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UNIVERSITY OF CALIFORNIA, SANTA BARBARA

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OFFICE OF RESEARCH

SANTA BARBARA, CALIFORNIA 93106-2050

Record Number 08981548
July 1, 1998

Calfed Bay Delta Program Office
1416 Ninth Street, Suite 1155
Sacramento CA 95814

Presented for your review is a request for support for the following described project:

TITLE: Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

PRINCIPAL INVESTIGATOR(S): Dr. T. DUNNE

ADMINISTERING UNIT/DEPARTMENT: INSTITUTE FOR EARTH SYSTEM SCIENCE

TYPE OF PROJECT: New

PREVIOUS AWARD NUMBER:

SUPPORT REQUESTED: $ 386,742

PERIOD REQUESTED: 10/01/98 - 09/30/01

Additional program information can be obtained from the Principal Investigator. All other inquiries should be directed to the undersigned at the letterhead address.

Your favorable consideration of this request will be appreciated. Should the project be approved, the award should be issued in the name of: The Regents of the University of California, c/o The Office of Research, University of California, Santa Barbara, CA 93106-2050.

Sincerely,

Dorothy C. Hall
Contracts & Grants Officer
(805) 893-4034

Enclosures
CC: Principal Investigator
Department Liaison

I -009760

I-009760

Figure 3

Standard Form 424B

OMB Approval No. 0348-0040

ASSURANCES — NON-CONSTRUCTION PROGRAMS

Public reporting burden for this collection of information is estimated to average 15 minutes per response, including time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding the burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to the Office of Management and Budget, Paperwork Reduction Project (0348-0040), Washington, DC 20503.

PLEASE DO NOT RETURN YOUR COMPLETED FORM TO THE OFFICE OF MANAGEMENT AND BUDGET, SEND IT TO THE ADDRESS PROVIDED BY THE SPONSORING AGENCY.

NOTE: Certain of these assurances may not be applicable to your project or program. If you have questions, please contact the awarding agency. Further, certain Federal awarding agencies may require applicants to certify to additional assurances. If such is the case, you will be notified.

As the duly authorized representative of the applicant I certify that the applicant:

1. Has the legal authority to apply for Federal assistance and the institutional, managerial and financial capability (including funds sufficient to pay the non-Federal share of project cost) to ensure proper planning, management and completion of the project described in this application.

2. Will give the awarding agency, the Comptroller General of United States, and if appropriate, the State, through any authorized representative, access to and the right to examine all records, books, papers, or documents related to the award; and will establish a proper accounting system in accordance with generally accepted accounting standards or agency directives.

3. Will establish safeguards to prohibit employees from using their positions for a purpose that constitutes or presents the appearance of personal or organizational conflict of interest, or personal gain.

4. Will initiate and complete the work within the applicable time frame after receipt of approval of the awarding agency.

5. Will comply with the Intergovernmental Personnel Act of 1970 (42 U. S. C. §4728-4763) relating to prescribed standards for merit systems for programs funded under one of the nineteen statutes or regulations specified in Appendix A of OPM's Standards for a Merit System of Personnel Administration (5 C. F. R. 900, Subpart F).

6. Will comply with all Federal statutes relating to nondiscrimination. These include but are not limited to: (a) Title VI of the Civil Rights Act of 1964 (P.L. 88-352) which prohibits discrimination on the basis of race, color or national origin; (b) Title IX of the Education Amendments of 1972, as amended (20 U. S. C. §1681-1683, and 1685-16861), which prohibits discrimination on the basis of sex; (c) Section 504 of the Rehabilitation Act of 1973, as amended (29 U. S. C. §794), which prohibits discrimination on the basis of handicaps; (d) the Age Discrimination Act of 1975, as amended (42 U. S. C. §6101-6107), which prohibits discrimination on the basis of age; (e) the Drug Abuse Office and Treatment Act of 1972 (P. L. 92-255), as amended, relating to nondiscrimination on the basis of drug abuse; (f) the Comprehensive Alcohol Abuse and Alcoholism Prevention, Treatment and Rehabilitation Act of 1970 (P.L. 91-616), as amended, relating to nondiscrimination on the basis of alcohol abuse or alcoholism; (g) §§523 and 527 of the Public Health Service Act of 1912 (42 U.S.C. 290 dd-3 and 290 ee-3), as amended, relating to confidentiality of alcohol and drug abuse patient records; (h) Title VIII of the Civil Rights Act of 1968 (42 U.S.C. §3601 et seq.), as amended, relating to nondiscrimination in the sale, rental or financing of housing; (i) any other nondiscrimination provisions in the specific statute(s) under which application for Federal assistance is being made; and (j) the requirements of any other nondiscrimination statute(s) which may apply to the application.

7. Will comply, or has already complied, with the requirements of Titles II and III of the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 (P.L. 91-646) which provide for fair and equitable treatment of persons displaced or whose property is acquired as a result of Federal or federally assisted programs. These requirements apply to all interests in real property acquired for project purposes regardless of Federal participation in purchases.

8. Will comply, as applicable, with provisions of the Hatch Act (5 U.S.C. §§1501-1508 and 7324-7328) which limit the political activities of employees whose principal employment activities are funded in whole or in part with Federal funds.

Previous Edition Usable

Standard Form 424B (Rev. 4-92)
Prescribed by OMB Circular A-102

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I-009761

Figure 3

Standard Form 424B (cont'd.)

9. Will comply, as applicable, with the provisions of the Davis-Bacon Act (40 U.S.C. §§276a to 276a - 7), the Copeland Act (40 U.S.C. §§276c and 18 U. S. C. §§874), and the Contract Work Hours and Safety Standards Act (40 U.S.C. §§327-333), regarding labor standards for federally assisted construction subagreements.

10. Will comply, if applicable, with flood insurance purchase requirements of Section 102(a) of the Flood Disaster Protection Act of 1973 (P.L. 93-234) which requires recipients in a special flood hazard area to participate in the program and to purchase flood insurance if the total cost of insurable construction and acquisition is $10,000 or more.

11. Will comply with environmental standards which may be prescribed pursuant to the following: (a) institution of environmental quality control measures under the National Environmental Policy Act of 1969 (P.L. 91-190) and Executive Order (EO) 11514; (b) notification of violating facilities pursuant to EO 11738; (c) protection of wetlands pursuant to EO 11990; (d) evaluation of flood hazards in floodplains in accordance with EO 11988; (e) assurance of project consistency with the approved State management program developed under the Coastal Zone Management Act of 1972 (16 U.S.C. §§1451 et seq.); (f) conformity of Federal actions to State (Clear Air) Implementation Plans under Section 176(c) of the Clear Air Act of 1955, as amended (42 U.S.C. §§ 7401 et seq.); (g) protection of underground sources of drinking water under the Safe Drinking Water Act of 1974, as amended, (P.L. 93-523); and (h) protection of endangered species under the Endangered Species Act of 1973, as amended, (P.L. 93-205).

12. Will comply with the Wild and Scenic Rivers Act of 1968 (16 U.S.C. §§1271 et seq.) related to protecting components or potential components of the national wild and scenic rivers system.

13. Will assist the awarding agency in assuring compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (16 U.S.C. 470), EO 11593 (identification and protection of historic properties), and the Archaeological and Historic Preservation Act of 1974 (16 U.S.C. 469a-1 et seq.).

14. Will comply with P.L. 93-348 regarding the protection of human subjects involved in research, development, and related activities supported by this award of assistance.

15. Will comply with the Laboratory Animal Welfare Act of 1966 (P.L. 89-544, as amended, 7 U.S.C. 2131 et seq.) pertaining to the care, handling, and treatment of warm blooded animals held for research, teaching, or other activities supported by this award of assistance.

16. Will comply with the Lead-Based Paint Poisoning Prevention Act (42 U.S.C. §§ 4801 et seq.) which prohibits the use of lead based paint in construction or rehabilitation of residence structures.

17. Will cause to be performed the required financial and compliance audits in accordance with the Single Audit Act of 1984 or OMB Circular No. A-133, Audits of Institutions of Higher Learning and other Non-profit Institutions.

18. Will comply with all applicable requirements of all other Federal laws, executive orders, regulations and policies governing this program.

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL	TITLE
Dorothy C Hall	Dorothy C. Hall Contract & Grant Officer
APPLICANT ORGANIZATION THE REGENTS OF THE UNIVERSITY OF CALIFORNIA	DATE SUBMITTED 7/1/98

Standard Form 424B (Rev. 4/92) Back

I —009762

I-009762

U.S. Department of the Interior

Certifications Regarding Debarment, Suspension and Other Responsibility Matters, Drug-Free Workplace Requirements and Lobbying

Persons signing this form should refer to the regulations referenced below for complete instructions:

Certification Regarding Debarment, Suspension, and Other Responsibility Matters - Primary Covered Transactions - The prospective primary participant further agrees by submitting this proposal that it will include the clause titled, "Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transaction," provided by the department or agency entering into this covered transaction, without modification, in all lower tier covered transactions and in all solicitations for lower tier covered transactions. See below for language to be used or use this form for certification and sign. (See Appendix A of Subpart D of 43 CFR Part 12.)

Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transactions - (See Appendix B of Subpart D of 43 CFR Part 12.)

Certification Regarding Drug-Free Workplace Requirements - Alternate I. (Grantees Other Than Individuals) and Alternate II. (Grantees Who are Individuals) - (See Appendix C of Subpart D of 43 CFR Part 12)

Signature on this form provides for compliance with certification requirements under 43 CFR Parts 12 and 18. The certifications shall be treated as a material representation of fact upon which reliance will be placed when the Department of the Interior determines to award the covered transaction, grant, cooperative agreement or loan.

PART A: Certification Regarding Debarment, Suspension, and Other Responsibility Matters - Primary Covered Transactions

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CHECK X IF THIS CERTIFICATION IS FOR A PRIMARY COVERED TRANSACTION AND IS APPLICABLE.

