Computational Assessments of Scenarios of Change in the Delta Ecosystem

CALFED Science Program Project SCI-05-C01-84
Semiannual Project Report
Report No. 4: September 1, 2007 – February 29, 2008

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Funding Source: ***BOR Reimbursible funds through USGS***

Project Location: U.S. Geological Survey, Menlo Park, CA

Brief Description of Project: This project constitutes a model-based approach for developing a long view of the Bay-Delta-River-Watershed system. The long view is developed through simulations with linked models to project changes under a range of plausible scenarios of climate change, Delta configurational changes, and land-use/population change. Elements of the Bay-Delta River-Watershed system addressed by this project are:

① Climate Modeling and Downscaling
② Sacramento-San Joaquin Watershed and San Francisco Bay Modeling
③ Delta Modeling: Hydrodynamics with Temperature and Phytoplankton
④ Sediment, Geomorphology and Tidal-Habitat Modeling
⑤ Fate and Effects of Selenium, Mercury, Silver and Cadmium
⑥ Invasive Species– *Potamocorbula*, *Corbicula*, and *Egeria*
⑦ Native and Alien Fish Population Trends

The cascading effects of changes under these scenarios will be followed as they propagate through these elements, from the climate system to watersheds to river networks to the Delta and San Francisco Bay.

BUDGET SUMMARY (All tasks should exactly match those identified in the project Scope of Work.)

Task #	% Complete (by dollars)	Amount Invoiced (Current Fiscal Year)	Amount Invoiced to Date (All Years)	Projected Expenditures next 6 months
1	10%	$0.00	$25,107.00	30000
2	57%	$0.00	$224,369.00	82000
3	69%	$0.00	$162,554.00	33000
4	67%	$0.00	$213,307.00	92000
5	56%	$0.00	$44,846.00	10000
6	9%	$0.00	$6,439.00	20000
7	27%	$0.00	$67,970.00	15000
8	6%	$0.00	$2,515.00	3500

PROJECT STATUS OVERVIEW

Status, in brief, of individual tasks (detailed reports follow):

September 2007 through February 2008

Task 1:

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:

Have now downscaled historical observations (for validation use), and simulated historical and 21st Century temperature and precipitation fields from two global climate models. Final revisions are being made.

Documentation of downscaling method recently published as http://www.energy.ca.gov/2007publications/CEC-500-2007-123/CEC-500-2007-123.PDF

Also, Cayan has produced a set of projections of sea level rise for the San Francisco Fort Point tide gage site for the 21st Century using the Rahmstorf scheme. Cayan is working with Knowles to investigate how sea level fluctuations propagate into Bay and Delta. Cayan delivered an overview of CASCADE to the State of the Estuary Conference in October 2007.

PROBLEMS OR DELAYS ENCOUNTERED:
Discovered some localized timing issues in the beta version of downscaled climate fields, several days of missing historical data in the observations files, and a tendency for daily temperature ranges to be too large or small as the downscaling method was initially deployed. Corrections to all of these problems have been developed and are in final stages of being implemented (grinding out the final numbers).

Regarding sea level rise, determination of water level fluctuations in the upper Bay and Delta is rather complex and is requiring an extensive investigation of observed historical water levels in the Bay/Delta. This work has begun but will require a few months to produce a credible analysis.

DELIVERABLES PRODUCED:
Beta versions of temperature and precipitation fields, Fall 2007.

Cayan, D.R., E.P. Maurer, M.D. Dettinger, M. Tyree, K. Hayhoe, 2008: Climate change scenarios for the California Region. *Climatic Change*. **26 January 2008 Online**

Cayan, D.R., P.D. Bromirski, K. Hayhoe, M. Tyree, M.D. Dettinger, R.E. Flick, 2008: Climate change projections of sea level extremes along the California Coast. *Climatic Change*. **26 January 2008 Online**.

Cayan, D.R., A.L. Luers, G. Franco, M. Hanemann, B.Croes, E. Vine, 2008: Overview of the California climate change scenarios project. *Climatic Change*. **26 January 2008 Online**.

Task 2:
ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: To achieve CASCaDE goals, a new approach to applying CALSIM was developed which may also eventually be employed by DWR.
PROBLEMS OR DELAYS ENCOUNTERED: Disaggregating the monthly flow data to daily at the downstream end of the watershed continues to challenge, but work is ongoing.
DELIVERABLES PRODUCED: monthly CALSIM output for 1st 100-year scenario

Task 3:
ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:
Hydrodynamics: A new bathymetric grid for the entire Delta region is completed. This grid incorporates improved representation of the channels based on a bathymetric database created by Richard Smith, USGS. The grid also represents levee heights throughout the Delta. These improvements were necessary to study sea level rise throughout the Delta. We are currently calibrating and verfying the model using this new grid.
Phytoplankton: A novel approach (using stable isotopes measured in clams) has been explored as a tool for validating modeled mixtures of phytoplankton populations emanating from four sources (Sacramento, San

Joaquin, Bay, initial condition Delta). A manuscript describing a conceptual model which explains the range of phytoplankton-transport time relationships observed in nature is near-submission ready.
Temperature: UC/Berkely worked on a statisical analysis of water temperature in the Delta based on historical data throughout the Delta. Based on daily averages and maximum temperatures, air temperature and water temperature are highly coorelated throughout the Delta with an exception near the temporary barriers. The slope of the correlation varies spatially. There are three distinct regions: Sacramento influenced, bay influenced, and San Joaquin influenced areas.

PROBLEMS OR DELAYS ENCOUNTERED:

Hydrodynamics: N. Monsen, the principal Delta hydrodynamic modeler, took a leave of absense from this project October 24, 2007-January 11, 2008 because of a family medical emergency.

DELIVERABLES PRODUCED:

Phytoplankton:

- L. Lucas presented a talk entitled "Modeling Phytoplankton Dynamics to Understand Sources and Losses in a Complex Tidal Low-Productivity System" by Lucas, Monsen, Stewart & Cloern at the Biennial Conference of the Estuarine Research Federation in Providence, RI (November 2007)
- Invited by the CALFED Bay-Delta Program, L. Lucas participated in a Delta Vision Eco-Design Brainstorming Session, in support of the development of a Delta Ecosystem Vision Statement to be presented to Governor Schwarzenegger's Delta Vision Blue Ribbon Task Force (October 2007)
- L. Lucas and co-authors received the Estuarine Research Federation's Pritchard Award, for the best geophysics paper published in the journal *Estuaries and Coasts* during the previous 2 years. The award winning manuscript entitled "Intra-daily variability of water quality in a shallow tidal lagoon: Mechanisms and implications" (2006) by Lucas, L. V., D. M. Sereno, J. R. Burau, T. S. Schraga, C. B. Lopez, M. T. Stacey, K. V. Parchevsky, and V. P. Parchevsky (Estuaries and Coasts 29(5), 711-730) describes the results of a previous CALFED funded study (http://estuariesandcoasts.org/cgi-bin/est/printabstract.cgi?ESTU2006_29_5_711_730) (November 2007)
- The 2006 manuscript by Lucas et al. was summarized in ERF's "Coastal and Estuarine Science News", an electronic newsletter for coastal managers emphasizing management implications of scientific findings (see http://www.erf.org/cesn/vol29n5.html#2).

Task 4:

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: We have completed hindcast modeling of the 1887-1922 and 1922-1942 periods, for Suisun Bay. We have found that model parameters (such as Delta configuration and sediment characteristics), vary with time. While agreement with net erosion measurements is relatively easy to modulate (by adjusting sediment parameters), spatial agreement is variable. Maximum spatial agreement was achieved during the 1942-1990 period, while minimum spatial agreement was achieved for the 1922-1942 period.
Also, completion of water level calibrations of the Delft3D model for use in hindcasting the bathymetric evolution of San Pablo Bay. Initial 3D runs for San Pablo Bay using two grain sizes were also completed.

PROBLEMS OR DELAYS ENCOUNTERED: None

DELIVERABLES PRODUCED:

- Neil Ganju delivered a presentation at the 2nd USGS Modeling conference in Perdido Beach, Alabama, describing the CASCaDE project to USGS researchers from other disciplines and regions.

- The journal article entitled “Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change”, by Neil K. Ganju and David H. Schoellhamer is in press at Continental Shelf Research.

- A journal article entitled “Temporal downscaling of decadal sediment load estimates to a daily interval for use in hindcast simulations”, by Neil K. Ganju, Noah Knowles, and David H. Schoellhamer was published by the Journal of Hydrology.

- A journal article by Ganju, N.K., Schoellhamer, D.H., and Jaffe, B.E., entitled “Simulation of decadal-timescale estuarine geomorphic change with a tidal-timescale model: Part I: application to historical change” is in review with the Journal of Geophysical Research-Earth Surface.

- A journal article by Ganju, N.K., and Schoellhamer, D.H., entitled “Simulation of decadal-timescale estuarine geomorphic change with a tidal-timescale model: Part II: application to future scenarios of climate and sediment supply” is in review with the Journal of Geophysical Research-Earth Surface.

Task 5:

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:

Identified a potential use of stable isotopes in invasive clams to help validate coupled hydrodynamic/phytoplankton model and to link changes in San Joaquin flows to the Bay to changes in Se concentrations in clams. Further evaluation is underway.

New analyses of stable isotope and Se data from Corbula amurensis showed a statistical link between a San Joaquin River isotopic signal and seasonal increases in Se concentrations in bivalves. This is the first positive evidence of the importance of changes in relative riverine inputs to the Bay on the Se issue. Further development of this data will greatly enhance our ability to model how changes in relative river inputs with climate change will influence Se contamination. A synthesis of Se literature has allowed us to develop trophic transfer coefficients for a large number of invertebrates, expanding our capabilities to model Se food web transfer in both the freshwater and brackish water parts of the Bay-Delta Ecosystem. Preliminary applications of the model to small sub-systems have begun.

PROBLEMS OR DELAYS ENCOUNTERED:

DELIVERABLES PRODUCED:

- Sam Luoma gave talks at the Isolated Facilities Workshop (Sep, 2007) and for the Water Quality Subcommittee of CALFED (Feb 2008) on water quality and future changes in the Delta.
- Robin Stewart gave an invited talk on Environmental Water Quality Issues in the Delta related to Within Delta Conveyance, at the Calfed workshop on “Within Delta Conveyance” in Sacramento, September, 2007.

Task 6:

We continued to refine model parameters and controlling factors for initial conditions for the bivalve models. (1) Upstream initial conditions for juvenile Corbula can be related to position of X2. Embayments near the upstream distribution limit therefore have a limited period for recruitment and we see one recruitment period in fall at these locations during normal runoff years and 2 or more recruitment periods during drought years. (2) The number of adult *Corbula* limits the number of recruits that can settle in a patch once the adults pass a threshold – an exponential relationship was derived for this phenomena. (3) Evaluation of Corbicula size data at historic DWR benthic stations shows that most stations have a baseline of 200-400 recruits/m^2 throughout the year. The exception to the baseline is the area surrounding the export pumps which appears to be less predictable.

Presentation: *Corbicula* and *Corbula* are stressing the restoration: Can we manage freshwater to limit their success? Presented by J. Thompson. Bi-Annual Estuarine Research Federation Meeting; Providence Rhode Is., Nov 2007.
Paper Submitted/Accepted: Thompson, J. *Corbula amurensis* in San Francisco Estuary. The Invasive Species Compendium. Produced by CABI. With support from US Department of Agriculture and others. (Hardcopy and Web version). http://www.cabi.org/datapage.asp?iDocID=180

Task 7:
ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: We are revising the simple review article regarding effects of climate change on fish populations. We will circulate this draft to the CASCADE group to determine if we will move forward with a publication. We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the life cycle models. We analyzed historical flow data from a variety of sources for the major tributary rivers to the San Francisco Estuary using the software package "Indicators of Hydrologic Alteration". We summarized patterns of flow before and after construction of the major hydrologic infrastrcture in the watershed. Projected flow patterns in each climate scenario will be similarly analyzed and compared to flow patterns from the previous two time periods.

Christa Woodley started her CALFED post-graduate fellowship on CASCADE issues in September. She is currently refining her dynamic energy budget models.

PROBLEMS OR DELAYS ENCOUNTERED: None. Waiting for model outputs.
DELIVERABLES PRODUCED: Abstract submitted to 2008 Annual Meeting of the California-Nevada Chapter of the American Fisheries Society and 2008 Meeting of American Fisheries Society "Streamflow characteristics of California's Central Valley Rivers: implications for native and invasive fishes"

<u>March 2007 through August 2007</u>

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:
A PI meeting was held by teleconference on 13 June 2007, and a mid-project PI meeting has been scheduled for 17-19 September 2007 at Ryde, CA, with invitations to the CALFED Science Program and outside collaborators/advisors.

Status, in brief, of individual tasks (detailed reports follow):

Task 1 (Climate): A recently published method for projecting rates of sea level rise is being employed, resulting in higher estimates than under previous methods. Despite some glitches, efforts to produced downscaled quantities based on coarse GCM runs have been largely successful and continue.

