National
Center for
Earth-surface
Dynamics

2007 Annual Report

An NSF Science and Technology Center

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General Information

1.a General Information

Date Submitted	May 01, 2007
Reporting Period	April 01, 2006 through March 31, 2007
Name of the Center	National Center for Earth-surface Dynamics
Name of the Center Director	Chris Paola
Lead University	University of Minnesota, Twin Cities
New Participating Institutions	Professor Robert Twilley Dept of Oceanography and Coastal Sciences 1002-Y Energy, Coast & Environment Bldg Louisiana State University Baton Rouge, LA 70803 Tel: 225/578-8806 Fax: 225/578-6307 Email: rtwilley@lsu.edu Purpose: To research wetland development and geomorphic characteristics of the Wax Lake and Atchafalaya delta regions.
Changes in Contact Information	Associate Professor David Mohrig Jackson School of Geosciences University of Texas, Austin 1 University Station C1100 Austin, TX 78712-0254 Tel: 512/471-2282 Fax: 512/471-5585 Email: mohrig@mail.utexas.edu

1.b Biographical Information for New Faculty by Institution

Professor Robert Twilley of Louisiana State University and Professor Fotis Sotiropoulos of the University of Minnesota have joined NCED as co-PIs. Biographical information for Twilley and Sotiropoulous are found in Appendix A: Biographic Information on New PIs.

1.c Annual Report Contact Person

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I. Context

This section is intended to place the results reported in the main body of this Annual Report in the context of the National Center for Earth-surface Dynamic's (NCED) Strategic and Implementation Plan (SIP) and its past history. This year (2006-2007) was a crucial year for NCED in that, along with all six Science and Technology Centers (STCs) in the "class of 2002", this year was the one in which we were evaluated for renewal for a further five years of activity. The timeline for the renewal has spanned nearly the whole of the current reporting period. The renewal proposal was submitted on November 1, 2005. Mail reviews were available to us in the spring of 2006. The critical evaluation site visit took place May 16-17, 2006. The report from that site visit is included in this Annual Report as Appendix I: Review Site Visit Report. During the summer and fall of 2006, NCED and the other 2002 STCs underwent a lengthy internal evaluation by the NSF Director's Review Board (DRB). The result of this was a favorable decision to renew NCED; we received official confirmation of this from NSF on March 9, 2007. A summary of the DRB panel's findings was presented to the NCED Director and Co-director by NCED's NSF technical coordinators (Rich Lane and Mike Ellis) on April 13, 2007.

As the renewal process concluded, we began work on tuning up our SIP for the next five years and also on implementing some of the improvements requested by the DRB. Some of the requested changes were in line with management decisions we had already made. One major change was that we moved to project-based rather than PI-based funding allocation. We did this by formalizing the Principal Investigator (PI) proposal process and allocating resources via the Integrated Projects (IPs). With regard to the SIP, the modifications are evolutionary, with the signal exception of the Subsurface Architecture (SA) IP. The major restructuring of SA is discussed in the next section and in the SA sections of this document. We note that the new SIP has not been finalized (nor has it been submitted to NSF for approval); as requested by the DRB, the SIP revision process will be completed this summer. But because the new sub-projects are already in use, the provisional revised SIP is included in this report as Appendix J: Provisional SIP.

Research

NCED's unifying scientific goal is expressed in our Statement of Purpose ("vision statement"): *to catalyze development of an integrated, predictive science of the processes shaping the surface of the Earth, in order to transform management of ecosystems, resources, and land use.* The two key words in this expression are *integrated* and *predictive*. NCED arose out of a consensus that progress in predicting the so-called critical zone—essentially, the near-surface environment—was being impeded by a stifling combination of disciplinary fragmentation (eg, geomorphology, ecology, hydrology, geochemistry, social sciences) and a tradition of descriptive science in some of the key disciplines. NCED is the first federally funded center specifically focused on integrated, predictive critical-zone science. Our PI group represents all of these major earth-surface disciplines. What binds us together, beyond a common interest in the Earth-surface environment, is a commitment to collaborating across our disciplinary specializations to reach our goal of critical-zone prediction. The practical side of our goal is restoration. Restoring environmental function, by its very nature, is based on prediction—what will be the outcome of a particular course of action (changing land use, modifying the form of a river channel, breaching a levee)? Currently, restoration—the most prominent facet of environmental management—is often done using "seat of the pants" methods with little or no scientific basis. Replacing that with an approach based on analysis and prediction would truly transform the way we manage the Earth-surface environment.