(1) The prospective primary participant certifies to the best of its knowledge and belief, that it and its principals:

(a) Are not presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded by any Federal department or agency;

(b) Have not within a three-year period preceding this proposal been convicted of or had a civil judgment rendered against them for commission of fraud or a criminal offense in connection with obtaining, attempting to obtain, or performing a public (Federal, State or local) transaction or contract under a public transaction; violation of Federal or State antitrust statutes or commission of embezzlement, theft, forgery, bribery, falsification or destruction of records, making false statements, or receiving stolen property;

(c) Are not presently indicted for or otherwise criminally or civilly charged by a governmental entity (Federal, State or local) with commission of any of the offenses enumerated in paragraph (1)(b) of this certification; and

(d) Have not within a three-year period preceding this application/proposal had one or more public transactions (Federal, State or local) terminated for cause or default.

(2) Where the prospective primary participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

PART B: Certification Regarding Debarment, Suspension, Ineligibility and Voluntary Exclusion - Lower Tier Covered Transactions

---

CHECK__ IF THIS CERTIFICATION IS FOR A LOWER TIER COVERED TRANSACTION AND IS APPLICABLE.

(1) The prospective lower tier participant certifies, by submission of this proposal, that neither it nor its principals is presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from participation in this transaction by any Federal department or agency.

(2) Where the prospective lower tier participant is unable to certify to any of the statements in this certification, such prospective participant shall attach an explanation to this proposal.

DI-2010
June 1988
(This form replaces DI-1953, DI-1954, DI-1955, DI-1960 and DI-1942)

PART E: Certification Regarding Lobbying
Certification for Contracts, Grants, Loans, and Cooperative Agreements

CHECK__ IF CERTIFICATION IS FOR THE AWARD OF ANY OF THE FOLLOWING AND THE AMOUNT EXCEEDS $100,000: A FEDERAL GRANT OR COOPERATIVE AGREEMENT; SUBCONTRACT, OR SUBGRANT UNDER THE GRANT OR COOPERATIVE AGREEMENT.

CHECK__ IF CERTIFICATION IS FOR THE AWARD OF A FEDERAL LOAN EXCEEDING THE AMOUNT OF $150,000, OR A SUBGRANT OR SUBCONTRACT EXCEEDING $100,000, UNDER THE LOAN.

The undersigned certifies, to the best of his or her knowledge and belief, that:

(1) No Federal appropriated funds have been paid or will be paid, by or on behalf of the undersigned, to any person for influencing or attempting to influence an officer or employee of an agency, a Member of Congress, and officer or employee of Congress, or an employee of a Member of Congress in connection with the awarding of any Federal contract, the making of any Federal grant, the making of any Federal loan, the entering into of any cooperative agreement, and the extension, continuation, renewal, amendment, or modification of any Federal contract, grant, loan, or cooperative agreement.

(2) If any funds other than Federal appropriated funds have been paid or will be paid to any person for influencing or attempting to influence an officer or employee of any agency, a Member of Congress, an officer or employee of Congress, or an employee of a Member of Congress in connection with this Federal contract, grant, loan, or cooperative agreement, the undersigned shall complete and submit Standard Form-LLL, "Disclosure Form to Report Lobbying," in accordance with its instructions.

(3) The undersigned shall require that the language of this certification be included in the award documents for all subawards at all tiers (including subcontracts, subgrants, and contracts under grants, loans, and cooperative agreements) and that all subrecipients shall certify accordingly.

This certification is a material representation of fact upon which reliance was placed when this transaction was made or entered into. Submission of this certification is a prerequisite for making or entering into this transaction imposed by Section 1352, title 31, U.S. Code. Any person who fails to file the required certification shall be subject to a civil penalty of not less than $10,000 and not more than $100,000 for each such failure.

As the authorized certifying official, I hereby certify that the above specified certifications are true.

THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

Dorothy C Hall

SIGNATURE OF AUTHORIZED CERTIFYING OFFICIAL

TYPED NAME AND TITLE Dorothy C. Hall
Contract & Grant Officer

DATE

DI-2010
June 1988
(This form replaces DI-1953, DI-1954, DI-1955, DI-1956 and DI-1943)

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I-009764

NDISCRIMINATION COMPLIANCE STATEMENT

NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

The company named above (hereinafter referred to as "prospective contractor") hereby certifies, unless specifically exempted, compliance with Government Code Section 12990 (a-f) and California Code of Regulations, Title 2, Division 4, Chapter 5 in matters relating to reporting requirements and the development, implementation and maintenance of a Nondiscrimination Program. Prospective contractor agrees not to unlawfully discriminate, harass or allow harassment against any employee or applicant for employment because of sex, race, color, ancestry, religious creed, national origin, disability (including HIV and AIDS), medical condition (cancer), age, marital status, denial of family and medical care leave and denial of pregnancy disability leave.

CERTIFICATION

I, the official named below, hereby swear that I am duly authorized to legally bind the prospective contractor to the above described certification. I am fully aware that this certification, executed on the date and in the county below, is made under penalty of perjury under the laws of the State of California.

AL'S NAME: Dorothy C. Hall

EXECUTED: July 1, 1998

EXECUTED IN THE COUNTY OF: Santa Barbara, CA

ECTIVE CONTRACTOR'S SIGNATURE: Dorothy C Hall

ECTIVE CONTRACTOR'S TITLE: Dorothy C. Hall, Contract & Grant Officer

ECTIVE CONTRACTOR'S LEGAL BUSINESS NAME: THE REGENTS OF THE UNIVERSITY OF CALIFORNIA

I-009765

C1040

Attachment H

COVER SHEET (PAGE 1 of 2)

May 1998 CALFED ECOSYSTEM RESTORATION PROPOSAL SOLICITATION

Proposal Title: Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

Applicant Name: The Regents of the University of California

Mailing Address: Office of Research
University of California
Santa Barbara, CA 93106

Telephone: 805/893-4034

Fax: 805/893-2611

Amount of funding requested: $ 386,742 for 3 years

Indicate the Topic for which you are applying (check only one box). Note that this is an important decision: see page _____ of the Proposal Solicatation Package for more information.

- ☐ Fish Passage Assessment
- ☑ Floodplain and Habitat Restoration
- ☐ Fish Harvest
- ☐ Watershed Planning/Implementation
- ☐ Fish Screen Evaluations – Alternatives and Biological Priorities
- ☐ Fish Passage Assessment
- ☐ Gravel Restoration
- ☐ Species Life History Studies
- ☐ Education

Indicate the geographic area of your proposal (check only one box):

- ☑ Sacramento River Mainstem
- ☐ Delta
- ☐ Suisum Marsh and Bay
- ☐ San Joaquin River Mainstem
- ☐ Landscape (entire Bay-Delta watershed)
- ☐ Sacramento Tributary: _____
- ☐ East Side Delta Tributary: _____
- ☐ San Joaquin Tributary: _____
- ☐ Other: _____
- ☐ North Bay: _____

Indicate the primary species which the proposal addresses (check no more than two boxes):

- ☐ San Joaquin and East-side Delta tributaries fall-run chinook salmon
- ☐ Winter-run chinook salmon
- ☐ Late-fall run chinook
- ☐ Delta smelt
- ☐ Splittail
- ☐ Green sturgen
- ☐ Migratory birds
- ☑ Spring-run chinook salmon
- ☑ Fall-run chinook salmon
- ☐ Longfin smelt
- ☐ *Steelhead trout*
- ☐ Striped bass

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OMB Approval No. 0348-0043

APPLICATION FOR FEDERAL ASSISTANCE

	2. DATE SUBMITTED: 6/3/098	Applicant Identifier:
1. TYPE OF SUBMISSION: *Application* [ ] Construction [ ] Non-Construction; *Preapplication* [ ] Construction [X] Non-Construction	3. DATE RECEIVED BY STATE:	State Application Identifier: SAI Exempt
	4. DATE RECEIVED BY FEDERAL AGENCY:	Federal Identifier:

5. APPLICANT INFORMATION

Legal Name: Regents of the University of California	**Organizational Unit:** Office of Research
Address (give city, county, state, and zip code): University of California, Santa Barbara, CA 93106	**Name and telephone number of the person to be contacted on matters involving this application (give area code):** PI: Thomas Dunne 805-893-7557; ADMIN CONTACT: Dorothy C. Hall 805-893-4034
6. EMPLOYER IDENTIFICATION NUMBER (EIN): 95-6006145W	**7. TYPE OF APPLICANT:** *(enter appropriate letter in box)* I A. State; B. County; C. Municipal; D. Township; E. Interstate; F. Intermunicipal; G. Special District; H. Independent School Dist.; I. State Controlled Institution of Higher Learning; J. Private University; K. Indian Tribe; L. Individual; M. Profit Organization; N. Other (Specify):
8. TYPE OF APPLICATION: [X] New [ ] Continuation [ ] Revision [ ] Supplement If Revision, enter appropriate letter(s) in box(es): [ ] [ ] A. Increase Award B. Decrease Awa C. Increase Duration D. Decrease Duration Other (specify):	**9. NAME OF FEDERAL AGENCY:** Department of the Interior
10. CATALOG OF FEDERAL DOMESTIC ASSISTANCE NUMBER: 15-614 TITLE: Coastal Wetland Planning, Protection & Restoration	**11. DESCRIPTIVE TITLE OF APPLICANT'S PROJECT:** Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology
12. AREAS AFFECTED BY PROJECT *(cities, counties, states, etc.):* Sacramento River Mainstem	

13. PROPOSED PROJECT: Start Date	Ending Date	14. CONGRESSIONAL DISTRICTS OF: a. Applicant	b. Project
10/1/98	9/30/01	22	22

15. ESTIMATED TOTAL PROJECT FUNDING:		16. IS APPLICATION SUBJECT TO REVIEW BY STATE EXECUTIVE ORDER 12372 PROCESS?
a. Federal	$ 386,742	a. YES. THIS PREAPPLICATION/APPLICATION WAS MADE AVAILABLE TO THE STATE EXECUTIVE ORDER 12372 PROCESS FOR REVIEW ON: DATE _____
b. Applicant	$	b. NO. [X] PROGRAM IS NOT COVERED BY E.O. 12372 [ ] OR PROGRAM HAS NOT BEEN SELECTED BY STATE FOR REVIEW
c. State	$ -0-	
d. Local	$ -0-	
e. Other	$ -0-	
f. Program Income	$ -0-	17. IS THE APPLICANT DELINQUENT ON ANY FEDERAL DEBT? [ ] YES If "Yes," attach an explanation. [X] No
g. TOTAL	$ 386,742	

