-level investigations that will greatly enhance the quality of these existing studies. Through my involvement in these studies, Dr. Harrison will be able to design and conduct ancillary water quality investigations to support his modeling activities. As part of these studies, he will have the opportunity to guide graduate and undergraduate students to assist with his research and modeling.

In sum, I feel that Dr. John Harrison would be an excellent candidate for a CalFed postdoctoral position examining ecological processes and their relationship to water management. He brings new ideas to the water quality monitoring arena that have the potential to greatly enhance our understanding of spatial and temporal patterns in Central Valley water quality.

Sincerely,

Dr. Randy Dahlgren
Professor of Soil Science and Biogeochemistry

Harrison, CBDA Fellowship-Research Mentor CV

CURRICULUM VITAE

May 2005

NAME: Randy Alan Dahlgren

TITLE: Professor of Soil Science & Biogeochemistry

ADDRESS: Soils and Biogeochemistry Section
Dept. Land, Air and Water Resources
University of California
Davis, CA 95616-8626

Telephone: (530) 752-2814
FAX: (530) 752-1552
E-mail radahlgren@ucdavis.edu

EDUCATION:

1987 Ph.D., College of Forest Resources, University of Washington, Forest Soils
1984 M.S., College of Forest Resources, University of Washington, Forest Soils
1981 B.S., College of Agriculture, North Dakota State University, Soil Science

POSITIONS HELD:

Professor of Soil Science, University of California-Davis, 7/97 to present
Associate Professor of Soil Science, University of California-Davis, 7/94 to 6/97
Visiting Scientist – Landcare Research and Massey University, Palmerston North, New Zealand 1/96 to 12/96
Assistant Professor of Soil Science, University of California-Davis, 2/89 to 6/94
Post-doctoral Research Associate, Dept. of Environmental Engineering, Syracuse University, 9/87 to 12/88
Research Assistant, College of Forest Resources, University of Washington, 6/81 to 8/87
Student Trainee, Soil Conservation Service, Summers 1978, 1979, 1980, Spring 1981

Administrative & Professional Activities:

Vice-Chair, Soils and Biogeochemistry Program, Dept. Land, Air and Water Resource (7/00 to 6/03)
Chair, Hydrologic Sciences Graduate Group (7/98 to 6/02)
Chair, College of Agriculture and Environmental Sciences Executive Committee (7/99 to 6/00)
Japanese Society for the Promotion of Science Fellowship (8/00 to 9/00)
Editorial Board – Soil Science and Plant Nutrition (1999 to 2002)
– Ecology and Ecological Monographs (2001 to present)
Review Panels: NSF Environmental Geochemistry and Biogeochemistry
National Research Council Associateship Program – Life Sciences
NASA Astrobiology Institute

Harrison, CBDA Fellowship-Research Mentor CV

Research Interests: Forest, rangeland and freshwater aquatic ecosystem biogeochemistry - interactions of hydrologic, geochemical, and biological processes in regulating nutrient cycling and surface and ground water chemistry; genesis and mineralogy in volcanic soils.

RESEARCH SKILLS:

Water analyses: ICP-OES, ICP-MS, AAS, Ion chromatography, TOC/TIC, pH and alkalinity, Al-fractionation, dissolved organic nitrogen (DON), QA/QC protocols. X-ray diffraction, IR spectroscopy, UV/Vis spectroscopy, gel permeation chromatography, SEM/TEM microscopy, plant tissue and soil digestions, standard solid-phase soil characterization, nutrient cycling, chemical equilibrium models, kinetic analysis, and computer applications.

TEACHING EXPERIENCE:

University of California, Davis

Science and Society 5	Crisis in the Environment?
Soil Science 10	Introductory Soil Science
Soil Science 105	Field Studies of Soil Resources
Soil Science 118	Soils in Land Use and the Environment
Soil Science 198	Undergraduate Seminar
Soil/Hydrologic Sci. 198	Water Quality Monitoring and Analysis
Soil Science 214	Soil Mineralogy
Soil Science/Ecology 219	Ecosystem Biogeochemistry
Ecology 201	Systems and Landscape Ecology
Ecology 230	Selected Ecosystem Analysis

HONORARY AND PROFESSIONAL SOCIETIES:

