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PI/PD Name: Laurel Larsen

Gender: ☐ Male ☒ Female

Ethnicity: (Choose one response) ☐ Hispanic or Latino ☒ Not Hispanic or Latino

Race:
(Select one or more)
- ☐ American Indian or Alaska Native
- ☐ Asian
- ☐ Black or African American
- ☐ Native Hawaiian or Other Pacific Islander
- ☒ White

Disability Status:
(Select one or more)
- ☐ Hearing Impairment
- ☐ Visual Impairment
- ☐ Mobility/Orthopedic Impairment
- ☐ Other
- ☐ None

Citizenship: (Choose one) ☒ U.S. Citizen ☐ Permanent Resident ☐ Other non-U.S. Citizen

Check here if you do not wish to provide any or all of the above information (excluding PI/PD name): ☒

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Ethnicity Definition:
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American Indian or Alaska Native. A person having origins in any of the original peoples of North and South America (including Central America), and who maintains tribal affiliation or community attachment.
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Native Hawaiian or Other Pacific Islander. A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.
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List of Suggested Reviewers or Reviewers Not To Include (optional)

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

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TITLE OF PROPOSED PROJECT **CAREER: Ecogeomorphic implications of organic particulates across scales: Impacts of surficial properties and interception on landscape dynamics**

REQUESTED AMOUNT	PROPOSED DURATION (1-60 MONTHS)	REQUESTED STARTING DATE	SHOW RELATED PRELIMINARY PROPOSAL NO. IF APPLICABLE
$ 697,539	60 months	01/01/15	

THIS PROPOSAL INCLUDES ANY OF THE ITEMS LISTED BELOW
- ☐ BEGINNING INVESTIGATOR (GPG I.G.2)
- ☐ DISCLOSURE OF LOBBYING ACTIVITIES (GPG II.C.1.e)
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- ☐ HISTORIC PLACES (GPG II.C.2.j)
- ☐ VERTEBRATE ANIMALS (GPG II.D.6) IACUC App. Date ______ PHS Animal Welfare Assurance Number ______
- ☒ FUNDING MECHANISM Research - other than RAPID or EAGER
- ☐ HUMAN SUBJECTS (GPG II.D.7) Human Subjects Assurance Number ______ Exemption Subsection ______ or IRB App. Date ______
- ☐ INTERNATIONAL ACTIVITIES: COUNTRY/COUNTRIES INVOLVED (GPG II.C.2.j)
- ☒ COLLABORATIVE STATUS Not a collaborative proposal

PI/PD DEPARTMENT Geography	PI/PD POSTAL ADDRESS 550 McCone Hall Berkeley, CA 947204740 United States
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CO-PI/PD				
CO-PI/PD				
CO-PI/PD				

CERTIFICATION PAGE

Certification for Authorized Organizational Representative (or Equivalent) or Individual Applicant

By electronically signing and submitting this proposal, the Authorized Organizational Representative (AOR) or Individual Applicant is: (1) certifying that statements made herein are true and complete to the best of his/her knowledge; and (2) agreeing to accept the obligation to comply with NSF award terms and conditions if an award is made as a result of this application. Further, the applicant is hereby providing certifications regarding conflict of interest (when applicable), drug-free workplace, debarment and suspension, lobbying activities (see below), nondiscrimination, flood hazard insurance (when applicable), responsible conduct of research, organizational support, Federal tax obligations, unpaid Federal tax liability, and criminal convictions as set forth in the NSF Proposal & Award Policies & Procedures Guide,Part I: the Grant Proposal Guide (GPG). Willful provision of false information in this application and its supporting documents or in reports required under an ensuing award is a criminal offense (U.S. Code, Title 18, Section 1001).

Certification Regarding Conflict of Interest

The AOR is required to complete certifications stating that the organization has implemented and is enforcing a written policy on conflicts of interest (COI), consistent with the provisions of AAG Chapter IV.A.; that, to the best of his/her knowledge, all financial disclosures required by the conflict of interest policy were made; and that conflicts of interest, if any, were, or prior to the organization's expenditure of any funds under the award, will be, satisfactorily managed, reduced or eliminated in accordance with the organization's conflict of interest policy. Conflicts that cannot be satisfactorily managed, reduced or eliminated and research that proceeds without the imposition of conditions or restrictions when a conflict of interest exists, must be disclosed to NSF via use of the Notifications and Requests Module in FastLane.

Drug Free Work Place Certification

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent), is providing the Drug Free Work Place Certification contained in Exhibit II-3 of the Grant Proposal Guide.

Debarment and Suspension Certification

(If answer "yes", please provide explanation.)

Is the organization or its principals presently debarred, suspended, proposed for debarment, declared ineligible, or voluntarily excluded from covered transactions by any Federal department or agency? Yes ☐ No ☒

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) or Individual Applicant is providing the Debarment and Suspension Certification contained in Exhibit II-4 of the Grant Proposal Guide.

Certification Regarding Lobbying

This certification is required for an award of a Federal contract, grant, or cooperative agreement exceeding $100,000 and for an award of a Federal loan or a commitment providing for the United States to insure or guarantee a loan exceeding $150,000.

Certification for Contracts, Grants, Loans and Cooperative Agreements

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 any agency, a Member of Congress, an 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 of Lobbying Activities,'' 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 and disclose accordingly.

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Certification Regarding Flood Hazard Insurance

Two sections of the National Flood Insurance Act of 1968 (42 USC §4012a and §4106) bar Federal agencies from giving financial assistance for acquisition or construction purposes in any area identified by the Federal Emergency Management Agency (FEMA) as having special flood hazards unless the:
(1) community in which that area is located participates in the national flood insurance program; and
(2) building (and any related equipment) is covered by adequate flood insurance.

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(1) for NSF grants for the construction of a building or facility, regardless of the dollar amount of the grant; and
(2) for other NSF grants when more than $25,000 has been budgeted in the proposal for repair, alteration or improvement (construction) of a building or facility.

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(This certification is not applicable to proposals for conferences, symposia, and workshops.)

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The AOR shall require that the language of this certification be included in any award documents for all subawards at all tiers.

CERTIFICATION PAGE - CONTINUED

Certification Regarding Organizational Support

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that there is organizational support for the proposal as required by Section 526 of the America COMPETES Reauthorization Act of 2010. This support extends to the portion of the proposal developed to satisfy the Broader Impacts Review Criterion as well as the Intellectual Merit Review Criterion, and any additional review criteria specified in the solicitation. Organizational support will be made available, as described in the proposal, in order to address the broader impacts and intellectual merit activities to be undertaken.

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When the proposal exceeds $5,000,000, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal tax obligations. By electronically signing the Certification pages, the Authorized Organizational Representative is certifying that, to the best of their knowledge and belief, the proposing organization:
(1) has filed all Federal tax returns required during the three years preceding this certification;
(2) has not been convicted of a criminal offense under the Internal Revenue Code of 1986; and
(3) has not, more than 90 days prior to this certification, been notified of any unpaid Federal tax assessment for which the liability remains unsatisfied, unless the assessment is the subject of an installment agreement or offer in compromise that has been approved by the Internal Revenue Service and is not in default, or the assessment is the subject of a non-frivolous administrative or judicial proceeding.

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When the proposing organization is a corporation, the Authorized Organizational Representative (or equivalent) is required to complete the following certification regarding Federal Tax Liability:

By electronically signing the Certification Pages, the Authorized Organizational Representative (or equivalent) is certifying that the corporation has no unpaid Federal tax liability that has been assessed, for which all judicial and administrative remedies have been exhausted or lapsed, and that is not being paid in a timely manner pursuant to an agreement with the authority responsible for collecting the tax liability.

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AUTHORIZED ORGANIZATIONAL REPRESENTATIVE	SIGNATURE	DATE
NAME Joyce So	Electronic Signature	Jul 23 2014 6:37PM

TELEPHONE NUMBER	EMAIL ADDRESS	FAX NUMBER
510-643-7365	joyceso@berkeley.edu	510-642-8236

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COVER SHEET FOR PROPOSAL TO THE NATIONAL SCIENCE FOUNDATION

FOR CONSIDERATION BY NSF ORGANIZATION UNIT(S) - continued from page 1
(Indicate the most specific unit known, i.e. program, division, etc.)

EAR - HYDROLOGIC SCIENCES

PROJECT SUMMARY

Overview:

The field of ecogeomorphology has primarily advanced through studies of the physics of flow and mineral sediment transport through vegetation. However, other aspects of ecology have significant potential to influence geomorphology. Particulate organic material can form coatings on stems or the bed and may comprise a major portion of the sediment pool. It often serves as a vector for contaminant transport yet also can facilitate biogeochemical reactions and enhance landform development and coastal sedimentation. However, the role of fine sediment transport processes in geomorphology remains poorly understood. This CAREER proposal (i) tests the null hypothesis that transport of fine sediment through vegetation canopies in a biofilm-rich environment is no different from that in a biofilm-poor environment, (ii) develops a quantitative, dimensionless relationship between hydrodynamic properties, biofilm and vegetation properties, and sedimentation via particle interception, and (iii) uses a new model to test the role of particle interception in real environments on delta evolution. A three-pronged approach of laboratory flume studies, field flume studies on the Wax Lake Delta, and numerical modeling is used to achieve these objectives. Closely integrated educational objectives targeting undergraduate students, graduate students and early-career scientists, restoration managers, and the general public will enhance understanding and intuition of concepts in fluids and sediment transport improve planning of marsh restoration and environmental flows.

Intellectual Merit :

This work fills a critical gap in our understanding of sedimentation in vegetation canopies. Although much progress has been made on understanding how vegetation patches affect flow, turbulence, and, to some extent, particle settling, there remain gaps in our understanding of the extent to which direct interception of particles by plant stems contributes to sedimentation. In ecogeomorphic models of marsh evolution or delta development, particle interception is either not represented at all or is based on flume studies with synthetic vegetation and idealized sediment, which have yielded conflicting results. These models potentially underestimate coastal sedimentation in environments where biological activity promotes flocculation and forms sticky coatings on surfaces. On the other hand, studies of colloid interception by biofilms on plants or on the bed have advanced understanding of the role of microscale chemistry and biofilm structure in civil and environmental engineering applications. However, these studies have focused primarily on the nature of surficial interactions under creeping flow conditions, largely neglecting hydrodynamic effects. Here we use novel approaches to understand the effects of hydrodynamics and biofilm coatings on sedimentation, using models to extrapolate that understanding to the landscape scale.

Broader Impacts :

This study will provide students in undergraduate lecture courses with unique hands-on experience with fluid mechanics and exposure to research, guide graduate students in the design of complex field experiments, and provide planning tools for the nation's major delta and wetland restoration projects. Integral to the work is the construction of the one-of-a-kind Biogeomorphology Research and Teaching (BRAT) flume, designed for the study of how hydrodynamics interacts with delicate biological structures. The only on-campus flume in the departments of Earth and Planetary Science and Geography, it will provide unique opportunities to build experimental modules into several lecture courses and the only exposure many students will have to flume research. Course modules will also be made available to the broader community through the SERC portal. The PI will design a short-course for the NCED Summer Institute on fine sediment transport dynamics, with an accompanying hands-on experimental opportunity for dual teaching-research purposes in the Outdoor Stream Lab. Outreach activities in collaboration with the San Francisco Exploratorium will educate the general public about the role of coastal marshes in land building and the rationale and challenges associated with coastal marsh restoration. The field and modeling components of this research will contribute to a seven-institution Delta Dynamics Collaboratory effort and establish new connections with restoration managers. The resulting modeling tool will improve predictions of land-building timescales and recommendations for vegetation and flow management for major marsh and delta restoration projects.

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For font size and page formatting specifications, see GPG section II.B.2.

Appendix Items:

*Proposers may select any numbering mechanism for the proposal. The entire proposal however, must be paginated. Complete both columns only if the proposal is numbered consecutively.

CAREER: Ecogeomorphic implications of organic particulates across scales: Impacts of surficial properties and interception on landscape dynamics

This CAREER proposal focuses on elucidating poorly understood fine particle sedimentation processes (Fig. 1). It is set in the context of a career focused on understanding the general mechanics and large-scale implications of organic sediment transport, and of disseminating that information to communities of geomorphologists, ecologists, restoration resource managers, the general public, and students. Specifically, this work seeks to (1) derive the functional form of particle interception by vegetation, (2) determine how that relationship changes when biofilm is present, (3) test the hypothesis that interception plays a significant role in delta and landform evolution, (4) educate the next generation of students about fine sediment transport processes and fluid dynamics, and (5) increase public understanding of land building processes in coastal ecosystems.

Although geomorphologists have made much progress in understanding sediment transport mechanics, we still grapple with understanding and predicting the dynamics of fine sediment—the fraction most enriched in organic matter. Natural particulate organic matter consists of plant and algae detritus, living communities of bacteria, diatoms, and algae, extracellular polymeric substances (EPS), fecal material, and soil material. It exists over a continuum of size and often aggregates with other organic or inorganic material. Challenges for prediction include dynamic aggregation and disaggregation processes as a function of flow, the porous structure and irregular shape of aggregates that cause settling velocities to differ from Stokes' Law predictions, and surficial properties (e.g., stickiness) that vary with temperature, ambient nutrient concentrations, light, and flow conditions [*Amos et al.*, 2004; *Winterwerp and Kesteren*, 2004; *Lundkvist et al.*, 2007; *Grabowski et al.*, 2011; *Salant*, 2011]. Nevertheless, quantifying environmental organic sediment sources and fate remains an important venture. Organic sediment represents a key connection between geomorphology and other disciplines such as ecology, biogeochemistry, environmental engineering, and climate science, as it represents a significant store and flux of carbon, nutrients, and contaminants.

In geomorphology there has been a recent growth of interest in the role of organic sediment transport processes in landform development and land building. One theory explaining the persistence of the parallel-drainage Everglades ridge and slough landscape is that transport of flocculent organic sediment away from the edges of ridges counters the ridges' natural tendency to expand [*Larsen and Harvey*, 2010, 2011]. At the coastal margin, deposition of organic sediment in deltaic and tidal marshes contributes to land building [*Fagherazzi et al.*, 2004; *Mudd et al.*, 2004; *Kirwan and Megonigal*, 2013]. Recent modeling studies suggest that the deposition of organic muds and fines in deltaic marshes may be more important to the persistence of deltas than previously thought [*Nardin and Edmonds*, in press]. These studies show how the presence of dense vegetation on deltas focuses sand through channels, inhibiting its spreading over the marsh plain relative to unvegetated conditions, while enhancing the deposition of mud and fines. Thus, while sand deposition is essential for forming the base on which vegetation grows and stabilizes new substrate, the long-term persistence of these regions in the face of subsidence and sea-level rise may hinge on the deposition of fines.

In both the quest to better quantify the role of inland waters in global carbon cycling (e.g., *Battin et al.*, 2008; *Franke et al.*, 2013; *Bengtsson et al.*, 2014) and understand the geomorphic role of fine sediment in land building and landform evolution, it is important to quantify sedimentation fluxes as mediated by vegetation and biofilms. In hydroecology, substantial research has focused on impacts of vegetation on flow, turbulence, and, more recently, sediment transport [*Nepf*, 2012; *Yager and Schmeeckle*, 2013; *Meire et al.*, 2014]. Vegetation decreases eddy scale and may dampen turbulence within canopies [*Ghisalberti and Nepf*, 2002; *Tanino and Nepf*, 2008], inhibiting entrainment and promoting settling [*Furukawa and Wolanski*, 1996; *Leonard and Reed*, 2002; *Mudd et al.*, 2010]. On the other hand, sparse vegetation canopies may enhance turbulence and promote erosion [*Bouma et al.*, 2007; *Follett and Nepf*, 2012; *Ortiz et al.*, 2013], and routing of water around discrete vegetation patches often promotes scour and may initiate channel formation [*D'Alpaos et al.*, 2007b; *Temmerman et al.*, 2007; *Vandenbruwaene et al.*, 2011].

In addition to its impacts on settling, vegetation may also enhance sedimentation through particle capture, which takes the form of direct interception, inertial impaction, diffusional deposition, or gravitational deposition. In shallow floodplain and wetland environments, particle capture is dominated by direct interception, which occurs when a sediment particle comes within one radius of a vegetation stem

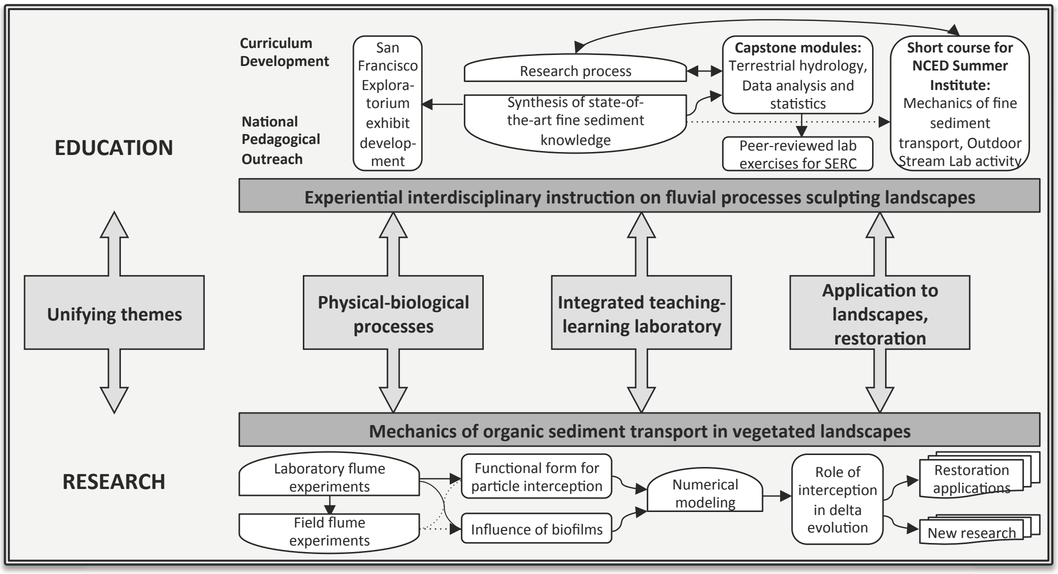

Figure 1. CAREER flowchart showing educational plan, research plan, and unifying objectives.