Apart from the renewal of NCED, carrying with it a national commitment to Earth-surface science, we note with pleasure that 2006 brought the realization of two major programs whose creation we have enthusiastically supported. The first is the Community Surface Dynamics Modeling System (CSDMS) project, which aims to develop a coherent modeling framework for predicting the evolution of the Earth's surface. It will be the first of its kind in the world. CSDMS is the brainchild of James Syvitski of the Institute of Arctic and Alpine Research (INSTAAR), University of Colorado, who is the founding director. CSDMS focuses on modeling, emphasizing large-scale modular numerical modeling, and thus nicely complements NCED, which focuses on process understanding and initial algorithm development. We hosted a final "preflight" workshop meeting in December 2005 for the proposal to fund the CSDMS, which was submitted in February 2006. Now that CSDMS is funded, we have plans in place to cement this close relationship via a postdoctoral research associate—and hopefully more than one in the future—to serve as a liaison and make sure that insight and information are transferred seamlessly between our two centers.

The second major development is the announcement by NSF of the new program for Critical-Zone Observatories (CZOs). The CZO program has been developed within NSF under the leadership of Surface Process Section Head Art Goldstein and NCED technical program officers Mike Ellis and Rich Lane. NCED Director Chris Paola, working with colleagues Sue Brantley (Director, Earth and Environmental Systems Institute, Penn State) and Rick Hooper (Director of the Consortium of Universities for Advancement of Hydrologic Scienc (CUAHSI) and NCED External Advisory Board (EAB) member), was heavily involved in the development and promotion of this new initiative.

Together, these new initiatives will involve hundreds of researchers and millions of dollars in funding. Along with the NCED renewal, they indicate that critical-zone science has entered a phase of vigorous growth and transformation. The transdisciplinary, predictive approach that NCED has championed is spreading, not just at the grass roots level but now also at the level of major research organizations. We predict confidently that in only a few years it will be the norm in Earth-surface science.

NCED research organization

Since 2006, NCED's research has been organized into three IPs: Desktop Watersheds (DW), Stream Restoration (SR), and Subsurface Architecture (SA). DW and SR have been the most closely linked in that both focus directly on environmental issues, and their primary application areas are to environmental management. SA was somewhat different in that it focused on translating insight on surface dynamics in depositional systems to prediction of 3D structure in the subsurface. Its primary application area was the oil industry. The destruction wrought on New Orleans and the Gulf Coast by Hurricane Katrina in August/September, 2005 accelerated our ongoing effort on delta dynamics and restoration. As the delta restoration program evolved, it became increasingly clear that developing the necessary predictive tools for designing a sustainable restoration program is a tremendous effort—enough to require the entire focus of the SA IP and more. (A summary of plans for extending the delta restoration project is included in the SA section below.) Thus, in 2006, we made the difficult but necessary decision to make delta restoration the entire focus of the SA IP. We stress that this is not a new direction for SA; it is simply a pragmatic narrowing of its focus to the single activity that is the highest social priority and the one best connected to the other IPs. The decision to focus on delta restoration means that NCED's research program is now entirely aimed at developing tools for predicting and restoring landscapes. There is a pleasing symmetry in the way that DW is aimed at erosional landscapes featuring tributary channel networks; SA is aimed at deltaic, ie, depositional/distributary landscapes; and SR is aimed at individual reaches, taking into account their connection to the whole network.

The revised focus of SA on delta restoration capitalizes, in an interesting way, on our original focus on the surface-to-subsurface connection. In a nutshell, the delta restoration problem arises from the fact that subsidence—whether natural or accelerated by humans—has continued in the delta even as we have engineered the Mississippi and its distributaries so as to drastically reduce the delivery of sediment to the delta top. The result is land loss at a rate estimated at one acre every 30 minutes. The lost land—mostly marsh and coastal forest—represents lost environmental services that include habitat, geochemical processing, fishery support, recreation, and a physical buffer against storms. The general idea of delta restoration is to develop methods whereby guided natural processes can rebuild at least part of the delta-top marshland and forest. The principal means of doing this would be through controlled avulsions (channel diversions) that would release water and sediment into currently sediment starved areas. Sediment alone is not enough—the process of land-building is fundamentally a bio-physical process in which biotic stabilization and trapping of sediment plays a crucial role.