American Society of Agronomy
Soil Science Society of America
Ecological Society of America
International Society of Soil Science
American Geophysical Union
Clay Minerals Society
California Forest Soils Council
Alpha Zeta
Xi Sigma Pi
Gamma Sigma Delta

PROFESSIONAL CERTIFICATION:

Certified Professional Soil Scientist

Certified by:

Harrison, CBDA Fellowship-Research Mentor CV

American Registry of Certified Professionals in Agronomy, Crops and Soils (ARCPACS)

Professional Soil Scientist Association of California

Harrison, CBDA Fellowship-Research Mentor CV

PEER REVIEWED PUBLICATIONS:

1 Ugolini FC, Dahlgren RA (1987) The mechanism of podzolization as revealed by soil solution studies. pp.195-203. *In* D. Righi and A. Chauvel, (eds.) Podzols et Podzolisation. AFES et INRA, AFES et INRA, Plaisir et Paris.

2 Vogt KA, Dahlgren RA, Ugolini FC, Zabowski D, Moore E, Zasoski R (1987) Aluminum, Fe, Ca, Mg, K, Mn, Cu, Zn and P in above- and belowground biomass. I. Concentrations in subalpine *Abies amabilis* and *Tsuga mertensiana*. Biogeochemistry 4:277-294.

3 Vogt KA, Dahlgren RA, Ugolini FC, Zabowski D, Moore E, Zasoski R (1987) Aluminum, Fe, Ca, Mg, K, Mn, Cu, Zn and P in above- and belowground biomass. II. Pools and circulation in a subalpine *Abies amabilis* stand. Biogeochemistry 4:295-311.

4 Ugolini FC, Dahlgren RA, Shoji S, Ito T (1988) Andosolization and podzolization as revealed by soil solution studies, South-Hakkoda, Northeastern Japan. Soil Sci. 145:111-125.

5 Dahlgren RA, Ugolini FC (1989) Aluminum fractionation of soil solutions from unperturbed and tephra-treated Spodosols, Cascade Range, Washington, USA. Soil Sci. Soc. Am. J. 53:559-566.

6 Dahlgren RA, Driscoll CT, McAvoy DC (1989) Aluminum precipitation and dissolution rates in Spodosol Bs horizons in the Northeastern USA. Soil Sci. Soc. Am. J. 53:1045-1052.

7 Dahlgren RA, Ugolini FC (1989) Formation and stability of imogolite in a tephritic Spodosol, Cascade Range, Washington. Geochim. Cosmochim. Acta 53:1897-1904.

8 Dahlgren RA, Ugolini FC (1990) The effects of tephra perturbations on soil processes in a tephritic Spodosol, Cascade Range, Washington. Geoderma 45:331-355.

9 Dahlgren RA, McAvoy DC, Driscoll CT (1990) Acidification and recovery of a Spodosol Bs horizon from acidic deposition. Environ. Sci. Technol. 24:531-537.

10 Ugolini FC, Dahlgren RA, Vogt KA (1990) The genesis of Spodosols and the role of vegetation in the Cascade Range of Washington, USA. pp. 370-380. *In* J. Kimble and R. Yeck (eds.) Proceedings of the ICOMOD-ISCOM Workshop. Academic Press, NY.

11 Dahlgren RA, Ugolini FC (1991) Distribution and characterization of short-range-order minerals in Spodosols from the Washington Cascades. Geoderma 48:391-413.

12 Kratz TK, Benson BJ, Blood E, Cunningham G, Dahlgren RA (1991) The influence of landscape position on temporal variability in four North American ecosystems. American Naturalist 138:355-378.

13 Dahlgren RA, Vogt KA, Ugolini FC (1991) The influence of soil chemistry on fine root aluminum concentrations and root dynamics in a subalpine Spodosol, Washington, USA. Plant and Soil 133:117-129.

14 Dahlgren RA, Singer MJ (1991) Nutrient cycling in managed and unmanaged oak woodland-grass ecosystems. pp. 337-341. *In* Proceedings of Oak Woodlands and Hardwood Rangeland Management-A Research Symposium. Gen. Tech. Rep. PSW-126. Berkeley, CA. PSW Forest and Range Experiment

Station, U.S. Department of Agriculture.