[*Palmer et al.*, 2004]. However, interception has been less studied than settling as a sedimentation process and is therefore often excluded in models of floodplain/wetland sedimentation [*Nardin and Edmonds*, in press; *Larsen and Harvey*, 2010, 2011], simulated only indirectly [*Allen*, 1997; *van de Koppel et al.*, 2005], or based on an empirical formulation [*Palmer et al.*, 2004] derived from a series of laboratory flume experiments with synthetic Pliolite particles and a single silicone-coated dowel [*D'Alpaos et al.*, 2007a; *Mariotti and Fagherazzi*, 2010; *Mudd et al.*, 2010]. All of these models likely underestimate sedimentation in their exclusion of surficial properties of collectors and particles. In real environments, stems are often coated with sticky biofilms that increase their effective radius and enhance interception efficiency; aggregates bound together with internal biofilms may similarly enhance sedimentation. ***By discounting the importance of particle interception in models of delta growth or tidal marsh accretion, geomorphologists could be missing a potentially significant term in coastal sedimentation budgets, with serious implications for restoration planning and management of coastal regions in the face of sea level rise.***

1. Likelihood of the importance of particle interception

A few studies suggest the potential importance of interception for sedimentation in biologically active environments. In the classic experiments of *Palmer et al.* [2004], adding roughness elements to stems increased particle capture, suggesting that epiphytic coatings may effectively enhance the number of collectors and increase sedimentation rates. Subsequent work [*Purich*, 2006] extended the range of Reynolds numbers and vegetation densities examined. Based on the resulting empirical relationships, *Purich* predicted that settling would dominate sedimentation in freshwater wetlands with low velocities and sparse vegetation, whereas interception would dominate in tidal marshes and seagrass meadows with dense vegetation. In contrast, using ranges of velocities and canopy characteristics reported for a broad sample of tidal marshes and theory derived from laboratory experiments [*Nepf*, 1999; *Palmer et al.*, 2004; *Tanino and Nepf*, 2008], *Mudd et al.* [2010] predicted that, in the absence of biofilms, particle capture is significant (comprising >10% of marsh sedimentation) only when flows exceed 10 cm s^{-1}.

Although *Leonard et al.* [1995] measured direct interception rates consistent with *Mudd et al.* [2010] in a *Juncus roemerianus* marsh (on average, 4-5% of total deposition), they suggested that vegetation communities containing epiphytic biofilms may capture sediment at a higher rate. Indeed, *Stumpf et al.* [1983] found that particle interception by *Spartina alterniflora* could comprise up to 50% of total deposition. Further, colloid tracer injection studies [*Saiers et al.*, 2003; *Huang et al.*, 2008] conducted in field flumes built around Everglades vegetation yielded stem capture efficiencies orders of magnitude higher than those predicted based on *Palmer et al* (namely, 29% for *Saiers et al.* compared to 9.6 x 10^{-8} computed using *Palmer et al.*). Thus, ***it is likely that existing models of sedimentation in plant canopies and its effects on landscape evolution grossly underestimate the role of particle interception in environments with biofilm coatings on plant stems and/or sediment aggregates***.

2. Scope of this proposal

The proposed work has three integrated educational and research objectives (Fig. 1) and uses laboratory, field, and numerical modeling approaches to experimentation. In phase I, an equation relating interception to hydrodynamic, particle, vegetation, and biofilm characteristics will be developed based on laboratory experiments in a new Biogeomorphology Research and Teaching (BRAT) Flume facility. In phase II, laboratory results will be extended to the field, using in situ flumes in two distinct regions of a growing lobe of the Wax Lake Delta, Louisiana. The upstream region has diverging flow and emergent clonal giants (*Phragmites australis*, *Zizaniopsis miliacea, Typha* spp*., Colocassia esculenta, Polygonum punctatum*) without extensive biofilm development. The downstream region has sheet flow and water lotus (*Nelumbo lutea*) that is extensively coated with biofilm (Fig. 3). Phase III will apply the experimental relation for interception to a new vegetation-sedimentation module for DeltaMod, an interdisciplinary community model of delta evolution developed in coordination with the Delta Dynamics Collaboratory. Integrated educational components include development of experiential capstone course modules using the BRAT flume, design of a new short course for the NCED Summer Institute, focused on the mechanics and implications of organic fine sediment transport, and partnership with the Exploratorium to design an exhibit on the nature of fine sediment and its role in coastal land building and marsh restoration projects.

3. Note on proposal resubmission

This proposal, while new as a CAREER proposal, is a resubmission of a previous set of proposals to G&LD and Instrumentation and Facilities, in which the BRAT flume facility was split out as a separate IF proposal. Both proposals generated enthusiasm from the reviewers and the panels (both were ranked as "Competitive; support if possible" but fell just below the "fund" line), yet both panels worried about the likelihood of success of each individual proposal should the companion proposal not be funded. Reviewers also critiqued the ambitious scope of the previous G&LD proposal, with its field, lab, modeling, and outreach components, and called for stronger justification for the need of the BRAT flume and its physical characteristics (i.e., length). The longer time frame and larger budget of a CAREER proposal more suitably accommodates the complete scope of the work. In the present proposal, the flume has been lengthened to allow for the complete adjustment of flow conditions to canopy drag, and more details about integration of the instruments are provided. To address additional reviewer concerns, this proposal also better describes how the work will be used by resource managers and improves and generalizes the characterization of biofilms.

4. Description of the BRAT flume

4.1. Need for new flume construction: The BRAT flume facility (Fig. 2) will fulfill teaching and research needs not presently available on the Berkeley campus and will be unique worldwide in its specialized accommodation of vegetation, biofilms, and delicate sediment aggregates (or organisms) while maintaining robust and repeatable flow conditions. Traditionally, cohesive sediment studies are conducted in racetrack flumes [*Mehta and Srinivas*, 1993; *Piedra-Cueva et al.*, 1997; *Larsen et al.*, 2009a] or rotating annular flumes [*Krishnappan*, 1993; *Petersen and Krishnappan*, 1994; *Larsen et al.*, 2009b], in which flow is driven by paddles or rotation of a lid, respectively, and sediment need not pass through pumps to recirculate. However, neither type of flume is appropriate for the present investigations. Most racetrack flumes have a large footprint (157,000 cm^2 is typical [*Nowell et al.*, 1989]) in order to recirculate flow horizontally without pumps while maintaining desirable flow conditions in the test section. Large-footprint flumes require large quantities of sediment to achieve steady inflow-outflow conditions, which is not conducive to the use of sediment collected from the field. Racetrack flumes also tend to trap sediment along the paddles, making them ill suited to well-mixed assumptions or mass-balance calculations. Rotating annular flumes have a smaller footprint but will not accommodate emergent vegetation, due to the presence of a lid. The BRAT flume is recirculating, driven by disc-flow pumps that, unlike standard pumps, can pass delicate aggregates or organisms without structural disruption. Flow is driven by rotating, evenly spaced discs, between which it remains laminar. The combination of floc-friendly recirculating pumps with an open channel that accommodates vegetation and biofilms and a relatively small footprint makes the BRAT flume unique among flumes at Berkeley and throughout the world in its ability to address questions about cohesive sediment dynamics in low-gradient vegetated environments.

The BRAT flume also provides new educational opportunities on the Berkeley campus. It will be the only main campus flume for both the Geography Department and Department of Earth and Planetary

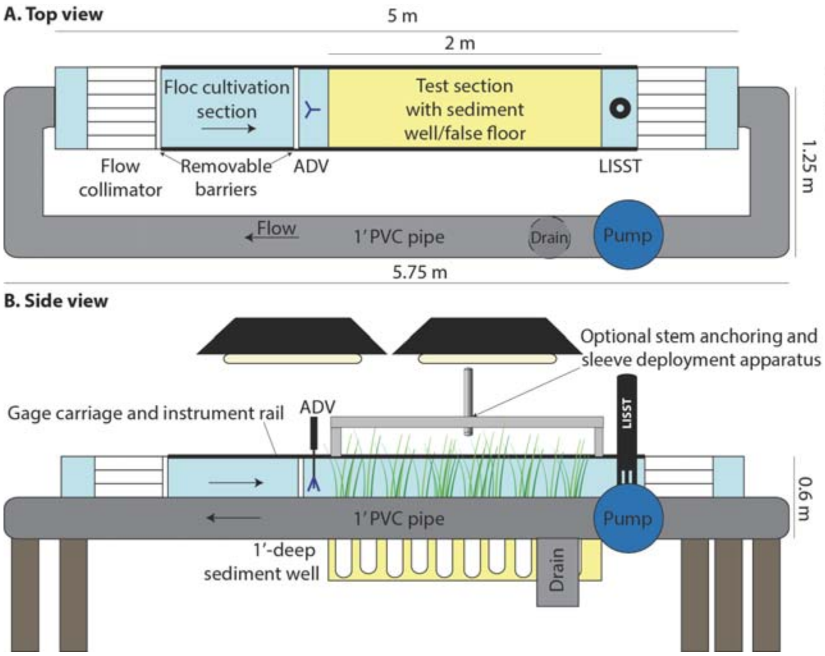

Figure 2. Design for the Biogeomorphology Research and Teaching flume. Large-diameter pipes and a disc-flow pump accommodate the recirculation of flow with minimal shearing, while a sediment well enables the emplacement of vegetation pots or dowels flush with the bed. Removable barriers upstream of the test section and grow lights facilitate the cultivation of biofilm. Instruments, including a laser-diffraction particle size analyzer and acoustic Doppler velocimeter, can be moved on the instrument rail. An optional apparatus over the test section enables stems to be anchored from above inside a sleeve, which can be slid over the stem at the end of the experiment, preserving captured particles.

Sciences. As such, it will facilitate the incorporation of new experiential learning opportunities and demonstrations into courses that are otherwise primarily lecture-based. Studies cite the loss of experiential learning opportunities in STEM fields with the growth of virtual/computer-based learning [*Baldock and Chanson*, 2006], despite their ability to help students grasp difficult concepts and strengthen their physical intuition, particularly in fluid dynamics [*Christodoulou*, 2004]. A search of the Journal of Geoscience Education yielded only two studies that mentioned flumes. The few studies that do describe pedagogical uses of flumes cite outcomes including increased student interest in the course, which translate into improved performance on homework and examinations and a smaller failure rate in the subject [*Baldock and Chanson*, 2006].

4.2. Technical description: The BRAT flume facility will occupy a room in the basement of McCone Hall designed for a flume, containing an overhead frame and electrical panel, a three-ton hoist, floor drain, reservoir, sink, and easy access to the outdoors. The 6-m x 60-cm x 60-cm BRAT flume has a 2-m test section with a 1'-deep well and false floor, which allows for the emplacement of plant plugs or synthetic vegetation. Overhead grow lights and a compartment upstream of the test section that can be temporarily walled off support the cultivation of biofilm and floc. With a boundary-layer trip in place after the honeycomb flow collimator, turbulence will be fully developed by the start of the test section. The length of the test section is sufficient for flow characteristics to adjust to the vegetation canopy, ensuring that samples collected toward the back half of the vegetation array avoid leading edge effects. According to *Nepf* [2012], the critical length scale for flow adjustment to vegetation canopies is $\frac{2(1-\varphi)}{C_D a}$, where ϕ is canopy porosity (typically 0.001-0.01 for marshes) and C_D is the vegetation drag coefficient (assumed 1). For marsh vegetation, a ranges from 0.01 to 0.07 cm^{-1}. Thus, the corresponding adjustment length scale ranges from ~140 cm to just under 200 cm.

The recirculation pipe is a large-diameter pipe (0.3 m at the smallest section) that transitions gradually in hydraulic radius in order to avoid large increases in velocity or turbulence that would disrupt floc structure. It is maintained at constant elevation, which minimizes settling. The slope of the channel bed itself is adjustable between 0% and 3% using a motorized tilting mechanism. The design velocity range is 0.1-14 cm s^{-1}, which spans velocities commonly found in coastal marshes, streams, and inland wetlands. Maximum flow depth is 55 cm. The flume will have a rail along its length and a cart for mounting instruments. For the proposed set of experiments, existing instrumentation (a Sequoia Scientific LISST-FLOC and a Nortek Vectrino II Profiler ADV) will be used. The LISST-FLOC is an in situ laser diffraction particle size analyzer that determines volumetric particle concentrations in 32 logarithmically spaced bins between 7.5 and 1500 μm. The Vectrino II Profiler is a small-footprint 100-Hz ADV that determines velocity at up to a 1-mm resolution in a 3-cm vertical profile. For most experiments, the LISST will acquire continuous data downstream of the vegetation array, while the ADV will acquire data upstream of the array. However, for each vegetation configuration, flow will be characterized within the array (by removing several stems) after the particle interception experiments. Prior to conducting any particle/vegetation experiments, turbulence and wall effects within the flume will be characterized through spatially dense ADV measurements. The extent to which particles settle within the flume in the absence of vegetation arrays will also be characterized for each new class of experimental sediment. During these experiments, the LISST will monitor the decay in sediment concentrations. Settling rates will then be determined through fitting an exponential decay function to the time series.

The flume will also be fitted with some custom instrumentation and accessories. A low-cost particle image velocimetry (PIV) system will be incorporated for flow visualization near the leading edge of the vegetation array and for use in the educational capstone modules. The system will be constructed with a 0.3-0.4 W laser pointer and a cylindrical lens that will create a horizontal light sheet, as described in *Wilkinson* [2014]. A custom top mount for vegetation stems or dowels will also be constructed for direct quantification of interception on select stems. The mount enables a sleeve to be lowered around the stem at the end of the experiment, allowing for removal of the stem without any loss of intercepted particles. This capability will enable comparison to other direct (e.g., draining the flume slowly and quantifying particles directly adhered to select stems) and indirect (e.g., through fitting an exponential decay term to a mass balance equation) methods of quantifying particle interception, allowing correction factors to be developed if necessary.

5. PHASE 1:
Research: Toward a functional form for particle interception in vegetated arrays
Education: Undergraduate/graduate experiential learning to enhance physical intuition of fundamental concepts in fluids and statistical analyses and improve research methods

5.1. Relevant theory: Phase 1 of the work focuses on developing the functional form of the equation for sedimentation by particle interception in biologically active environments. This phase draws upon previous work from two different approaches, which predict contrasting phenomena. First, particle capture efficiency, η [-], is defined as the ratio of the width of the particle streamlines ultimately captured on the stem to the stem diameter, d_s [L] [*Palmer et al.*, 2004]. Then, the gross particle interception flux [*Mudd et al.*, 2010], Q_i [$ML^{-2}T^{-1}$], is

$$Q_i = \eta CUah\ , \qquad [1]$$

where C is the suspended particle concentration [$ML^{-3}T^{-1}$], U is the flow magnitude [$L\ T^{-1}$], a is vegetation frontal area per unit volume [L^{-1}], and h is the length of the stems exposed to flow [L] (equal to flow depth in emergent vegetation). Working with a single cylinder at intermediate stem Reynolds numbers ($50 \leq \mathrm{Re}_s \leq 500$), *Palmer et al.* [2004] found the capture efficiency on smooth stems to be related to Re_s and the ratio of particle diameter to stem diameter (R):

$$\eta = 0.224\,\mathrm{Re}_s^{0.718} R^{2.08}\ . \qquad [2]$$

Separately, environmental engineers working on filtration of colloidal-sized particles in vegetated wastewater treatment cells have arrived at a different functional form for η applicable to creeping flow conditions. Colloid filtration theory separates η into a product of the contact efficiency, η_0, and the attachment efficiency, α. The contact efficiency is a function of Re_s and the Peclet number (Ud_s/D, where D is the dispersion coefficient of the sediment) [*Wu et al.*, 2011]:

$$\eta_0 = 0.0044\mathrm{Re}_s^{-0.94}\mathrm{Pe}^{-0.003}. \qquad [3]$$

Meanwhile, α is an empirical function of the London number (N_{LO}), the first electrokinetic parameter (N_{E1}), and the double-layer force parameter (N_{DL}), which describe the probability of binding to the collector via van der Waals interactions once contact has been made [*Wu et al.*, 2012]. Several

Table 1. Summary of experimental conditions for previous interception studies		
Study	**Particle size (μm)**	**Re_s**
Palmer et al. 2004	177-210	50-500
Purich 2006	212-250	70-660
Fauria 2013	11 (mode)	18-558
Wu et al. 2014	0.3-2	0.02-1.2

investigators have found that a correction term for additional effects of natural organic matter (N_{LEK}) is also necessary [*Phenrat et al.*, 2010; *Wu et al.*, 2014]:

$$\alpha = 10^{-0.13} N_{LO}^{0.20} N_{EI}^{-1.05} N_{DL}^{0.15} N_{LEK}^{-0.21}. \quad [4]$$

Parameterizing α requires knowledge of the surface potential of the particles and the collector and the surficial double-layer thickness. In examining carboxylated colloid filtration by millet stems, *Wu et al.* [2014] used reported values for standard humic and fulvic acid, treating just the correction term as the fitting parameter.