Task 2 (Watershed/hydrology): CALSIM and the USBR stream temperature models are running succesfully and have been use to reproduce results from a prior DWR climate study for preliminary use by Cascade. Development of a new elevation dataset covering the Bay-Delta is complete and analysis of vulnerability to sea level rise is underway.

Task 3 (Delta hydrodynamics, temperature, and phytoplankton):
Hydrodynamics: Through a detailed analysis of historical years, we identified the base case scenarios for CASCaDE. We will use year long simulations driven by WY1992 conditions to define a present day "dry year" and WY1999 conditions to define a present day "wet year."
Phytoplankton: Data synthesis and analysis has been conducted to set up a base "validation" case for the coupled hydrodynamic-phytoplankton model. In addtion, a manuscript is in preparation for a peer-reviewed journal describing a simple conceptual model describing the relationship between transport time scales (e.g. residence or flushing times) and phytoplankton biomass or other reactive water quality constituents.

Task 4 (Geomorphology/sediments): We have finalized the calibration of the geomorphic model to historical bathymetric change, and have applied those methods to four 20 y scenarios of warming, sea-level rise, and decreased sediment supply. Preliminary results show the relative importance of streamflow timing/magnitude, sea-level rise, and sediment supply.
Completion of initial Delft3D model grid for use in hindcasting the bathymetric evolution of San Pablo Bay.

Task 5 (Contaminants): Progress during this period was focused on further resolving key parameters to be included in Hg and Se models. Because interactions among the key processes controlling mercury fate and bioavailability are not well understood, we have decided to focus Hg modeling efforts to include first-order processes that are better understood including the strong relationship between methymercury concentrations in water and those in biota.

Task 6 (Invasives): Analyses of recruitment data for the bivalves has at all USGS and DWR benthic stations has been done with respect to the position of X2. The recent change in fall freshwater pumping schedules has helped broaden this distribution study and clarify some trends. We are now examining the data to see if there are periods with increased mortality of adults with change in velocity and/or salinity.

Task 7 (Fish): Continued literature review and compilation of environmental tolerances of fish species of interest. Compilation of historical and recent flow data for major tributary rivers in the watershed. Initial analysis of flow patterns before and after construction of major water management infrastructure. Christa Woodley the new CALFED post-doc has largely completed her dissertation and will begin working on CASCADE issues. Dr. Bill Bennett was granted supplemental CALFED funding to become a full member of the CASCADE team.

Task 8 (Admin): Two project matrices were composed to clarify our efforts—one to to identify the time scales of processes to be considered by each individual task, and a second to describe the ultimate products of each cascade task, organized by time scale. These are available on the project web site, http://sfbay.wr.usgs.gov/cascade. An internal project sftp/folder-share site was also set up for storing and exchanging data.

PROBLEMS OR DELAYS ENCOUNTERED:

Task 1 (Climate): We are thinking about how to translate coastal sea level rise into the upper San Francisco Bay and Delta--we don't presently know how much attenuation there will be.

Have needed to revise plans to accommodate request for climate scenarios of gridded humidities and winds, in addition to planned temperature and precipitation scenarios. Have been fighting with an odd problem with irreproducible results from downscaling code (numbers are always reproducible) but something the code completes 100 yr scenarios (according to logs and interim printouts) but one pieces of the actual gridded data files show up; my current theory is that I have been running into some subtle large-file issues with the compiler I am using. Also noticing some weakening of trends in downscaled fields that do show up, and am hoping that that is also some odd artifact of the large-file issue.

Task 2 (Watershed/hydrology): Problems encountered in the work with CALSIM and the USBR stream temperature model fall in two categories. First, both models run at a monthly time step, while daily outputs of flow rates and temperature are needed for Cascade. Second, CALSIM has only been run using historically based inputs, corresponding to the period 1922-1994. For Cascade, it is desirable to force CALSIM and the other models directly with inputs derived from climate runs depicting projected variability over the next century. See discussion under Task 2 detail for proposed solutions.

Task 3 (Delta hydrodynamics, temperature, and phytoplankton): The cooperative agreeement between the USGS and UC/Berkeley to fund the empirical temperature model is slowly progressing though USGS Bureaucracy. No significant work on this model can occur until this agreement is in place.

MILESTONES/DELIVERABLES:

- Nancy E. Monsen, James E. Cloern, and Jon R. Burau. 2007. Effects of Flow Diversions on Water and Habitat Quality: Examples from California's Highly Manipulated Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. Vol. 5, Issue 3 (July 2007), Article 2. http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art2

- The journal article entitled “Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change”, by Neil K. Ganju and David H. Schoellhamer was revised in accordance with reviewer comments for Continental Shelf Research.

- A journal article entitled “Temporal downscaling of decadal sediment load estimates to a daily interval for use in hindcast simulations”, by Neil K. Ganju, Noah Knowles, and David H. Schoellhamer was submitted to Journal of Hydrology.

- An abstract for the 2007 Estuarine Research Federation meeting entitled “Applying a Tidal-timescale Model to Simulate Decadal-timescale Scenarios of Estuarine Geomorphic Change”, by Neil K. Ganju and David H. Schoellhamer was accepted for an oral presentation.

- J. Thompson spoke as an invited participant in the variable delta workshop held by CALFED in April 2007 to discuss the possibilty of limiting the spatial distribution of *Corbula* in the western Delta by altering freshwater flow. This data was available due to the analyses that we have done in CASCADE.

- J. Thompson spoke as an invited participant at the "Workshop for Environmental Modeling of California Central Coast" summarizing the CASCADE modeling project. The participants were primarily modelers from the Naval Research Lab, Naval Post Graduate School, UC Santa Cruz, and the Montery Bay Aquarium Research Institute.

- J. Cloern co-authored the Ecosystems chapter of a document commissioned by the CALFED Science Program: *State of Science for the Bay Delta System*

- J. Cloern participated in a CALFED Science Program-sponsored meeting to discuss new policies to manage salinity variability in the Delta to enhance habitat for native species.

- J. Cloern gave an invited talk at the 2007 annual meeting of the Interagency Ecological Program: *Phytoplankton in San Francisco Bay*

- A new paper was published online that describes results of a CALFED-supported study to measure the ecosystem-scale significant of the connectivity across habitats: Cloern, J.E. 2007. Habitat Connectivity and Ecosystem Productivity: Implications from a Simple Model. The American Naturalist 169:E21-E33, http://www.journals.uchicago.edu/AN/journal/issues/v169n1/41465/41465.web.pdf

PERSONNEL CHANGES:
None.

CONTRACT MODIFICATIONS:
None.

September 2006 through February 2007

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: Team meetings were held regularly during this period, on Sept 8, Nov 6, and Dec 4 in 2006, and Jan 17 and Jan 29-30 in 2007. On Jan 29, the team provided a briefing to USGS managers, the CALFED Interim Science Lead, and the Chair of the Independent Science Board, along with project advisors and collaborators. This meeting and the PI meeting that followed on 1/30 were very productive for us, and the 1/29 agenda and our letter of response to our advisors are attached with this report.

Another particularly useful meeting held in the last six months was the Nov 6 meeting. The team performed an all-day "thought experiment" in which we considered the likely impact of a severe drought on the various systems under study in CASCaDE. This experiment was performed largely without the use of models and based primarily on the team's collective expertise and knowledge of the Bay-Delta system. This was effectively our first scenario run-through, and provided us with a much more detailed idea than we previously had of what will be involved in evaluating the actual scenarios of change. This meeting is discussed more in the Task 1 subsection.

Status, in brief, of individual tasks (detailed reports follow):

Task 1 (Climate): Downscaling procedures are in testing phase, results from a paleoclimate study will help in developing drought scenario, and an effort to hire a student to develop statistical models of Delta quantities to supplement Delta model runs is underway, though the focus has shifted to finding a student in the Bay area rather than in San Diego.

Task 2 (Watershed/hydrology): Preliminary inundation studies complete and presented at meetings, next phase underway. Effort continues to get CALSIM and stream temp models running locally, and a collaboration with USGS San Diego has begun which should provide better representations of agriculture and deep groundwater in Central Valley.

Task 3 (Delta hydrodynamics, temperature, and phytoplankton): The bathymetric grid for the Delta-TRIM model has been revised and data representing levee breach scenarios have been expanded, model development has continued, and meteorological data has been obtained and processed prior to provision to the climate component for use in developing downscaled quantities which will be used by Task 3.

Task 4 (Geomorphology/sediments): We have finalized the calibration of the geomorphic model to modern sediment flux data, constructed a historical sediment load time-series, and developed a computationally efficient time-stepping procedure for the hindcasting model.

Task 5 (Contaminants): More detail for this task's conceptual model was filled in.

Task 6 (Invasives): Model development continues, building on new results from a Delta-wide study and a continued literature review.

Task 7 (Fish): Continued literature review and model-building. Also a new postdoc has received a CALFED fellowship to join this CASCaDE task. See Task 7 report below for details.

Task 8 (Admin): Of note is the acquisition of a CASCaDE web server for internal use, and, eventually, to provide a more extensive public web presence.

PROBLEMS OR DELAYS ENCOUNTERED:

N. Monsen, the principal Delta hydrodynamic modeler, has been on leave since November and will return in March.

MILESTONES/DELIVERABLES:

- A journal article entitled "Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change", by Neil K. Ganju and David H. Schoellhamer was submitted to the proceedings of the 2006 Physics of Estuaries and Coastal Seas Conference, Astoria, Oregon, to appear in Continental Shelf Research.

- A journal article entitled "Reconstruction of daily sediment loads from the Sacramento/San Joaquin Delta, 1851-1959", by Neil K. Ganju, Noah Knowles, and David H. Schoellhamer was drafted.

- Malamud-Roam, F., Dettinger, M.D., Ingram, B.L., Hughes, M., and Florsheim, J., 2007, Holocene climates and connections between the San Francisco Bay estuary and its watershed: San Francisco Estuary and Watershed Science, 5(1), 28 p., http://repositories.cdlib.org/jmie/sfews/ vol5/iss1/art3

- Two oral presentations by Noah Knowles titled "Projecting Inundation In the San Francisco Bay-Delta Due to Sea Level Rise" were presented at the 3rd annual California Climate Change Research Conference in September, and at the CALFED Science Conference in October.

PERSONNEL CHANGES:
None.

CONTRACT MODIFICATIONS:
None.

March 2006 through August 2006

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS: Most activity during the period covered by this semiannual report has centered on development of models and methods, as well as some data gathering and preliminary analysis. Task 1 (Climate/Downscaling) progress has mostly been in the areas of (a) extending and testing the downscaling method that will be used to turn global-climate-model outputs into local weather scenarios for other tasks, and (b) coordinating with other tasks as to what data they will require and what forms and processing of that data we will require in order to meet project needs. Task 2 (Watershed/Estuary Modeling) has focused on obtaining and configuring the various needed models, and some analysis of the impacts of sea level rise. Task 3 (Delta) has seen significant activity in the development/refinement of the hydrodynamic, phytoplankton, and temperature model components, laying the necessary groundwork for performing simulations under the proejct's scenarios. Task 4 (sediments/geomorphology) has made substantial progress in the development, calibration, and validation of a geomorphological model of Suisun Bay. Task 5 (Metals) has begun preliminary experiments to accomplish the necessary bioaccumulation modeling. Task 6 (Invasives) is compiling the environmental and bivalve data necessary to derive the bivalve biomass model parameters, has established the protocol for connecting the phytoplankton and bivalve models, has begun the analysis of recruitment and biomass data, and has worked with the modelers and GIS specialists on assigning grazing rates to the grid in the Delta Trim model. Task 7 (Fish) has performed an extensive literature review and has begun compiling physiological/habitat need data for species of interest, and has also initiated contact with other researchers on the issue of Egeria mapping in the Delta. Task 8 (Administration) has overseen organization of multiple team meetings, budget and report generation, and organization/updating of the project's internal website.

PROBLEMS OR DELAYS ENCOUNTERED:
Task 1 has had some difficulty in finding a suitable postdoctoral researcher to hire. This is considered a temporary problem.

MILESTONES/DELIVERABLES:

- Cayan, D.R., Bromirski, P., Hayhoe, K., Tyree, M., Dettinger, M., and Flick, R., submitted, Climate change and the potential for sea-level extremes along the California coast: f Climatic Change, 24 p.

- An abstract entitled "Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change", by Neil K. Ganju and David H. Schoellhamer was accepted for an oral presentation at the 2006 Physics of Estuaries and Coastal Seas Conference, September 18-22, 2006, Astoria, Oregon.

- Two abstracts for oral presentations by Noah Knowles titled "Projecting Inundation In the San Francisco Bay-Delta Due to Sea Level Rise" have been accepted at the 3rd annual California Climate Change Research Conference in September, and at the CALFED Science Conference in October.

- Invited presentation to the Water Operations Management Team discussing the ramifications of decreased exports in fall and the possible implications that could have on the Pelagic Organism Decline – August 15 in Sacramento – J. Thompson

PERSONNEL CHANGES:
None.

CONTRACT MODIFICATIONS:
None.