15 Ugolini FC, Dahlgren RA (1991) Weathering environments and occurrence of imogolite/allophane in selected Spodosols and Andisols. Soil Sci. Soc. Am. J. 55:1166-1171.

16 Dahlgren RA, Ugolini FC, Shoji S, Ito T, Sletten RS (1991) Soil forming processes in Alic Melanudands under Japanese pampas grass and oak vegetation. Soil Sci. Soc. Am. J. 55:1049-1056.

17 Dahlgren RA, Marrett DM (1991) Organic carbon sorption in arctic and subalpine Spodosol B horizons. Soil Sci. Soc. Am. J. 55:1382-1390.

18 Ugolini FC, Dahlgren RA, LaManna J, Nuhn W, Zachara J (1991) Mineralogy and weathering processes in recent and holocene tephra deposits of the Pacific Northwest, USA. Geoderma. 51:277-299.

19 Tanji K, Ong CGH, Dahlgren RA, Herbel MJ (1992) Evaporite formation in agricultural evaporation ponds. Are evaporite salts environmental hazards? California Agriculture 46:18-21.

20 Ong CGH, Dahlgren RA, Tanji KK (1992) X-ray diffraction pattern reduction and computer-rendered line peak spectra for mineral analysis. Computers and Geosciences 18:517-529.

21 Dahlgren RA, Walker WJ (1993) Aluminum release rates from selected Spodosol Bs horizons: effect of pH and solid-phase aluminum pools. Geochim. Cosmochim. Acta 57:57-66.

22 Dahlgren RA (1993) Comparison of soil solution extraction procedures: Effect on solute chemistry. Comm. Soil Sci. Plant Anal. 24:1783-1794.

23 Shoji S, Nanzyo M, Dahlgren RA (1993) Volcanic Ash Soils - Genesis, Properties and Utilization. Elsevier, Amsterdam. 288p.

24 Takahashi T, Dahlgren RA, van Susteren P (1993) Clay mineralogy and chemistry of soils formed in volcanic materials in the xeric moisture regime of northern California. Geoderma 59:131-150.

25 Dahlgren RA, Driscoll CT (1994) The effect of whole-tree clear-cutting on soil processes in the Hubbard Brook Experimental Forest, New Hampshire, USA. Plant and Soil 158:239-262.

26 Dahlgren RA, Saigusa M (1994) Aluminum release rates from allophanic and nonallophanic Andosols. Soil Sci. Plant Nutr. 40:125-136.

27 Dahlgren RA (1994) Soil acidification and nitrogen saturation from weathering of ammonium-bearing rock. Nature 368:838-841. See also News and Views, 368:810.

28 Dahlgren RA, Walker WJ (1994) Solubility control of KCl extractable aluminum in soils with variable charge. Comm. Soil Sci. Plant Anal. 25:2201-2214.

29 Dahlgren RA (1994) Weathering environments and the formation of noncrystalline materials in volcanic ash soils. Proceeding of the 15th World Congress of Soil Science. Acapulco, Mexico. 8a:106-115.

30 Takahashi T, Dahlgren RA, Sase T (1994) Formation of melanic epipedons under forest vegetation in

the xeric moisture regime of northern California. Soil Sci. Plant Nutr. 40:617-628.

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BOOK REVIEWS:

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Stanford University

STANFORD, CALIFORNIA 94305-5020 U.S.A.

PROF. PETER M. VITOUSEK
DEPARTMENT OF BIOLOGICAL SCIENCES
OFFICE (650) 725-1866 FAX (650) 725-1856
VITOUSEK@STANFORD.EDU

May 17, 2005

California Sea Grant College Program
Scripps Institution of Oceanography
8602 La Jolla Shores Drive, Building T-16
La Jolla, CA 92037

Dear people,

I am writing in support of Dr. John Harrison for your postdoctoral position. John received his Ph.D. in Geological and Environmental Sciences here; I was on his committee, and stayed rather close to both the overall research program of which his thesis is part, and to his thesis in particular. I believe I know his work and capabilities well.