Notably, equations [2] and [3] differ in the direction of response of η to Re_s. Recent studies conducted in arrays of vegetation in flumes [*Purich*, 2006; *Fauria*, 2013; *Wu et al.*, 2014] are consistent with the decreasing η with Re_s suggested by equation 3. *Purich* found that η was highest at low Re_s and intermediate vegetation densities, which empirically were associated with the highest vorticities and vortex shedding frequencies. All capture efficiencies in the arrays of vegetation were lower than the *Palmer et al.* [2004] estimate, which *Purich* attributed to vortex shedding in the stem wakes diverting streamlines and particles away from downstream stems. While *Wu et al.* [2014] similarly found a decrease in η with increasing Re_s, colloid filtration theory overpredicted the observed η. The authors attributed the overestimate to steric repulsion and the need for the attachment efficiency term α to incorporate the negative impact of hydrodynamic shearing. *Importantly, neither the* Palmer et al. *[2004] equation nor colloid filtration theory adequately predict particle capture within arrays of vegetation. The mismatch between* Palmer et al. *[2004] and the recent experiments in Table 1 is particularly concerning, as widely used marsh and delta sedimentation models use that formulation.*

5.2. Research hypotheses: Clearly, to evaluate the significance of particle interception for sedimentation, a formulation is needed for particle interception in vegetated arrays. However, it is difficult to synthesize existing experimental data because they were collected over a wide range of flow regimes and particle sizes (Table 1). Based on the physics of flow around cylinders and previous studies, two regimes of importance likely govern contact efficiency η_0 in the environment.

5.2.1. Regime 1: $Re_s < 40$. ***Observed***: capture efficiency decreases strongly with Re_s [*Wu et al.*, 2011, 2012]. ***Proposed explanation:*** For $5<Re_s<40$, a single flow separation bubble forms behind vegetation stems with two attached vortices. At higher Re_s within this region, the size of the flow separation bubble and eddies grows. With growth of the eddies, the core of the eddies moves farther from the rear of the plant stem. Particles smaller than eddy scales tend to accumulate near the center of vortices [*Durham et al.*, 2013], and hence it becomes less likely that particles will approach the stem near enough for van der Waals forces to result in attachment. ***Prediction***: Based on the key physics, I expect η_0 to vary as a strongly negative function of Re_s, a positive function of R^* (as smaller particles and larger stems would increase the distance between particles trapped in eddies and the stem's radius of capture), and a positive function of P, the ratio of particle density to water density (as higher particle density will result in greater inertial impaction). Here R^* is defined based on the effective radii of the particles and stems, which incorporates additional thickness due to biofilm coverage. Canopy density will be important in reducing flow velocities in the wake through drag, proportional to $[(ah)(1\text{-}ad)]^{-1/2}$. In this regime, the functional form of η_0 would be:

$$\eta_0 \sim \left(\frac{\mathrm{Re_s}}{\sqrt{(ah)(1-ad)}}\right)^{c1} R^{*c2} \mathrm{P}^{c3}, \quad [5]$$

where the c_1 - c_3 exponents are constants of the dimensional analysis.

5.2.2. Regime 2: $Re_s > 40$. ***Observed:*** capture efficiency decreases slightly with Re_s but is relatively insensitive to Re_s [*Purich*, 2006]. Capture efficiency is highest at intermediate vegetation density. ***Proposed explanation***: For $40<Re_s<150$, the eddies behind plant stems detach, resulting in a laminar wake—a von Karman vortex street. At $150<Re_s<300$, the wake becomes transitional to turbulence. Throughout the vortex shedding regime, capture efficiency within the array will be less than that predicted by *Palmer et al.* [2004], as the streamlines approaching stems will have significant vorticity, which, by the logic above, will decrease the number of particles that come within the stem's radius of capture relative to the straight-streamline case of *Palmer et al.* [2004]. As eddy scale within a vegetation patch is set by the smaller of stem spacing or stem scale [*Tanino and Nepf*, 2008], eddy size will not change with Reynolds number, and particle capture efficiency should be more sensitive to eddy shedding frequency, with high shedding frequency (e.g., at intermediate vegetation density) increasing the likelihood of particle capture by stems (due to the reduced timescale for particles to migrate to the center of vortices and the greater likelihood of inertial escape from eddies). $\mathrm{Re_s}$, however, would become important in governing inertial impaction (which would increase with $\mathrm{Re_s}$ and particle mass) and shearing (which would decrease attachment efficiency). ***Prediction:*** η_0 will vary as a weak function of $\mathrm{Re_s}$ (through its influence on vortex shedding frequency and particle inertia), a positive function of R^*, a positive function of the particle-wake Peclét number (defined as $\mathrm{Pe_w} = Ud_p/D_t$, where d_p is particle diameter and D_t is the turbulent dispersion within the wake), and a positive function of P. Recognizing that within vegetation canopies, D_t scales as Ud_s [*Lightbody and Nepf*, 2006; *Tanino and Nepf*, 2008], $\mathrm{Pe_w}$ can be subsumed into R^*. Finally, canopy density will be important not just for reducing flow velocity but also for increasing turbulent kinetic energy, which, given the results of *Purich*, should increase contact efficiency. Turbulent kinetic energy in stem wakes is proportional to $U^2(ad)^{2/3}$ [*Nepf*, 2012]. The velocity dependency will be subsumed by $\mathrm{Re_s}$, leading to the prediction of the functional form of η_0 as

$$\eta_0 \sim \left(\frac{\mathrm{Re_s}}{\sqrt{(ah)(1-ad)}}\right)^{c5} R^{*c6}(ad)^{c7}\mathrm{P}^{c8}. \qquad [6]$$

Note that in both eqs. [5] and [6], $\mathrm{Re_s}$ is computed from the velocity upstream of the vegetation array (as in a flume). If (as in the field) U were measured directly within the vegetation canopy, the denominator of the $\mathrm{Re_s}$ term would not be needed. Given the similar form of equations [5] and [6], the more general equation [6] can be taken as representative, recognizing that the constant exponents would differ substantially between the two flow regimes (and that c_7 would approximately equal zero for the lower Reynolds number regime).

5.3. Attachment efficiency: Apart from changing effective particle and collector diameters, the main role of biofilm in changing particle interception rates will be through manipulating attachment efficiency. In colloid filtration theory, attachment efficiency is parameterized using eq. [6]. This equation is not ideal for geomorphic applications, as the required parameters will be highly variable in the environment, difficult to measure, and not necessarily relevant in fresh waters or for larger particles. Just as compositional and structural characteristics of organic matter are thought to be more important than ionic/charge interactions in governing aggregation/cohesion in freshwater [*Droppo et al.*, 1997; *Droppo*, 2001; *Wotton*, 2007], it is likely that these characteristics are also key independent variables in an expression for attachment efficiency. The results of *Wu et al.* [2012] further suggest that, because of hydrodynamic shearing, a Reynolds number dependency also needs to be incorporated into the expression for α. However, because experiments can only measure η, the product of η_0 and α, the Reynolds number dependency in eq. [6] conflates its role in contact efficiency with its role in attachment efficiency.

A growing body of studies suggests that attachment efficiency should be a function of biofilm structural and compositional characteristics [*Sutherland et al.*, 1998; *Underwood and Smith*, 1998; *Yallop et al.*, 2000; *Searcy et al.*, 2006; *DiCesare et al.*, 2012]. To derive a functional form for α on the basis of these characteristics in a statistically robust manner would require a large number of flume experiments outside the scope of this proposal (though an exciting future direction). Instead, the objectives here are to test the simple hypothesis that biofilm presence changes capture efficiency and to quantify the magnitude of the change in a way relevant to prediction of coastal sedimentation in three major regions of management interest in the US.

5.4. Experimental plan: BRAT flume experiments: The first set of experiments in this phase will elucidate the functional form of interception in vegetation arrays in the absence of biofilm, using arrays of simulated vegetation (paraffin-coated 0.15-0.2-mm dowels) and synthetic fluorescent particles. For each of the two flow regimes, experiments will be conducted in a full factorial design, with three levels of *a* (0.02, 0.05, and 0.07 cm^{-1}), three levels of particle size (1, 50, 100 μm), and three velocity increments spanning each regime. By using different colors of particles, the three sizes can be run simultaneously, reducing the total number of runs. Particle interception near the downstream edge of the vegetation array will be quantified photographically (as in *Palmer et al.* [2004]) and through the settling-corrected exponential decay term from LISST concentrations monitored downstream (as in *Fauria* [2013]). For calibration purposes for subsequent experiments, stems will also be scraped after being photographed and analyzed on a fluorometer [*Goodman and Larsen*, in preparation]. Settling within the flume will be determined from characterization experiments run in the absence of vegetation; vegetation-mediated settling within the arrays will be measured directly from slides deployed within the test section.

The second set of experiments will evaluate the extent to which interception dynamics change with the addition of biofilm. As in *Droppo* [2007] and *DiCesare et al.* [2012], biofilm will be cultured on the synthetic stems through injection of seed biofilm material and incubation under grow lights, under similar levels of nutrient and major ion concentrations as the native environment. The culturing process takes seven days, after which biofilm community composition is relatively stable [*Araya et al.*, 2003]. Seed biofilm will be obtained from the Wax Lake Delta, Everglades, and San Francisco Bay through the assistance of collaborators working in those locations.

Once the culturing is complete, experiments will be run with three particle sizes, at three velocities within the vortex shedding regime, and a single level of *a.* To improve the generality of these experiments and to set them up for use in future studies focused on deriving the functional form of α, biofilms will be characterized through metrics hypothesized to be drivers of attachment efficiency: roughness (measured through confocal laser scanning microscopy and quantified based on the mean deviation from the mean thickness) [*Searcy et al.*, 2006; *DiCesare et al.*, 2012], fractal dimension [*Shen and Ganczarczyk*, 2005], surface-area-to-volume ratio [*Searcy et al.*, 2006], water- and EDTA-extractable polysaccharides [*De Brouwer et al.*, 2002, 2005], water-soluble EPS [*De Brouwer et al.*, 2005], total carbohydrates [*Pacepavicius et al.*, 1997], chl-*a* [*Steinman et al.*, 1996], total specific (i.e., DOC-normalized) fluorescence [*Larsen et al.*, in preparation], and the specific fluorescence of distinct spectral components found ubiquitously in organic matter pools [*Cory and McKnight*, 2005; *Larsen et al.*, 2010].

The third set of experiments will repeat the second set, using cultivated flocculated fine sediment instead of synthetic particles. Biofilm-rich floc will be cultivated within the flume in a temporarily contained area (Fig. 4) using the method of *Droppo et al.* [2007]. Kaolinite will be combined with unfiltered or coarsely filtered site water and incubated under grow lights until biofilm development is apparent. Floc will then be labeled using a fluorescent marker (Rhodamine WT), in accordance with a method developed by Larsen and an undergraduate research assistant [*Goodman and Larsen*, in preparation]. Rhodamine WT sorbs to irreversibly to floc with a Freundlich isotherm, its fluorescent fingerprint unchanged upon sorption. Labeling floc is accomplished by incubating it in a concentrated solution of dye, straining it through cheesecloth, and rinsing it. Just prior to the initiation of experiments, the vegetation stem array will be temporarily removed so flume waters can be mixed to attain a uniform concentration of floc.

5.5. Educational plan: Building interdisciplinary student experiences with fluids into lecture courses: Phase I of the educational plan involves development of new capstone modules for Larsen's undergraduate and graduate courses. In addition to fulfilling needs for students to build intuition about the physics of fluid flow, sediment transport and time series analyses, these capstone modules serve the dual purpose of addressing research needs and expanding on the experiments described above. Additional cross-module objectives include increasing student familiarity with the scientific method and their experience in working on interdisciplinary problems with teams of peers from diverse educational and social backgrounds. Descriptions of the capstone modules will be peer-evaluated and published on the SERC "On the cutting edge" teaching activities repository, along with suggestions for how to generalize the exercise for other types of flumes.

5.5.1. Capstone Modules for GEOG/ESPM c136, Terrestrial Hydrology. This course is a large (~50-student) upper-division undergraduate course taught as a lecture course with in-class activities and group assignments. Students draw primarily from Earth and Planetary Sciences, Environmental Science, Policy and Management, and Geography, and often have not had much exposure to the physics of fluid flow. For the capstone modules, students will be broken into smaller groups of ten students and assigned to complete a guided flume exercise outside of class time. Both Larsen and graduate students will serve as mentors for the students in these exercises. ***Capstone Module 1:*** Fundamentals of open-channel flow. Learning objectives: 1) Understand the no-slip condition and how it leads to gradients in velocity away from walls. 2) Recognize the difference between laminar and turbulent flow and the relationship to Reynolds number. 3) Gain experience with different techniques for flow and discharge measurement and compare/contrast their effectiveness. 4) Understand concepts of steady and unsteady flow and how changing slope changes flow conditions. Research objectives: Characterize flow in the BRAT flume. Students will compare several techniques for measuring the flume's discharge, including a float tracer technique, obtaining velocity profiles along a transect with an ADV, and a dye plume injection at different vertical levels. Students will experiment with a boundary layer trip and will visualize turbulence in a laser light sheet created with a 100 mW laser pointer and cylindrical lens.

Capstone Module 2: Understanding foundational ecohydrological processes. Learning objectives: 1) Have an authentic research experience, from experimental design, through execution and data analysis. 2) Gain a foundational understanding of basic influences of vegetation on flow and sediment transport. Research objectives: Expand set of conditions/parameters under which interception is quantified. In this capstone, which will serve as a final project, student groups will develop hypotheses about particle transport in arrays of cylinders or single cylinders with biofilms. Hypotheses may focus on how different spatial configurations of the cylinders influence particle interception, how interception varies at different vertical levels, or how different particle or stem sizes influence interception. Students will then work with the graduate student to implement a simple experiment in the BRAT flume, collecting data with the ADV, through PIV, and/or sample collection. Students will analyze and document their results and will also produce a related written report based on a literature survey of a potential application of their work (e.g., wastewater treatment wetlands, marsh restoration, modeling contaminant transport dynamics).

<u>5.5.2. Capstone Module for GEOG 2xx: Statistics and Multivariate Data Analysis for Research.</u> This module addresses several key needs at the graduate level. The course itself meets the need for a rigorous, research-oriented statistics and data analysis course that is accessible to students from non-math backgrounds. It is the PI's experience that many of these students struggle with attaining an intuitive understanding of spectral analysis. Through this interdisciplinary exercise, students will be able to visualize the movement of eddies past a recording ADV probe. By first visualizing the physical phenomenon and then performing common time series analyses, students will enhance their intuitive understanding of these techniques. Learning objectives: 1) Gain an intuitive sense for instrument error and physical processes as causes of temporal variability in datasets. 2) Apply common time-series data analysis techniques to a dataset that students collected firsthand, including power spectral analyses, autocorrelations, cross-correlations, filtering, and gap filling. Research objectives: Characterize flow in the flume in unvegetated or vegetated conditions (depending on research needs). In this exercise, students will participate in the collection of data using the ADV. The ADV software enables real-time visualization of instantaneous beam velocities and statistics. Within the measurement area, students will visualize the corresponding physical processes by viewing dye filaments in the laser light sheet. Data will be obtained in a bare flume and behind one or more cylinders.

6. PHASE 2:
Research: Field-testing hypotheses about particle interception in deltaic wetlands
Education: Short-course on fine sediment transport, with experiential component

<u>6.1. Motivation:</u> Sedimentation and land building rates are of paramount interest in efforts to restore coastal wetlands and predict impacts of sea-level rise. The Mississippi River Delta has been losing land since 1932 at a mean rate of 42.92 $km^2\, yr^{-1}$ due to subsidence, sea level rise, and a lack of replenishment of sediment from upstream [*Couvillion et al.*, 2011]. However, portions of the Delta are growing due to new diversions of water and sediment. The Wax Lake Delta (WLD) is building new land at a rate of 2.0 $km^2\ yr^{-1}$ subaerially [*Roberts*, 1997] and prograding at 0.3 km yr^{-1} [*Parker and Sequeiros*, 2006]. It has been receiving 30-40% of Atchafalaya River discharge (10-12% of Mississippi River discharge) since 1942 [*McManus*, 2002; *Roberts et al.*, 2003] and became subaerial in 1973. Despite growth of the WLD, models predict that even optimized diversions of the Mississippi River cannot compensate for land loss in the greater Mississippi River Delta complex, because of the limited availability of suspended sediment [*Blum and Roberts*, 2009]. On the other hand, recent studies provide hope for limiting land loss through controlled river diversions [*Falcini et al.*, 2012; *Nittrouer et al.*, 2012]. However, one of the uncertainties in the rate of land building is particle interception [*Blum and Roberts*, 2009; *Paola et al.*, 2011]. In order to plan restoration strategies based on knowledge of suspended sediment discharge and its relationship to sedimentation rates and wetland growth, quantification of real particle interception rates is needed.

On a more fundamental level, the evolution of delta geomorphology remains poorly understood [*Paola et al.*, 2011]. Different processes (shoreline bifurcation induced by progradation and mouth-bar deposition, aggradation-induced avulsion, and wave action) may sculpt deltas with fundamentally different morphologies [*Jerolmack*, 2009], but within a delta, dominant mechanisms leading to deposition may vary temporally (e.g., cold front-induced reworking of material from the continental shelf versus flood-induced deposition), with repercussions for delta morphology [*Reed*, 1989; *Li et al.*, 2011]. Modeling studies have suggested that cohesive sediment produces deltas that are more elongated (i.e., with birdfoot-like shapes) than those formed by noncohesive sediment [*Edmonds and Slingerland*, 2010]. Sediment cohesion is often used as a surrogate for the effects of vegetation on geomorphic processes [*Corenblit et al.*, 2007; *Peakall et al.*, 2007], and the effects of particle interception on delta evolution may be consistent with those of sediment cohesion. In contrast, *Pasternack and Brush* [2002] postulated that retention of sediment within vegetation might produce deltas with a steeper, shorter gradient.

Clearly, there is much to learn about how fine sediment moves through deltas and about the spatially explicit interplay between vegetation community dynamics, sedimentation, and the evolution of delta geomorphology [*Paola et al.*, 2011]. Here we extend the results of the laboratory studies to the field in order to test the empirically derived form of the expression for particle interception and to better understand its role in biogeomorphic feedbacks. In phase 3, this understanding is extended to new models of delta geomorphology.