18. TO THE BEST OF MY KNOWLEDGE AND BELIEF, ALL DATA IN THIS APPLICATION/PREAPPLICATION ARE TRUE AND CORRECT. THE DOCUMENT HAS BEEN DULY AUTHORIZED BY THE GOVERNING BODY OF THE APPLICANT AND THE APPLICANT WILL COMPLY WITH THE ATTACHED ASSURANCES IF THE ASSISTANCE IS AWARDED.

a. Typed Name of Authorized Representative	b. Title	c. Telephone Number
Dorothy C. Hall	Contracts and Grants Officer	(805)893-4034
d. Signature of Authorized Representative: Dorothy C Hall		**e. Date Signed:** 7/1/98

Previous Editions Not Usable — Standard Form 424 (REV 4-88)

PLEASE SEND AWARD DOCUMENTS TO: Contract & Grant Officer, Office of Research, University of California, Santa Barbara, CA 93106

I-009768

I-009768

Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

Investigators: Thomas Dunne, Professor
Michael Singer, Graduate Student Researcher

Executive Summary

Due to ecosystem degradation and flood catastrophes stemming from major river valley development, California is rethinking past development projects involving construction of river controls (e.g. levees, inter-basin water transfers) that were aimed at transforming natural wetlands into productive farmland. A new effort has been born with intent to restore valley floor environments for the purpose of enhancing water quality, protecting wildlife and reducing flood damage: the CALFED Bay-Delta Program, overseen by the California state and Federal governments. Some of the Ecosystem Restoration Program Plan (ERRP) goals include creation of river meander corridors, manipulation of sediment supplies, and alteration of flow releases below dams to mimic natural flow regimes. However, without a comprehensive, quantitative, process-based study of sediment and hydraulic regimes and the channel morphology within an entire river basin, any restoration effort would at best address only a small part of the problem, and at worst cause further unanticipated degradation. We propose to conduct such a study that would serve as a predictive tool for decision-makers attempting to approximate the "natural" and other potential states of the river system.

A major regional restorative effort such as CALFED might benefit from an understanding of the quantitative physical relationships between proposed restoration activities and their intended goals. We see the opportunity to develop concepts regarding the effects that stressors such as alteration of flow and sediment transport, and changes in channel morphology have on target habitats, using evidence from quantitative, empirical research. The current Category III RFP (Floodplain Management and Restoration topic) solicits proposals which "identify and acquire lands within the floodplains of the major rivers of the Central Valley and its tributaries." However, identifying, classifying, acquiring, and slating lands for restoration based merely on current states of physical form can belie transient states of a system that are based on processes rather than form (Schumm, 1977; Kondolf, 1995a). For example, desired backwater channel habitat for a particular target species may only exist during floods of a certain magnitude or in an area and time of sediment deposition. Determinations of suitable habitat founded on rudimentary land classification without knowledge of processes which create the form often lead to failure of the effort (Kondolf, 1995a). In the Sacramento River basin, we see the opportunity for a large-scale study, which would quantify processes and variability inherent in a large river basin and thus provide the underpinnings for a systematic approach to present and future restoration activities.

Ecosystem rehabilitation and flood control planning both require knowledge of the processes which govern transport of water and sediment, and of the history of river channel change. It is well known, in a general way, that river channel change results from a set of erosional and depositional processes by which a river adjusts to perturbations in flow, sediment supply, and local boundary conditions. However, in order to understand and predict the circumstances under which large-scale flooding will occur or specific habitat will be affected, it is necessary to obtain a system-wide perspective of a river basin and to gather information on the variable regimes of material transport within a river. There exists a long historical record of measurements of sediment concentration and streamflow throughout the Sacramento basin and a long historical record of perturbations to the system. Yet, we are not aware of any comprehensive, quantitative process studies of the sediment and hydraulic regimes as they relate to resultant channel changes in the Sacramento basin.

As CALFED embarks upon a program of significant riparian-zone management, it becomes important to understand the flux regimes which govern channel and floodplain morphology. We would utilize this opportunity to investigate the following questions. What does empirical evidence tell us about changes in sediment and hydraulic regimes during the past half-century and what were the resulting morphological changes? What further regime changes can we expect with the advent of restoration measures involving changes in flow and sediment supply? How would these regime changes affect channel morphology and thus the evolution of "restored" valley floors?

With the goal of answering these questions we are working to quantify empirical relationships between the regimes of water and sediment, morphological process, and resultant form of river channels and floodplains within the Sacramento basin. These historical relationships will be used to develop a river adjustment model, which will be validated against new empirical data from the Sacramento basin. Our aim is to construct a supply-process-form model with a minimum amount of calibration that could be applied to any large lowland river system to predict river adjustment under different land-use scenarios.

Such a model could be used by CALFED to target restoration policy by identifying which restorative strategies are appropriate for different reaches in the basin. It would allow CALFED to strike a balance between seemingly opposing goals of flood control and habitat restoration by determining the compatibility of these goals for particular river reaches, as well as prioritizing reaches for a particular restoration goal. As such, our model would provide a unifying restoration framework upon which the various CALFED agencies could achieve stated ERRP goals in synchronicity and with complementary strategies. We have already confirmed such a model's usefulness with the US Geological Survey Water Resources Division-Sacramento and the US Army Corps of Engineers-Sacramento.

Our first task in developing this model is evaluating the sediment mass balance of the Sacramento River basin to gain insight into the sediment and hydraulic regimes of the river system and to target areas of morphological adjustment. This empirical investigation will enable us to represent the variability of the Sacramento River system. We will then utilize this information on variability as input for our basin-scale model. We have already begun some of this work with the resources supplied by UC Santa Barbara, and with data and advice from the Army Corps of Engineers.

This research project requires funding for empirical investigation in the first year of the funding period. Activities in this stage will include data collection, historical reconstruction of the state of the channel and floodplain, and quantification of the variability of the flow and sediment supply. In the subsequent two years, funding is requested for development of a model based on the historical data collected and assimilated during the first year. These activities include numerical modeling of river and floodplain adjustment to variable regime inputs and land use changes. Our long-term objective is to develop a predictive model capable of determining the response of reaches of channel and floodplain to alterations of flow and sediment transport regimes. The model would be designed to anticipate the effects of various resource management scenarios on the river system at a reach-averaged scale of resolution. In focusing attention and understanding on reaches that lose or accumulate sediment and thereby undergo morphological change, the modeling effort would interface with higher-resolution modeling studies of channel shifting (Larsen and Mount, UC Davis) and with field measurement programs of bedform transport and channel change (R. Dinehart, USGS). Such collaboration of sediment accounting and modeling across scales could unify understanding of basin-scale and within-reach scale processes of sedimentation and habitat change in the Sacramento River basin.

We have experience with large rivers, system perturbations, and sediment variability models. Dunne and colleagues have conducted a study of the channel-floodplain sediment budget of a 2500 km reach of the Amazon River and the associated geological and hydrological controls and morphological results (Meade, 1985; Mertes et al., 1996; Dunne et al., 1998; Mertes and Dunne, in press). They continue to study and model the supply of sediment to the Amazon from the Andes Range (Aalto and Dunne, 1996) and the flow regimes of the entire Amazon River basin with a combination of computer simulation and satellite remote sensing under NASA's Earth Observing System program. Dunne and Malmon are currently investigating the long-term fate and transport of radioactively contaminated sediments through valley floors of tributaries of the Rio Grande River downstream of Los Alamos National Laboratory, New Mexico. For the Paraguay-Paraná River system in South America, we conducted an Environmental Defense Fund review of the hydraulic and sedimentation aspects of the proposed channelization project, Hidrovia. In the Pacific Northwest, Dunne and colleagues have conducted a number of studies of sediment supply and channel change (Lehre et al., 1983; Collins and Dunne, 1989; Collins and Dunne, 1990). And in the Oregon Coast Range we have constructed stochastic models of sediment supply and transport, which provide insight into variability in sediment regime (Benda and Dunne, 1997a,b). We intend to combine these experiences in field investigation, data analysis, and model development in the Sacramento River basin.

Large-scale Spatial and Temporal Patterns of Flow and Sediment Transport in the Sacramento River Basin and Their Influence on Channel and Floodplain Morphology

Investigators: Thomas Dunne, Professor
Donald Bren School of Environmental Science & Management
University of California
Santa Barbara, CA 93106
Phone: (805) 893-7557
FAX: (805) 893-7612
E-mail: tdunne@bren.ucsb.edu

Michael Singer, Graduate Student Researcher
Donald Bren School of Environmental Science & Management
University of California
Santa Barbara, CA 93106
Phone: (805) 893-8816
FAX: (805) 893-7612
E-mail: bliss@bren.ucsb.edu

Institution: University of California, Santa Barbara
Institute for Computational Earth System Science

Taxpayer ID#: 95-6006145W

Type of Organization: Non-Profit Educational

Project Period: October 1, 1998—September 30, 2001

ABSTRACT

In this century, humans have witnessed numerous examples of river adjustment to anthropogenic perturbations. However, there have been no attempts at constructing a scientific model which accurately represents such adjustments over large river basins. Consequently, most assessments of river adjustment are made after the fact and involve anecdotal interpretations (e.g. Schumm and Winkley, 1994, "The Variability of Large Alluvial Rivers"). To fill this gap, we will develop a predictive model of river adjustment to perturbations based on data from the Sacramento River basin in California. We will quantify historical empirical relationships between supply materials, process, and resultant form of river channels and floodplains within the Sacramento basin. These relationships will be used to develop a river adjustment model, which will be validated against new measurements from the Sacramento basin. Model applications include flood control and habitat restoration.