John tackled a difficult problem in his thesis research—one that was difficult in several dimensions. His research was motivated by an interest in nitrous oxide emissions resulting from N fertilization in an intensive subtropical agricultural system in Mexico. While emissions of this greenhouse gas from fertilized fields have been measured multiple times, emissions from groundwater, riparian areas, and N-enriched streams and drainages represent the largest uncertainty in our global analysis of nitrous oxide. These uncertainties persist because the measurements are difficult... Second, he worked in agricultural drains—an aquatic environment, where his advisor has little expertise. Third, the work was carried out in a rapidly developing region of Mexico—and to make it work, John had to develop contacts, permissions, tools, and collaborators for working in what can be a challenging environment.

In spite of these difficulties, John did some excellent work, work leading to several first-rate publications. He nailed down the nitrous oxide fluxes from his system, and their controls, with a combination of repeated measurements and field and lab experiments. It's very nice work, and it will make a substantial contribution to his original question. In the course of this work, he became aware of powerful diurnal variation in oxidation/reduction (redox), one of the possible controls of microbes that carry out nitrous oxide production and emission—and he put together a beautiful analysis of redox changes and their biogeochemical implications over a daily cycle. His work draws on Fe and Mn as well as N and C; it looks at the annual implications of this diel variation as well as the shorter-term dynamics.

John's work has been interdisciplinary; indeed, it could not have been successful otherwise. The project he works on is a collaboration among Mexican and U.S. agronomists, terrestrial ecologists, economists, estuarine ecologists, hydrologists, and biosphere/atmosphere specialists—and John was an excellent contributor to that project. His own work is very much on the interface of ecology, hydrology, and microbial geochemistry.

If I can be of any further assistance, please don't hesitate to contact me.

Sincerely,

Peter Vitousek
Professor of Biological Sciences

STANFORD

SCHOOL OF
EARTH SCIENCES

OFFICE OF THE DEAN

May 19, 2005

California Sea Grant College Program
Scripps Institution of Oceanography
8602 La Jolla Shores Drive
Building T-16
La Jolla, CA 92037

Dear Members of the Selection Committee:

I am writing on behalf of John Harrison, who is applying for a CalFed Postdoctoral Fellowship. I have known John since 1997, and was his thesis advisor until he graduated two years ago. I know him well, and can speak to his strengths.

John Harrison came to Stanford with a strong academic background as well as experience in both ecological research and international environmental policy. These experiences made him one of the three most prepared graduate students I've ever worked with. During his graduate program, he used these areas of experience, along with several new areas of learning, to develop and carry out a unique, difficult, and ultimately successful area of research on the dynamics and biogeochemistry of surface water systems in an agricultural landscape.

During his years at Stanford, John amazed me with the comfort level he displayed in the midst of multiple tasks. For example, in his second year of graduate school, he successfully took courses, wrote proposals, co-authored and published a manuscript, organized a major field study, and created, found funds for, and organized a cross-campus biogeochemistry seminar series. He is organized and hard working, and has plenty of common sense to get him through.

In terms of his dissertation research, John worked independently to establish a set of field and lab studies in Mexico, building on one of my already-established collaborations with Mexican researchers. In developing and carrying out his research on the consequences of solution transport of nitrogen to freshwater and coastal systems, John quite independently developed the right contacts in our Sonora, Mexico field site, and the right methods for

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05/19/2005 12:39 6507256596 STANFORD EARTH SCI PAGE 02

measurement of processes in freshwater and coastal marine systems. He also set up a new analytical system in my lab, and pioneered its use almost single-handedly. In interpreting the results of his research, John was able to identify the missing pieces and uncertainties, and to develop reliable means for reducing them. He submitted and was granted a NASA pre-doctoral fellowship and a NSF dissertation improvement award. In short, he's shown that he knows how to develop creative research ideas, find support for them, and pursue them, successfully and independently, to completion.

John is also a very good communicator. He writes well and easily, and has since his first year at Stanford. As a graduate student, he was successful in grant writing with far less than the typical input from me. He completed his dissertation papers with considerable speed and independence. And in the opportunities that I've had to see him teach and speak, he has been articulate, organized, and relaxed.

John Harrison is very smart, focused, has good time-management skills, works remarkably independently, knows how to work in groups, and has plenty of common sense. I think he has the potential to be a leader in the future. I strongly recommend him for a CalFed Postdoctoral Fellowship.