6.2. Hypotheses:

- In contrast to previous predictions [*Purich*, 2006; *Mudd et al.*, 2010], interception in biofilm-rich environments will be a significant (>10%) term in sedimentation budgets under moderate to low-energy flow conditions within dense vegetation.
- Within emergent clonal vegetation on the WLD, sedimentation is dominated by settling, with limited accretion of fine material. Within *Nelumbo*, particle capture becomes a significant term in sedimentation, leading to substantial accretion of fine sediment.

6.3. Experimental design: Following *Harvey et al.* [2011] and *Huang et al.* [2008], temporary flumes will be installed in two regions in WLD (Fig. 3) for *in situ* interception studies. The sites contrast in age, position relative to the shoreline, vegetation community, and biofilm coverage. The 10-m long x 1-m wide flume will be constructed from 0.2 cm-thick PVC sheets, sunk into the ground around intact vegetation communities, sealed at the edges, and held in place by external steel fence posts. The flumes will be aligned parallel to flow and open at both ends. Removable extensions angled outward at 15° will be appended to the upstream portion, enabling experiments to be run under ambient or enhanced (2x) flow conditions. This design has previously been applied in streams [*Gibbins et al.*, 2007; *Vericat et al.*, 2008].

The flumes will contain an ADV, LISST-FLOC, and two sampling manifolds, placed upstream and downstream in the flume. Sampling intake ports will be set at multiple water depths and pumped simultaneously via peristaltic pumps. Vegetation will be cleared from the outlet of the flume, allowing for emplacement of an acoustic Doppler current profiler (ADCP), to be used for precise computation of flow rates. At the entrance particulate tracer will be introduced as a line source. Tracer will be recovered in sediment traps [*Gacia et al.*, 1999] deployed within the canopy (to assess settling fluxes) and on select vegetation stems, which will be harvested by surrounding stems with a hinged cylinder and/or clipping. Ambient settling velocity distributions will be analyzed with a settling column as in *Larsen et al.* [2009a].

6.4. Experimental plan: Experiments will be performed towards the end of the flood period (April-May) and again during a winter cold front. In January cold fronts occur at a 3-7 day interval [*Roberts*, 1997]. During a front, onshore winds can drive deposition of fine sediments resuspended from the continental shelf onto the marsh surface [*Moeller et al.*, 1993; *Allison et al.*, 2000]. Vegetation is typically senescent during cold fronts, with little biofilm coverage. Hence, the paired studies in space and time examine the key contrasting mechanisms of deposition that drive delta morphology.

Two consecutive runs—ambient and elevated flow—comprise each experiment. Between the runs, select stems will be harvested for direct quantification of intercepted particles. Pumped samples will provide measurements of depth-dependent distributions of labeled suspended sediment upstream and downstream of the test section. Following completion of the first set of experiments, the flume walls will

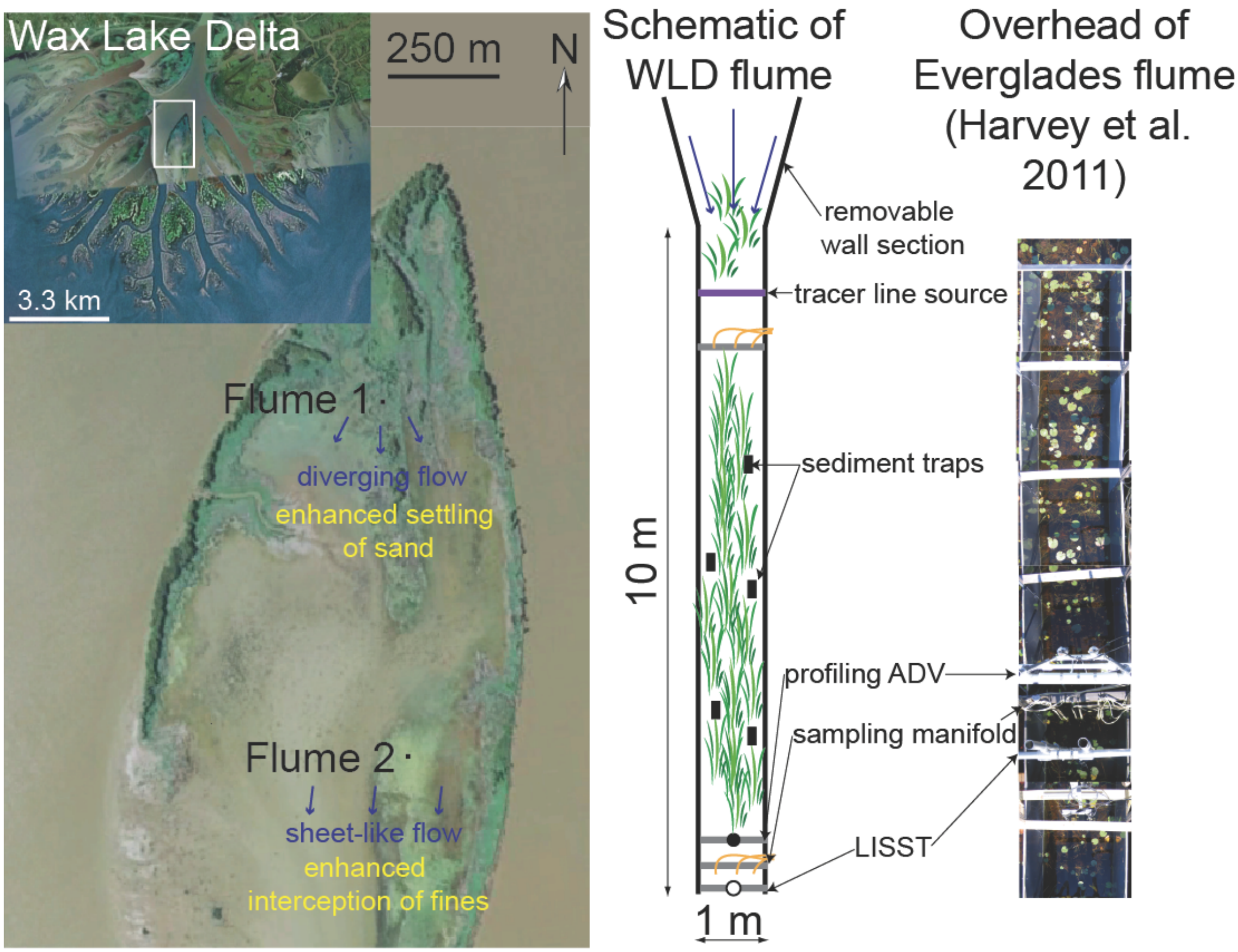

Figure 3. Proposed deployment of field flumes on Mike Island, Wax Lake Delta. The upstream location, colonized by emergent clonal giants, has little biofilm development, while the downstream location, colonized by water lotus, has extensive epiphytic biofilms. We hypothesize that vegetation will increase sedimentation primarily through enhanced settling upstream, which will sequester sand, and through enhanced interception downstream, which will sequester fines that would otherwise be transported to the Gulf of Mexico. The field flume will be modeled after flumes used previously by Larsen and collaborators in the Everglades (right).

be removed (to prevent flume-induced scour or deposition), but a corner will be marked with flagged conduit and GPS-tagged. During the subsequent January experiment, the flumes will be reinstalled in the same location. After the removal of flume walls, vegetation will be harvested in 0.25 m^2 plots to quantify dimensional properties of the plant canopy within the flume.

6.5. Educational Plan: Short course on fine sediment transport: Phase 2 of the educational plan involves developing a one-day short course for the NCED Summer Institute on fine sediment transport, with an experiential component in the Outdoor Stream Lab at St. Anthony Falls Lab. The short course will complement the phase 2 fieldwork, allowing for methodological testing and expanding the range of environmental conditions examined as part of this research. Larsen is well connected with NCED and plans to teach a course on flow through vegetation in August 2014. Attendees of the NCED Summer Institute are a multi-institutional group of graduate students, postdocs, and early career scholars.

Topics to be covered in the fine sediment short course include environmental implications of fine sediment, the mechanics of cohesive sediment transport (entrainment, settling, porosity, aggregation and disaggregation dynamics), field measurement and modeling strategies, notable case studies, and a discussion of knowledge gaps. The format of the course will be a mixture between lecture, discussion, and hands-on experience with models. Students will work together in groups to build the physics of fine

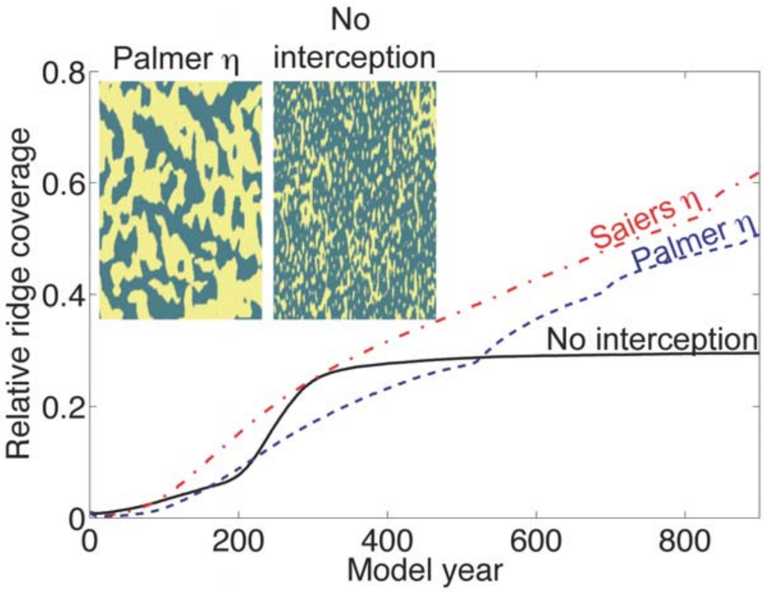

Figure 4. Strikingly different geomorphic outcomes result from including particle interception in a model (RASCAL) of flow-vegetation-sediment feedbacks in the Everglades [*Larsen et al.*, 2010; 2011]. Planform views of the end of the trajectories are depicted, with ridges in yellow and sloughs in green. Particle interception causes ridges to grow together and, in this scenario, prevents a stable configuration with high slough coverage. Particle capture efficiencies from *Saiers et al.* [2003] and *Palmer et al.* [2004] are examined. In the NCED fine sediment short course, students will update this model with the results of more comprehensive interception flume studies.

sediment transport into several existing models of flow-vegetation-sediment feedbacks, ranging from a reduced-complexity cellular automata model of Everglades landscape evolution (Fig. 4) to more detailed models available through the CSDMS model clearinghouse, such as AquaTellUs [*Overeem*, 2005].

Traditionally, the NCED Summer Institute culminates with students collaborating on an open-ended, hands-on experiment in a flume or the Outdoor Stream Lab. Students are given free reign to pick a project, but it is anticipated that the discussion of knowledge gaps in fine sediment research will stimulate interest in conducting a fine sediment experiment in the Outdoor Stream Lab. Anticipating this outcome, supplies and equipment for these experiments will be ready for students' use, including the LISST, ADV, photographic equipment, and fluorescent dyes and particles. The timing of the experiment (see Timeline) is appropriate for it to benefit the field flume experiments as a trial run. Further, because the vegetation and sediment characteristics in the Outdoor Stream Lab differ from those of the WLD, these experiments are expected to contribute knowledge over a broader range of the parameter space.

7. PHASE 3:
Research: Effects of particle interception on delta evolution
Education: Outreach on the role of fine sediment-vegetation interactions in coastal restoration

Phase 3 is the "applications" phase of this process-focused research. The research component is focused on testing the large-scale implications of particle transport on delta evolution through the use of modeling. The educational component involves partnership with the Exploratorium to provide public outreach on the science behind restoration of coastal marshes and deltas, with a strong emphasis on local (Bay-area) salt marsh restoration.

7.1. Hypothesis: Particle interception in biologically active environments such as the WLD is a significant term in the sedimentation budget during the flood period and influences the shape and timescale of delta evolution. Deltas with substantial particle interception will be more elongated (birdfoot-like) than those without, and rates of delta growth will be faster.

7.2. Incorporating Particle Interception into Delta Modeling: This work interfaces with the *NSF FESD Type II: A Delta Dynamics Collaboratory* (see attached letters of collaboration), involving researchers at seven universities and culminating in a comprehensive model of physical and ecological processes affecting delta evolution (DeltaMod: A Morphodynamics Modeling Toolbox). The model will be coded in Delft3D open-access source code and will consist of a library of modules accessible through a common user interface for computation and visualization, hosted through the Community Surface Dynamics Modeling System (www.csdms.colorado.edu).

This experimental work will produce a new module for vegetation's effects on sedimentation. The module will link directly to separate modules simulating vegetation distribution and ecology, as well as modules providing suspended sediment supply, flow velocity, and vegetation ecology in a spatially explicit manner (see letter of collaboration from Robert Twilley). Based on this set of inputs, the vegetation sedimentation module would simulate net interception using the field-calibrated eq. [6], as well as net particle settling, simulated using the approach of *Mudd et al.* [2010]. In this approach, the effective settling velocity is modeled as the difference between settling in quiescent water and the upward velocity of sediment particles, equal to κu_*, where κ is von Karman's constant, and u_* the shear velocity. *Mudd et al.* [2010] show that in arrays of emergent vegetation,

$$u_* = \sqrt{\frac{0.20\alpha_k^2 u^2 \left(C_D a d_s\right)^{2/3}}{\rho}}, \quad [7]$$

where a_k is a coefficient reported to be 0.9 by *Nepf* [1999] and ρ is the density of water.

Realizations of the model with and without the interception term and with a range of inputs controlling vegetation distribution will be run to quantify the importance of interception on delta evolution. Results from different model realizations will be compared to actual delta images using connectivity-orientation curves, which plot the normalized linear connectivity of channels and islands (similar to the reciprocal of a multiscale sinuosity index) over a range of angular bearings [*Larsen et al.*, 2012]. Connectivity-orientation curves compactly quantify large amounts of information about landscape structure and can be compared using Kolmogorov-Smirnov statistics to evaluate the similarity between different landscapes.

7.3. Partnership with the Exploratorium to construct exhibit on fine sediment and marsh restoration: The Exploratorium receives over 1.1 million visitors per year and houses approximately 600 exhibits in house at any given time, with other exhibits deployed in public spaces throughout San Francisco. The educational outreach component of this proposal involves partnering with a team at the Exploratorium (see letter of collaboration) to develop an exhibit focused on fine sediment and its role in marsh restoration. Learning objectives include: 1) gaining understanding of why marshes are important for preventing land loss at coastal margins, 2) understanding that marshes could play a valuable role in carbon sequestration, 3) gaining appreciation for "pond scum" and "icky, squishy sediment"—its composition and its role in ecosystems, as well as its role as a potential pollutant, and 4) increasing awareness of marsh restoration projects.

The process of exhibit development is itself experimental, actively evolving during evaluation of early prototypes through observations of visitors' experience. One possibility would be an exhibit that allows participants to smell, see, and feel the fine, cohesive sediment that comprises many parts of the San Francisco Bay and coastal marshes, while learning about its role in ecosystems and landscape development. Participants would be able to see close-up the intricate communities of organisms that colonize these "floating biofilms," become intimately familiar with concepts of entrainment, settling, and sedimentation, and read about how that sediment is important to the health of the Bay and ecosystems worldwide. Another possibility would be a tilting-table exhibit simulating a marsh or delta undergoing subsidence and sea-level rise. Users would be able to turn knobs and control the emergence of simulated vegetation, as well as rates of subsidence and flow. Accompanying text would link their microscale experiment to contemporary delta and marsh restoration projects.

8. Evaluation of educational program success

The PI will work with Cheryl Schwab, evaluator for Berkeley's CiBER-IGERT program, to assess the effectiveness of the educational plan. The evaluation will use both formative and summative assessment approaches to monitor the development and implementation of educational activities [*Frechtling*, 2002]. The objectives of the educational activities in Fig. 1 target three areas: 1) concepts and techniques, 2) data analysis, and 3) research methodology. These areas provide a conceptual framework from which to build measures to assess how people learn [*National Research Council*, 2003] and develop an understanding of fine sediment processes and impacts. We will follow a four-step assessment development process [*Wilson*, 2004]. 1) Create a construct map to identify the levels of development or progress for the selected areas (i.e. variables, approaches, attitudes and skills). The construct map will contain levels of development or success, and the characteristic abilities and activities corresponding to each level. 2) From this construct map instruments (i.e., surveys, interviews and questionnaires) will be created to collect information about the impact of the educational activities. 3) Generate a scoring guide or outcome space to translate the information from our instruments into quantitative data or scores. 4) Finally, use a measurement or interpretational model to relate the quantitative data to the levels of development in our construct map.

9. Additional Broader Impacts

This proposal will support a graduate student in the completion of a dissertation. The student will have the opportunity to co-supervise undergraduate students through Berkeley's Undergraduate Research Assistantship Program, through which Larsen has mentored six students since 2013, one of whom is now first author on a paper nearing submission [*Goodman and Larsen*, in preparation]. Larsen is committed to maintaining a diverse research group, which is presently >50% female and contains two students on Chancellor's Fellowships, given to students from underrepresented or underprivileged backgrounds. Outside of the initial uses planned here, the BRAT flume will be available to other users for research and educational purposes and will stimulate new interdisciplinary and multi-institutional collaborations (Table 2). A dedicated BRAT flume calendar will facilitate coordination across users.

This work is also closely aligned with marsh and delta restoration efforts. With its new vegetation sedimentation module, the DeltaMod model will be used to evaluate the impacts of different delta management scenarios, including proposed new diversions of the Mississippi and Achafalaya Rivers. Collaborators at LSU will serve as a conduit for the results of this study to the Coastal Protection and Restoration Authority (see Robert Twilley's letter). Further, by incorporating a particle interception module into the Everglades landscape model RASCAL in one of the NCED Summer Institute activities, this work will improve predictions of landscape degradation or persistence under different Everglades flow release scenarios. Larsen is active in monthly Everglades project conference calls with managers at the Army Corps of Engineers and South Florida Water Management District and as a participant and session organizer at the biennial Greater Everglades Ecosystem Restoration meeting. Last, Larsen and the graduate student will propose a session on geomorphic impacts of organic sediment at AGU in year 4 of the project, with an accompanying journal special issue targeted for *Geomorphology* or *ESPL*.