DETAILED PROJECT STATUS (BY TASK)

This section should be a cumulative overview of the activities performed to date and include both current and past information for each task. Please list all new information at the top of each task section so that it is clear which information is the most recent. At the end of the project, this section will serve as a full historical record of all activities performed on the project.

TASK 1: CLIMATE MODELING AND DOWNSCALING

September 2007 through February 2008

Task 1:
Have now downscaled historical observations (for validation use), and simulated historical and 21st Century temperature and precipitation fields from two global climate models. Final revisions are being made to these products (after some beta testing by California WSC colleagues). Provided beta version of downscaled fields from one climate model and emissions scenario to Task 2 to allow testing and development of next steps. Moving on to downscaling of humidity and solar radiation next. Documentation of downscaling method recently published as

http://www.energy.ca.gov/2007publications/CEC-500-2007-123/CEC-500-2007-123.PDF

Participated in Ryde project meeting and field trip, September 2007. Made a presentation at USGS HQ re: our downscaling efforts and products, 1 Nov 2007, which can be heard as a podcast at http://tenaya.ucsd.edu/~dettinge/20071101_GlobalChange2_Downscaling.mp3 (with slides available at http://tenaya.ucsd.edu/~dettinge/downscaling07.ppt). Participated in PES/CASCADE planning meeting in Menlo Park, February 2008.

Discovered some localized timing issues in the beta version of downscaled climate fields, several days of missing historical data in the observations files, and a tendency for daily temperature ranges to be too large or small as the downscaling method was initially deployed. Corrections to all of these problems have been developed and are in final stages of being implemented (grinding out the final numbers).

Cayan has produced a set of projections of sea level rise for the San Francisco Fort Point tide gage site for the 21^{st} Century using the Rahmstorf scheme. Projections are produced from simulated global surface air temperature from several global climate models (GCMs). These secular changes caused by global sea level rise are used along with predicted tides, weather fluctuations and a measure of El Nino/Southern Oscillation to estimate hourly sea level series for the San Franciso station, associated with each of the GCM runs. Cayan is working with Knowles to investigate how sea level fluctuations propagate into Bay and Delta.

Cayan delivered an overview of CASCADE to the State of the Estuary Conference in October 2007.

Cayan is linking the model climate change scenarios used in CASCADE with those being used in an ongoing California climate change scenarios assessment.

Determination of water level fluctuations in the upper Bay and Delta is rather complex and is requiring an extensive investigation of observed historical water levels in the Bay/Delta. This work has begun but will require a few months to produce a credible analysis.

March 2007 through August 2007

Dan Cayan: In our effort to simulate sea levels for the CASCADE scenarios, Cayan has worked on adopting a scheme to published by Rahmsdorf (2006) to project sea level rise from climate change model simulated global air temperature. In the process, we extracted global air temperatures from selected global climate models for use in the CASCADE study and produced preliminary sea level rise trajectories. From these estimates, based on a small set of model simulations, sea level changes by about +30cm over present day levels by 2050 in each of the estimates but begins to diverge in the following decades. By 2100 the amount of sea level rise ranges from about 60cm to about 85cm in this limited set of estimates.

Mike Dettinger: I have been trying to finalize the downscaling code, with some persistent and odd problems described above. The code has been used to downscale a GCM-model-grid (250 km gridded) historical observations record of the real world temperature and precipitation (1950-99) with results that are very skillful (compared to the 12-km gridded observations) and that recapitulate the skills of our version of the method that was implemented earlier on matlab (for another project). I have downscaled a historical-climate simulation (1950-2000) from the GFDL CM2.1 climate model, also with convincing results. My problems (it seems now in hindsight) began when I moved up to working with 100-yr future scenarios (moving from manipulation of 4

Gb files for 50 year historical examples to > 8 Gb files for future scenarios). I am recoding now to work from a bunch of 25-yr segments instead currently (when I'm not on the road).

September 2006 through February 2007

This semester, Task 1 progress continued in the areas of (a) extending and testing the downscaling method that will be used to turn global-climate-model outputs into local weather scenarios for other tasks, and (b) coordinating with other tasks as to what data they will require and what forms and processing of that data we will require in order to meet project needs. (a) CASCaDE Task 1 will use our newly developed "method of constructed analogs" to transform output from very coarse resolution climate simulations into local weather time series that are statistically like observations that have more typically been used to drive models in other tasks. During this semester, Task 1 has contributed to revisions to the manuscript,

Hidalgo, H.G., Dettinger, M.D., and Cayan, D.R., submitted, Downscaling daily US precipitation and temperatures using constructed analogues: J. Climate, 24 p.

performed much more testing of the downscaling method in climate-change mode, that is, as applied to outputs from climate-model projections rather than on coarse-grid historical observations. Some new climate-change scenarios have been downscaled onto 12 km grids, in testing mode.

A mini-scenario was prepared for a CASCADE team meeting, to represent in temporal detail what a future drought might look like. Each of the several climate-change scenarios being considered by CASCADE was surveyed in order to find one with a severe (albeit brief) drought episode sometime around 2050. Two scenarios had such drought episodes, and we chose to provide team members with climate data from the warmer of the two candidates. Un-downscaled daily temperatures, precipitation, solar insolation, winds, and humidities were provided to team members for a climate-model grid cell near the Delta, for them to consider and try to discern potential effects in their respective models. These time series were focus of a team meeting on Nov 6, 2006, and helped to motivate several new CASCADE efforts, including a search for non-model indices that might be used to recognize future changes and thresholds (e.g., how often are there 5-day sustained warm and calm periods that might be expected to influence stratification and phytoplankton growth) and a compilation of key temporal scales and linkages within each of the scientific disciplines represented in CASCADE.

(b) Task 1 has continued its regular communications with team members from other Tasks, to determine which weather series the other Tasks will require and from which stations. In mid December, the other Tasks completed extraction of those observed time series for use in historical runs of their own models and for use by the downscaling effort of Task 1 These observation time series will be the training materials for the downscaling that Task 1 will be performing. The programming to downscale directly to station data, rather than gridded data as in Hidalgo et al (submitted, mentioned above) is almost complete.

Although its not really a Task 1 effort (having mostly been accomplished prior to the project), our new review of the paleoclimate literature for California:

Malamud-Roam, F., Dettinger, M.D., Ingram, B.L., Hughes, M., and Florsheim, J., 2007, Holocene climates and connections between the San Francisco Bay estuary and its watershed: San Francisco Estuary and Watershed Science, 5(1), 28 p., http://repositories.cdlib.org/jmie/sfews/ vol5/iss1/art3 has now been published. This is relevant to Task 1 because the review and data analysis it contains bears on our decision about how best to develop a climate scenario that mirrors the megadroughts of the medieval period, as one end member among the climate-change scenarios to be addressed within CASCaDE. Most relevantly, the paper demonstrates that the Sacrament and San Joaquin River flows during the megadrought periods did not include annual-runoff totals that were markedly less than those encountered during the historical period (fig. 6), but rather "just" included many more of the lower-historical-tercile runoff totals than have been encountered in the historical period. This means that we can draw analog years from the historical record, and should not need to constructed wholly new levels of dry years, when constructing detailed megadrought scenarios. Thus the next time we do a drought scenario, we can manufacture our own and provide pretty much complete spatial downscaled detail.

In September 2006, members of the Task 1 team participated and presented results in a meeting, called by UC Berkeley and Lawrence Livermore Laboratory economists, engineers, and scientists, to learn more about and present background regarding Delta Levee Risks from climate change, floods, and earthquakes. Team members organized and chaired three Climate Change sessions at the CALFED Science Conference in October 2006, and presented study results. Team members also presented results and plans to USGS management and CALFED leadership (Ott, Healey, and Mount) in January 2007, including discussions of what CASCADE will accomplish and what will be left to be resolved later.

As a result of discussions during our mini-scenario meeting in November, it became clear that a second track that will provide less-complete, but more readily computed, complements to the full Delta TRIM hydrodynamic model are needed by the project. Since Task 1 has had no luck hiring a post-doc to help with the downscaling efforts, and since we have decided that those tasks will have to be shouldered by team members already participating in the Task, we have agreed to help fund and to provide direction to a student (to be identified and hired, most likely through Mark Stacey at UC Berkeley) who will undertake the development of statistical models for prediction of some key water temperatures and salinities in the Delta, as a complement and extension of the Task 3 efforts. Team members in Menlo Park are coordinating with Stacey to see that we have a student working on this effort by summer.

March 2006 through August 2006

This semester, Task 1 progress has mostly been in the areas of (a) extending and testing the downscaling method that will be used to turn global-climate-model outputs into local weather scenarios for other tasks, and (b) coordinating with other tasks as to what data they will require and what forms and processing of that data we will require in order to meet project needs. (a) CASCaDE Task 1 will use our newly developed "method of constructed analogs" to transform output from very coarse resolution climate simulations into local weather time series that are statistically like observations that have more typically been used to drive models in other tasks. At the onset of the study, the method had been developed, tested extensively on historical data, tested cursorily on a climate change simulation, and the historical efforts documented in a manuscript:

Hidalgo, H.G., Dettinger, M.D., and Cayan, D.R., submitted, Downscaling daily US precipitation and temperatures using constructed analogues: J. Climate, 24 p.

During this semester, in coordination with a Scripps/Lawrence Livermore joint study, Task 1 has performed much more testing of the downscaling method in climate-change mode, that is, as applied to outputs from

climate-model projections rather than on coarse-grid historical observations. A hundred years of "control run" (no changes in greenhouse gases) by the NCAR Parallel Climate Model has been provided by Lawrence Livermore (with more on the way) and has been downscaled and tested. Results are encouraging although it has become clear that the climate models have somewhat different weather characteristics than the real world, differences that can not really be fixed within the downscaling process. Those differences are fairly subtle and will be a fact of life, most likely, until the climate models themselves are improved.
Furthermore, a journal article describing the model that will be used to project sea levels under various scenarios of warming or just plain sea-level rise was completed and submitted to the journal:

Cayan, D.R., Bromirski, P., Hayhoe, K., Tyree, M., Dettinger, M., and Flick, R., submitted, Climate change and the potential for sea-level extremes along the California coast: f Climatic Change, 24 p.

(b) Task 1 has also been in regular communications with team members from other Tasks, to determine which weather series the other Tasks will require and from which stations. The other Tasks are extracting and providing those observed time series to Task 1 (still in progress) and then the observation time series will be the training materials for the downscaling that Task 1 will be performing.

Finally although its not really a Task 1 effort (having mostly been accomplished prior to the project), our new review of the paleoclimate literature for California:

Malamud-Roam, F., Dettinger, M.D., Ingram, B.L., Hughes, M., and Florsheim, J., in press, Holocene climates and connections between the San Francisco Bay estuary and its watershed: San Francisco Estuary and Watershed Science, 34 p.

Returned from journal reviews this semester and required minor revisions, including finalization of all the figures. The paper has now been accepted by the journal and should be out in the journal's next issue. This is relevant to Task 1 because the review and data analysis it contains bears on our decision about how best to develop a climate scenario that mirrors the megadroughts of the medieval period, as one end member among the climate-change scenarios to be addressed within CASCaDE. Most relevantly, the paper demonstrates that the Sacrament and San Joaquin River flows during the megadrought periods did not include annual-runoff totals that were markedly less than those encountered during the historical period, but rather "just" included many more of the lower-historical-tercile runoff totals than have been encountered in the historical period. This means that we can draw analog years from the historical record, and should not need to constructed wholly new levels of dry years, when constructing detailed megadrought scenarios.

TASK 2: WATERSHED AND ESTUARY MODELING

<u>September 2007 through February 2008</u>

Significant progress has been made in this Task in the past 6 months on the potential roadblocks described in the last report. Recall that a primary goal of this Task 2 is to take downscaled climate data from Task 1 (daily gridded precipitation and temperatures corresponding to each climate scenario), use it to drive the BDWM hydrological model, use the simulated (unimpaired) outflows from BDWM in the headwater (aka "rim") basins above the major reservoirs to drive the DWR's management model, CALSIM, and ultimately provide time series of daily managed flows at downstream locations throughout the watershed to other Tasks. The major hurdles to be cleared in achieving this goal, described fully in the previous report, were 1) implementing some reasonable method of disaggregating the monthly CALSIM output to the needed daily time scale, and 2) running CALSIM using the 100-year time series corresponding directly to the various chosen GCM/emission scenarios, as opposed to the usual historical mode of CALSIM operation.

The latter problem, ostensibly the most vexing, was addressed first. The chosen solution involved, in short, feeding CALSIM inflows derived directly from hydrological simulations driven by the downscaled climate runs and generating the corresponding demand time series and temporal lookup tables by resampling the 73-year record--comparing statistical characteristics of future hydrology to those in the record and selecting the best match. In more detail, the steps in this procedure follow:

1) The model basins of BDWM were re-configured to match the DSA basin divisions used by CALSIM.

2) Ran BDWM for JY1948-2003 using Hamlet et al input data (Pr, Tx, Tn) & output from the regional spectral model (RSM, running at SIO/UCSD) (humidity, wind spd) as the historical forcing data. The unimpaired flow outputs were aggregated to monthly.