Sincerely,

Pamela Matson

Pamela Matson
Goldman Professor of Environmental Studies
Naramore Dean of the School of Earth Sciences

RUTGERS
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11 May 2005

California Sea Grant College Program
Scripps Institution of Oceanography
8602 La Jolla Shores Drive, Building T-16
La Jolla, CA 92037

Dear Members of the Review Committee:

It is with great enthusiasm that I write this letter in support of Dr. John Harrison's application for a CalFed Post-doctoral Fellowship. My first interactions with John Harrison were at scientific conferences when he was a graduate student. During the past approximately two years Dr. Harrison has been a post-doctoral fellow in my group. He is highly motivated, is a broad and integrative thinker, is persistent and focused, works well independently and collaboratively, takes projects to completion (i.e., publication), is a good communicator, and is clearly headed towards being a leader in ecosystem biogeochemistry.

As a post-doc in my group, Dr. Harrison has primarily worked on a project developing spatially explicit, biogeochemical models of nutrient export from watersheds to coastal ecosystems globally. An overall goal of this project is to increase knowledge of the impact of anthropogenic and natural factors in watersheds on nutrient (N, P, C and Si) export to coastal systems around the world. This project is international and interdisciplinary and is comprised of research scientists from nine countries (Global Nutrient Export from WaterSheds – Global NEWS workgroup). Dr. Harrison came to the project with a background in biogeochemistry at relatively small scales (site specific studies within rivers, within individual watersheds), but with little background at the global scale or with GIS. He very quickly began to learn to think at the regional and global scale, taught himself ARC-GIS and began to use and revise existing formulations of nutrient export models for global watersheds. More recently, he has taken a strong leadership role in developing new models of nutrient export and applying them at global scales. For example, he took the lead in developing a spatially explicit, dissolved inorganic phosphorus model which he then applied and validated for watersheds around the world. The first manuscript from that work has now been accepted for publication in *Global Biogeochemical Cycles*. Dr. Harrison works well independently as well as collaboratively. In collaboration with other Global NEWS scientists, he developed the first global model of dissolved *organic* N, P and C (DOM) export from rivers to coastal systems. That paper has now been accepted for publication as well (*Global Biogeochemical Cycles*). He has assisted a number of working group members in the development of models for other nutrients/forms (e.g., dissolved inorganic N (accepted *GBC*; and particulate N, P and C). Throughout this project Dr. Harrison has demonstrated his ability to work integratively not only across a broad range of environments (terrestrial, freshwater and coastal marine), but also across a broad range of disciplines (biogeochemistry, geomorphology, hydrology, microbial ecology, etc.).

Dr. Harrison has taken on a number of leadership roles as Co-Chair of this global modeling project. For example, he was involved in the planning and running of two international

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workshops at UNESCO in France, has written progress reports, developed and maintained a web site for the project, and maintained communication with numerous members of the working group to keep the overall project moving forward.

Dr. Harrison is an excellent writer. This was evident in his contributions to proposals that we have written during the past year. He has contributed many important ideas to these proposals and expressed them clearly, concisely and compellingly. We are currently co-authoring a chapter for a new book on "Nitrogen in the Marine Environment" edited by Capone, Carpenter, Bronk and Mulholland. In addition, John is working on a number of manuscripts resulting from his post-doc research that will be submitted in the next few months. He takes projects to completion.

Dr. Harrison has very good oral communication skills. He has made presentations on his post-doctoral project at a number of national/international scientific conferences during the past two years. This includes Gordon, Estuarine Research Federation, American Geophysical Union, and Ecological Society of America conferences. He makes effective use of these conferences for not only two-way communication of science, but also for building a strong network of colleagues.

In summary, I believe that Dr. Harrison will be an outstanding leader in the field of biogeochemistry. His work will span a range of scales, encompassing both terrestrial and aquatic ecosystems, using a combination of modeling and field/lab experimental approaches. The CalFed Fellowship will provide him with important new opportunities to expand on his past research in new directions.

Please contact me (732-932-6555 x342; sybil@marine.rutgers.edu) if I can provide any additional information about this excellent scientist that will assist you in making your decision.