BACKGROUND

The morphology of a river is determined by the interaction of water and sediment within a channel network. A river flows in an intricate path, entraining and transporting a supply of water and sediment, augmented by tributaries. The river deposits and re-mobilizes the sediment along its valley floor. Where the river lies entirely within its own mobile alluvium, it is classified as an alluvial river, and often obeys certain regularities of form and behavior that allow prediction (Leopold et al., 1964; Schumm, 1977). In some places, subtle tectonic movements or the outcropping of resistant substrate may constrain the channel in ways that are less predictable.

Fluvial landforms contain information on the depositional and erosional activities of the river, as it continually adjusts to the variable amounts of water and sediment that enter its channel network. It is the spatial and temporal variability of these landforms through the fluvial system which determines the potential flood conveyance capacity, stability of natural and engineered river courses, and the complexity of river channel and riparian habitat (Dunne, 1988; Kondolf and Wolman, 1993; Kondolf, 1995a; Kondolf, 1995b).

The Central Valley Project Improvement Act (CVPIA) and its Anadramous Fish Restoration Program (ARFP) call for restoring habitats and eliminating stressors with strategies including flow alteration and physical modification of river channels (Kondolf et al., 1996). In order to make strategic plans for and to identify lands for acquisition to achieve ERRP floodplain restoration and flood control goals in accordance with the CVPIA, classification is necessary. Channel and floodplain classification provides a language for communication across disciplines and a geomorphological framework for selecting restoration strategies (Kondolf, 1995a). There have been numerous efforts to classify channel and floodplain morphology within reaches of each zone of the fluvial system (Kondolf, 1995a). These have included classifications according to channel form or appearance on coarse scales (entire basin) (Schumm, 1977) and fine scales (single river reach) of detail, the latter highlighting habitat considerations (Bisson et al., 1982; Frissell et al., 1986).

There have been few attempts to classify river system morphology according to the processes which created its physical form (Whiting and Bradley, 1993; Montgomery and Buffington, 1997). We maintain Montgomery and Buffington's (1997) assertion that a process-based understanding of spatial linkages within entire watersheds is fundamental for assessing channel and floodplain morphology, as well as for predicting channel response to perturbations. Our process-based model will allow land managers to target flood control and restoration policies on the appropriate areas and processes in accordance with their goals.

System-Wide View

The fluvial system can be divided into three distinct zones: the production zone, the transport zone, and the deposition zone (Schumm, 1977, p.3), each of which functions differently in terms of its net

transport of materials and thus, its erosional and depositional processes. Despite frequent examples of local divergences from this generalization, it is a useful approximation as a foundation for conceptual models. The upper-tributary production zone generates water and sediment materials for transport. Channels in the production zone frequently exhibit irregular meander and braided morphology (Chang, 1988) with beds of coarse sediment or bedrock and dissected floodplains. In the Sacramento fluvial system, this zone includes the headwaters area to Hamilton City, including the tributaries. The transport zone is characterized by large transport corridors with intermittent inputs of water and sediment from larger tributaries, and by broad floodplains subject to periodic inundation. Morphologically this zone is the most stable of the three (although it is by no means stable) and is the most prominent, longest zone in large rivers (Chang, 1988). In the Sacramento River it comprises the river reaches from Hamilton City to Sacramento. The deposition zone serves as a sink for transported materials and is described as a mouth, delta, or fan of distributary channels. This zone has an unstable morphology which continually shifts sediment and aggrades, maintaining its channel slope (Chang, 1988) as the delta base level subsides. The Sacramento River Bay-Delta is usually defined as beginning downstream of Sacramento.

All zones in the fluvial system are linked. That is, deposition or erosion in one reach of a fluvial zone will affect transport in adjacent zones both upstream and downstream. These adjacent reaches will in turn, affect material transport in their adjacent reaches, and even far downstream. It is apparent that research on material transport processes on the scale of one particular reach cannot represent the fluvial system as a whole, because it does not evaluate feedbacks in material transport between river reaches, including effects far downstream. This spatial variability of transport must be considered along with the temporal variability associated with lags between peaks in flow and sediment transport (Mareus, 1989; Lemke, 1991) and floodplain storage and remobilization (Dietrich, et al., 1982; Dacey and Lerman, 1983; Dunne et al., 1998). A basin-scale study of spatial and temporal regime variability will develop a process-based understanding of material transport within the fluvial system.

Regime Variability

Several major variables govern the spatial and temporal variability of alluvial river morphology and behavior (Schumm and Winkley, 1994). The most important of these are the coupled variables of streamflow and sediment discharge, which depend on drainage basin characteristics and land use. Sediment supply to an alluvial river is driven stochastically by rainstorms, which affect streamflow and thus, the intensity of erosional and depositional activities within a river system (Schumm, 1977, p. 29-30; Benda and Dunne, 1997b). There have been recent efforts to characterize the dynamic sediment regime of a river system in terms of its statistical properties. This is accomplished by computing the probability of the transport system being in any of various states (sediment supply limited v. flow transport limited) (Benda and Dunne, 1997a) based on historical changes in observed sediment transport data (Lemke, 1991). Such a characterization would allow one to construct a river routing model that represents the fluctuations in the transport system over time. This approach takes into account the memory of a fluvial system (Knighton, 1984, p. 162) as it continually adjusts to perturbations or controls.

Adjustment to Controls

Throughout the fluvial system there are constraints, or controls, on material transport, which result in some level of morphologic adjustment on the part of the river system. Such controls, or perturbations, are either natural (e.g. tectonic, climatic) or anthropogenic (e.g. dams, levees, channel re-alignment, gravel mining). As new perturbations are imposed, adjustments are made by the fluvial system, which can radically change a river's planform and cross-section. However, there has been no research effort at creating a reach-integrated, basin-wide view of morphologic adjustment. Such a broader perspective could facilitate the planning of restoration efforts in river systems in the context of widely acknowledged, but rarely quantified, basin-scale cumulative effects.

Flood control planning and ecosystem rehabilitation both need to be based on understanding of the history of river channel change and therefore of materials flux regimes. It is well known that river channel change results from a set of erosional and depositional processes by which a river adjusts to perturbations. For example, when dams are installed, a river system goes through a complex process of adjustment (Schumm, 1981; Williams and Wolman, 1984; Xu, 1990) to changes in supply of water and sediment. Morphological adjustments to reservoirs are typified by backwater effects and sediment deposition upstream of the dam and by scour of bed material downstream (Chien, 1985). Mining within river basins also contributes to complex responses in river systems. This can occur as a result of: extra-valley-floor mining, with sediment disposal that causes the fluvial system to adjust its transport rates and channel form; or intra-valley-floor mining, wherein the system must adjust to a decrease in riverbed or floodplain sediment. Extra-valley floor mining causes river width-depth ratios to increase (Gilbert, 1917; Knighton, 1989), as the system shifts from supply limited to transport limited. Intra-valley floor mining can cause bed elevations and width-depth ratios to decrease (Collins and Dunne, 1989; 1990), and can cause channel migration as flow is deflected from in-stream gravel pits (Dunne and Leopold, 1978). Channelization, or channel dredging and straightening for navigation or flood control, has effects similar to those of intra-valley floor mining with the added tendency for acceleration of bank erosion and meandering (Neill and Yaremko, 1988) and piping of levees and dikes (Olson et al., 1942; Feldman, 1973; Laddish, 1997; Schalk and Jacobson, 1997).

In all these cases morphological adjustments have been described by their resultant form characteristics of cross-sectional channel geometry (Gregory and Park, 1974; Williams and Wolman, 1984; Xu, 1996), bed material sizes (Williams and Wolman, 1984), and longitudinal profile (Chien, 1985). However, in the context of complex river response, attempts to explain the physical processes associated with adjustments have relied upon qualitative assessments (Xu, 1990), thus preventing their accurate application in other localities with different spatial and temporal scales of material flux and levels of disturbance. We will construct a process model of reach-length channel and floodplain morphological adjustment within the Sacramento River basin that is based on an excellent historical empirical dataset.

GEOGRAPHICAL BACKGROUND

As stated in the ERRP Vol. 2, the Sacramento River provides important spawning, rearing, and migratory habitat to anadromous fish populations including chinook salmon (fall and spring runs), steelhead, white sturgeon, green sturgeon, striped bass, and American shad. The river drains the northern part of the Central Valley of California and has a total drainage area of 6.8×10^4 km^2 comprising over one half of the total drainage area into the San Francisco Bay system (Porterfield, 1980). It is "the largest and most important riverine ecosystem in the State of California," (ERRP, Vol. 2, p.113). The Sacramento River flows south from its source in the Trinity Mountains near Siskiyou Lake through the counties of Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Yolo, Sacramento, and Solano to its mouth, the confluence of the San Joaquin River at Suisun Bay. It drains the 60mi wide x 260mi long Sacramento Valley, a broad fertile alluvial lowland basin located between the Sierra Nevada and the Coast Range (Harwood and Helley, 1987). Despite the fact that 50% of the basin flow is controlled by reservoirs, the Sacramento River basin is the principal source of water and sediment discharged to the Sacramento/San Joaquin Bay-Delta (Porterfield, 1980). The region is riddled with dams, levees, dikes, and gravel mining operations, which affect the geomorphic character of rivers and their floodplains, consequently affecting fish and wildlife habitat, as well as the ability of river systems to attenuate flood events. This study is focused on the North Sacramento and Sacramento Valley Ecological Zones (see ERRP, Vol. II, Figures 8 and 9).

APPROACH

We will be investigating the processes of morphological adjustment within the Sacramento River basin at various scales of interest. Our aim is to understand these processes on a time scale appropriate for designing restoration strategies (i.e. decades). In order to accurately represent the variability of materials flux regimes (water and sediment), it will be necessary to employ a stochastic approach, which will simulate material supply inputs from historical empirical data (the sediment budget). Spatially we will frame the study around the river system as an entire unit, in order to understand how adjustments to perturbations are translated through the fluvial system. To test that this coarse-scale characterization is correct we will subject our model to empirical checks based on data recently collected by the Corps of Engineers and the Geological Survey, and possibly by other agencies. We will also examine whether our predictions are physically consistent with those of other modeling efforts and measurement programs that are focused on finer (within-reach) scales of resolution.