3) These monthly BDWM outputs were calibrated to match corresponding CALSIM inputs for overlapping period from 2020 level of development (“LOD-2020”) “base case”, WY1949-1994: 12 sets (1 for each calendar month) of calibrations using previous 12 month's total flow from BDWM output and "current” month's flow from BDWM output as regressors. The goal of this step was to ensure that the time series derived from the BDWM runs are optimally representative of the input regime CALSIM has always used.

4) I obtained data for one downscaled scenario (“GFDL-A2”) from Mike Dettinger. These data were clipped and interpolated to the BDWM model grid.

5) The necessary BDWM preprocessing routines were run (mainly for the vegetation component of the model), then the 2001-2100 simulation of unimpaired hydrology was performed using daily annual climatologies for humidity, solar radiation, and wind speed.

6) I transformed the resulting BDWM output to CALSIM inputs using the calibrations from Step 3. These transformed time series were written into the new WY2001-2100 CALSIM input file.

7) For CALSIM inputs other than these freshwater inflows (e.g., time series of freshwater demands), I developed “resampled” 100-year monthly series by matching from existing LOD-2020 “base case” (WY 1922-1994) CALSIM inputs.
   The method used to determine best match from the WY1922-1994 Base Case dataset for a given “future” year (2001-2100) was as follows:

   Monthly flows were summed over all major headwaters to produce timeseries of basinwide headwater runoff for the 2001-2100 projection and the 1922-1994 base case.

   For each year of the 100-year projection, the best match from the 1922-1994 base case was selected according to the metric:

Normalized RMS err between monthly WY hydrographs
+ weighted difference of previous year's total flow

> The result is a sequence of years from the 1922-1994 record that "optimally" represents the 100-yr projection. All 100-yr demand time series, etc. are then constructed based on the original 1922-1994 input data and written to the new, 100-yr input file.

The resulting monthly simulated flows generated by CALSIM appear reasonable, and reflect the role of management according to present-day management infrastructure, strategies, and to a projected 2020 level of development. Output from this method is already being applied by the USGS groundwater modeling project, through collaboration with Randy Hanson (this potential collaboration was mentioned in the last report). Also, DWR Modeling Branch, the maintainers and operators of CALSIM, invited Noah Knowles to speak to them about this new way of applying their model. They seemed quite interested in assisting with the further development and application of this approach in their own climate-change-related efforts.

The next challenge, that of implementing some reasonable method of disaggregating the monthly CALSIM output to the needed daily time scale, was then addressed. Work on this problem is ongoing, but a promising approach has been implemented and is undergoing testing and revision. This approach is analagous to the "constructed analogs" approach used by Mike Dettinger in the downscaling applied in Task 1. In this method, the BDWM-simulated total unimpaired runoff above a point of interest in the watershed, say, Vernalis in the San Joaquin basin, is used in conjunction with historical flow data at that point (e.g., DAYFLOW data) to "downscale in time", or temporally disaggregate, the monthly CALSIM outputs. This work as follows: for a given month of simulated future flow, the BDWM unimpaired runoffs are totaled above the outflow point of interest to yield a daily time series for that month. The time series of the corresponding total runoff from the historical BDWM run is then examined to find months which most closely match the flow pattern of the future month. After a certain number of patterns have been found, a regression is used to determine coefficients corresponding to each pattern which optimally reconstruct the future month of flow. This set of coefficients is then applied to those same historical months, but now using the target flow data (e.g., DAYFLOW @ Vernalis). The resulting reconstruction is taken to represent the daily downstream flow pattern which best corresponds to the upstream unimpaired runoff pattern for the given month. Finally, the daily time series is linearly scaled so the monthly total flow equals that simulated by CALSIM for that month at that site. This entire process is repeated, in automated fashion for each month of the 100-yr climate scenario, ultimately producing managed, daily flows, corresponding to the daily climate forcings comprised in that scenario. As stated, this method is still under development, but shows some promise.

Finally, some more progress has been made in the effort to assess the risk of inundation due to sea level rise. DWR has provided a preliminary version of its new 1-m LIDAR dataset, which will greatly improve our ability to estimate the effects of sea level rise in the Delta. Also, with the assistance of CALFED/CBDA, access to an IfSAR dataset was granted; these data are being used to fill a critical gap in the Petaluma/Sonoma Creek watersheds. A presentations on this work was given to the BCDC, in an ongoing cooperation between their own efforts to study this problem and ours.

March 2007 through August 2007

CALSIM code is successfully running on our Windows machines, though the Linux port has been put on hold. The Linux port progressed to the final stage which will involve replacing the numerical solver code with an open-source version, since the Windows version is proprietary and prohibitively expensive on the Linux platform. Though this effort is still considered worthwhile, it is on hold and the Windows version of CALSIM is being used to expedite the processing of CASCaDE data. The two projects will continue in parallel and hopefully merge in the future.

The USBR stream temperature model is also successfully running at the USGS. The software was set up and learned with the generous assistance of Russ Yaworsky of the USBR. The runs performed by Russ and others at DWR using CALSIM and the stream temperature model in producing the DWR report "Progress on Incorporating Climate Change into Management of California's Water Resources" were repeated locally. The four climate change scenarios presented in that report correspond to four scenarios to be be explored in CASCaDE. Data output from these runs were made available to other team members (primarily Task 8) for use in preliminary analysis and model development on the project's internal sftp site.

Problems encountered in the work with CALSIM and the USBR stream temperature model fall in two categories. First, both models run at a monthly time step, while daily outputs of flow rates and temperature are needed for Cascade. Second, CALSIM has only been run using historically based inputs, corresponding to the period 1922-1994. For Cascade, it is desirable to force CALSIM and the other models directly with inputs derived from climate runs depicting projected variability over the next century.

In an attempt to solve the first problem, simulation files corresponding to the DWR Historical Simulation Report of 2003 have been obtained from DWR. This simulation was intended to reproduce, to the best of CALSIM's capabilities, conditions that actually occurred during a recent historical period. While there are clear discrepancies between the resulting outputs and observed behavior during that period, these runs represent the closest approximation of model to reality. My intent is to contruct statistical relationships between model outputs and observed time series using these runs, and including other relevant factors, such as meteorological forcings, as additional "independent variables". Using these relationships, other CALSIM output may be "downscaled" to more closely represent real-world variability, and may then be used in absolute as opposed to the usual CALSIM "comparitive" mode.

The second problem is likely to be even trickier. The main reason non-historically based simulations have not been performed with CALSIM is that several of the inputs, primarily freshwater demands, have been derived for the historically based series described above. These will need to be re-derived for any other forcing time series we wish to use. There are also likely other complications that will arise in thie effort, as this has not been attempted with CALSIM before.

Development of a high-resolution, high-accuracy photogrammetric-based elevation dataset covering nearly the entire Bay and Delta is essentially complete, with the possibility of minor corrections if determined necessary. Analysis is proceeding expanding on previous efforts discussed in the previous report. Both the base data set and the methodology have been substantially improved and should offer the most accurate assessments of effects of sea level rise, including vulnerability to inundation, currently available.

In a related project, the BDWM watershed model has been successfully upgraded to include a biogeochemical vegetative component that allows the hydrologic simulations under the CASCaDE scenarios to include the effects of vegetation on hydrology, a capability not available in previous studies of the system's response to climate change. A report describing and evaluating this capability has been submitted to GCAP.

September 2006 through February 2007

The study of inundation due to sea level rise has completed the preliminary phase. Results were presented at the CALFED Science Conference and at the 2nd annual California Climate Change Conference. The next phase involves the development of a much more accurate elevation dataset, repeating the prior analysis using the data, and then taking the next step by refining our estimates of tidal bahavior under sea level rise using the TRIM model. Funding has been obtained from CALFED to develop the new dataset, and the necessary paperwork is being processed. Several agencies have expressed interest in this effort. Of particular interest is the possibility of providing the San Francisco Public Utilities Commission with estimates of the frequency with which sea water is likely to backflow into the storm drain system, causing water quality and urban flood-risk issues. The SFPUC has been contacted and will be "kept in the loop" regarding future results. Also, the BCDC, which has been pursuing a similar but complementary effort of their own, has been contacted and I (Noah Knowles) will meet with them on March 15th to initiate a closer collaboration to ensure each of our efforts continues to complement the other's.

Substantial revisions to the CALSIM code have been undertaken. The code has almost completely ported to the Linux operating system, which is a necessary step as all other models used by this task also run on Linux, and must be able to easily communicate results to and from CALSIM. Work continues on this port. The collaboration with Russ Yaworsky of USBR also continues to transfer their stream temperature model to our local computers. Significant progress on this front is expected in the next several months.

In a related project, the initial modifications to the BDWM watershed model to incorporate the BIOME-BGC vegetation model are nearly complete. A report detailing the capabilities of the combined model is in progress. This improved modeling system will allow the hydrologic simulations under the CASCaDE scenarios to include the effects of vegetation on hydrology, a capability not available in previous studies of the system's response to climate change.

Finally, communications have begun with Randy Hanson of USGS San Diego, who is part of a team developing a cutting-edge groundwater of Central Valley. Their team is also evaluating the effects of climate change, and we plan to join efforts to the extent possible. Their model includes deep groundwater, agricultural operations, aquifer drawdown and recharge, and surface operations in the Valley. All these components are only crudely represented in CASCaDE, and this collaboration should prove particularly beneficial to our efforts.

March 2006 through August 2006

The initial phase of the watershed and estuary modeling component of CASCaDE involved acquisition and initial configuration of the models to be employed by this component, as well as a GIS-based study of near-shore terrain elevations in order to assess which areas adjacent to the Bay-Delta are susceptible to inundation due to rising sea levels.

First, a two-dimensional version of the high-resolution hydrodynamic San Francisco Bay model, TRIM-2D, was obtained from Dr. Ralph Cheng (USGS) and configured to run on a local workstation. This model was then used to generate high-resolution current fields for use in calibrating a coarser box model of the Bay, the Uncles-Peterson (UP) model. The goal is to use TRIM-2D to generate calibration coefficients for the UP model which correspond to successinve increases of mean sea level. The corresponding analysis is in progress. TRIM-2D will also be used to estimate tidal ranges throughout the Bay, and to generate boundary conditions for DELTA-TRIM (Task 3) near Martinez.

Next, a hydrostatic wind model of surface winds in the Bay area was obtained (also from Dr. Cheng). This model may be used to generate wind fields in the region corresponding to the different climate scenarios, for use by other CASCaDE components, including the sediment/geomorphology component (Task 4).

Third, the model used to simulate reservoir operations, CALSIM-II, has been obtained and is being configured for the multiple runs which will be necessary for the CASCaDE project. The model source code is being reconfigured for this purpose. This reconfiguration is nearly complete. We have agreed to keep DWR Modeling Section informed of any changes we make to their code.

Fourth, our cooperator at USBR, Russell Yaworksy, has been re-contacted, and has agreed to assist us in setting up their CALSIM-compatible stream temperature model on our machines. With Russ' assistance, we will begin this work as soon as CALSIM-II is reconfigured and successfully running.

Finally, a study of areas around the Bay and Delta that are vulnerable to inundation by sea level rise is nearly complete as a first major deliverable from this Task. This study evaluates the effects of a projected sea level rise of 20-80 cm over the coming century, which will cause new areas surrounding the San Francisco Bay and Delta to be inundated, with a wide variety of ecological and socioeconomic consequences. Available elevation and land-use data are used to characterize the areas at greatest risk of inundation. The projected inundated areas are primarily intertidal. The dominant inundated land-use types are wetlands adjacent to the Bay and areas that are presently croplands around the Delta periphery. The effects of sea level rise would also combine with projected higher flood stages due to reduced snowpack and with continued land subsidence to significantly increase the risks of levee failure in and around the Delta. Results from this study will be presented at the 3rd annual California Climate Change Research Conference in September, and at the CALFED Science Conference in October.

TASK 3: DELTA MODELING: HYDRODYNAMICS, TEMPERATURE, AND PHYTOPLANKTON

September 2007 through February 2008

3.1 HYDRODYNAMIC MODELING

A new bathymetric grid for the entire Delta region is completed. This grid incorporates improved representation of the channels based on a bathymetric database created by Richard Smith, USGS. The grid also represents levee heights throughout the Delta. These improvements were necessary to study sea level rise throughout the Delta. We are currently calibrating and verfying the model using this new grid.

All observed data available for the base case scenarios (1992, 1999) has been downloaded. This data will be used to drive and verify model results. This database will be made availabe to all PIs for their studies as well. These baseline simulations will be run through Delta TRIM in the next month.

3.2 PHYTOPLANKTON MODELING

Further development and refinement of the Delta phytoplankton model occurred during this period. Novel validation tools for the phytoplankton model were explored. In particular, we investigated the use of Stewart's stable carbon and nitrogen isotope measurements in Delta clams as a tool for validating mixtures of four source populations of phytoplankton (Sacramento, San Joaquin, Bay, initial condition Delta) calculated by the model. Significant (R^2=.78) relationships between isotopic signatures ($\delta^{15}N$) calculated based on model predicted phytoplankton source mixtures and $\delta^{15}N$ measured in clam tissues by A.R. Stewart throughout the Delta were found; less strong but still significant (R^2=0.66) relationships between measured $\delta^{15}N$ and $\delta^{15}N$ calculated based on model predicted water mixtures were also found. A presentation on the potential of this validation approach was given at the Biennial Conference of the Estuarine Research Federation in Providence, RI, in November 2007. This validation technique, which we have not seen used in this way before, is promising, but further investigation and vetting of this concept is needed.