Sincerely,

Sybil Seitzinger

Sybil P. Seitzinger
Director, Rutgers/NOAA
Cooperative Marine Education &
Research Program

President-elect, ASLO

TO VERIFY: TRANSLUCENT GLOBE ICONS MUST BE VISIBLE WHEN HELD TOWARD A LIGHT SOURCE

THE NAME OF THE UNIVERSITY APPEARS IN SMALL WHITE PRINT ACROSS THE FACE OF THIS 11 X 8 1/2 DOCUMENT

STANFORD UNIVERSITY

OFFICE OF THE REGISTRAR
STANFORD, CA 94305-3005

Name : Harrison,John Arthur
Student ID : 04583068

Roger Printup
University Registrar

This officially sealed and signed transcript is printed on red SCRIP-SAFE® security paper with the name of the university printed in white type across the face of the document. A raised seal is not required. When photocopied a security statement containing the institution name will appear. A BLACK ON WHITE OR A COLOR COPY SHOULD NOT BE ACCEPTED!

Print Date : 11May 2005

----- Stanford Degrees Awarded ------

Degree : Doctor of Philosophy
Confer Date : 03Apr 2003
Plan : Geological and Environmental Sciences

------- Academic Program -------

Program : Geol & Environ Sci
01Sep 1997 : Geological and Environmental Sci (PhD) Major
Completed Program

----- Beginning of Academic Record -----

1997-1998 Autumn

Course		Title	Att	Ern	Grd
BIOSCI	302	TOPICS POP BIO	1.00	1.00	S
GES	295	REMOTESENSING/GIS	3.00	3.00	A-
STATS	160	STATISTIC METH	5.00	5.00	A-

1997-1998 Winter

Course		Title	Att	Ern	Grd
BIOSCI	124	PLANT ADAPTATIONS	4.00	4.00	A
GES	257	CLIMATE VARIABIL.	3.00	3.00	A+
GES	260	BAJA SEMINAR	2.00	2.00	CR

1997-1998 Spring

Course		Title	Att	Ern	Grd
BIOSCI	304	POPULATION BIO	1.00	1.00	S
GES	499	RES: GENL GEOL	8.00	8.00	S

1997-1998 Summer

Course		Title	Att	Ern	Grd
GES	499	RES: GENL GEOL	9.00	9.00	S

1998-1999 Autumn

Course		Title	Att	Ern	Grd
CEE	365A	ATMOSPHERIC SCI	1.00	1.00	CR
GES	322	SEM. IN BIOGEOCHEM	1.00	1.00	S
GES	422	RES: BIOGEOCHEM	7.00	7.00	A

1998-1999 Winter

Course		Title	Att	Ern	Grd
GES	322B	SEM IN BIOCHEMISTR	2.00	2.00	A
GES	422	RES: BIOGEOCHEM	7.00	7.00	S

1998-1999 Spring

Course		Title	Att	Ern	Grd
GES	220	BIOGEOCHEMISTRY	3.00	3.00	CR
GES	265	SOIL CHEM DYMANICS	3.00	3.00	CR
GES	422	RES: BIOGEOCHEM	3.00	3.00	A

1998-1999 Summer

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	S

1999-2000 Autumn

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

1999-2000 Winter

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

1999-2000 Spring

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

1999-2000 Summer

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	8.00	8.00	A

2000-2001 Autumn

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

2000-2001 Winter

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

2000-2001 Spring

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	9.00	9.00	A

2000-2001 Summer

Course		Title	Att	Ern	Grd
GES	422	RES: BIOGEOCHEM	3.00	3.00	A

2001-2002 Autumn

Course		Title	Att	Ern	Grd
GES	422	RESEARCH IN BIOGEOCHEMISTRY	10.00	10.00	A

2001-2002 Winter

Course		Title	Att	Ern	Grd
GES	422	RESEARCH IN BIOGEOCHEMISTRY	9.00	9.00	A

2001-2002 Spring

Course		Title	Att	Ern	Grd
GES	802	TGR DISSERTATION	0.00	0.00	S

2001-2002 Summer

Course		Title	Att	Ern	Grd
GES	802	TGR DISSERTATION	0.00	0.00	S

2002-2003 Autumn

Course		Title	Att	Ern	Grd
GES	802	TGR DISSERTATION	0.00	0.00	S

END OF TRANSCRIPT

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