Table 2: Additional course enhancements and collaborations resulting from installation of Biogeomorphology Research and Teaching Flume (see accompanying letters)

Course	Department	Instructor	Description
EPS 117: Geomorphology	Earth and Planetary Sciences	W. E. Dietrich	Design of new laboratory component to complement field component of major class project.
EPS 217: Fluvial Geomorphology	Earth and Planetary Sciences	W. E. Dietrich	Class exercise on hydraulics, initial motion, and sediment transport. Second exercise on influence of biota.
CEE 200C: Mixing and Transport in the Environment	Civil and Environmental Engineering	E. A. Variano	Demonstration on suspended sediment transport in vegetated flow
ESPM C216: Freshwater Ecology	Environmental Science, Policy and Management	S. M. Carlson	Demonstration of methods in stream ecology
ESPM 115C: Fish Ecology	Environmental Science, Policy and Management	S. M. Carlson/ M.E. Power	Demonstration of measurement of boundary shear stress
Institution	**Department**	**Investigator**	**Topic**
U.C. Berkeley	Civil and Environmental Engineering	E. A. Variano	Methods comparison and testing for sediment motion and aggregate formation, effects of currents on air-water-gas exchange in vegetated flow
U.C. Berkeley and Holy Names College	Integrative Biology	M. E. Power and collaborators (M. Limm, M. Koehl)	Algal detachment dynamics, effects of light and nutrient regimes on algal mats and floc buoyancy
San Francisco State University	Geosciences	L. S. Sklar	Effects of biotic and abiotic factors on travertine growth
U.C. Berkeley	Environmental Science, Policy and Management	S. M. Carlson	Examination of fish use of refugia under different flows and substrates

10. Integration with career objectives

This proposal is a natural extension and complement to a career that has focused thus far on understanding the sources, transport processes, and ecological/geomorphic implications of fine sediment in the environment. This work builds on expertise in the entrainment and settling of flocculent organic sediment and how it impacts landscape pattern in the Everglades, together with expertise in using optical signatures of organic sediment to track its source, with applications to the Chesapeake Bay watershed and the Everglades [*Goodman and Larsen*, in preparation; *Larsen et al.*, in preparation, 2010]. The work described here is critical for gaining a process-based understanding of how fine sediment and organic carbon are redistributed heterogeneously across landscapes. Applications to restoration are multifold, ranging from improved design of planting strategies for coastal marsh restoration to the design of ecological flow regimes in places where organic sediment redistribution may be critical for geomorphology (e.g., Everglades) or for maintaining water quality (lower Owens River, CA).

In the latter landscape, where Larsen has initiated early work, accumulation of flocculent organic sediment within tule canopies at the river margins has been implicated in driving dissolved oxygen sags during habitat-forming flow releases and triggering fish kills. Understanding the dynamics of such carbon-oxygen-nutrient-biotic interactions, and how they are influenced by sediment transport, represents the most intriguing future direction for this research. For example, to what extent does sediment transport drive metabolism and dissolved oxygen dynamics in low-gradient environments? How do fine sediment redistribution events affect salmonid persistence in disconnected pools in coastal California streams during the dry summer months? The greater process-oriented understanding that will result from the proposed work, together with the physical resources (i.e., the BRAT flume) will position the PI well to address questions about fine sediment-biological/biogeochemical feedbacks over the long-term trajectory of her career. A logical next step would be to perform another set of experiments in the BRAT flume to statistically elucidate the functional form of attachment efficiency based on general biofilm characteristics (i.e, those examined here, but over a much wider range of variability). Another future direction would be to use this new understanding, together with emerging work on biofilm-related priming, to quantify the role of organic sediment deposition in coastal marshes on respiration fluxes of terrigenous carbon worldwide.

11. Timeline

	Year	I				II				III				IV				V			
	Quarter	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
PHASE 1	Flume installation and characterization	■	■																		
	Interception experiments with no biofilm			■	■	■															
	Interception experiments with stem biofilm						■	■	■												
	Interception experiments with stem biofilm and floc									■	■	■									
	Terrestrial Hydrology capstone module development and teaching	■								■								■			
	Data Analysis/Statistics capstone module development and teaching					■								■							
PHASE 2	Spring WLD flume experiments										■										
	Winter WLD flume experiments													■							
	Develop short course for NCED Summer Institute						■	■							■	■					
PHASE 3	Development of DeltaMod module														■	■	■	■			
	Run model scenarios for delta evolution																		■	■	■
	Exploratorium exhibit development					■	■	■	■	■	■										
	AGU special session on geomorphic impacts of fine sediment																■				
	Manuscript preparation and submission						■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
	Evaluation/assessment of educational plan										■	■			■	■			■	■	

12. Results from prior NSF support

1) "The Art and Science of Reduced-Complexity Modeling in the Environmental Sciences" (27-29 March 2013; NSF EAR 1263851, 12/15/12-11/30/14). **Intellectual merit:** The workshop brought together 35 ecologists and earth scientists in an interdisciplinary attempt to develop a synthetic approach for determining the appropriate level of detail in models of landscapes and for using such models to deductively understand feedbacks driving the evolution of environmental systems. This approach is synthesized in *Larsen et al.* [2014]. **Broader impacts:** Materials from the workshop and a working educational toolbox containing simple models for educational purposes is available at https://sites.google.com/site/ rcmworkshop/home, in concurrence with the Data Management Plan.

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BIOGRAPHICAL SKETCH – Laurel G. Larsen

Department of Geography • University of California, Berkeley

(a) Professional Preparation (Education)

Washington University	Systems Science and Mathematics; Environmental Studies	B.S.	2003
Washington University	Dept. of Earth and Planetary Sciences	M.A.	2003
University of Colorado	Dept. of Civil and Environmental Engineering	Ph.D.	2008

(b) Appointments

2013 -	Assistant Professor, Department of Geography, University of California, Berkeley.
2013-	Affiliate, Energy Resources Group, University of California, Berkeley.
2013 -	Faculty Research Ecologist, National Research Program, US Geological Survey.
2011-	Affiliate, National Center for Earth Dynamics, University of Minnesota.
2009-2012	Research Ecologist, U.S. Geological Survey, Reston, VA.
2011-2012	Adjunct Assistant Professor, Dept. of Geology, University of MD, College Park.
2008-2009	Research Hydrologist, U.S. Geological Survey, Reston, VA.

(c) Products

(i) Products most closely related to the proposal

1. **Larsen, L. G.**, C. Thomas, M. B. Eppinga, and T. Coulthard. 2014. Understanding complexity through exploratory modeling. *Eos, Trans. Am. Geophys. Union*, in press.
2. **Larsen, L. G.**, J. Choi, M. K. Nungesser, and J. W. Harvey. 2012. Directional connectivity in hydrology and ecology. *Ecological Applications* 22:2204-2220.
3. **Larsen, L. G.** and J. W. Harvey, 2011. Modeling of hydroecological feedbacks predicts distinct classes of wetland channel pattern and process that influence ecological function and restoration potential. *Geomorphology* 126: 279-296.
4. Harvey, J. W., G. B. Noe, **L. G. Larsen**, D. J. Nowacki, and L. E. McPhillips, 2011. Field flume reveals aquatic vegetation's role in sediment and particulate phosphorus transport in a shallow aquatic ecosystem. *Geomorphology* 126: 297-313.
5. **Larsen, L. G.**, J. W. Harvey, and J. P. Crimaldi, 2009. Morphologic and transport properties of natural organic floc, *Water Resources Research* 45, W01410, doi:10.1029/2008WR006990.

(c) (ii) Other significant products

6. **Larsen, L.G**., G. R. Aiken, J. W. Harvey, G.B. Noe, and J. P. Crimaldi, 2010. Using fluorescence spectroscopy to trace seasonal DOM dynamics, disturbance effects, and hydrologic transport in the Florida Everglades. *Journal of Geophysical Research* 115*,* G03001, doi: 10.1029/2009JG001140.
7. **Larsen, L. G.**, J. W. Harvey, and J. P. Crimaldi, 2009. Prediction of bed shear stresses and landscape restoration potential in the Everglades. *Ecological Engineering* 35, 1773-1785.
8. **Larsen, L.G.**, J.W. Harvey, G. B. Noe, and J. P. Crimaldi, 2009. Predicting organic floc transport dynamics in shallow aquatic ecosystems: Insights from the field, the laboratory, and numerical modeling, *Water Resources Research* 45, W01411, doi:10.1029/2008WR007221.
9. **Larsen, L. G.** and J. W. Harvey, 2010. How vegetation and sediment transport feedbacks drive landscape change in the Everglades and wetlands worldwide. *The American Naturalist* 176(3), E66-E79.
10. **Larsen, L.G**., J.W. Harvey, and J.P. Crimaldi, 2007. A delicate balance: ecohydrological feedbacks governing landscape morphology in a lotic peatland, *Ecological Monographs* 77(4), 591-614.

(d) Synergistic activities

1. Curriculum development. Developed two new courses at the University of California, Berkeley, each with web interfaces for critical discussion (see links from esdlberkeley.com).
   GEOG 244: Complex Environmental Systems. Spring 2013, 2014.
   GEOG C136: Water in the Terrestrial Environment. Spring 2014.
2. Developed vignettes for Key Concepts in Geomorphology textbook, Bierman and Montgomery (Eds.), 2013. W. H. Freeman.

Larsen, L. When streams unravel: the tale of Plum Creek, CO. http://serc.carleton.edu/vignettes/collection/68181.

Larsen, L. How is Everglades geomorphology like that of arid Australian rivers and boreal bogs? http://serc.carleton.edu/vignettes/collection/68180.

3. Lecturer, National Center for Earth Dynamics Summer Institute, August 2014. Designed short course titled “Modeling flow and deposition in vegetation patches: emerging techniques, applications and frontiers”.
4. Conference chair, The Art and Science of Reduced-Complexity Modeling in the Environmental Sciences, NSF-sponsored workshop in Boulder, CO, March 27-29, 2013. Also convened seven technical sessions on hydroecology and ecogeomorphology at national and international scientific meetings (AGU, GSA, ASLO) 2008-2014.
5. Author of childrens’ book “One Night in the Everglades” (Taylor Trade Publishing, 2012). Part of the LTER Children’s Book Series. Available in English and Spanish and with accompanying curriculum module, used in south Florida elementary schools.

(e) Collaborators and Other Affiliations
Collaborators and co-editors: George Aiken (USGS), Antoine Aubeneau (Northwestern), Nick Aumen (USGS), Jordan Barr (NPS), Christopher Bernhardt (USGS), Kenna Butler (USGS), Kaelin Cawley (U Colorado), Thomas Coulthard (U Hull), Vic Engel (USGS), Maarten Eppinga (Utrecht U), Sara Ferrón U Hawaii), Tom Givnish (U Wisconsin), Jud Harvey (USGS), David Ho (U Hawaii), Doug Jerolmack (U Pennsylvania), Lynn Leonard (UNC-Wilmington), Morgan Maglio (USGS), Raleigh Martin (UCLA), Paul McCormick (Jones Ecol. Res. Center), Diane McKnight (University of Colorado), Lauren McPhillips (Cornell), Christopher McVoy (South Florida Engineering and Consulting), Dorothy Merritts (Franklin & Marshall), Susan Newman (SFWMD), Greg Noe (USGS), Martha Nungesser (SFWMD), Aaron Packman (Northwestern), Ken Rutchey (SFWMD), Colin Saunders (SFWMD), Audrey Sawyer (U Kentucky), Katherine Skalak (USGS), Fred Sklar (SFWMD), Susa Stonedahl (St. Ambrose), Christopher Thomas (BGS), Craig Tobias (U Connecticut), Joel Trexler (FIU), Tiffany Troxler (FIU), John Volin (U Connecticut), Robert Walter (Franklin & Marshall), Deb Willard (USGS).

Graduate advisors: John Crimaldi (University of Colorado); Raymond Arvidson (Washington University in St. Louis).

Thesis advisor and postgraduate scholar sponsor:
Graduate Advisees; total number 6; all: Saalem Adera (Berkeley PhD student), Morgan Williams (Berkeley, PhD student), Mollie van Gordon (Berkeley, PhD student), Jan Hildebrand (TU Munich/Berkeley, MS student), Jen Natali (Berkeley, PhD student, co-advisor), Cleo Woelfle-Erskine (Berkeley, PhD student, co-advisor)
Postdocs; total number 2; last 5 years: Katherine Skalak (USGS), Danielle Watts (Berkeley)

BIOGRAPHICAL SKETCH – Shawn Lani
Founding Director, Studio for Public Spaces, Exploratorium

(a) Professional Preparation (Education)

University of California, Davis	English/Creative Writing & Art History	B.A.	1991
John F. Kennedy University	Museum Studies (Design and Education)	M.A.	1995

(b) Appointments

2013 -	Founding Director, Studio for Public Works, The Exploratorium
2009-2013	Curator of Outdoor Works, Exploratorium
2005-2009	Senior Artist, Exploratorium
1995-2005	Exhibit Developer, Exploratorium

(c) Products
(i) Products (exhibitions) most closely related to the proposal

1. November, 2005: "Icy Bodies" installed: Technorama, Suisse
2. 2003: Phreatophyte, "Water in a New Way" exhibition and public forum: SomArts Gallery, San Francisco Sponsored by the L.A. Municipal Water District
3. 2000: Water Towers, East and West
   Outdoor public art sculpture: Collaboration with Eric Dimond and Gary Strang, Landscape Architect
   Project Architect: David Baker and Associates
4. 2000: Planetary Landscapes, Chabot Planetarium, Oakland, Ca
   Ned Kahn, Michael Reynolds, curators. 2003-present: touring internationally.
5. 1997: Turbulent Landscapes, the Exploratorium, San Francisco
   Peter Richards, Curator. 1998-present: touring internationally.

(c) (ii) Other significant products (exhibitions)

6. January, 2006: Reconsidered Materials, The Exploratorium, San Francisco. Charles Sowers and Mark Fisher collaboratives.
7. January, 2004: ExNet Exhibition, American Museum of Natural History, New York
8. 2001: Magnetism, Technorama, Winterthur, Switzerland
   Remo Besio, Director
9. 1998: Nothing But Time, Southern Exposure juried exhibition, San Francisco
   David Ross, Director of SFMOMA, Curator

(d) Synergistic activities

1. 2002-2004: Lead, annual Exhibit Development Workshop. Exploratorium, San Francisco
2. 2004: IPAM Exchange. Landesmuseum, St. Polten, Austria
3. 2005: University of Chicago Residency with Charles Sowers: Dr. Sidney Nagel and Dr. Heinrich Jaeger: Soft Condensed Matter Material Scientists
4. 2004: Development Residency: Rochester Museum of Science, Rochester, NY
5. Artist in Residence, Technorama, Winterthur, Switzerland

(e) Collaborators and Other Affiliations
Collaborators and co-editors: Mark Stacy (University of California, Berkeley)

SUMMARY PROPOSAL BUDGET

YEAR 1

ORGANIZATION: University of California-Berkeley				FOR NSF USE ONLY		
				PROPOSAL NO.	DURATION (months)	
					Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: Laurel Larsen				AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Laurel Larsen - Assistant Professor	0.00	0.00	0.50	2,661	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	2,661	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				27,002	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				29,663	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				8,642	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				38,305	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
Biogeomorphology Research and Teaching Flume $ 202,640					
TOTAL EQUIPMENT				202,640	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				620	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ 0					
2. TRAVEL 0					
3. SUBSISTENCE 0					
4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				6,258	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				6,258	
H. TOTAL DIRECT COSTS (A THROUGH G)				247,823	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
UC Berkeley standard overhead, 1/1/15-6/30/15 (Rate: 56.5000, Base: 18518) (Cont. on Comments Page)					
TOTAL INDIRECT COSTS (F&A)				21,018	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				268,841	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				268,841	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: Laurel Larsen	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: Joyce So	Date Checked	Date Of Rate Sheet	Initials - ORG

1 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET COMMENTS - Year 1

**** I- Indirect Costs**
UC Berkeley standard overhead, 7/1/15-12/30/15 (Rate: 57.0000, Base 18518)

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **University of California-Berkeley**			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Laurel Larsen**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Laurel Larsen - none**	0.00	0.00	0.50	2,714	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	2,714	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				27,542	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				30,256	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				9,493	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				39,749	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				620	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				6,408	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				60,350	
6. OTHER				4,015	
TOTAL OTHER DIRECT COSTS				70,773	
H. TOTAL DIRECT COSTS (A THROUGH G)				111,142	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **UC Berkeley standard campus overhead (Rate: 57.0000, Base: 66830)**					
TOTAL INDIRECT COSTS (F&A)				38,093	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				149,235	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				149,235	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Laurel Larsen**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Joyce So**	Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 3

ORGANIZATION: **University of California-Berkeley**				FOR NSF USE ONLY	
PROPOSAL NO.				DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR: **Laurel Larsen**				AWARD NO.	