A near-submission ready manuscript has been prepared for a peer-reviewed journal and describes a simple conceptual model explaining the relationship between transport time scales (e.g. residence or flushing times) and phytoplankton biomass in aquatic systems. A classical expectation in aquatic ecology is that as transport time increases, phytoplankton biomass also increases. In reality, a range of relationships (or non-relationships) may be detected. Positive, negative, variable, and insignificant relationships may be found to exist between phytoplankton biomass and residence time within and across real aquatic systems such as rivers, estuaries, floodplains, and lakes. The simple conceptual model we describe in this manuscript explains why each of these relationships may be observed in nature. We expect the manuscript to be submitted for publication within weeks.

3.3 TEMPERATURE MODELING

UC Berkeley worked on a statisical analysis of water temperature in the Delta based on historical data throughout the Delta. Based on daily averages and maximum temperatures, air temperature and water temperature are highly coorelated throughout the Delta with an exception near the temporary barriers. The slope of the correlation varies spatially. There are three distinct regions: Sacramento influenced, bay influenced, and San Joaquin influenced areas.

UC Berkeley also is working on a mechanistic analysis of water temperature. So far, the daily cycle is well reproduced. However, the equilibrium temperature lower than observed. One hypothesis is that this difference, which is greater in the winter, could be due to over estimate of net longwave radiation.

<u>March 2007 through August 2007</u>

3.1 HYDRODYNAMIC MODELING

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS

3.1.1. Base case scenarios for CASCaDE

This semester, I did a detailed analysis of historical years to identify the base case scenarios for CASCaDE. In order to discuss changes that occur as the result of the different scenarios in CASCaDE, we must first define the current conditions in the Delta. The base case scenario needs to represent the current natural flow variability of the system. I will run two Delta TRIM simulations, driven at the boundaries by a dry and wet year hydrograph, to describe the present day system.

I propose to use a year long simulations driven by WY1992 conditions to define a present day "dry year" and WY1999 conditions to define a present day "wet year." These years were selected based on a number of criteria including: 1) ranking of water year based on total Delta flow using the dayflow (WY1975-2006), 2) hydrograph shape compared to 20th and 80th percentile flows for each day based on the historical record, and 3) availability of field data to drive the model. Based on a discussion with the CASCaDE PIs (6/13/2007), I determined that I needed to use data for an actual year rather than synthesize a year based on dayflow in order for the model to be driven with a realistic hydrograph and to use actual operations of the Clifton Court Forebay gates, which is opened and closed 2-3 times a day based on operator decisions rather than a fixed criteria such as tide height.

3.1.2 GIS Database

The Delta GIS Database that was developed last summer was transferred to a computer for use by Task #3 (hydrodynamics, phytoplankton) and Task #6 (invasive species). The database has been used this semester to visualize the Delta TRIM grid. Scripts were written to translate the grid cell depths into a form that can be read by Delta TRIM. We anticipate using the GIS database in the next 6 months to incorporate Yolo Bypass bathymetry into the the Delta TRIM grid domain.

DELIVERABLES

A paper was submittted, accepted and published in San Francisco Esturary and Watershed Science during this semester:

Nancy E. Monsen, James E. Cloern, and Jon R. Burau. 2007. Effects of Flow Diversions on Water and Habitat Quality: Examples from California's Highly Manipulated Sacramento-San Joaquin Delta. San Francisco Estuary and Watershed Science. Vol. 5, Issue 3 (July 2007), Article 2. http://repositories.cdlib.org/jmie/sfews/vol5/iss3/art2

The paper was based on previous CALFED work. This paper is significant to the present research because it discusses how water and habitat quality are altered due to changes in barrier, gate and pump operations in the Delta. We need to currectly model these operations and discussing the influence of these operations in the context of future scenario simulations in CASCaDE.

3.2 PHYTOPLANKTON MODELING
ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:

Data synthesis and analysis has been conducted to set up a base "validation" case (beginning in the April 2002 time period) for the coupled hydrodynamic-phytoplankton model. This involves finding, analyzing, converting, interpolating, extrapolating etc. data describing benthic grazing rates, zooplankton grazing rates, light attenuation coefficients, surface irradiance, and photosynthesis-irradiance parameters. Additional work on learning and implementing GIS tools for parameter interpolation across the model grid has continued. A manuscript is in preparation for a peer-reviewed journal describing a simple conceptual model describing the relationship between transport time scales (e.g. residence or flushing times) and phytoplankton biomass or other reactive water quality constituents; the simple conceptual model presented can be valuable in guiding the intuition of ecosystem decision makers as they consider physical or hydrologic changes to the Delta that may change transport and flushing and thus water quality and ecology.

3.3 TEMPERATURE MODELING

ACHIEVED OBJECTIVES, FINDINGS, AND CONTRIBUTIONS:

PIs Monsen, Lucas, and Stacey met on (6/25/07) to identify the tasks and concept for the simplified empirical temperature model. Stacey's graduate student, Wayne Wagner, is beginning to download temperature data throughout the Delta. We have identified temporary barrier operations as one compenent that need to be incorporated into the emperical method as temperatures on either side of the barriers is significantly different. This finding is consistentant with the findings of Monsen et al. 2007. Monsen created a database of historical temporary barrier operations for Stacey and Wayner to use in their analysis.

PROBLEMS OR DELAYS ENCOUNTERED:

The cooperative agreeement between the USGS and UC/Berkeley to fund this section of research is slowly progressing though USGS Bureaucracy. No significant work on the empirical tempearture model can occur until this agreement is in place.

<u>September 2006 through February 2007</u>

3.1 HYDRODYNAMIC MODELING

During this time period, we have continued various "nuts and bolts" activities necessary for moving us toward Delta production simulations. These activities include model refinement, development of ancillary tools for processing related data, and data gathering.

3.1.1 GIS Grid Improvements

The previous work with scientists in the USGS Geologic Division to convert aerial photographs into levee and dry land elevations continued during this period. Elevations for levees, currently dry Delta islands, and areas surrounding Suisun Marsh, have been merged with the original Delta bathymetry grid of currently wet(able) areas of Suisun Bay and the Delta and will be used in scenarios involving sea level rise or levee rupture.

A GIS based methodology was set up and transferred to CASCaDE scientists for editing the bathymetric grid. This will replace the previous outdate application used to perform this task.

3.2 PHYTOPLANKTON MODELING

3.2.1 GIS Grid Improvements

During this period, we continued work with Amy Mathie in the USGS Geologic Discipline to develop a GIS based method to 1) incorporate discrete measurments of benthic grazing rate, 2) overlay them on the bathymetry grid, then 3) interpolate between those measurements and produce a full grid of grazing rates for use in the model. Mathie tested several approaches for the interpolation and settled on one which will interpolate only along wet areas (i.e. not across dry land). Mathie trained Monsen and Lucas on how to implement this method and how to use the GIS software to manually edit grids of grazing rates. This overall approach should be useable for other biological input parameters for which discrete measurements are available but for which the model will require a fully populated grid.

3.2.2 Model Development

We continued to identify and trouble-shoot isolated numerical issues causing instabilities (e.g. at gates), so that rigorous accounting of mass can be performed. The new GIS tools have greatly assisted us in visualizing spurious model output and isolating numerical problems.

3.3 TEMPERATURE MODELING

3.3.1 Quality Control and Processing of Meteorological Data

Meteorological data (downloaded and preprocessed in the previous period) was checked for quality and reasonableness and was further processed to develop ancillary parameters (e.g. daily max or min). In all, 20-year time series for 14 parameters at 4 stations were delivered to Mike Dettinger for downscaling from global climate models to local climate scenarios for the future climate change cases we will ultimately run. This data is relevant to not only the water temperature model, but also to the phytoplankton and hydrodynamic models. The 14 meteorological parameters are:

1. Daily precipitation
2. Daily solar radiation
3. Daily average relative humidity
4. Daily min relative humidity
5. Daily max relative humidity
6. Daily average air temperature
7. Daily min air temperature
8. Daily max air temperature
9. Daily average dew point
10. Daily average vapor pressure
11. Daily average wind speed
12. Daily min wind speed
13. Daily max wind speed
14. Direction of daily max wind speed

3.3.2 Additional Simpler Empirical Models of Salinity and Temperature

Through the last few CASCaDE team meetings, it became evident that some of the "downstream" modeling components (e.g. bivalves, fish, egeria, contaminants) will need a method for predicting Delta salinity and water temperatures for a much larger ensemble of climate change scenarios than the detailed, computationally intensive DELTA-TRIM model can reasonably perform. We collectively discussed the idea of developing a "simpler" perhaps empirically based and computationally very efficient model of salinity and temperature that could be driven by outputs from the hydrologic and climate models. This simpler model would produce salinity and temperature distributions less detailed than what the TRIM model can calculate, but these coarser distributions should be of great use to the ecological components of CASCaDE. We have discussed this modeling need with Professor Mark Stacey at UC Berkeley, and he has agreed to work with us and a graduate student to develop this new modeling capability.

March 2006 through August 2006

3.1 HYDRODYNAMIC MODELING

In phase 1 of this project, we are laying the groundwork necessary to run the different scenarios. The major tasks for this 6 month period have been: A) improving the bathymetric grid and incorporating information about levee heights and island elevations, B) identifying the TRIM output required by '"downstream" models, and C) establishing communication with the Delta Risk Management Strategy (DRMS) program.

3.1.1 GIS Grid Improvements

Because the grid editing software currently used to update bathymetric data for TRIM was inadequate for the current application, we are changing our approach to use GIS. To do this migration, we obtained GIS help from the Geologic Division of the USGS/Menlo Park. The goals for the GIS work are to: a) establish a method to get the TRIM bathymetry grid in and out of GIS so we have a more robust editing system and b) create a method to interpolate benthic data for use in the phytoplankton modeling (see Subtask 2 below).

Significant additional information became available as a result of discussions during this process. The levee failure scenario requires knowledge of both levee heights around the islands and the elevations of the islands that would be flooded in the event of levee failure. An expert in the translation of aerial photography into digital elevations volunteered his time to translate recent photographs of the central and western regions of the Delta into a form that could be merged with the Delta TRIM bathymetric data. This information has been incorporated into the GIS database and will be translated into an expanded bathymetric grid for Delta TRIM. In addition, detailed elevation information for the marsh region around Suisun Bay was incorporated into the database. This is a region that may be inundated during sea level rise scenario. (See Figures 3.1-3.3.)

3.1.2 TRIM Outputs

All tasks that are "downstream" of the Delta TRIM model met on March 22, 2006 to discuss the output that each task will require. There were two primary issues discussed:

1) What time are we going to use as a base case?

Because of natural variability in this system, it is hard to define just one year to use as a basis for "current day." We determined that defining the "current day" base case does not need to happen before starting work on the future scenario periods. However, TRIM scenarios need to run for a full year because of the unique characteristics of each season. For the calibration/verification of models (other than TRIM-hydro, phyto, temperature), we will used observed data rather than TRIM output.

Nancy Monsen, Jim Cloern, and Alan Jassby (UC/Davis) met subsequently to establish an approach to define distributions of key parameters in the historical past. We are currently using the BDAT database to establish distributions of data based on month, location and water year type.

2) What constituents are important outputs from the model?

The general conclusion was that we would like to store as much output from the model as possible to limit the number of TRIM runs. We will store the data on a server to which every group has assess. We ideally would like hourly data at each grid cell.

3.1.3 Establishing communication with DRMS program

Nancy Monsen attended a DRMS meeting at the URS Cop. Offices in Sacramento, CA on 5/8/2006. The purpose of this meeting was to discuss with the operators of the State Water Project and Central Valley Project how water project water management decisions would be made in the event of catastrophic levee failure. One of the agenda items was an overview of the DRMS program and what it is trying to accomplish and an overview of the water management modeling teams goals. The meeting allowed us to identify places where our work will overlap with DRMS and products that CASCaDE can produce that will assist the DRMS effort.

Since the meeting, Ralph Svetich (DWR, DRMS program manager) has been in contact with Nancy Monsen several times in order to convey information about their climate change scenario development. This information has been forwarded on to the appropriate people within the CASCaDE group.

3.2 PHYTOPLANKTON MODELING

3.2.1 GIS Grid Improvements

As mentioned above, we have begun work with colleagues in the USGS Geologic Division to obtain assistance in incorporating benthic (clam) grazing rate values at discrete measurement locations in the Delta from several previous CALFED funded studies so that, ultimately, interpolated maps of benthic grazing rate throughout the TRIM model domain could be generated for input to the model. So far, grazing rate and related information has been QC'ed, processed, incorporated into the GIS environment, and overlaid on the bathymetry grid for the model (see Figures 3.4-3.5).