Sediment Budget

Kondolf, et al. (1996) recommend that design of channel modification projects be based on "sound understanding of the site's larger geomorphic context, which requires a historical geomorphic study, and analysis of potential sediment transport at a site." Quantifying sediment supply within a river system requires construction of a sediment budget or a mass balance of sediment, which will enable land managers to anticipate localities of sediment deposition, storage residence times, and modes of re-mobilization (Reid and Dunne, 1996). A sediment budget involves accounting for all major sediment sources, storage sites, and sinks within a river basin, all of which can vary in time and space. For the case of large alluvial river, it accounts for rates and processes of erosion and sediment transport within the river and its floodplain. A historical reconstruction of the basin sediment budget is necessary to complete this task because historical data sources give information on rates and magnitudes of changes in a fluvial system. Although sediment budgets have been more commonly applied in small river basins (Reid and Dunne, 1996), there have been approximations for large basins that highlight important areas and processes of bank erosion or deposition in the system of sediment transport (Kesel et al., 1992; Reid and Dunne, 1996; Dunne et al., 1998). We will evaluate the sediment budget for the Sacramento River basin, which in turn will provide supply inputs for our supply-process-form model.

Sediment Routing Model

We will relate the empirical sediment budget results to flow volumes, channel hydraulics, and other controls by assimilating the sediment transport measurements into a routing model. The purpose of this exercise is to provide a physically sound explanation of the measurements and to generalize from the recorded data to a broader range of environmental scenarios. We will drive the model with historical flow regimes during verification, and with probability distributions of flow for predictions of future conditions. A mathematical model would allow us to consider, for example the probable effect of an alteration of flow regime, or channel engineering activity on sediment supply, or on the sediment budget of particular reaches. A reach-averaged sediment budget prediction of this kind can then be used to focus attention on zones in which morphological change is to be expected. Empirical correlations between sediment accumulation or removal and changes in channel-floodplain morphology can then be used to assess probable changes. This activity will be followed by higher-resolution model analyses of morphological change within reaches. Model output will describe the magnitude and spatial location of predicted sediment storage within the entire river system given cross-sectional inputs on the current morphology. The modeling will be facilitated by new empirical three dimensional river profiles made available to us by the US Army Corps of Engineers, flow and suspended sediment records from USGS, and bed-material surveys from USGS.

EXPECTED BENEFITS

This research will result in a characterization of the effects stressors have upon natural transport regimes and thus, indirectly upon target species within the Sacramento River. We will quantify the role of the following stressors upon net transport of sediment: alteration of flows, floodplain and marshplain changes, and channel form changes. Our modeling effort will enable prediction of long term landform adjustment resulting from variable hydrological and sediment regimes. It will allow policymakers to anticipate resultant morphological conditions relevant to habitat restoration and flood control strategies such as setback levees or restoration of "natural" streamflow regimes.

Employing this basin-scale, integrated approach will provide understanding of the entire Sacramento River basin, from source to mouth. The model will yield a thorough picture of morphological channel-floodplain adjustment to regime variability and perturbations over a period of decades. This knowledge would be useful not only in the restoration of large river basins, but in aiding design of new river development projects, which are burgeoning in the developing world.

Data Collection

For this study we are compiling an excellent dataset for a large river basin study. In addition to streamflow and sediment concentration records, topographic and other maps for the Sacramento basin, we have been locating and collecting: engineering records; cross-sectional geometrical surveys; aerial photographic coverage of the Sacramento basin from the 1920's to the present; fine resolution Digital Elevation Models; special-mission NASA air photos documenting 1997 flooding; data on California storm magnitudes and intensity from NOAA; and new Corps of Engineers 3-D river profiles. These data enable us to perform this research in conjunction with on-going restoration efforts in California.

Basin Characterization

We have already begun to characterize the variability within the Sacramento River basin by correlating sediment and streamflow discharge data (example in Figure 1) both temporally and spatially with storm data (Figure 2). Figure 1 shows sediment and water discharge during an 18-day storm in 1979. Figure 2 shows daily precipitation values for the first four days of this storm. This exercise provides information on how the entire basin's sediment regime responds to storms of different magnitudes and intensities. By characterizing this response and validating it with channel and floodplain morphology from aerial photographs we may begin to build a probability distribution of storm systems that will stochastically drive our model of morphological change.

Conclusion

As suggested in the Executive Summary we have confirmed that our proposed study is complementary to ongoing work and research in the Bay-Delta (Harris, Pers. comm., R. Dinchart, Pers. comm.). We have been collaborating with Jeff Harris of the United States Army Corps of Engineers in Sacramento to obtain new and historical Sacramento River data in order to build a model that utilizes the latest technology and that will be compatible with Army Corps priorities.

The Sacramento River basin provides an excellent opportunity for CALFED to look to the larger scale for understanding of channel-floodplain process and variability, which will provide a framework for its rapidly expanding restoration effort. By addressing the problems of the Sacramento Bay-Delta with an integrated, comprehensive approach of this kind the CALFED Bay-Delta Program could set the international standard for restoration of large lowland river systems.

References

Aalto, R.E. and Dunne, T., 1996. Geomorphic controls of Andean denudation rates. Eos, Transactions, American Geophysical Union, 77(46): 245.

Benda, L. and Dunne, T., 1997a. Stochastic forcing of sediment routing and storage in channel networks. Water Res. Research, 33(12): 2865-2880.

Benda, L. and Dunne, T., 1997b. Stochastic forcing of sediment supply to channel networks from landsliding and debris flow. Water Res. Research, 33(12): 2849-2863.

Bisson, P.A., Nielsen, J.S., Palmason, R.A. and Grove, L.E., 1982. A system of naming habitat types in small streams, with examples of habitat utilization by salmonids during low streamflow. In: N.B. Armantrout (Editor), Proceedings of a Symposium on Acquisition and Utilization of Aquatic Habitat Inventory Information. Western Division of the Amer. Fisheries Soc., Portland, OR, pp. 62-73.

Chang, H.H., 1988. Fluvial Processes in River Engineering. Krieger Pub. Co., Malabar, FL, 432 pp.

Chien, N., 1985. Changes in river regime after the construction of upstream reservoirs. Earth Sur. Proc. and Landforms, 10: 143-159.

Collins, B. and Dunne, T., 1990. Fluvial geomorphology and river-gravel mining : a guide for planners, case studies included 98, Cal. Div. Mines and Geol., Sacramento.

Collins, B.D. and Dunne, T., 1989. Gravel transport, gravel harvesting, and channel-bed degradation in rivers draining the southern Olympic Mountains, Washington, U.S.A. Environmental Geology and Water Sciences, 13(3): 213-224.

Dietrich, W., 1982. Settling velocity of natural particles. Water Res. Research, 18(6): 1615-1626.

Dinehart, R., 1998. .

Dunne, T., 1988. Geomorphologic contributions to flood control planning. In: V.R. Baker, R.C. Kochel and P.C. Patton (Editors), Flood Geomorphology. Wiley & Sons, New York, pp. 421-438.

Dunne, T. and Leopold, L.B., 1978. Water in Environmental Planning. W.H. Freeman and Co., San Francisco, 818 pp.

Dunne, T., Mertes, L., Meade, R. and Richey, J., 1998. Exchanges of sediment between the flood plain and channel of the Amazon River in Brazil. Geol. Soc. Amer. Bulletin, 110(4): 450-467.

Feldman, A.D., 1973. Downstream effects of the levee overtopping at Wilkes-Barre, PA during Tropical Storm Agnes. 37, Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA.

Frissell, C.A., Liss, W.J., Warren, C.E. and Hurley, M.D., 1986. A hierarchical framework for stream habitat classification: Viewing streams in a watershed context. Env. Management, 10(2): 199-214.

Gregory, K.J. and Park, C., 1974. Adjustment of river channel capacity downstream from a reservoir. Water Res. Research, 10(4): 870-873.

Harris, J., 1998. .

Harwood, D.S. and Helley, E.J., 1987. Late Cenozoic tectonism of the Sacramento Valley, California. 1359, US Geol. Survey, Wash. D.C.

Kesel, R.H., Yodis, E.G. and McCraw, D.J., 1992. An approximation of the sediment budget of the lower Mississippi River prior to major human modification. Earth Surface Processes and Landforms, 17(7): 711-722.

Knighton, A.D., 1984. Fluvial Forms and Processes. Edward Arnold, London, 218 pp.

Knighton, A.D., 1989. River adjustment to changes in sediment load: the effects of tin mining on the Ringarooma River, Tasmania, 1875-1984. Earth Sur. Proc. & Landforms, 14: 333-359.

Kondolf, G.M., 1995a. Geomorphological stream channel classification in aquatic habitat restoration: uses and limitations. Aquatic Cons.: Marine & Freshwater Ecosys., 5: 127-141.

Kondolf, G.M., 1995b. Managing bedload sediment in regulated rivers: Examples from California, USA. In: J.E. Costa, A.J. Miller, K.W. Potter and P.R. Wilcock (Editors), Natural and Anthropogenic Influences in Fluvial Geomorphology. Amer. Geophysical Union, Wash. D.C., pp. 239

Kondolf, G.M., Vick, J. and Ramirez, T., 1996. Salmon spawning habitat rehabilitation in the Merced, Tuolumne, and Stanislaus Rivers, California: An evaluation of project planning and performance. 90, University of California Water Resources Center, Berkeley, CA.

Kondolf, G.M. and Wolman, M.G., 1993. The sizes of salmonid spawning gravels. Water Res. Research, 29(7): 2275-2285.

Laddish, K.M., 1997. Mathematical modeling of levee setbacks for a hypothetical river: A comparison of shear stress and critical shear stress. Term Paper Thesis, UC Berkeley, Berkeley, CA, 28 pp.

Lehre, A.K., Collins, B.D. and Dunne, T., 1983. Post-eruption sediment budget for the North Fork Toutle River drainage, June 1980 June 1981. Zeitschrift fuer Geomorphologie, Supplementband, 46: 143-163.

Lemke, K., 1991. Transfer function models of suspended sediment concentration. Water Resources Research, 27(3): 293-305.