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Laurel Larsen - Assistant Professor**	0.00	0.00	0.50	**2,769**	
2.					
3.					
4.					
5.					
6. (**0**) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	**0**	
7. (**1**) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	**2,769**	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (**0**) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	**0**	
2. (**0**) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	**0**	
3. (**1**) GRADUATE STUDENTS				**28,093**	
4. (**0**) UNDERGRADUATE STUDENTS				**0**	
5. (**0**) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				**0**	
6. (**0**) OTHER				**0**	
TOTAL SALARIES AND WAGES (A + B)				**30,862**	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				**10,417**	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				**41,279**	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				**0**	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				**5,620**	
2. FOREIGN				**0**	
F. PARTICIPANT SUPPORT COSTS					
1. STIPENDS $ **0**					
2. TRAVEL **0**					
3. SUBSISTENCE **0**					
4. OTHER **0**					
TOTAL NUMBER OF PARTICIPANTS (**0**) TOTAL PARTICIPANT COSTS				**0**	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				**7,577**	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				**500**	
3. CONSULTANT SERVICES				**5,000**	
4. COMPUTER SERVICES				**0**	
5. SUBAWARDS				**0**	
6. OTHER				**8,315**	
TOTAL OTHER DIRECT COSTS				**21,392**	
H. TOTAL DIRECT COSTS (A THROUGH G)				**68,291**	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **UC Berkeley standard campus overhead (Rate: 57.0000, Base: 58433)**					
TOTAL INDIRECT COSTS (F&A)				**33,307**	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				**101,598**	
K. RESIDUAL FUNDS				**0**	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				**101,598**	
M. COST SHARING PROPOSED LEVEL $ **0**	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME: **Laurel Larsen**	FOR NSF USE ONLY		
	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*: **Joyce So**	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

YEAR 4

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Laurel Larsen

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Laurel Larsen - Assistant Professor**	0.00	0.00	0.50	2,824	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	2,824	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				28,655	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				31,479	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				11,427	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				42,906	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				5,620	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				5,077	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				500	
3. CONSULTANT SERVICES				5,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				8,315	
TOTAL OTHER DIRECT COSTS				18,892	
H. TOTAL DIRECT COSTS (A THROUGH G)				67,418	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **UC Berkeley standard campus overhead (Rate: 57.0000, Base: 56574)**					
TOTAL INDIRECT COSTS (F&A)				32,247	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				99,665	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				99,665	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME	FOR NSF USE ONLY		
Laurel Larsen	INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME*	Date Checked	Date Of Rate Sheet	Initials - ORG
Joyce So			

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

YEAR 5

FOR NSF USE ONLY		
PROPOSAL NO.	DURATION (months)	
	Proposed	Granted
AWARD NO.		

ORGANIZATION
University of California-Berkeley

PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR
Laurel Larsen

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Laurel Larsen - Assistant Professor	0.00	0.00	0.50	2,880	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	0.50	2,880	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (1) GRADUATE STUDENTS				29,228	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				32,108	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				11,670	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				43,778	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.)					
TOTAL EQUIPMENT				0	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				620	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				3,927	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				500	
3. CONSULTANT SERVICES				5,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				0	
TOTAL OTHER DIRECT COSTS				9,427	
H. TOTAL DIRECT COSTS (A THROUGH G)				53,825	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) UC Berkeley standard campus overhead (Rate: 57.0000, Base: 42764)					
TOTAL INDIRECT COSTS (F&A)				24,375	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				78,200	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				78,200	

M. COST SHARING PROPOSED LEVEL $ 0 AGREED LEVEL IF DIFFERENT $

PI/PD NAME
Laurel Larsen

ORG. REP. NAME*
Joyce So

FOR NSF USE ONLY		
INDIRECT COST RATE VERIFICATION		
Date Checked	Date Of Rate Sheet	Initials - ORG

 *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

SUMMARY PROPOSAL BUDGET

Cumulative

	FOR NSF USE ONLY		
ORGANIZATION University of California-Berkeley	PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR Laurel Larsen	AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. Laurel Larsen - none	0.00	0.00	2.50	13,848	
2.					
3.					
4.					
5.					
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.00	0.00	2.50	13,848	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (0) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	0.00	0.00	0.00	0	
3. (5) GRADUATE STUDENTS				140,520	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				154,368	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				51,649	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				206,017	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 202,640					
TOTAL EQUIPMENT				202,640	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				13,100	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				29,247	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				1,500	
3. CONSULTANT SERVICES				15,000	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				60,350	
6. OTHER				20,645	
TOTAL OTHER DIRECT COSTS				126,742	
H. TOTAL DIRECT COSTS (A THROUGH G)				548,499	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)					
TOTAL INDIRECT COSTS (F&A)				149,040	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				697,539	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				697,539	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME Laurel Larsen	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* Joyce So	Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

BUDGET JUSTIFICATION

A. Senior Personnel
Funding for two weeks of summer salary is requested for PI Larsen in each year of the project. A projected annual cost-of-living increase of 2% is assumed.

B. Other Personnel
Funding is requested for one graduate student for each year of the project. Salary is billed at the beginning student rate of GSR step 3, 50% time during the academic year (9 months), and 100% time during the summer (3 months). A projected annual cost-of-living increase of 2% is assumed.

C. Fringe Benefits
Fringe benefits are billed according to the approved composite "limited" rates in the table below. Note that the project starts midway through FY15 and ends midway through FY20.

	FY15	FY16	FY17	FY18	FY 19	FY 20
Faculty	18.1%	19.1%	20.0%	20.4%	20.9%	21.4%

Fringe benefits additionally include graduate student tuition and fee remission, which is based on the current and projected rates for California residents. Tuition and fee remission for one semester for each year of the grant equates to the following:

Year 1	Year 2	Year 3	Year 4	Year 5
$8147	$8962	$9858	$10844	$11061

D. Permanent Equipment
An integral part of this experiment is the Biogeomorphology Research and Teaching (BRAT) flume. The flume is of custom design, to be built by Engineering Laboratory Design, Inc. (ELD). ELD has constructed many of the research flumes at the Saint Anthony Falls Laboratory and Berkeley's Richmond Field Station. The quoted cost of the flume is $201,215 and is broken down in the attached manufacturer's quote. Additional components of the flume design include a ceiling of grow lights ($500) and an integrated low-cost particle image velocimetry (PIV) system. The system will be constructed as described in http://opensourcepiv.weebly.com/parts-and-how-to-build.html and will cost approximately $925.

E. Travel
As part of the travel budget, we request conference registration funds for Larsen and one graduate student to attend the AGU General Assembly Meeting in San Francisco for each year of the project. In the final year of the project, we will propose an AGU session on the role of particle interception in land building and sedimentation. AGU registration fees are $415 for senior members and $205 for graduate student members.

An integral part of the work is to perform two sets of field flume experiments on the Wax Lake Delta: one in late spring during a period of high river discharge and one during a January cold front. The former experiments will occur during year 3 of the proposal; the latter will occur at the start of year 4. Both Larsen and the graduate student will participate in the fieldwork. A minivan will be rented to transport people and large equipment to the boat ramp. For each trip, the total cost of travel *for two people*, based on a two-week (14-day) trip is broken down as follows:

Airfare	$700
Minivan rental	$600
Lodging, Morgan City	$2252
Per diem	$1348
Gasoline for minivan	$100
Total	**$5,000**

F. Other Direct Costs

1. Materials and Supplies

Materials and supplies needed for this work include fluorescent dyes for labeling natural aggregates (e.g., Rhodamine WT, which retails at $127 for a liter of concentrate at Cole Parmer), and fluorescent microspheres—smooth, non-sticky control particles used in distinguishing the role of stem biofilm in sedimentation processes from that of biofilms coating aggregates ($777 for 60 mL on Fisher Scientific). Other expendable items include laboratory consumables (tubing, weigh boats, pipet tips, reagents for the DOC instrument, seed particles for the PIV, $3000/year, years 1-4; $2000 for year 5), and field consumables (instrument batteries and maintenance, miscellaneous hardware, sample bottles, $1000/year for the two years in the field). In year 3, $2500 is requested for the materials needed to construct the two field flumes in the Wax Lake Delta, $2100 of which is needed for the plastic sheeting that forms the walls of the flumes, and the rest of which will be used to purchase metal stakes, wooden cross-beams, and materials for instrument mounts. The breakdown of Materials and Supplies costs is as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Dyes	$150	$300	$300	$300	$150
Fluorescent microspheres	$3,108	$3,108	$777	$777	$777
Field flume materials			$2,500		
Field consumables			$1,000	$1,000	
Lab consumables	$3,000	$3,000	$3,000	$3,000	$3000
Total	**$6,258**	**$6,408**	**$7,577**	**$5,077**	**$3,927**

2. Publication Costs

Publication charges are budgeted in the amount of $500/year for years 3-5. It is anticipated that this amount will cover 5 journal publications, project website maintenance, and poster printing for meetings.

3. Consultant Services

Funds are budgeted in years 3-5 for an external evaluator (Cheryl Schwab) to help in the assessment of the educational component of the project. The requested funds ($5000/year) will support 2 weeks of Schwab's time annually. Schwab was previously contracted by the University to evaluate its IGERT program.

4. Computer Services

None

5. Subawards

A $60,350 subaward to the Exploratorium is budgeted for exhibit development, an essential part of the outreach component of this proposal.

6. Other

The breakdown of "other" direct costs is as follows:

	Year 1	Year 2	Year 3	Year 4	Year 5
Shipping		$500	$500	$500	
Airboat and access charges			$4,800	$4,800	
Microscopy lab facilities charges		$3,105	$700	$700	
Custom machining for flume		$500			
Total	**$0**	**$4,015**	**$8,315**	**$8,315**	**$0**

Shipping. Funds in the amount of $500/year for the middle three years of the study are requested for shipping instruments and samples between the lab and the field and vice-versa. Funds will cover the cost of collaborators shipping biofilm-coated vegetation, sediment, and water from sites in the Wax Lake Delta and Florida Everglades, and shipping instruments and samples associated with the Wax Lake Delta field work.

Airboat and site access charges. To access the sites on Mike Island within the Wax Lake Delta, an airboat is needed. For each trip, we have budgeted for 8 days of airboat use and site access, at $600/day. The breakdown is: $400 for the airboat contract + $100 for airboat gas + $100 for truck gas used in hauling the airboat from LSU to the field site.

Microscopy lab facilities charges. The Berkeley Molecular Imaging Center allows students to use their laser confocal scanning microscope on an hourly fee basis after they have undergone training. Training charges are billed at a flat rate of $215, included in the charges for year 2 of the study. Use of the microscope is billed at $35/hour. In year 2, 80 hours of usage time are budgeted; in years 3 and 4, 20 hours per year are budgeted.

***Custom machining for flume**.* This category includes the cost of materials and labor for constructing the overhead sleeve and anchor for vegetation stems and for different false floor configurations to support synthetic arrays of vegetation.

G. Indirect Costs

University of California, Berkeley overhead is charged on all direct costs except for equipment and tuition remission. The following UCB-approved schedule for IDC is used:

	Year 1		Year 2	Year 3	Year 4	Year 5
	FY 15	FY 16	FY 16-17	FY 17-18	FY 18-19	FY 19-20
Rate	56.5%	57.0%	57.0%	57.0%	57.0%	57.0%
Base	$18,518	$18,518	$66,830	$58,433	$56,574	$42,764

SUMMARY PROPOSAL BUDGET

YEAR 2

ORGANIZATION **Exploratorium**			FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Shawn Lani**			AWARD NO.		

A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)
1. **Shawn Lani - Sr. Artist and Curator**	0.20	0.00	0.00	1,375	
2.					
3.					
4.					
5.					
6. (0) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0	
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.20	0.00	0.00	1,375	
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)					
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0	
2. (7) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	2.00	0.00	0.00	12,175	
3. (0) GRADUATE STUDENTS				0	
4. (0) UNDERGRADUATE STUDENTS				0	
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0	
6. (0) OTHER				0	
TOTAL SALARIES AND WAGES (A + B)				13,550	
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,280	
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				19,830	
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) **Fine sediment exhibit** $ 33,000					
TOTAL EQUIPMENT				33,000	
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0	
2. FOREIGN				0	
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0					
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0	
G. OTHER DIRECT COSTS					
1. MATERIALS AND SUPPLIES				0	
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0	
3. CONSULTANT SERVICES				0	
4. COMPUTER SERVICES				0	
5. SUBAWARDS				0	
6. OTHER				7,520	
TOTAL OTHER DIRECT COSTS				7,520	
H. TOTAL DIRECT COSTS (A THROUGH G)				60,350	
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE) **(Rate: , Base:)**					
TOTAL INDIRECT COSTS (F&A)				0	
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				60,350	
K. RESIDUAL FUNDS				0	
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				60,350	
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $				

PI/PD NAME **Shawn Lani**	FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Joyce So**	Date Checked	Date Of Rate Sheet	Initials - ORG

 ***ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET**

SUMMARY PROPOSAL BUDGET

Cumulative

ORGANIZATION **Exploratorium**				FOR NSF USE ONLY PROPOSAL NO.	DURATION (months) Proposed	Granted
PRINCIPAL INVESTIGATOR / PROJECT DIRECTOR **Shawn Lani**				AWARD NO.		
A. SENIOR PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates (List each separately with title, A.7. show number in brackets)	NSF Funded Person-months CAL	ACAD	SUMR	Funds Requested By proposer	Funds granted by NSF (if different)	
1. **Shawn Lani - Sr. Artist and Curator**	0.20	0.00	0.00	1,375		
2.						
3.						
4.						
5.						
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET JUSTIFICATION PAGE)	0.00	0.00	0.00	0		
7. (1) TOTAL SENIOR PERSONNEL (1 - 6)	0.20	0.00	0.00	1,375		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)						
1. (0) POST DOCTORAL SCHOLARS	0.00	0.00	0.00	0		
2. (7) OTHER PROFESSIONALS (TECHNICIAN, PROGRAMMER, ETC.)	2.00	0.00	0.00	12,175		
3. (0) GRADUATE STUDENTS				0		
4. (0) UNDERGRADUATE STUDENTS				0		
5. (0) SECRETARIAL - CLERICAL (IF CHARGED DIRECTLY)				0		
6. (0) OTHER				0		
TOTAL SALARIES AND WAGES (A + B)				13,550		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)				6,280		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A + B + C)				19,830		
D. EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM EXCEEDING $5,000.) $ 33,000						
TOTAL EQUIPMENT				33,000		
E. TRAVEL 1. DOMESTIC (INCL. CANADA, MEXICO AND U.S. POSSESSIONS)				0		
2. FOREIGN				0		
F. PARTICIPANT SUPPORT COSTS 1. STIPENDS $ 0 2. TRAVEL 0 3. SUBSISTENCE 0 4. OTHER 0						
TOTAL NUMBER OF PARTICIPANTS (0) TOTAL PARTICIPANT COSTS				0		
G. OTHER DIRECT COSTS						
1. MATERIALS AND SUPPLIES				0		
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				0		
3. CONSULTANT SERVICES				0		
4. COMPUTER SERVICES				0		
5. SUBAWARDS				0		
6. OTHER				7,520		
TOTAL OTHER DIRECT COSTS				7,520		
H. TOTAL DIRECT COSTS (A THROUGH G)				60,350		
I. INDIRECT COSTS (F&A)(SPECIFY RATE AND BASE)						
TOTAL INDIRECT COSTS (F&A)				0		
J. TOTAL DIRECT AND INDIRECT COSTS (H + I)				60,350		
K. RESIDUAL FUNDS				0		
L. AMOUNT OF THIS REQUEST (J) OR (J MINUS K)				60,350		
M. COST SHARING PROPOSED LEVEL $ 0	AGREED LEVEL IF DIFFERENT $					
PI/PD NAME **Shawn Lani**				FOR NSF USE ONLY INDIRECT COST RATE VERIFICATION		
ORG. REP. NAME* **Joyce So**				Date Checked	Date Of Rate Sheet	Initials - ORG

C *ELECTRONIC SIGNATURES REQUIRED FOR REVISED BUDGET

Budget Justification for Exploratorium Subcontract:

A. Senior Personnel
Shawn Lani, Sr. Artist and Curator of Outdoor Works, will be PI, devoting 25 hours of time to the project, overseeing project direction and exhibit development ($1,375).

B. Other Personnel
This category includes all staff generally associated with exhibit development and fabrication, outreach, visitor research, and project management. Veronica Garcia- Luis, Visitor Research and Evaluation, Co-PI, will contribute 15 hours of time directing project research and evaluation ($525). Eric Dimond, Project Director, will contribute 60 hours, focusing on community partnerships, project leadership, and leading the design collaborations ($2,700). Other staff include an Exhibit Engineer/Fabricator (100 hours; $3,600), a Writer/Editor (20 hours; $700), a Graphic Designer (20 hours; $700), a researcher/scientist (10 hours; $350), and a builder (100 hours; $3,600).

C. Fringe Benefits
Fringe benefits on salaries are at 46.35%.

D. Permanent Equipment
The materials cost of producing the exhibit is budgeted at $33,00. This total assumes $30,000 in exhibit materials and supplies, $500 for graphics production, $800 for structural engineering, $1,200 for permit fees, and $500 for shipping charges.