3.2.2 Model Development

The existing biological portions of the TRIM code have been restructured and further modularized to increase compatibility with hydrodynamic and temperature modules. We have investigated and solved issues related to the grid and numerics causing, in isolated cases and usually near boundaries, negative phytoplankton concentrations. Work is continuing to develop a rigorous mass accounting procedure to assure the absence of any spurious (e.g. numerically induced) sources or sinks of phytoplankton biomass in the model and ensure strict mass conservation. Historical data for zooplankton biomass has been obtained, for use in calculating zooplankton grazing rates in the model. Lucas, Thompson and Parchaso have met twice to develop and refine strategies for coupling models of clams and phytoplankton.

3.3 TEMPERATURE MODELING

From June 2006-August 2006, Dr. Mark Stacey, associate professor of Civil/Environmental Engineering at the University of California/Berkeley provided technical assistance to further develop the temperature module component of TRIM. The priority temperature modeling tasks for 2006 were: A) Identify the meteorological stations within the Delta to be used to drive the temperature module, B) Develop a technique to translate daily temperature data into a diurnal signal, and C) Delta scale calibration.

3.3.1 Identify the meteorological stations to drive the temperature module

Four historical CIMIS stations were identified as stations that will be used to drive the temperature module:

Brentwood*	Central Delta	1985-2006
Manteca	South Delta	1987-2006
Nicolaus	North Delta	1983-2006
Davis	North Delta	1982-2006

* Primary station

All historical data (~20 years) for all stations was downloaded and processed into a form that can be used by Mike Dettinger (Task 1) to drive the model for future scenarios. The constituents for each station included:

Daily	Hourly
CIMIS Eto (mm)	CIMIS Eto (mm)
Precip (mm)	Precip (mm)
Sol Rad (W.sq.m)	Sol Rad (W.sq.m)
Avg vapor pressure (kPa)	Vapor pressure (kPa)
Air temp (degree C) (Max, Min, Avg)	Air temp (degree C)
Rel. humidity (%) (Max, Min, Avg)	Rel. humiditiy (%)
Dew point (degree C)	Dew point (degree C)
Avg. wind speed (m/s)	Wind speed (m/s)
Wind run (km)	Wind direction (km)
Avg soil temp (degree C)	Soil temp (degree C)

There are data quality flags on some of this data. We are going through a quality control process to identify gross outliers in the datasets. Once the quality control is complete, the data will be provided to Task 1 for processing for our specific scenarios.

3.3.2 Translate daily temperature data into a diurnal signal

For all scenarios, the watershed model will provide daily temperatures to drive the TRIM model. This information needs to be translated into a diurnal signal for model stability reasons. Dr. Stacey is developing a technique where a separate calculation is done outside the model domain for a "bathtub." The output from this separate simulation will drive the model boundaries. This technique is still under development.

3.3.3 Calibration for full Delta domain

The first step in the process was to identify and fix a logic problem in the current code that was caused by the migration of the original code to the modular form of the code. The problem has been isolated to a small sub-section of the code.

TASK 4: SEDIMENTS/GEOMORPHOLOGY

<u>September 2007 through February 2008</u>

We have completed hindcast modeling of the 1887-1922 and 1922-1942 periods, for Suisun Bay. We have found that model parameters (such as Delta configuration and sediment characteristics), vary with time. While agreement with net erosion measurements is relatively easy to modulate (by adjusting sediment parameters), spatial agreement is variable. Maximum spatial agreement was achieved during the 1942-1990 period, while minimum spatial agreement was achieved for the 1922-1942 period.

Also, detailed calibration was carried out for the Delft3D San Francisco Estuary model, which has a model domain from Point Reyes to Sacramento and Vernalis. The calibration included tidal constituent analysis both in terms of phases and amplitudes and sediment load along the estuary. Preliminary calculations of typical sediment transport over the year were made. These resulted in a predicted yearly sediment budget for San Francisco Estuary (using a 2D approach) and in detail for Suisun and San Pablo Bays, where a 3D approach was applied. Results will be used to act as boundary conditions for a model focusing on San Pablo Bay. This model will include 3D hydrodynamics, sediment transport, and account for the effect of wind-generated waves.

March 2007 through August 2007

Hindcasting of bathymetric change, 1867-1887

As a preliminary step for evaluating future scenarios of climate change, we must investigate model performance for historical periods and develop computational methods to reduce input needs and time requirements. We have successfully calibrated the ROMS model to decadal-timescale bathymetric change in Suisun Bay, for the period 1867-1887, using the bathymetric change data of Cappiella et al. (1999). Model modifications included the use of a more advanced wind-wave module and innovative time-stepping techniques: the morphological hydrograph and morphological acceleration factor. Model parameters that were modified include bed sediment parameters and wave period; these modifications are warranted because the 1867-1887 period is a different temporal period than the modern simulations of the last modeling simulations (detailed in previous progress reports), and in these simulations we use a different wind-wave module which allows for feedback between geomorphic evolution and the calculated wave height.

We have performed a successful hindcast of bathymetric change in Suisun Bay, between 1867-1887, when sediment supply was increased due to hydraulic mining. The observations of Cappiella et al. (1999) provide a bathymetric change data set for calibration purposes. Major idealizations used include synthetic functions for seaward SSC, wind speed, and salinity. Computational expense is reduced through the use of a morphological acceleration factor, that scales tidal-timescale bed changes by a constant value, and updates the bathymetry within the model. Reconstruction of historical freshwater flows and sediment loads led to the identification of a limited set of hydrographs, known as morphological hydrographs, which provide the same bathymetric change as the set of real hydrographs. Performance of the model is quantified by comparing observed net depth changes, in specific depth intervals, with simulated depth changes. Each morphological hydrograph is modeled separately, and the results are composited. Mean error was 5%, quantified as the areally weighted error as a percentage of depth; i.e. in 1 m of water the error is 0.05 m. Qualitative patterns of erosion and deposition within Suisun Bay are also modeled well. Performance is also evaluated using the Brier Skill Score (BSS), though this does not adjust error relative to depth. Decomposition of the BSS, over depth intervals, is a useful tool for evaluating performance in different depth regimes. This modeling framework provides a quick and robust approach for simulating geomorphic change in estuaries, especially when computational power and data availability are limited. Additional findings of note include the applicability of the morphological acceleration factor in intertidal systems and non-stationary sediment supply conditions.

Preliminary 20 year scenarios of warming, sea-level rise, and decreased sediment supply

In the previous efforts we established the validity of our approach towards modeling sediment transport on the tidal, annual, and decadal-timescale. With this tool, we can now simulate changes in geomorphology in response to future scenarios, including climate change, sea-level rise, and decreased watershed sediment supply. The primary effects of climate change on Suisun Bay are the alteration of the freshwater flow hydrograph (Knowles and Cayan, 2002), and sea-level rise (Ryan et al., 1999). Climate simulations have demonstrated that a moderate warming over California will lead to decreased snowpack, causing earlier and flashier flows. Continued warming throughout the world, combined with polar icecap loss, will increase the volume of the world's oceans, and increase sea level. In addition to these climatically induced changes, an ongoing decrease in sediment supply from the Central Valley and Sierra Nevada (Wright and Schoellhamer, 2004) may be a signal of equal or greater relevance. The results of the previous chapter show that net sediment load induces greater changes in bathymetry than shape of the hydrograph, so it is necessary to include a scenario of decreasing sediment supply.

There have been no previous studies analogous to this in the literature, but it is possible to infer what changes may be induced by climate change and decreasing sediment loads. A flashier hydrograph will alter the seasonal pattern of sediment transport, by transporting more sediment seaward earlier in the water year. Dry season landward transport may increase and move further landward in response to decreased dry season freshwater flows. Therefore seasonal patterns of sediment transport will be intensified, thereby intensifying seasonal changes in geomorphic change.

Sea-level rise will push the salinity intrusion limit landward, turning all portions of the estuary saltier. This may also intensify gravitational circulation and landward sediment transport, shifting depositional patterns landward. An increase in sea-level rise will also slightly alter the wind-wave resuspension patterns, especially in shallower areas. Interaction between water depth and wave-induced bottom orbital velocity will alter the energy transferred to the sediment bed. Overall, this will change the cross-shore profile of erosion and deposition. In areas with fringing mudflats and tidal wetlands, this interaction may be critical to the survival of intertidal areas.

The most certain change in future conditions may be watershed sediment supply. Since the peak in sediment loads during hydraulic mining in the Sierra Nevada, a persistent decrease in sediment loads from the Central Valley has been observed by several researchers. The most recent study, by Wright and Schoellhamer (2004), noted a 50% decrease in sediment loads from the Sacramento River since 1957. This trend is largely attributed to a reduction in available mining debris and sediment trapping in reservoirs behind dams. As this trend continues, sediment loads may continue to decrease. This will increase the importance of seaward sediment loads to Suisun Bay for maintaining elevation. Nonetheless, a reduction in watershed sediment loads will ultimately lead to a relative increase in erosion throughout San Francisco Bay.

We have currently completed modeling simulations of four 20 y scenarios: 1) base-case; 2) 2030 warming and sea-level rise; 3) 2030 decreased sediment loads and sea-level rise; and 4) 2030 warming, decreased sediment loads, and sea-level rise. Preliminary results suggest that moderate warming by 2030 (which alters the timing and magnitude of streamflow) has a relatively minor effect on geomorphic change, as compared to a 6 cm increase in sea-level or a 37% reduction in watershed sediment supply. Sea-level rise alters the wave climate and reduces sediment redistribution, and promotes deposition in shallow (<2 m) areas of Suisun Bay. Decreased sediment loads, especially in wet years, reduces overall sediment delivery and deposition in Suisun Bay. These results will appear in the PhD dissertation of Neil Ganju.

Progress was also made towards running a hindcast model of the bathymetric evolution of San Pablo Bay over the last 150 years using a 2D numerical model. A curvilinear grid has been developed covering San Fransisco Bay using the most recent measured bathymetries and a schematized area covering the Delta and San Joaquin River, the Sacramento River and the Yolo by-pass. The aim of this model is to derive boundary conditions for a smaller scale model later to be developed on the San Pablo Bay area and to allow for long-term morphodynamic modeling under different (schematized) river discharge scenarios. The tidal hydrodynamics of the model have been calibrated and partly validated for high and low river discharges. Next steps include calibration of sediment transport under different river discharges and coupling to smaller scale San Pablo Bay model.

<u>**September 2006 through February 2007**</u>

Calibration to modern flux data

The Suisun Bay geomorphic evolution model was calibrated to several years of modern sediment flux data: 1997, 1998, 2002, 2003, and 2004. An eight-parameter sensitivity test was also performed on the calibrated model. It was determined that the model was most sensitive to wave energy, due to the non-linear relationship between wave energy and bed shear stress. These efforts were presented at the 2006 Physics of Estuaries and Coastal Seas Conference, in Astoria, Oregon, and a manuscript was submitted to the conference volume, to appear in Continental Shelf Research.

Preliminary one-year scenario exercise

The aforementioned calibrated model was used to evaluate the effect of sea-level rise and flashier flows on sediment transport. This exercise was intended to provide a brief look at the model’s response to simple changes in forcing. The main result was that the non-linear interaction between sea-level rise and hydrograph shape is important, and can contribute to significant changes in morphology, especially in the shallow portions of Grizzly and Honker Bays.

Hindcasting of bathymetric change

The hindcasting of 1867-1990 bathymetric change is dependent on formulation of historical load time-series, and a time-stepping procedure (detailed in last progress report). Both the load time-series and time-stepping procedure have been modified since the last progress report.

The methodology for generating the load time-series has remained unchanged, however the flow data used for matching historical hydographs was updated. We now use the unimpaired flow estimates generated by Noah Knowles’ BDWM instead of Dayflow. This accurately represents the unimpaired nature of the hydrograph during the historical era (pre-1930). The unimpaired flow estimates are available for 1967-1987, which provides 21 years of possible matches. This revised approach is detailed in a journal article in preparation.

The time-stepping procedure has also been modified, to follow a more robust method. First, the hydrograph from each year is compared to four “prototype” hydrographs, each of which represents a frequently-occurring hydrograph shape. Each prototype hydrograph is then used to drive the geomorphic model separately, for a one-year period. The geomorphic results for each prototype are then superimposed (with weighting appropriate to the frequency of occurrence). This procedure will be tested for the 1867-1887 bathymetric change period.

<u>**March 2006 through August 2006**</u>

The four major activities which have been completed for this task are, in reverse chronological order, 1) development of historical boundary conditions for hindcast modeling of bathymetric change; 2) development of a time-stepping procedure to reduce computational load; 3) validation of the sediment transport model with recent sediment flux data; and 4) calibration of a sediment transport model to recent sediment flux data. These activities are all calibration/validation exercises, in order to ensure that future modeling of climate change scenarios are robust and sound. The details of these activities are listed below.