Leopold, L., Wolman, M.G. and Miller, J.P., 1964. Fluvial Processes in Geomorphology. Books in Geology, W.H. Freeman & Co., San Francisco, CA, 522 pp.

Marcus, A.W., 1989. Lag-time routing of suspended sediment concentrations during unsteady flow. Geol. Soc. Amer. Bull., 101: 644-651.

Meade, R.H., 1985. Suspended sediment in the Amazon River and its tributaries in Brazil during 1982-84. 85-492, US Geol. Survey.

Mertes, L.A.K., Dunne, T. and Martinelli, L.A., 1996. Channel-floodplain geomorphology along the Solimoes-Amazon River, Brazil. GSA Bulletin, 108(9): 1089-1107.

Mertes, L.A.K. and Dunne, T., 1998. Conditions for sediment transport in the Amazon River from the Pleistocene to Present. Quaternary International, in press.

Montgomery, D.R. and Buffington, J.M., 1997. Channel-reach morphology in mountain drainage basins. Geol. Soc. Amer. Bull., 109(5): 596-611.

Neill, C.R. and Yaremko, E.K., 1988. Regime aspects of flood control channelization. In: W.R. White (Editor), International Conf. on River Regime. John Wiley & Sons, Wallingford, UK, pp. 317-329.

Olson, C.L., Clark, F.W. and Hyatt, E., 1942. Preliminary report on the flood of Feb. 1942 in Sacramento Valley, CA with particular reference to damage caused by break in Feather River levee of Reclamation District 803, Dept. of Public Works, Div. of Water Res., Sacramento, CA.

Porterfield, G., 1980. Sediment transport of streams tributary to San Francisco, San Pablo, and Suisun Bays, California, 1909-66. 80-64, US Geological Survey, Menlo Park.

Reid, L.M. and Dunne, T., 1996. Rapid Evaluation of Sediment Budgets. Catena-Verlag, Cremlingen, Germany, 160 pp.

Schalk, G.K. and Jacobson, R.B., 1997. Scour, sedimentation, and sediment characteristics at six levee-break sites in Missouri from the 1993 Missouri River flood. 97-4110, US Geol. Survey, Rolla, Missouri

Schumm, S.A., 1977. The Fluvial System. J. Wiley & Sons, New York, 338 pp.

Schumm, S.A., 1981. Evolution and response of the fluvial system, sedimentologic implications. Soc. Econ. Paleontol. and Minerol. Special Publication, 31: 19-29.

Schumm, S.A. and Winkely, B.R., 1994. Schumm, S.A. and Winkley, B.R., 1994. The Variability of Large Alluvial Rivers, S.A. Schumm and B.R. Winkley (Editors), The Variability of Large Alluvial Rivers. ASCE Press, New York, pp. 467.

The character of large alluvial rivers. In: S.A. Schumm and B.R. Winkley (Editors), The Variability of Large Alluvial Rivers. ASCE Press, New York, pp. 467.

Whiting, P.J. and Bradley, J.B., 1993. A process-based classification system for headwater streams. Earth Surface Proc. & Landforms, 18: 603-612.

Williams, G.P. and Wolman, M.G., 1984. Downstream effects of dams on alluvial rivers. 1286, Geological Survey, Washington, D.C.

Xu, J.X., 1990. An experimental study of complex response in river channel adjustment downstream from a reservoir. Earth Sur. Proc. & Landforms, 15: 43-53.

Xu, J.X., 1996. Channel pattern change downstream from a reservoir: An example of wandering braided rivers. Geomorphology, 15: 147-158.

Budget Justification

We already possess much of the equipment with which to complete this project. Our laboratory at UCSB is equipped with high speed NT PCs, a UNIX workstation, Arc/INFO and other necessary software, a digitizer, a Total Station, and a Differential Global Positioning System (GPS). The three-year budget requests support for one Graduate Student Researcher, one laboratory assistant, purchase of aerial photos, a laptop computer for field use with our GPS, a digital camera for documenting river reaches digitally, a data storage disk for the high volume of necessary data, a simple coring device, and travel expenses. Other project data will be acquired through our contacts in various agencies.

In addition to travel to the Sacramento basin, we request travel support to make a site visit to CALFED's European counterpart, the Romanian government's Danube Delta Biosphere Reserve, in order to gain insight from its ongoing restoration experience. The Danube project has begun restoration activities by breaching levees and dikes, thus providing a field laboratory for studying morphological change associated with land-use change. By visiting Danube restoration sites we could witness processes too complex to be modeled, as well as the unintended consequences of such a restoration effort on a spatial scale relevant to CALFED. We already have long-established contacts with geomorphologists who study large tributaries of the Danube. In addition to official CALFED symposia, we will publicize our research effort annually at the Fall Meeting of the American Geophysical Union.

The project will be conducted in two phases: I) the empirical characterization phase and II) the modeling phase. Phase I will be conducted over the first year of the funding period. The primary tasks during this phase are data acquisition and basin characterization. Subtasks include: collection of field ground control points with GPS; registration and rectification of aerial photographs; digitization of historical Sacramento maps; and correlation of historical sediment and storm data with morphological change in the basin.

Phase II will be conducted during the second and third years of the funding period. The primary task is building a basin scale sediment routing model. Subtasks include: building probability distributions of storms as a stochastic driver of the model; numerical modeling of sediment transport; model calibration using new river profile data with MicroStation SE and In-Roads software; modification of a well-tested sediment routing model (FLUVIAL-12) for use on this project; and field verification of modeling results.

Standard Form 424A

OMB Approval No. 0348-0044

BUDGET INFORMATION - NON-CONSTRUCTION PROGRAMS

SECTION A - BUDGET SUMMARY

Grant Program Function or Activity (a)	Catalog of Federal Domestic Assistance Number (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. CALFED Bay-Delta Program	15-614	$ 0	0	$ 121,832	$	$ 121,832
2.						
3.						
4.						
5. TOTALS		$ 0	0	121,832		121,832

SECTION B - BUDGET CATEGORIES

6. Object Class Categories	GRANT PROGRAM, FUNCTION OR ACTIVITY				Total
	(1) CALFED Bay-Delta Program	(2)	(3)	(4)	(5)
a. Personnel	$ 53,955	$	$	$	$ 53,955
b. Fringe Benefits	11,856				11,856
c. Travel	13,691				13,691
d. Equipment	4,700				4,700
e. Supplies	2,600				2,600
f. Contractual	0				0
g. Construction	0				0
h. Other	0				0
i. Total Direct Charges (sum of 6a-6h)	86,802				86,802
j. Indirect Charges	35,030				35,030
k. TOTALS (sum of 6i and 6j)	$ 121,832	$	$	$	$ 121,832
7. Program Income	$ -0-	$	$	$	$ -0-

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Standard Form 424. . (cont'd)

SECTION C - NON-FEDERAL RESOURCES				
(a) Grant Program	(b) Applicant	(c) State	(d) Other Sources	(e) TOTALS
8.	$ 0	$ 0	$ 0	$ 0
9.				
10.				
11.				
12. TOTALS (sum of lines 8 and 11)	$ 0	$ 0	$ 0	$ 0

SECTION D - FORECASTED CASH NEEDS					
	Total for 1st year	1st Quarter	2nd Quarter	3rd Quarter	4th Quarter
13. Federal	$ 121,832	$ 37,612	$ 17,290	$ 17,290	49,640
14. Non Federal	0	0.00	0	0	0
15. Total (sum of lines 13 and 14)	$ 121,832	$ 37,612.00	$ 17,290.00	$ 17,290.00	$ 49,640.00

SECTION E - BUDGET ESTIMATES OF FEDERAL FUNDS NEEDED FOR BALANCE OF THE PROJECT				
(a) Grant Program	FUTURE FUNDING PERIODS (Years)			
	(b) First	(c) Second	(d) Third	(e) Fourth
16. CALFED Bay-Delta Program	$ 131,912	$ 132,998	$	$ 0
17.				
18.				
19.				
20. TOTAL (sum of lines 16 - 19)	$ 131,912	$ 132,998	$ 0	$

SECTION F- OTHER BUDGET INFORMATION			
(Attach additional Sheets if Necessary)			
21. Direct Charges:	$86,802	22. Indirect Charges: (50% Provisional)	$35,030
23. Remarks			

CALFED Bay-Delta Program
Thomas Dunne
University of California, Santa Barbara
Institute for Computational Earth System Science

DETAILED BUDGET

SALARIES	Period/ mos.	% Time	First Year 10/01/98- 9/30/99	Second Year 10/01/99- 9/30/00	Third Year 10/01/00- 9/30/01
1. Principal Investigator - T. Dunne					
Professor of Environmental Science & Management					
a. Summer month @ 1/9 annual rate of					
$125,100 1st yr.	1	100%	$ 13,900		
$131,355 2nd yr.	1	100%		$ 14,595	
$137,923 3rd yr.	1	100%			$ 15,325
b. Academic period	9	5%	0	0	0
2. Lab Assistant I - TBD					
@ $1,809 /mo. 1st yr.	12	100%	21,708		
@ $1,845 /mo. 2nd yr.	12	100%		22,140	
@ $1,882 /mo. 3rd yr.	12	100%			22,584
3. Graduate Student Researcher II - Michael Singer					
@ $2,476 /mo. 1st yr. academi	GSR II 9	49%	10,919		
@ $2,476 /mo. 1st yr. summer	GSR II 3	100%	7,428		
@ $2,601 /mo. 2nd yr. academi	GSR III 9	75%		18,907	
@ $2,601 /mo. 2nd yr. summer	GSR III 3	100%		8,403	
@ $3,086 /mo. 3rd yr. academi	GSR IV 9	75%			20,831
@ $3,086 /mo. 3rd yr. summer	GSR IV 3	100%			9,258
	Salaries Subtotal		$ 53,955	$ 64,045	$ 67,998