E. Travel
None.

F. Participant Support Costs
None

G.6 Other Expenses
This category includes the cost of equipment rental for installation and deinstallation of the exhibit ($800) and the cost of ongoing maintenance. Maintenance is budgeted at $35 per hour for 8 hours per month over 24 months, for a total of $6,720.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Laurel Larsen

Other agencies (including NSF) to which this proposal has been/will be submitted.
N/A

Support: ☐ Current ☐ Pending ☒ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
NRT-DESE: Environment and Society: Data Science for the 21st Century (DS421)
Source of Support: National Science Foundation
Total Award Amount: $2,999,915 Total Award Period Covered: Jan 2015-Dec 2019
Location of Project: Berkeley, CA
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Collaborative Research: Landscape evolution and sediment-nutrient fluxes in a wetland-stream restoration experiment
Source of Support: National Science Foundation
Total Award Amount: $175710 Total Award Period Covered: Aug 2012-July 2014
Location of Project: Lancaster, PA
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
The art and science of reduced-complexity modeling in the environmental sciences
Source of Support: National Science Foundation
Total Award Amount: $38,974 Total Award Period Covered: FY 2013, with 1-year NCE
Location of Project: Boulder, CO
Person-Months Per Year Committed to the Project. 0 Cal: 0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Evaluating water quantity-water quality tradeoffs in a restored Everglades
Source of Support: USGS-NPS Water Quality Partnership Program
Total Award Amount: $150000 Total Award Period Covered: Oct 2012-Sep 2015
Location of Project: Miami, FL
Person-Months Per Year Committed to the Project. Cal: 0 Acad: Sumr:

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Impacts of transport processes on aquatic ecosystem services
Source of Support: USGS
Total Award Amount: $24139 Total Award Period Covered: Oct 2013-Sep 2014
Location of Project: Berkeley, CA
Person-Months Per Year Committed to the Project. Cal: 2 Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Laurel Larsen

Other agencies (including NSF) to which this proposal has been/will be submitted.
N/A

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

BIGDATA: F: CSD: Distant early warnings in the informationscape:
Predicting critical transitions in spatially explicit datasets

Source of Support: National Science Foundation

Total Award Amount: $618,904 Total Award Period Covered: Jan 2015-Dec2017

Location of Project: Berkeley, CA

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 1

Support: ☒ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Doctoral Dissertation Research: Understanding dynamic water sources and
impacts on fish to design optimal water conservation strategies

Source of Support: NSF

Total Award Amount: $16000 Total Award Period Covered: May 2014-April 2016

Location of Project: Berkeley, CA

Person-Months Per Year Committed to the Project. 0 Cal: Acad: Sumr:

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

CAREER: Ecogeomorphic implications of organic particulates across scales:
Impacts of surficial properties and interception on landscape dynamics

Source of Support: NSF

Total Award Amount: $697,539 Total Award Period Covered: Jan 2015-Dec 2019

Location of Project: Berkeley, CA

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr: 0.5

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support

Project/Proposal Title:

Source of Support:

Total Award Amount: $ Total Award Period Covered:

Location of Project:

Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Current and Pending Support

(See GPG Section II.D.8 for guidance on information to include on this form.)

The following information should be provided for each investigator and other senior personnel. Failure to provide this information may delay consideration of this proposal.

Investigator: Shawn Lani

Other agencies (including NSF) to which this proposal has been/will be submitted.
N/A

Support: ☐ Current ☒ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
CAREER: Ecogeomorphic implications of organic particulates across scales
Impacts of surficial properties and interception on landscape dynamics
Source of Support: NSF
Total Award Amount: $60,350 Total Award Period Covered: Jan 2016-Dec 2016
Location of Project: San Francisco, CA
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

Support: ☐ Current ☐ Pending ☐ Submission Planned in Near Future ☐ *Transfer of Support
Project/Proposal Title:
Source of Support:
Total Award Amount: $ Total Award Period Covered:
Location of Project:
Person-Months Per Year Committed to the Project. Cal: Acad: Sumr:

*If this project has previously been funded by another agency, please list and furnish information for immediately preceding funding period.

Facilities, Equipment, and Other Resources

The Environmental Systems Dynamics Laboratory, located within Berkeley's Geography Department in McCone Hall, is a standard wet lab, with sink, fumehood, refrigerator, freezer, high-precision balances, a drying oven, centrifuge, adjustable pipets, standard laboratory glassware, and deionized water. Another room contains computing facilities, with quad core Linux and PC desktop servers. Graduate student office space is available in the room with computing facilities. Specialized instrumentation within the lab to be used in support of this proposal includes:

- Horiba Jobin Yvon Aqualog fluorometer: A scanning, 3-D fluorometer that obtains simultaneous fluorescence and absorbance spectra. This instrument will be used to analyze concentrations of fluorescently labeled particle tracers and fluorescent microspheres, obtain chlorophyll-*a* readings on biofilm extracellular polymeric substances (EPS), and perform spectrophotometric assays of EPS carbohydrates.

- Qsonica ultrasonic processor with sapphire-tipped horn: Used to ultrasonically disaggregate fluorescently labeled floc particles for analysis in the fluorometer. Disaggregation is necessary to ensure that particles remain suspended during the reading. Ultrasonic probes with sapphire-tipped horns are standard equipment for floc disaggregation, as they minimize sample contamination with material from the horn itself.

- Sequoia Scientific LISST-Floc: A submersible, *in situ* laser-diffraction particle size analyzer that obtains volumetric concentrations of suspended particles in 32 logarithmically spaced size bins between 7.5 μm and 1500 μm. Since experimental durations are too short to result in substantial accumulation of settled material on instrument windows, the LISST will be used in a vertical configuration, as has been done previously in *in situ* flume experiments (Harvey et al., 2011).

- Settling column: A thermally insulated, 95 x 5 x 5 cm settling column used to image settling of individual flocs. The column is mounted to a frame that also supports a high-speed digital SLR (see below) and flash. Identical to the settling column used in the experiments of Larsen et al. (2009a).

- High-speed digital SLR: A Nikon D2XS, equipped with a 60 mm micro-Nikkor lens optimized for imaging fine particles.

- Nortek Vectrino II: A small-footprint acoustic Doppler velocimeter designed for high-resolution measurements in flumes and/or in the field. Over a vertical range of 3 cm, the Vectrino II can profile three-component velocity at a 1-mm resolution and 100 Hz sampling rate. This capability makes the instrument well suited for obtaining detailed velocity and Reynolds stress profiles near boundaries, reducing the uncertainty in calculations of boundary shear stress.

Field equipment additionally includes:

- Three YSI 600OMS V2 single-(optical) parameter sondes. Each sonde is equipped to measure turbidity, temperature, and conductivity.

- A Toshiba Toughbook laptop

The future Biogeomorphology Research And Teaching flume facility will be located in a laboratory on the ground floor of McCone Hall. Though the laboratory was designed specifically for a flume facility, the space is currently unoccupied. The 744 ft^2 room contains a floor drain, a 3-ton hoist, and a 6.6 m x 2.9 m overhead frame with electrical power. It also contains laboratory benches and cabinets along one well, a sink, and easy access to the outdoors through two nearby doors.

The Wax Lake Delta field site coincides with the location of a separately funded effort to build a Delta Dynamics Collaboratory, which includes instrumentation of the Wax Lake Delta as an observatory (see attached letter of collaboration). Boats and access permits established through that effort will be available to Larsen. This work will also benefit from a suite of measurements simultaneously being made on Mike Island within the Wax Lake Delta, including continuous water levels, nutrient concentrations, turbidity, lidar surveys, and vegetation surveys.

The Berkeley Molecular Imaging Center is a campus-wide resource that offers training to campus affiliates and run time on the scanning confocal microscopes for a modest hourly fee. Available instruments include a Zeiss LSM 780, Zeiss LSM 710 – Optimus Prime, Zeiss 510 NLO Axiovert 200M Maitai HP, Zeiss LSM 510 Meta/NLO Axioimager with Maitai Deepsee, and Zeiss 5-Live.

INTEGRATED EARTH DATA APPLICATIONS
iedadata.org

Data Management Plan

Primary Investigator: Larsen, Laurel
Institution: University of California, Berkeley
Project: CAREER: Ecogeomorphic implications of organic particulates across scales: Impacts of surficial properties and interception on landscape dynamics
NSF Division: EAR **Solicitation Info:** Faculty Early Career Development (CAREER) **Submission Date:** 07/23/2014

Overview: Flume experiments in the laboratory and field will generate samples of suspended sediment, settled suspended sediment, particulates on vegetation stems, vegetation stem characteristics, and biofilm characteristics. PIV techniques will generate high-speed photographic images of fluid particles in motion. Instruments deployed within the flumes will supply continuous streams of data on flow velocities, turbulence characteristics, and suspended sediment size distributions. Additionally, numerical modeling will generate code and model outputs.

Data description: Experimental data will be generated from at least 36 experiments in a laboratory flume and four experiments in two field flumes. Up to 100 model runs will also generate data. See detailed description below.

Description of existing data and samples: Delft 3D modeling code that is being developed by collaborators will be used, with modification, to model delta evolution processes. The code will be available through the Community Surface Dynamics Modeling System repository (csdms.colorado.edu).

Data analysis summary: 1. Suspended sediment samples: Total mass, mass of labeled particles, distributions of settling speed and particle size
2. Sediment trap samples: Total mass, mass of labeled particles
3. Vegetation samples: Stem diameters, stem frontal areas
4. Biofilm samples: roughness, fractal dimension, surface-area-to-volume ratio, water- and EDTA-extractable polysaccharides, water-soluble EPS, total carbohydrates, chl-*a*, total specific fluorescence, specific fluorescence of distinct spectral components found ubiquitously in organic matter pools
5. LISST instrument data: particle size distributions, mass and volumetric concentrations, mean particle size
6. ADV data: velocity profiles, mean velocities, turbulence intensities, Reynolds stresses, bed shear stresses, signal strength
7. Model-generated data: Simulated topography, flow, vegetation distribution, and sediment budget terms. Landscape structure will be analyzed using a variety of geostatistics, including directional connectivity statistics.
8. Publications: Scientific publications summarizing study findings will be prepared for the peer-reviewed literature in accordance with standard practice. Data products supporting the manuscripts will be made available immediately following publication.

Includes field work? Yes

Description of field work: Field flume experiments will be conducted at two locations on the Wax Lake Delta, and each experiment involves two runs: a low-flow condition and a high-flow condition. Instruments continuously generating data include a Sequoia Scientific laser-diffraction particle size analyzer (LISST) and an acoustic Doppler velocimeter (ADV). Samples to be collected include pumped water samples for analysis of suspended sediment (from three depths in the water column at two locations in the flume), sediment collected in sediment traps (five per flume), and vegetation/ epiphytic biofilm (0.25 square-meter harvested plots).

<u>Expected data product #1</u>
Data type: Model
Responsible investigator: Larsen
Product description: Vegetation module source code for Delft 3-D delta evolution model and supporting documentation and model outputs.
Intended repository: CSDMS

Timeline for data release: Two Years from acquisition/analysis

<u>Expected data product #2</u>
Data type: Experimental
Responsible investigator: Larsen
Product description: Flume Experimental data: Data analysis products will be stored as CSV files, with accompanying metadata created using the DataUp tool, which is sponsored by the California Digital Library. Metadata will describe the conditions (i.e., water level, flow rate, sediment input, vegetation configurations), sampling dates/times, deployment locations (x-y-z coordinates) for each flume run, the purpose of the project, the source dataset (for higher-level data products), the permanently archived location of the source dataset, the permanently archived location of any code used to generate the analysis, and all column headings/variable names. Metadata will also describe the software necessary to view the data products, information about version control and version history, and the terms of use (i.e., proper citation of the data).

Level 0 (raw data) from flume experiments:
1. One-minute particle size distributions – Excel spreadsheets in which each row is a separate time stamp; columns are volumetric concentrations of particles in each size class. Separate tabs represent separate instruments deployed simultaneously during the experiment.
2. 1 Hz ADV data – Tab-delimited ASCII data containing time stamp, x-y-z velocity components, signal correlation, signal amplitude, and signal-to-noise ratio.
3. Vegetation data – Excel spreadsheets containing information about the length, width, and species identification of each measured stem segment in 20-cm vertical increments.
4. Intercepted sediment mass – Excel spreadsheet documenting the directly measured total sediment mass on particle stems, dimensional information about the corresponding stems, and fluorescence intensity at the peak wavelength of the tracer dye.
5. Settled sediment mass – Excel spreadsheet documenting the total sediment mass in sediment traps and fluorescence intensity at the peak wavelength of the tracer dye.
6. Photographs of sediment aggregates in settling column.
7. Scanning confocal microscope images of biofilm – accompanied by metadata describing experimental conditions.

Level 1
1. Intercepted sediment mass – Excel spreadsheet containing the mass of tracer sediment on stems (one row per stem, with the mean provided in a summary tab)
2. Mass concentrations in sediment traps – Excel spreadsheet containing the mass of tracer sediment in traps (one row per trap, with the mean provided in a summary tab), calculated from the volumetric concentrations and settling velocity distributions using Stoke's Law.
3. Topology of EPS – Excel spreadsheet with one row per EPS scanning confocal microscope image, containing columns for each roughness or fractal dimension metric
4. EPS composition – Excel spreadsheet with one row per sample, containing columns with data on chl-a concentration, total EPS, EDTA-extractable EPS, and water-extractable EPS
5. Settling velocity distributions – Excel spreadsheet containing settling velocities and corresponding particle size from settling column experiments.

Level 2
1. Particle interception efficiencies – Excel spreadsheets containing stem capture efficiencies, calculated by direct measurement (one row per stem, with the mean provided in a summary tab) and by difference (a bulk measurement).

Level 3
1. Summary of all final data products from flume runs: An Excel spreadsheet with one row per experiment, with columns representing the mean of each highest-level analysis listed above, together with information about the configuration of the flume during the run.

Intended repository: DataONE, via ONEShare Repository member node

Timeline for data release: Two years from acquisition/analysis

UNIVERSITY OF CALIFORNIA, BERKELEY

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DEPARTMENT OF GEOGRAPHY
507 McCone Hall # 4740
BERKELEY, CALIFORNIA 94720-4740
(510) 642-3903
FAX (510) 642-3370

3 July 2014

Dear NSF Review Panel:

As the chair of the Geography Department at Berkeley, I am happy to provide this letter of support for Dr. Laurel Larsen's CAREER proposal, titled "Ecogeomorphic implications of organic particulates at multiple scales: Impacts of surficial properties and interception on landscape dynamics." Dr. Larsen has been in her tenure-track position as Assistant Professor for 1.5 years; hence she is eligible for the CAREER program.

Expectations for Larsen's progression to tenure include her successful establishment of a nationally renowned research program in physical geography while carrying a teaching load of three semester-long courses per year. The goals of Larsen's CAREER proposal are consistent with the Department's and University's expectations. Larsen is emerging as a leader in ecogeomorphology research, and her work has already influenced key management decisions on restoration of the Everglades. That track record has caused other restoration managers to reach out to her, including, recently, Inyo County Water, which is tasked with managing restoration of the lower Owens River in California. Larsen is a rare scientist who combines expertise in the field and laboratory flumes with numerical modeling, giving her unique skills both to gain new understanding of processes at small scales and to evaluate their implications at the landscape scale. The proposed research in her CAREER proposal is a natural extension of her previous work and will further her standing as a leader in the field of ecogeomorphology. Consequently, she has our department's strongest support.

Larsen's research and teaching goals are well aligned with the mission of the Geography Department, which includes promoting scholarship about earth's landscapes and human relationships to the environment. We have a long-standing tradition of combining rigorous empirical work with conceptual and theoretical analyses, grounded in recognition of the importance of spatial processes. Larsen's proposed experiments to elucidate poorly understood dynamics of sediment transport, combined with the use of models to predict the impacts of these processes over spatially heterogeneous landscapes and provide tools for restoration and management, align perfectly with our mission.

We are also highly supportive of the educational component of her proposal. Few of our classes presently have an integrated laboratory component. Installation of the Biogeomorphology Research and Teaching flume in McCone Hall, which the Geography department shares with the department of Earth and Planetary Sciences, will present a novel and enriching educational opportunity for undergraduate students in both departments, on top of the research opportunities it will provide for graduate students and postdocs. Early discussions about the flume with graduate and undergraduate students from these two departments and Civil and Environmental Engineering have already generated much enthusiasm. The new modules that Larsen is proposing for her Terrestrial Hydrology course are appropriate and will likely be well received by the students. Likewise, the module that she proposes for her Statistics and Multivariate Data Analysis for Research course will provide graduate students from a broad range of backgrounds with hands-on and much-needed experience with time series data acquisition and analysis. We also embrace the outreach partnership that Larsen proposes with the San Francisco Exploratorium, which not only provides positive exposure for the Department but also enhances public awareness of Bay area environmental water projects—a topic of interest for many in the Department and University. Meanwhile, we support Larsen's proposed teaching at the National Center for Earth Dynamics Summer Institute. It will not interfere with her departmental teaching obligations and will further her standing as a leader in the field, which has our strongest support.

Our Department is committed to supporting Larsen's professional development and providing mentorship through the pre-tenure years. Larsen's official mentor in the Department is Dr. Kurt Cuffey, a glacial geomorphologist who has been meeting with Larsen approximately monthly since the start of her career at Berkeley. In addition, Larsen receives ad hoc mentoring from others inside and outside of the Department, including myself, Bill Dietrich and David Shuster (EPS), Mary Power (Integrative Biology), and Stephanie Carlson (Environmental Science, Policy and Management). Our commitment to Larsen's success includes providing her with a new laboratory, office space for graduate students and postdocs, storage space for field equipment, and financial resources through her faculty startup package. I conduct annual reviews to provide Larsen with feedback and guidance about her progress to tenure.

Please consider this letter evidence of our Department's strongest support of Larsen's proposal and her overall professional development. I am hopeful that the panel's enthusiasm for the work of this early-career investigator will equal our own.

Sincerely,

Nathan F. Sayre
Associate Professor and Department Chair
510-664-4072 (tel)
nsayre@berkeley.edu

14 July 2014

Dr. Laurel Larsen
Assistant Professor, Department of Geography
University of California, Berkeley

Dear Dr. Larsen:

Your recent conversations with Steve Gennrich and Bryce Johnson have generated enthusiasm about the possibility of developing an exhibit on fine sediment and its role in the restoration of San Francisco Bay salt marshes. Consider the Exploratorium an eager partner in your outreach efforts should your proposal get funded.

As you have discussed with Steve, your ideas would be well suited for an outdoor exhibit in a public space, such as the new exhibit space we are planning with the Presidio and Crissy Field, or an indoor exhibit. Should your work be funded, you would be working with the Studio for Public Spaces team to develop the exhibit. The Living Systems Gallery and Observatory Gallery might also advise on the exhibit development. Our exhibit development process is like a research experiment involving visitor and staff input on ideas and prototypes that evolve over time. The ideas that you have articulated in the prospectus that you have shared with us—a hands-on experience of the smell, feel, and close-up look of organic sediment, or a demonstration of how fine sediment transport in marshes can help coastal regions persist in the face of subsidence and sea-level rise, together with a connection to information about local salt marsh restoration—are strong starting points for this process.