4.1 DEVELOPMENT OF HISTORICAL BOUNDARY CONDITIONS

Sediment load data are available for the upstream boundaries of the domain (Freeport and Vernalis on the Sacramento and San Joaquin Rivers, respectively) for periods beginning in 1959. Hindcasting simulations require sediment load data for 1867-1990, therefore a method must be found to estimate daily sediment loads for 1867-1959. The first step is acquiring freshwater flow data.

4.1.1 Determination of total yearly flow

The eight-river index (California Department of Water Resources) is a measure of unimpaired flow into the Delta, and prior to water exports this represents the total flow into the Delta. This record is available back to 1906. Meko et al. (2001) developed a yearly time-series of total Sacramento River and San Joaquin flow using tree-ring chronologies, for the period 868-1977. This provides an estimate of total flows for 1867-1906.

4.1.2 Construction of monthly hydrograph

Monthly total flows are available from the eight-river index, though combined values are provided for October/November, June/July, and August/September. Flow was split evenly between months with shared total flows. The monthly flows were compared with monthly precipitation totals from Sacramento, which span 1878-present. The total flow in a month was linearly regressed against the prior precipitation in the water year, for example, total January flow was regressed against total precipitation from October, November, December, and January. The regression spans 1906-1929, prior to major water diversions, when the eight-river index was a good measure of flow into the Delta. Using the regression equation with 1877-1906 precipitations data yields monthly flow estimates from 1877-1906.

4.1.3 Comparison of monthly hydrographs

It is assumed that two years with similar monthly hydrographs share similar daily hydrographs. Therefore, the shape of monthly hydrographs from 1877-1928 were compared to monthly hydrographs from the period 1929-present, where daily data are available. For example, the monthly hydrograph from water year 1890 was cross-correlated with each of the 75 hydrographs from 1929-2003. The hydrograph from 1929-2003 that matched the 1890 shape closest was selected as the corresponding year, say, 1945. The daily hydrograph from 1945 was then used as the daily hydrograph for 1890. Multipliers were applied, if necessary, to maintain the same total flow as estimated from prior steps.

4.1.4 Comparison of yearly total flow

For the period 1867-1877 there are limited precipitation data, so the total yearly flow was compared with the total yearly flow from 1929-2003. The year with the closest total flow was used as the surrogate daily hydrograph. Again, total flow was maintained.

4.1.5 Estimation of sediment loads

The sediment rating curve relationship $QC=aQ^b$, was used to estimate sediment loads. The coefficient "b" (represents the erosive stream power) was determined using 2000-2003 data, with a value of 1.13. Coefficient "a" represents the sediment supply, and was used as the calibration parameter. Calibration data are from Gilbert (1917) (7.4 Mt/y, for 1849-1914) and Porterfield (1980) (3.5 Mt/y for 1909-1966). While these numbers are period averages, coefficient "a" was modified to yield the same period averages using daily data. Both Gilbert (1917) and Porterfield (1980) provide volumetric load estimates, these were converted to mass load estimates using an average density of 529 kg/m^3 (Krone 1979).

4.2 DEVELOPMENT OF TIME-STEPPING PROCEDURE

Analysis of model results suggests that fluxes over the most dynamic periods (winter, summer) can be extrapolated individually to represent seasonal dynamics accurately. This procedure was tested for the two modeled water years. Two four-week periods were selected to represent 1) winter conditions (high freshwater flow with episodic wind-waves), and 2) summer conditions (low freshwater flow and steady diurnal wind-waves). The four-week period contains tidal variability due to the 14-day spring-neap cycle, which is critical for sediment transport processes. The center of the winter modeling period is determined as the time of peak sediment load, and two weeks are modeled before and after the peak. The fluxes are extrapolated for the time between elevated freshwater flow in the fall, and the return to baseline summer flow. The net sediment flux is then multiplied by a factor of 1/3, as this is the most dynamic period (the remainder of the winter is less dynamic). The beginning of the summer period is identified as the time at which baseline flows return, to the end of the water year. The temporal center is identified, and two weeks before and after are modeled. The same extrapolations are performed for the summer period. The two-season time-stepping method results in a net export of 2.96 Mt for 1997 as compared to the actual result of 2.74 Mt. These small deviations are minimal, and suggest that this time-stepping procedure is suitable for decadal-scale simulations, where computational expense must be minimized.

4.3 VALIDATION TO WATER YEAR 2004 FLUXES

The calibrated model is validated using flux data from water year 2004. Therefore we calibrate to a relatively dry period, and the mechanics of the model are validated during a much wetter period. Validation will be quantified in reference to simulating the correct net flux between Suisun Bay and the Delta (Mallard Island cross-section), and the correct net flux between Suisun Bay and Carquinez Strait (Benicia Bridge cross-section) within the error bounds of the flux measurements (McKee et al. 2006; Ganju and Schoellhamer in press). Preliminary model results compared well with sediment flux estimates as computed by McKee et al. (2006) and Ganju and Schoellhamer (in press) in terms of the seasonal pattern, with export during high flows and import during the summer low-flow season. However, the net sediment import for 2004 was estimated at 0.006 Mt by Ganju and Schoellhamer (in press), while the model results show a net export of 2.35 Mt. This discrepancy is attributed to poor agreement in the low-flow season, when landward dispersive flux is maximized. During this season, fluxes are extremely sensitive to the synthetic seaward sediment boundary condition. Future efforts will refine this boundary condition, especially for dry years.

4.4 CALIBRATION TO WATER YEAR 1997 FLUXES

The seaward suspended-sediment concentration boundary condition and sediment properties (i.e. bed shear strength, settling velocity, erosion rate) are calibrated to the water year 1997 data. This period contains peak freshwater flows that are 3.5 times greater than the 2004 period, and yearly cumulative flow is a factor of two larger. Therefore we will calibrate to a relatively extreme (in terms of freshwater flow) period, and the mechanics of the model will be validated during a drier period. Landward boundary conditions and the remaining seaward boundary conditions are specified as outlined above. Calibration goals are to simulate the correct net flux between Suisun Bay and the Delta (Mallard Island cross-section), and the correct net flux between Suisun Bay and Carquinez Strait (Benicia Bridge cross-section) within the error bounds of the flux measurements (McKee et al. 2006; Ganju and Schoellhamer in press). Model results compared well with sediment flux estimates as computed by McKee et al. (2006) and Ganju and Schoellhamer (in press). The seasonal pattern of sediment flux was represented, with export during high flows and import during the summer low-flow season. The net sediment export for 1997 was estimated at 2.83 Mt by Ganju and Schoellhamer (in press), while the model results show a net export of 2.74 Mt.

We have developed an estuarine geomorphic model based on a traditional tidal timescale hydrodynamic/sediment transport model, by idealizing boundary conditions, applying novel calibration procedures, and implementing a simplified time-stepping method. The Regional Oceanic Modeling System (ROMS) was developed for Suisun Bay, for the purpose of hindcasting historical geomorphic change and modeling future scenarios of geomorphic change. Seaward boundary conditions were idealized using tidal harmonic prediction for tidal stage and velocity, and a synthetic time-series for sediment concentrations was constructed by applying typical seasonal wind patterns and the spring-neap tidal signal. Calibration of these idealized boundary conditions and bed sediment parameters was accomplished using sediment flux data for the boundaries of Suisun Bay from water years 1997 and 2004. Calibrating to sediment fluxes guarantees that modeled net geomorphic change will not exceed the total supply of sediment from landward and seaward sources. The successful simulations of 1997 and 2004 allow for the development of a time-stepping method that reduces computational expense. The method involves simulating the two distinct sediment-transport seasons of Suisun Bay as month-long periods, then extrapolating the results of each compressed period for the entire season. Computational time for hindcasting and future scenario simulations is now reduced by 85% using this simplified method. Boundary conditions for the historical period were developed by analyzing proxies for freshwater flow and sediment loads. The sediment load time-series for the period 1867-1990 will allow for hindcasting simulations of bathymetric change.

An abstract entitled “Calibration of an estuarine sediment transport model to measured cross-sectional sediment fluxes for robust simulation of geomorphic change”, by Neil K. Ganju and David H. Schoellhamer was accepted for an oral presentation at the 2006 Physics of Estuaries and Coastal Seas Conference, September 18-22, 2006, Astoria, Oregon. This presentation details the calibration and validation procedure that was used to develop the geomorphic model; this same model will now be used for the hindcasting and scenarios modeling.

TASK 5: FATE AND EFFECTS OF METALS

September 2007 through February 2008

We spent time evaluating stable isotope data in Corbula and Corbicula, both as tools to validate the Lisa Lucas' coupled hydrodynamic/phytoplankton model (she presented this work at the Estuarine Research Federation conference in Florida this past fall) and to predict the influence of changing San Joaquin flows on Se concentrations in clams at Carquinez St. in Suisun Bay. We requested further funding through Calfed's call for supplementary funds for existing projects to analyze archived Corbula samples for Selenium and Stable isotopes (monthly for years 2003 – 2007) to complete dataset from 1999 through 2007 and to add more variable water years (2003 – 2007).

New analyses of stable isotope and Se data from Corbula amurensis showed a statistical link between a San Joaquin River isotopic signal and seasonal increases in Se concentrations in bivalves. This is the first positive evidence of the importance of changes in relative riverine inputs to the Bay on the Se issue. Further development of this data will greatly enhance our ability to model how changes in relative river inputs with climate change will influence Se contamination. A synthesis of Se literature has allowed us to develop trophic transfer coefficients for a large number of invertebrates, expanding our capabilities to model Se food web transfer in both the freshwater and brackish water parts of the Bay-Delta Ecosystem. Preliminary applications of the model to small sub-systems have begun.

Robin Stewart also began working with quantile regression as a tool for separating influences of geochemical/trophic level and morphological attributes on mercury accumulation in food webs. She presented this work in the fall at the Society of Environmental Toxicology and Chemistry conference in Milwaukee, WI.

March 2007 through August 2007

Progress during this period was focused on further resolving key parameters to be included in Hg and Se models. We attended the Calfed Hg Review workshop where key processes controlling mercury fate and bioavailability in the San Francisco Bay and Delta were discussed. Although there has been significant progress made on key processes it was apparent that the interactions among the processes are complex and the ultimate impacts on Hg fate and bioaccumulation remain unclear. For this reason we will focus Hg modeling efforts to include first-order processes that are better understood including, the strong relationship between methymercury concentrations in water and those in biota. Other second-order processes are known including the amount of reactive mercury and activity of the bacterial community, but their influence on methylmercury concentrations in water are not fully understood. Very preliminary work on the transport of dissolved MeHg from wetlands suggests that wetlands could be a source of MeHg to the surrounding environment. We will work with Nancy Monsen using passive tracer simulations to determine how the wetland MeHg mixes with the Delta water and if increased wetland/flooded habitat could elevate baseline MeHg concentrations in the delta.

We also spent time discussing data needs with other co-PIs as they develop their models.

September 2006 through February 2007

The primary progress this period was development and fleshing out of the conceptual model clarifying how climate change will affect the influence of Se and Hg in the estuary. Primary findings after assembling the model were that:

Shifts in relative inflows of the San Joaquin River and Sacramento River must be considered as influences on sources of the two metals. If SJR inflows increase relative to Sacramento inflows, then Se inputs will increase with impacts cascading through the food web. However, Hg inputs could decrease.

Factors that affect success of metal-vulnerable fish species will also have a cumulative effect with Se and Hg, but the effects differ among species and metals. Sturgeon are very vulnerable to any shifts Se and Hg inputs because a) both are reproductive toxin and Se are already likely to be affecting sturgeon, b) sturgeon have very low fecundity so any recruitment losses could have long –term implications. Shifts in climate that increase both Se and Hg could result in cumulative effects from the two toxins. Sacramento splittail on the other hand are very fecund but vulnerable in low flow years (when recruitment suffers as a result of habitat loss). Se effects on recruitment would affect splittail primarily in low flow years; becoming a cumulative impact of potential significance if extreme years or droughts become more frequent. Striped bass are unlikely to be affected by Se but are quite vulnerable to Hg, although population effect models must factor in their fecundity.

March 2006 through August 2006

Preliminary experiments to accomplish the necessary bioaccumulation modeling are underway. Crucial hyper-accumulators in the delta are being characterized (these are the best indicators). Species include the bivalve Corbicula and the snail Lymnaea sp. We will conduct the modeling work during the next fiscal year.

The following related papers have also been published:

Croteau, M.N., Luoma, S.N., and Stewart, A. R. Trophic Transfer of Metals Along Freshwater Food Webs: Evidence of Cadmium Biomagnification in Nature. Limnology and Oceanography, v. 50, 1511-1519, 2005.

Croteau, M.N., Luoma, S.N. Delineating Copper Accumulation Pathways for the Freshwater Bivalve Corbicula Using Stable Copper IsotopesEnvironmental Toxicology and Chemistry, V. 24, pp. 2871-2878. 2005.