FRINGE BENEFITS

1. Principal Investigator - T. Dunne					
Base sum: $13,900 @	2.70%	1st yr.	$ 375		
$14,595 @	2.70%	2nd yr.		$ 394	
$15,325 @	2.70%	3rd yr.			$ 414
2. Lab Assistant I - TBD					
Base sum: $21,708 @	24.00%	1st yr.	5,210		
$22,140 @	24.50%	2nd yr.		5,424	
$22,584 @	25.00%	3rd yr.			5,646
3. Graduate Student Researcher I - Michael Singer					
Base sum: $10,919 @	1.10%	1st yr. academic	120		
$7,428 @	2.70%	1st yr. summer	201		
$18,907 @	1.10%	2nd yr. academic		208	
$8,403 @	2.70%	2nd yr. summer		227	
$20,831 @	1.10%	3rd yr. academic			229
$9,258 @	2.70%	3rd yr. summer			250

DETAILED BUDGET (cont'd)	First Year 10/01/98-9/30/99	Second Year 10/01/99-9/30/00	Third Year 10/01/00-9/30/01
4. Graduate Student Health Insurance Plan*	$ 1,024	$ 1,126	$ 1,239
5. Graduate Student Fees for Graduate Student Researcher*	4,926	5,419	5,960
Benefits Subtotal	$ 11,856	$ 12,798	$ 13,738
SUPPLIES			
1. Airphotos, 200 at $10.00 each	$ 2,000	$	
2. Auger	300		
Supplies Subtotal	$ 2,300	$	
EQUIPMENT (Includes taxes and shipping)			
1. Laptop Computer	$ 3,500		
2. Digital Camera	600		
3. 9 GB Hard Disk	600		
Equipment Subtotal	$ 4,700	$ 0	$ 0
TRAVEL (increases @ 10%/yr)			
Domestic			
1. Field Campaign - Sacramento river, 30 days car rental at $40/day and 30 days per diem at $120/day for 2 person.	$ 8,400	$ 9,240	$ 10,164
Foreign			
1. 1 RT SB - Romania, airfare $2000 plus 7 days per diem at $283 per/day and 5 days at $262 per day.	$ 5,291	$ 0	$ 0
Domestic and Foreign Subtotal	13,691	9,240	10,164
PUBLICATION COSTS (increases @ 10%/yr)	$ 0	$ 1,000	$ 1,100
OTHER DIRECT COSTS (Increases @ 10%/yr)			
1. Long-distance phone, photocopying, fax and project mailing costs**	$ 300	$ 330	$ 363
2. MicroStation SE software		2,500	
3. Inroads software		2,500	
Other Direct Costs Subtotal	$ 300	$ 5,330	$ 363
Total Direct Costs	$ 86,802	$ 92,413	$ 93,363

DETAILED BUDGET (cont'd)

	First Year 10/01/98-9/30/99	Second Year 10/01/99-9/30/00	Third Year 10/01/00-9/30/01
INDIRECT COSTS			
On-campus rate*** of Modified Total Direct Costs			
Base sum: $76,152 @ 46.00% 1st yr.	$ 35,030		
$85,868 @ 46.00% 2nd yr.		$ 39,499	
$86,164 @ 46.00% 3rd yr.			$ 39,635
TOTAL COSTS	$ 121,832	$ 131,912	$ 132,998
TOTAL COSTS THREE YEARS	$ 386,742		

* Provided to all Teaching Assistants and Graduate Student Researchers employed at 25% time or more.

** Communication costs for collaboration with other researchers related to this project.

*** This is the DHHS negotiated, predetermined, on-campus indirect cost rate for the period 7/1/97 through 6/30/00. The rate thereafter is provisional.

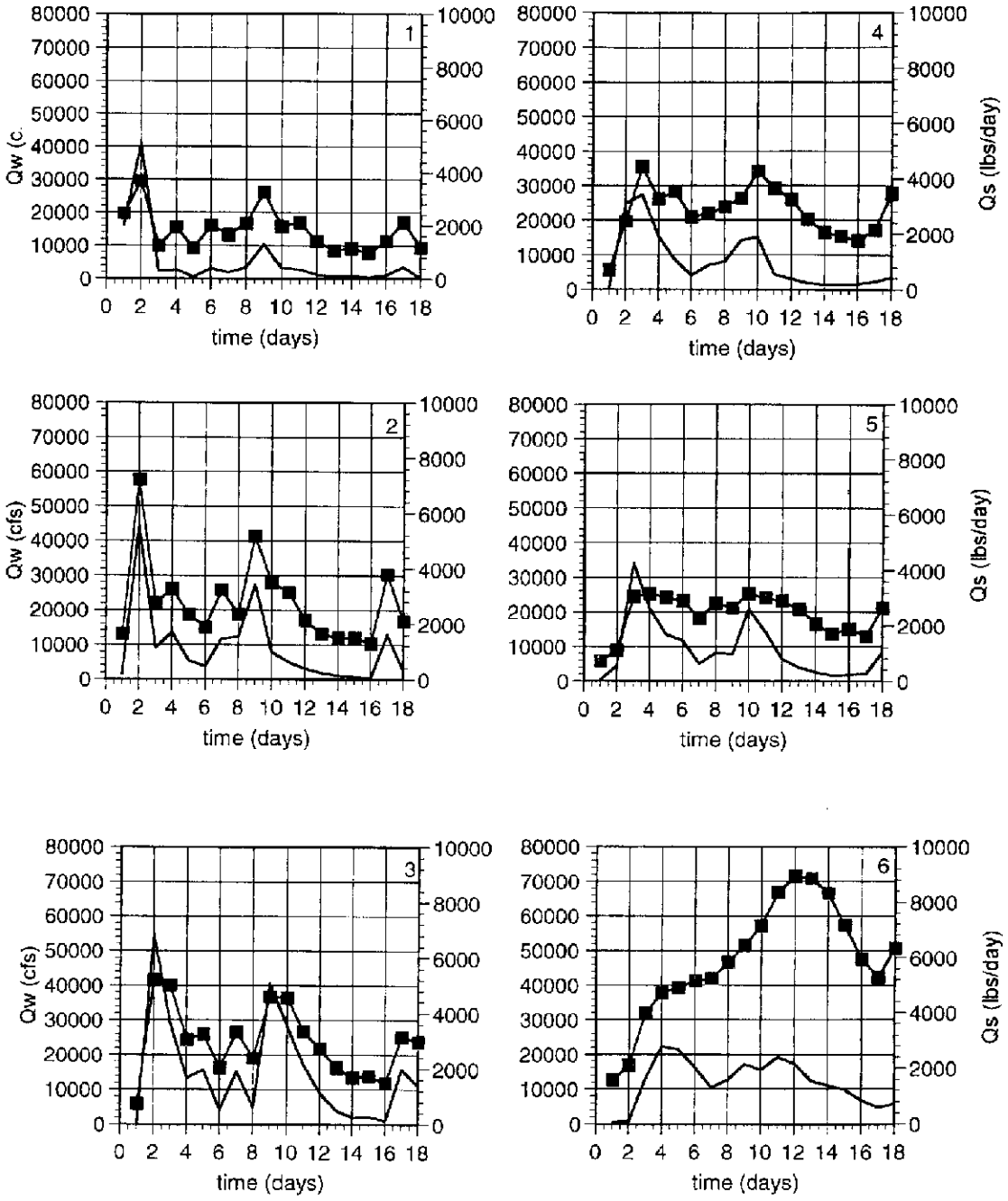

Figure 1. Sediment discharge (blue) and water discharge for an 18-day storm over six gauging stations (numbered in upper-left corner).

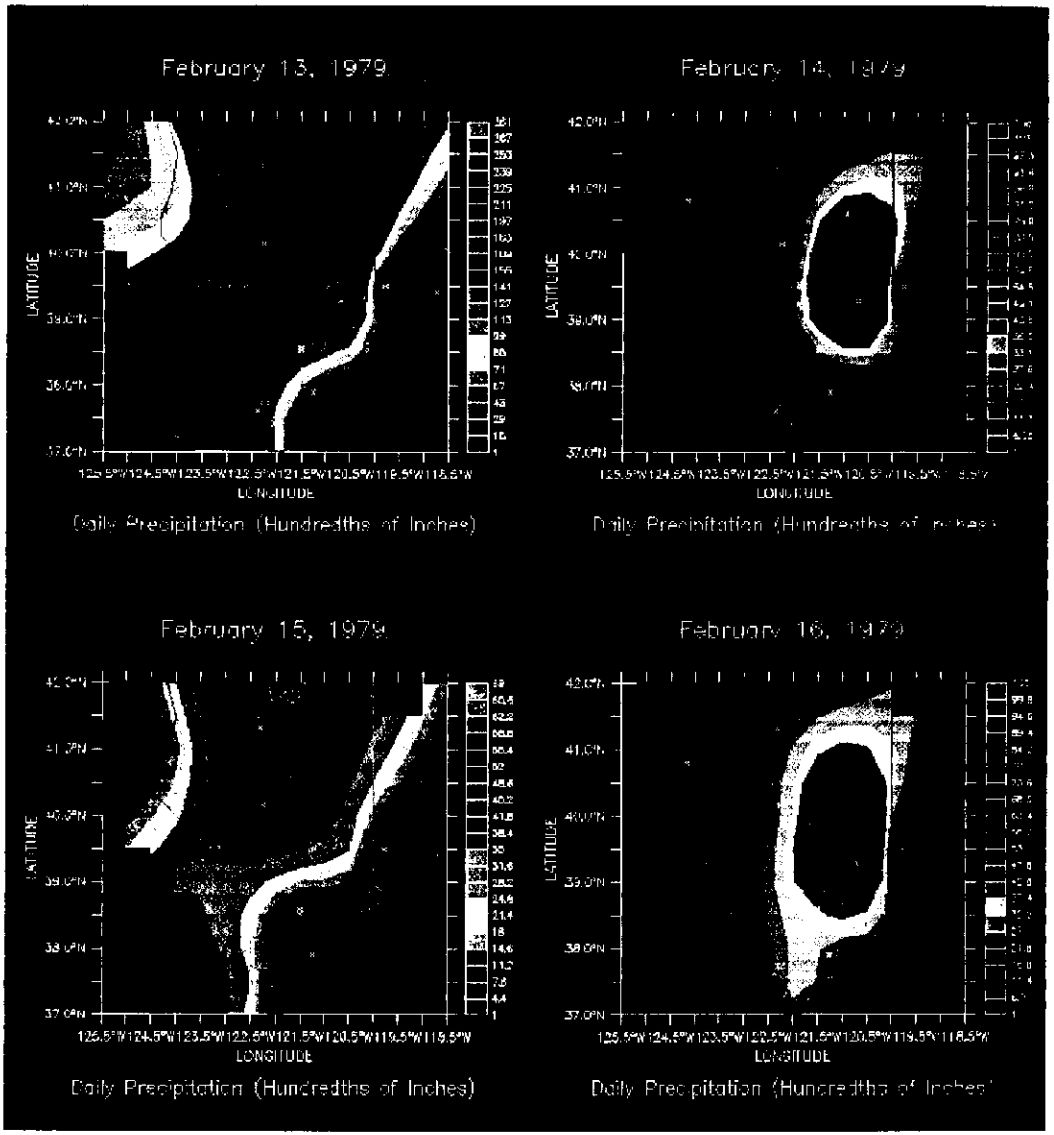

Figure 2. Four days of storm data from NOAA used in conjunction with sediment and streamflow data to characterize basin response.