We have enjoyed a productive partnership with other NSF-sponsored researchers at UC Berkeley (e.g., Mark Stacey in Civil Engineering, who I understand put you in touch with us) and look forward to expanding that partnership further. We hope for a successful outcome for your proposal.

Sincerely,

Thomas Rockwell

Tom Rockwell
Director of Exhibits

DEPARTMENT OF GEOLOGICAL SCIENCES
JACKSON SCHOOL OF GEOSCIENCES

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http://www.geo.utexas.edu

July 13, 2014

Dear Laurel,

I am very pleased to strongly support your NSF CAREER proposal entitled, *Ecogeomorphic implications of organic particulates across scales: Impacts of surficial properties and interception on landscape dynamics*. For the past 7 years my research group has been busy collecting high resolution subaerial and subaqueous topographic data that define the rapidly growing Wax Lax Delta in southern Louisiana. The original portion of this field work was funded by the National Center for Earth-surface Dynamics, a NSF Science & Technology Center, as part of its project on the science surrounding delta restoration and management. Data collection at Wax Lake Delta has continued and expanded as a field observatory with real-time sensor arrays is finally coming online there as part of the funded *NSF FESD: A Delta Dynamics Collaboratory* project. Clearly the role of vegetation on sedimentation is extremely important at Wax Lake Delta and there is no one presently involved with the delta observatory who is studying the relationship between biofilms and particle interception rates by plants. It would greatly benefit the observatory to have you and your research group tackle this important process at Wax Lake Delta. Your field and laboratory studies will provide the measurements necessary to produce an accurate numerical module quantifying this significant sedimentation process. As lead PI on the delta collaboratory I will make sure that you are included in deployment decisions for the observation platforms at Wax Lake Delta, particularly those located on the tops of flooded islands and at channel margins. I will also make sure that you are aware of and have access to all of the data types being assembled for the delta. I am confident that through this interaction we can optimize the potential of the observatory and your field experiments. Finally, collaboratory participants can provide you with technical advice on construction of your field flumes, as well as logistical support during their installment at Wax Lake Delta. I wish you the best of luck with your research on this important topic.

Sincerely,

David Mohrig

David Mohrig
John E. "Brick" Elliott Centennial Professor in Geological Sciences
Jackson School of Geosciences
The University of Texas at Austin
2275 Speedway, Mail Stop C9000
Austin, TX 78712-1722, USA
phone: 512-471-2282
e-mail: mohrig@jsg.utexas.edu

July 17, 2014

Dear Dr. Larsen:

This letter of commitment expresses my intent to work with you as an evaluator on your CAREER proposal titled "Ecogeomorphic implications of organic particulates across scales: Impacts of surficial properties and interception on landscape dynamics." For the budgeted amount of $15,000, I intend to invest 375 hours of work in the project. As we have discussed, I will help you in designing an evaluation plan that will use both formative and summative assessment approaches to monitor the development and implementation of educational activities. I will help you in creating a construct map to identify the levels of development or progress for your selected metrics, advise you on data collection techniques. Once you collect the data, I will help in generating a scoring guide to translate measurements into scores and in interpreting scores in the context of the construct map.

I look forward to working with you in the event that your proposal is funded.

Sincerely,

Cheryl J. Schwab

Cheryl Schwab

SAN FRANCISCO STATE UNIVERSITY

LEONARD S. SKLAR, PH.D.
ASSOCIATE PROFESSOR OF GEOLOGY
DEPARTMENT OF EARTH & CLIMATE SCIENCES

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Dr. Laurel G. Larsen
Department of Geography
University of California
Berkeley, CA 94720

July 20, 2014

Dear Laurel,

I am pleased to offer this letter of support for your proposal "Ecogeomorphic implications of organic particles across scales" requesting support from NSF for construction of the Biogeomorphology Research and Teaching (BRAT) flume.

Thank you for your invitation to conduct collaborative experiments in the BRAT flume. The facility you are proposing would be ideal for controlled laboratory experiments to answer exciting new questions on the interactions between biotic and abiotic processes in travertine precipitation. This work would build on my previous NSF-funded field investigation of biogeomorphic feedbacks in regrowth of travertine step-pools following dam removal in Fossil Creek, Arizona. There we found rates of travertine deposition are strongly correlated with biotic factors, including growth of algae and emergent vegetation and trapping of suspended organic material. However, understanding and modeling this dynamic system will require teasing apart the complex interactions among plant species assemblages, microbial diversity, supply of light and nutrients, water chemistry, flow hydraulics and fine sediment dynamics.

Your design of the BRAT flume includes components essential to the experiments I envision, such as the ability to circulate travertine flocs that precipitate on floating organic particles, the LISST instruments to document particle size distribution of suspended material, ADVs to quantify flow turbulence, and lights to support growth of algae and emergent plants.

I would conduct these experiments together with my student research advisees in our BS and MS programs in geosciences at San Francisco State University. SFSU is an urban, primarily undergraduate institution that ranks 14th in the nation in awarding undergraduate degrees to members of under-represented ethnic minority groups. Over the past 10 years I have mentored 24 student researchers, including 10 women and 7 from ethnic minority communities, many of whom have published their work in peer-reviewed journals and gone on to graduate programs at leading institutions.

I am excited by your vision for the BRAT flume as both a facility for cutting-edge cross-disciplinary science, and a catalyst for innovative, multi-institutional collaboration; I eagerly await news of the (hopefully successful) outcome of your proposal!

Sincerely,

Leonard S. Sklar

Dr. Laurel Larsen 19 July 2014
U.C. Berkeley, Department of Geography

Dear Laurel,

I'm writing to express my strongest support for your proposal to build a Biogeomorphology Research and Teaching Flume Facility on the U.C. Berkeley campus. The flume presents an exciting collaboration opportunity, and the facility would also provide resources beneficial to my teaching. One unique and particularly attractive feature of this flume to a freshwater ecologist is the non-shearing nature of the pump, which enables the use of motile organisms in the flume under different flow and suspended sediment regimes. One exciting research opportunity is in exploring fish behavior under different flows, including the importance of substrate as refugia during high flow events or rapid water drawdowns due to water extraction for agriculture. As a teaching tool, the flume would be a great place to demonstrate methods in stream ecology, such as measurement of discharge and flow velocity. The Vectrino II velocimeter, with its optimized capability for measuring boundary shear stresses, would be an asset in course field or laboratory exercises, including my classes on Fish Ecology and Freshwater Ecology.

I am fully supportive of this proposal and believe the Biogeomorphology Research and Teaching Flume would be a great asset to investigators in diverse fields, both on- and off-campus.

Sincerely,

Stephanie Carlson

Stephanie Carlson

Assistant Professor
Department of Environmental Science, Policy and Management
130 Mulford Hall #3114
University of California
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BERKELEY, CALIFORNIA 94720-3140

Dr. Laurel Larsen
U.C. Berkeley, Department of Geography

July 21, 2014

Dear Laurel,

I am very excited about the new collaborations with you that your CAREER proposal will provide. I am particularly enthusiastic about the ability to study flocculation processes in a small-footprint recirculating flume. One of the questions of interest in my research deals with the source of nutrients that fuel algal blooms near the mouth of the Eel River and the extent to which autochthonous production within the river contributes significantly to coastal marine food webs and productivity. These studies inform a larger ongoing NSF-funded collaboration among Profs. Inez Fung, Bill Dietrich and Jim Bishop (Earth and Planetary Science) and Zack Powell and myself (Integrative Biology) to examine the impact of the Eel River on offshore marine phytoplankton blooms. A missing link in our understanding of nutrient budgets that supply coastal marine phytoplankton in this region is the role of particulate nutrient export from the river. In particular, drifting mats of large, filamentous algae and floc, and the extent to which floc dynamics—aggregation/disaggregation, settling, resuspension—could influence coastal nutrient cycling in ways yet unrecognized. The ability to control nutrient concentrations and flow conditions in a flume small enough to use imported Eel River water and algae will be an invaluable asset that opens the door to exciting collaboration possibilities, as we discussed during your last visit. We could, for example, examine the effects of light, thermal, and nutrient regimes on algal mat and floc buoyancy, integrity and drift dynamics. The flume would also be well suited to studies of algal detachment.

As part of the Wax Lake Delta Collaboratory, I am also particularly enthusiastic about the application of the flume to understanding macrophyte-sedimentation interactions in the Wax Lake Delta. One of the needs of the overall delta modeling effort is for more process-based research on vegetation-induced sedimentation that clearly leads to functional relationships that can be used in modeling. I am happy to see that your proposed field and laboratory flume research would meet this need. Meanwhile, our work on vegetation ecological dynamics could serve as useful inputs to your DeltaMod module.

To summarize, the Biogeomorphology Research and Teaching flume facility will be a great development for my ongoing research, and would provide good opportunities for graduate students who want to work on any of these topics. I strongly support your efforts to engage an interdisciplinary group of scientists in this endeavor.

Sincerely,

Mary E Power

Mary E. Power
Professor, Integrative Biology
Faculty Director, Angelo Coast Range Reserve

UNIVERSITY OF CALIFORNIA, BERKELEY

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DEPARTMENT OF EARTH AND PLANETARY SCIENCE
307 MCCONE HALL
(510) 642-3993

July 21, 2014

Laurel Larsen
Department of Geography

Dear Laurel,

I am writing to offer my collaboration in your application to build a unique flume facility to explore biogeomorphic processes. The influence of biota on sediment transport and channel morphology has emerged as a central research area, both of theoretical importance and practical significance. The experience you bring to this project from your field work and prior experimental investigations, and the mechanistic understanding and the breadth of your crossdisciplinary knowledge, I am sure, will take us in new directions. This is why we were so pleased you accepted recently a faculty position at Berkeley!

As you know, I designed the basement room in McCone Hall (the building that both Geography and Earth and Planetary Science are based) to be used for a teaching/research flume facility- with a floor drain, 3 ton hoist, overhead frame and power. It was a field of dreams effort during our building restoration, and now that goal can be realized with the vision that you propose. The instrumentation (including a very precise ADV) and design (e.g. special pump, instrument cart, and sediment recirculation) you propose are essential and well planned. This will lead to a unique and highly productive experimental facility.

Your plans will also make the flume facility regularly used for instruction. As you know, we teach our undergraduate majors and graduate courses in McCone and by having this flume in the building we can include hands-on experimental observations as part of our teaching. I teach an undergraduate geomorphology course (EPS 117) (40 student enrollment) with one of four projects devoted to fluvial processes. The availability of this flume will allow me to design a laboratory component to match the field project. This is especially valuable given that it is not possible to take students to channels with active sediment transport- or even high flow- during the course. I also teach a graduate lecture course on sediment transport mechanics and river morphodynamics. We have used simple small flumes with primitive instrumentation for years as a laboratory component of the course at an off-campus facility. Your flume and instrumentation will enable the students to make research grade observations, and learn much more about river mechanics. It will also introduce them to the influence of biotic processes. The graduate course (EPS 217) has enrollments now approaching 30 students and includes many students from engineering (as well as students from Landscape architecture, Environmental Science Policy and Management, Geography and other programs).

I look forward to housing the Biogeomorphology Research and Teaching Flume Facility in my basement lab and seeing the discoveries and enhanced teaching it will enable.

Sincerely,

William E. Dietrich
Professor

UNIVERSITY OF CALIFORNIA, BERKELEY

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July 21, 2014

Department of Civil and Environmental Engineering
623 Davis Hall
Berkeley, CA 94720-1710

Re: NSF Proposal

Dr. Larsen:

This letter indicates my interest in the collaboration opportunities that the flume construction as part of your CAREER proposal will promote. As a researcher with active work in collecting and using sediment transport data, I find the proposed Biogeomorphology Research and Teaching flume facility to be both innovative and useful.

I look forward to working together by sharing information and cooperating on and scheduling coordinated measurement campaigns when appropriate. Specifically, I anticipate that it will be very exciting to conduct the 3D Lagrangian tracking measurements in which my research group specializes in the facility that you are proposing. Together, we could learn a significant amount about the basic dynamics of sediment motion and aggregate formation by combining and comparing our respective measurement techniques (including Eulerian laser diffraction particle size analysis, floc imaging) in using this facility.

Beyond this immediately obvious and rewarding collaboration opportunity, I also see a number of other ways in which your proposed facility will contribute to the academic endeavors underway here at UC Berkeley. The facility offers an excellent pedagogical opportunity for my graduate class: Civil & Environmental Engineering 200C, Mixing and Transport in the Environment. Your facility would allow the students to directly observe suspended sediment transport in a vegetated flow, which would help them cement the concepts that we cover on this topic. I would also be interested in using this facility to test some hypotheses about air-water gas exchange in vegetated flows. My research group has investigated the effect of wind, waves, and thermal convection on this process, but have not yet directly measured the effect of currents. Your proposed facility would be perfect for this, especially due to the recirculation and the gentle nature of the impeller.

Please let me know if there is any additional way I can be of assistance.

Very Best Regards,

EA Variano

Evan Variano
2014.07.21 15:26:34
-07'00'

Evan A. Variano
Associate Professor
Civil & Environmental Engineering

Sea Grant Louisiana

Louisiana Sea Grant College Program
Office of the Executive Director

July 20, 2014

Laurel G. Larsen, Ph.D
Assistant Professor, Dept. of Geography, University of California
507 McCone Hall, Berkeley, CA 94720-4740

Dear Laurel,

This is letter of collaboration for your NSF proposal entitled "Ecogeomorphic implications of organic particulates: Impacts of surficial properties and interception on landscape dynamics" being submitted to IF Program. As you know, Louisiana Sea Grant has a very extensive and active education and outreach program associated with coastal science and engineering issues that span the disciplines in natural and social sciences. I would like to mention several research investigators that Sea Grant has funded here in Louisiana that may contribute components of a delta model using Wax Lake Delta as a system of study that would interact in useful ways with a vegetation sedimentation module. In addition, I am involved with a project funded by NSF, known as the Delta Collaboratory, including our recent work at LSU to develop a nutrient biogeochemistry model, along with Dr. Scott Duke-Sylvester at UL Lafayette that is developing a vegetation ecology model. We would be glad to include you in our planning process, workshops, etc. for the Delft3D model as part of the Delta Observatory that has been funded by NSF. In addition, we would be glad to provide access to datasets from the Delta Observatory for use in planning the locations of the flumes and characterizing conditions on Mike Island during the flume experiment. Given some ability to coordinate field trips to the Wax Lake Observatory, LSU will be glad to provide some logistical support to our field research sites. Again, this would particularly be of mutual benefit of how the flumes might be beneficial to addressing hypotheses concerning nutrient biogeochemistry of deltaic coasts.

Also, we would very much like to partner with your proposed research with the education opportunities here in Louisiana Sea Grant Program. We have recently focused on education and outreach opportunities at Wax Lake Delta to teach the principles of delta restoration to teachers and students. In addition, Sea Grant has been involved with helping to support the Wax Lake Observatory that will be linked to this outreach effort to develop teaching modules in K-12 classrooms on coastal restoration issues here in Louisiana (and deltas around the world).

I look forward to working in partnership with your new NSF proposed project to strengthen our understanding of the Mississippi River Delta.

With best regards,

Sincerely,

Robert R. Twilley
Executive Director
Professor, Oceanography and Coastal Sciences, LSU

239 Sea Grant Building • Baton Rouge, LA 70803 • (225) 578-6445 • Fax (225) 678-6331 • rtwilley@lsu.edu • www.laseagrant.org

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July 22, 2014

UNIVERSITY OF CALIFORNIA - BERKELEY

Earth and Planetary Sciences

45cm x 60cm x 5m Research Flume

DETAILED PRICE BREAKDOWN

1. **45cm x 60cm x 5m Research Flume**..........$141,685.00
   45.0cm wetted depth (60cm total height) x 60.0cm wide x 5m long working section. Discflo Model 402-12-2D pump belt-driven by AC Motor. Variable frequency controller for regulating pump shaft RPM. 25L/s (400 gpm) maximum flow rate. Arranged for either 230VAC or 460VAC/3ϕ/60Hz Electrical Service.

2. **Magnetic Flow Meter with Transmitter**..........$6,725.00
   Rosemount, Inc. Model 8705 Magnetic Flowmeter. 2" diameter

3. **Slope Mechanism**..........$32,890.00
   Modifications and additions to the flume supporting framework to allow for motorized adjustment of the flume slope. Slope range: 0% to +3%.

4. **Gauge Carriage and Rails**..........$5,365.00
   Precision ground stainless steel round rods, with intermittent supports, will be fitted to the bars at the top of both channel sidewalls. A carriage fabricated of anodized aluminum and riding on four linear bearings, will be provided. A device will be fitted that will enable the carriage to be locked at any position along the length of the rail.

5. **Digital Point Gauge**..........$2,085.00
   An **ELD**, proprietary design, manually positioned point gauge with a precision, electronic digital readout will be furnished. The range of the standard unit is 20.00cm (7.87"). A variety of points will be provided to allow measurement over the depth of the channel.

6. **Shipping via Specialized Motor Freight**..........$5,690.00
   Lake City, MN to Berkeley, CA

7. **On-site Installation Services**..........$6,775.00
   An **ELD** representative to assist in the unloading, placement, assembly, and commissioning of the system. UC Berkeley responsible for providing all equipment necessary to move components to the laboratory site and a mechanically/physically able individual to assist in the installation. This is estimated to take five (5) working days.

TOTAL:..........$201,215.00

Please note:

(1) This quotation (reference quotation no. Q006214) will be valid through October 3, 2014.

(2) Our current production schedule indicates that shipment could be affected approximately 26 weeks after receipt of an order.

(3) Terms of Payment: 25% with purchase order.
65% net 30 days from date of shipment.
10% net 30 days after 21 day acceptance period to start after completion of flume installation and commissioning.