TASK 6: INVASIVE SPECIES

September 2007 through February 2008

We continued to refine model parameters and controlling factors for initial conditions for the bivalve models. (1) Upstream initial conditions for juvenile Corbula can be related to position of X2. Embayments near the upstream distribution limit therefore have a limited period for recruitment and we see one recruitment period in fall at these locations during normal runoff years and 2 or more recruitment periods during drought years. (2) The number of adult *Corbula* limits the number of recruits that can settle in a patch once the adults pass a threshold – an exponential relationship was derived for this phenomena. (3) Evaluation of Corbicula size data at historic DWR benthic stations shows that most stations have a baseline of 200-400 recruits/m^2 throughout the year. The exception to the baseline is the area surrounding the export pumps which appears to be less predictable.

Presentation: *Corbicula* and *Corbula* are stressing the restoration: Can we manage freshwater to limit their success? Presented by J. Thompson. Bi-Annual Estuarine Research Federation Meeting; Providence Rhode Is., Nov 2007.
Paper Submitted/Accepted: Thompson, J. *Corbula amurensis* in San Francisco Estuary. The Invasive Species Compendium. Produced by CABI. With support from US Department of Agriculture and others. (Hardcopy and Web version). http://www.cabi.org/datapage.asp?iDocID=180

March 2007 through August 2007

Analyses of recruitment data for the bivalves has at all USGS and DWR benthic stations has been done with respect to the position of X2. The recent change in fall freshwater pumping schedules has helped broaden this distribution study and clarify some trends. We are now examining the data to see if there are periods with increased mortality of adults with change in velocity and/or salinity.

J. Thompson spoke as an invited participant in the variable delta workshop held by CALFED in April 2007 to discuss the possibilty of limiting the spatial distribution of *Corbula* in the western Delta by altering freshwater flow. This data was available due to the analyses that we have done in CASCADE.

J. Thompson spoke as an invited participant at the "Workshop for Environmental Modeling of California Central Coast" summarizing the CASCADE modeling project. The participants were primarily modelers from the Naval Research Lab, Naval Post Graduate School, UC Santa Cruz, and the Montery Bay Aquarium Research Institute.

September 2006 through March 2007

We continue to compile the environmental and bivalve data necessary to derive the model parameters. We are completing the analysis of *Corbicula* biomass to see if there is a relationship between bivalve growth rate and the transport of San Joaquin River-derived phytoplankton. We are writing up our analysis of Delta-wide *Corbicula* distribution (abundance and biomass) and show that the distribution of new recruits is related to flow conditions (they are present most places but in fewer numbers in the center of large rivers) and the distribution of adults is related to advected sources of phytoplankton and locally produced phytoplankton. The recent spread of *Corbula* up river with a change in fall water export schedules has allowed us to examine the fall recruitment and increased survival into adulthood of this bivalve during periods when salt water extends up river for a short time period and the analyses of this recent data are ongoing.

We are also acquiring literature estimates of growth, mortality and natality rates for *Corbicula* to compare them with the rates that we are deriving. We plan to run the model with a range of values from the literature to show the potential population size in this system if the clams were given sufficient food.

We have established a protocol for developing a statistical range of bivalve distributions for different scenarios. Based on statistical models of freshwater flowrate and salinity and temperature, we will develop a range of initial distributions for the bivalves for each scenario. Therefore we will be able to establish some error for our distributions (ie we will use the distributions that we determined from the salinity distribution to establish a range of initial conditions). We are looking into the possibility of doing similar ensemble forcasting for a range of growth and mortality parameters.

March 2006 through August 2006

Food web changes that result in increases or decreases in phytoplankton may affect water quality and may determine the success of higher trophic level animals. Similarly, changes in phytoplankton biomass, availability of contaminants, and availability of organisms that bioaccumulate contaminants will affect the trophic transfer of contaminants in the system. Thus, two of the primary objectives of the CASCADE study are to establish the distribution and magnitude of phytoplankton biomass and to determine the level of bioaccumulation of Hg, Se, and Cd in the Delta and North Bay for prescribed scenarios. The goal of Task 6 is to develop simple models to determine the biomass of two filter-feeding bivalves (*Corbula amurensis* and

Corbicula fluminea) that have the potential to limit the production of phytoplankton and are capable of bioaccumulating contaminants in a full variety of habitats in the Delta and North Bay.

We are compiling the environmental and bivalve data necessary to derive the model parameters. This includes the compilation of USGS and CA Dept. of Water Resources data from stations in Carquinez Straits, through the North Bay and into the Delta. Our first set of analyses has included examining the time series of *Corbicula* abundance data at a south central location in the Delta to determine if recruitment can be related to export/inflow water ratios and West Outflow parameter (DWR data), fish barrier position, and the relative flows between the Sacramento and San Joaquin Rivers. We are now compiling the data available for biomass at that location to see if there is a relationship between bivalve growth rate and the transport of San Joaquin River-derived phytoplankton. We are also completing an analysis of Delta-wide *Corbicula* distribution (abundance and biomass) and how the distribution of new recruits and adults is related to the following: hydrologic conditions, possible sources of advected phytoplankton, known sources of locally produced phytoplankton, temperature, salinity, and habitat parameters (includes size of waterway, natural vs man-made infrastructure, morphology of channel if appropriate). The recent spread of *Corbula* up river with a change in fall water export schedules has allowed us to examine the fall recruitment and increased survival into adulthood of this bivalve during periods when salt water extends up river for a short time period.

In discussions with the hydrodynamic (Monsen) and phytoplankton (Lucas) modelers we have established a protocol for how to connect the phytoplankton and bivalve models and established a timeline for variables needed from the hydrodynamic model to establish habitat type in the Delta and North Bay.

We have compiled the information for data sources and availability of data. The analyses of some of the *Corbicula* recruitment and biomass data has been started at the south central Delta locations. Our analyses of the *Corbicula* data shows there to be at least a weak relationship between West Outflow (SJR water flow past Jersey Pt is negative with "reverse" flow) and *Corbicula* abundance. Analyses of the *Corbula* distribution data shows that increasing salinity in fall increases the success of bivalve recruitment in the Sacramento River and down to the confluence which increases their biomass by the next summer.

TASK 7: NATIVE AND ALIEN FISH POPULATION TRENDS

<u>September 2007 through February 2008</u>

We are revising the simple review article regarding effects of climate change on fish populations. We will circulate this draft to the CASCADE group to determine if we will move forward with a publication. We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the life cycle models. We analyzed historical flow data from a variety of sources for the major tributary rivers to the San Francisco Estuary using the software package "Indicators of Hydrologic Alteration". We summarized patterns of flow before and after construction of the major hydrologic infrastrcture in the watershed. Projected flow patterns in each climate scenario will be similarly analyzed and compared to flow patterns from the previous two time periods.

Christa Woodley started her CALFED post-graduate fellowship on CASCADE issues in September. She is currently refining her dynamic energy budget models.

March 2007 through August 2007

We continued to compile information regarding effects of climate change on fish populations. We produced a first draft of a simple review article for a journal and circulated it among selected colleagues for review. The draft is currently being revised. We continued to summarize existing information on the environmental tolerances of our fish species of interest. This information will feed directly into the life cycle models. We are also considering publishing this information in some form because it will be of interest to a wide range of fisheries researchers in California. We have compiled historical flow data from a variety of sources for the major tributary rivers to the San Francisco Estuary. We are using the software package "Indicators of Hydrologic Alteration" to summarize patterns of flow before and after construction of the major hydrologic infrastrcture in the watershed. Projected flow patterns in each climate scenario will be similarly analyzed and compared to flow patterns from the previous two time periods.

Christa Woodley has largely completed her dissertation and will begin working on CASCADE issues in September. Dr. Bill Bennett was granted supplemental CALFED funding to participate as a full member of the CASCADE Team.

September 2006 through February 2007

We continue to compile the bibliography regarding effects of climate change on fish populations. We have started summarizing collected information of the environmental tolerances of our fish species of interest. This information will feed directly into the life cycle models. We have also begun summarizing past work on effects of climate change on fish populations. We are currently considering producing a simple review article for a journal.

I recruited Christa Woodley, a finishing PhD student with Dr. Joseph Cech at University of California Davis to apply for a CALFED fellowship to work on the CASCADE project. I introduced Christa to the project and helped her with her application package. Christa was selected to receive a fellowship and will be developing more detailed dynamic energy budget models. I am acting as Christa's community mentor, basically facilitating her interactions with the CASCADE Team. Dr. Bill Bennett and Dr. Peter Moyle will be acting as Christa's research advisors at University of California Davis.

March 2006 through August 2006

I (Larry Brown) used the funds for this period to pay a biological technician to do library research under my direction. We have assembled a bibliographical database of approximately 130 articles documenting the different methods previous researchers have used to infer effects of climate change on fish populations or assemblages. We have also started to compile information on the temperature tolerances and other physiological and habitat needs of species that might be affected by climate change.

I met with Bill Bennett (UC Davis) and Jan Thompson to better define the information needs of the biology portions of CASCADE (Tasks 6 and 7). Notes regarding the outcome of that meeting were distributed to the CASCADE PIs.

Bill Bennett and I met with Susan Ustin (slustin@ucdavis.edu) and Sepalika Rajapakse (srajapakse@cstars.ucdavis.edu) of the Center for Spatial Technologies And Remote Sensing (CSTARS, http://www.cstars.ucdavis.edu/) at UCD with regard to their mapping of Egeria beds in the Delta.. Susan Ustin (Director of the Center) and Sepalika are very interested in collaborating with us. They have some great data and are interested in making the biological connections from their imagery to the ecosystem. They currently have aerial hyperspectral surveys of SAV for the last 3 years (2003-2005) with imagery from mid- to late June for the entire Delta and partial coverages for 2002. They also have partial imagery for October of last year. These data are available as GIS shape files and they are willing to provide the files to CASCADE. This information was forwarded to Nancy Monsen to be forwarded to the GIS folks helping with CASCADE.

TASK 8: PROJECT ADMINISTRATION

September 2007 through February 2008

We organized meetings of the CASCADE Principal Investigators on:

- 17-19 September 2007 (in Ryde, CA). Each PI gave a progress report followed by group discussion; we also heard presentations from our collaborators: Bill Bennett (UC Davis) - linkages between data exploration and the dynamic energy budget (individual-based) modeling of striped bass; Wayne Wagner/Mark Stacey (UC Berkeley) - plans for modeling salinity and temperature from historic monitoring data and future scenarios; Dano Roelvink - Delta-Bay long-term morphological modeling; phase 1, setup of hydrodynamic model
- 4 December 2007 (by teleconference). Highlights included updates on: Robin Stewart – modeling approaches for mercury in food webs; Noah Knowles -- progress in translating Mike Dettinger's downscaled climate scenarios into hydrology; Dave Schoellhamer/Neil Ganju – spinoff project with Jon Takekawa on bird habitats; Nancy Monsen - progress to greatly improve the model representation of bathymetry in the North Delta
- 13 February 2008 (by teleconference). Each PI gave a progress report followed by group discussion; we also began the process of developing the next five-year plan for the USGS Priority Ecosystems Science initiative that provides USGS matching support the CALFED funding of the CASCADE project

March 2007 through August 2007

We composed a matrix to identify the time scales of processes to be considered by each individual task. This matrix is archived and available on the cascade website: http://sfbay.wr.usgs.gov/cascade/reports/ProcessMatrix_MASTER.xls A second synthesis matrix describes the ultimate products of each cascade task, organized by time scale. This summary is also available online: http://sfbay.wr.usgs.gov/cascade/reports/ProductsMatrix_MASTER.xls . The purpose of these matrices is to summarize and clarify the goals and outcomes of individual modeling components of the project. We thank Sarah Foster for donating her time to compile and organize these summaries.

A PI meeting was held by teleconference on 13 June 2007, and a mid-project PI meeting has been scheduled for 17-19 September 2007 at Ryde, CA, with invitations to the CALFED Science Program and outside collaborators/advisors.

September 2006 through February 2007

Multiple meetings were organized, and budget and report preparation were undertaken as usual. Also, a project server was purchased for internal use, and ultimately to provide CASCaDE with a public web presence. Several meetings with our IT staff were held to coordinate setup of this server, and to design the interface by which it will be accessed by team members. Server setup is underway and it should be ready for initial team usage within a couple of months. A public web presence beyond our current portal (http://sfbay.wr.usgs.gov/cascade) is not anticipated this year.

March 2006 through August 2006

This has been the project "spin-up" period—getting individual accounts in place, beginning the process of hiring postdocs, etc. At the same time, the real work of the project has gotten well underway, as discussed in this report. As part of Task 8, multiple team meetings have been organized, with non-Menlo Park members attending via videoconference. CASCaDE meetings have taken place on February 22-23, March 22, March 27, April 28, May 19, and July 17, with another meeting planned for September 8. Numerous smaller meetings have also been attended by team members, including Mike Dettinger's presentation at the California Water and Environmental Modeling Forum, March 1, 2006, Jim Cloern and Lisa Lucas' presentation at the Western Region Water Science Symposium, March 21, 2006, Nancy Monsen's attendance at the Delta Risk Management Strategy Meeting, May 8, 2006, and Neil Ganju's attendance of the Delta Vision Conference, June 6-7, 2006. As part of Task 8, relevant notes and materials from these meetings have been assembled and posted regularly on the CASCaDE Project internal website. Other completed administrative tasks include budget management and production of this report.