THOMAS DUNNE: CURRICULUM VITAE

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EDUCATION B.A. 1964 Cambridge Univ., UK; Ph.D. 1969 Johns Hopkins University, (Geography)

HONORS Fulbright Scholar, 1964; Robert E. Horton Award, American Geophysical Union, 1987; National Academy of Sciences, 1988; Fellow, American Geophysical Union, 1989; Guggenheim Fellowship, 1989; American Academy of Arts and Sciences, 1993; Fellow, California Academy of Sciences, 1996; National Research Council Wolman Distinguished Lecturer, 1997; National Academy of Sciences Warren Prize for Fluviatile Geology, 1998.

CURRENT RESEARCH INTERESTS

Hydrology, sediment transport, and sedimentation in valley floors

Field studies and modeling of river-basin sediment budgets.

Field and theoretical studies of drainage basin and hillslope evolution

PUBLICATIONS (last 4 years)

T. Dunne, K. X Whipple, and B.F. Aubry, Microtopography of hillslopes and the initiation of channels by Horton overland flow, In: **Evolving Concepts in Fluvial Geomorphology** (ed. J.E. Costa), American Geophysical Union, Geophysical Monograph, 1995.

L.A.K. Mertes, T.Dunne, and L.A Martinelli, Channel-floodplain geomorphology along the Solimões-Amazon River, Brazil, **Geological Society of America Bulletin**, 108, 1089-1107, 1996.

L.M. Reid and T. Dunne, **Rapid Evaluation of Sediment Budgets**; Geo-Ecology Texts, Catena Verlag, Reiskirchen, Germany, 164pp, 1996.

D. J. Miller and T. Dunne, Topographic perturbations of regional stresses and consequent bedrock fracturing; **Journal of Geophysical Research Solid Earth**, 101, B11, 25,523-25,536, 1996.

L. Benda and T. Dunne, Stochastic forcing of sediment supply to channel networks by landsliding and debris flow: **Water Resources Research**, 33, 2849-2863,1997.

L. Benda and T. Dunne, Stochastic forcing of sediment storage and transport in channel networks; **Water Resources Research**, 33, 2865-2880, 1997.

T. Dunne, L.A.K. Mertes, R.H. Meade. J.E. Richey, and B.R. Forsberg, Exchange of sediment between the channel and floodplain of the Amazon River in Brazil, **Geological Society of America Bulletin**, 110, 450-467, 1998.

L. Benda, D. J. Miller, T. Dunne, G.H. Reeves, and J.K. Agee, Dynamic landscape systems: In: **Ecology and Management of Streams and Rivers in the Pacific Northwest Ecoregion** (edited by R. Naiman and R. Bilby), Springer Verlag, New York, 1998.

T. Dunne, Hydrologic science.... on a planet... in landscapes... in the future, In **Hydrologic Science:**

Taking Stock and Looking Forward (ed. D. Freyberg), National Academy Press, Washington DC, 1998.

T. Dunne, Critical data requirements for prediction of erosion and sedimentation in mountain drainage basins, **Jour. American Water Resources Association**, accepted, 1998.

OTHER RELEVANT PUBLICATIONS

T. Dunne and **L.** B. Leopold, **Water in Environmental Planning**, W. H. Freeman Co., San Francisco, 818 pp., 1978.

W. E. Dietrich and T. Dunne, Sediment budget for a small catchment in mountainous terrain, **Zeitschrift für Geomorphologie**, Supplement Band 29, 215-230, 1978.

W. E. Dietrich, J. D. Smith, and T. Dunne, Flow and sediment transport in a sandbedded meander, **Journal of Geology**, 87, 305-315, 1979.

W. E. Dietrich, T. Dunne, N. F. Humphrey and L. M. Reid, Construction of sediment budgets for drainage basins, **Sediment Budgets and Routing in Forested Drainage Basins**, U.S. Forest Service General Technical Report PNW-141, Pacific Northwest Forest and Range Expt. Sta., 5-23, 1982.

A. K. Lehre, B. D. Collins, and T. Dunne, Post-eruption sediment budget for the North Fork Toutle River drainage, June 1980-June 1981, **Zeitschrift für Geomorphologie**, Suppl. Bd. 46, 143-163, 1983.

T. Dunne and L. H. Fairchild, Estimation of flood and sedimentation hazards around Mt. St. Helens (1), **Shin-Sabo, J. Erosion Control Engineering Soc. Japan**, 36(4), 12-22, 1984.

T. Dunne and L. H. Fairchild, Estimation of flood and sedimentation hazards around Mt. St. Helens (2), **Shin-Sabo, J. Erosion Control Engineering Soc. Japan**, 37(1), 13-22 1984.

W. E. Dietrich, J. D. Smith, and T. Dunne, Boundary shear stress, sediment transport, and bed morphology in a sand-bedded meander during high and low flow. In: **River Meandering**, Amer. Soc. Civil Engineers, 632-639, 1984.

R. H. Meade, T. Dunne, et al., Storage and remobilization of suspended sediment in the Lower Amazon River of Brazil, **Science**, 228, 488-490, 1985.

T. Dunne, Geomorphological contributions to flood-control planning; In **Flood Geomorphology** (Eds. V. R. Baker, R. C. Kochel, and P. C. Patton), Wiley & Sons, NY, 421-438, 1988.

B. D. Collins and T. Dunne, Gravel transport, gravel harvesting, and channel-bed degradation in rivers draining the Southern Olympic Mountains, Washington, USA, **Environmental Geology and Water Science**, 13, 213-224, 1989.

J. E. Richey, L. A. K. Mertes, T. Dunne, and five others!, Sources and routing of the Amazon River floodwave; **Global Biogeochemical Cycles**, 3, 191-204, 1989.

B. D. Collins and T. Dunne, **Fluvial Geomorphology and River-gravel Mining**, Spec. Pub. 98, Division of Mines and Geology, California Department of Conservation, 29 p., 1990.

COMMITTEE REPORTS

Alluvial fan flooding: definition and criteria, U.S. National Research Council, (with other members of the Committee on Alluvial Fan Flooding, 1996.

The Hidrovía Paraguay-Paraná Navigation Project: Report of an Independent Review, by T. Dunne, J. Melack, B. Melia, J. Paggi, S. J. Paggi, T. Panayotou, H. Rattner, E. Salati, I. Klabin, T. Scudder, and M. Clemens, Environmental defense Fund, Washington, DC, 214 p., 1997.

ADVISOR M.G. Wolman, Johns Hopkins University

Ph.D. STUDENTS A.G. Price, J. E. Fitzgibbon, D.P. Dethier, G.S.O. Ongweny, C. J. McCarthy, W. E. Dietrich, L. H. Fairchild, L. M. Reid, W. Zhang, L. A. K. Mertes, D. J. Miller, L. E. Benda, K. X Whipple, J. J. Major.

Thomas Dunne is a Professor of Environmental Science and Management, and of Geological Sciences at the University of California Santa Barbara. He conducts field and theoretical studies of drainage-basin, hillslope, and fluvial geomorphology, and in the application of hydrology and geomorphology to landscape management and hazard analysis.

While working for the USDA Agricultural Research Service (1966-1969) and McGill University (1971-1973), he conducted research on the effects of topography, soil characteristics, and vegetation on runoff processes under rainfall and snowmelt in Vermont and Canada. While teaching at the University of Nairobi (1969-1971), he initiated a long-running research interest in African environments, including experimental studies of runoff and erosion processes, and statistical studies and field surveys of the effects of land use on hillslope erosion and river-basin sediment yields. He also conducted occasional studies of reservoir sedimentation, water quality, and erosion due to charcoal production and grazing. This work, between 1969 and 1991, was supported by foundations, the United Nations, US and Kenya agencies.

While teaching in the Department of Geological Sciences at the University of Washington (1973-1995), he studied landsliding and debris flows; drainage-basin sediment budgets in natural and managed forests; tephra erosion and debris-flow sedimentation on active volcanoes; and sediment transport and channel morphology in sand-bed and gravel-bed river channels. He also conducted several studies related to resource management, such as the impacts of gravel harvesting on the river-channel sedimentation and morphology; impacts of timber harvest on erosion and sedimentation; and effects of flow diversion and reservoir management on sedimentation.

He now leads an Interdisciplinary Science Team, participating in the NASA Earth Observing System, that studies hydrology, sedimentation, biogeochemistry, and environmental change in the Amazon River Basin of lowland Brazil and the Andes Range of Bolivia. The work has been funded by NASA, NSF, and the US Geological Survey. His particular scientific role in the project involves: field measurements of soil properties, runoff and erosion processes on hillslope scales; sediment transport and floodplain sedimentation, and modeling of streamflow and sedimentation throughout the whole basin employing data from ground networks and satellites.

He has gained experience of geomorphic and hydrologic processes related to development projects through research, travel and consultancies in many parts of the world, and has expressed some of that experience in teaching courses, advising government agencies, writing papers, and co-authoring two textbooks.