Diversions on a scale to rebuild a major delta would be a very large project—perhaps the largest natural engineering project ever attempted. Yet we know relatively little about how the delta worked, before human interference, when it maintained itself naturally against subsidence and sea-level rise. The modern delta, heavily altered by humans, provides only limited opportunity to study natural delta-building processes (the best example, Wax Lake Delta, is NCED's primary delta field site). However, thanks to the self-recording nature of depositional systems, an archive of natural delta forms and case studies lies just beneath the surface—if we can learn to recover the information stored there and use it quantitatively. Hence the new SA project structure combines development of engineering-style predictive tools (eg, numerical models of delta lobe growth) with a program to extract information on natural-system behavior from the stratigraphic record and harness it for environmental restoration. This initiative draws on everything we have learned over the past five years about how surface dynamics are recorded in subsurface strata and also on our extensive collaboration with the oil industry, whose cooperation we will need to obtain critical subsurface data. The delta initiative will be, to our knowledge, the first-ever large-scale attempt to “reverse engineer” a natural system from the sedimentary record. To carry it off, we need a bigger team than NCED can support. Hence, with NCED PIs and funds serving as a nucleus, we have formed a new, larger group that will develop the Mississippi Delta Restoration Program. We began making our case with NSF last June at a meeting with then-Assistant Director Margaret Leinen, her associate Marge Cavanaugh, NCED NSF managers Rich Lane and Mike Ellis, and many other NSF officials. We are working intensively with our growing PI team, with input from NSF, to develop an extended program for delta restoration by harnessing natural delta-building processes. Now that SA has modified its focus to delta prediction and restoration, NCED’s three IPs are more closely interconnected than ever. They form three focal areas within a web of interdisciplinary research. Questions that unify our research across all the IPs include:

1. What are useful approximations to the dynamic laws governing coupled ecologic, physical, and geochemical processes that shape landscapes, and what is the most effective way to apply these imperfectly known laws to critical-zone prediction?

2. How do local interactions create and interact with recurring coherent structure in the landscape over a range of time and space scales, and how can we exploit these recurring structures to improve critical-zone prediction?

3. How can we combine improved prediction of critical-zone processes with human decision-making in order to transform environmental management and restoration?

Overall, we are pleased with the convergence of NCED research over the past year, even as we look forward to improving it further. The year’s highlights from each IP are summarized below.

Deskstop Watersheds

The goal of DW is *to discover and advance the fundamental relations needed to predict landscape evolution and to model the coupling of ecosystem, landscape, and land-use dynamics.* This year, we made extensive improvements in our monitoring capability at our focus field site, the Angelo Coast Range Reserve (ACRR). The wireless network is up and running and will be expanded further this year. Sensors for a variety of environmental variables and biotic responses (including acoustic and video recordings) are being deployed according to sampling designs guided by DW hypotheses.

Significant progress has been made in understanding sediment transport, channel incision, and sediment routing processes. We have: 1) developed a new model for landslide size; 2) obtained dates and rates of erosion and channel incision in the ACRR that suggest variations that may be driven by climate; 3) dated past movement on a large, deep-seated landslide at the ACRR; 4) developed a model for stochastic production and transport of soil by tree throw; 5) documented, for the first time, that granular flow incision into rock can be scaled by inertial stresses of the flow; 6) advanced a new theory for coverage effects and suspension wear on fluvial incision into bedrock; 7) explained the slope dependency in critical shear stress in steep shallow flows (typically over boulders); and 8) developed models that show the transport of sand across gravel beds.

At the ACRR, we have been mapping ecosystem processes (eg, denitrification, stream metabolism), as well as distributions, abundances, performances, and interactions of key organisms, through the drainage network and investigating environmental controls of these patterns and processes. We are attempting prediction through two routes. One route is empirical: Use engineering approaches (eg, statistical upscaling and dimensionless analysis) to discover scale-free predictors of biomass or process intensity that can be read or inferred from topographic maps. The other route uses targeted experiments to determine why changes in ecological regimes or ecosystem processes occur along environmental gradients (eg, down drainage networks or across valleys), then combines process-based understanding with modeling to predict how thresholds between these regimes would shift with land use, climate, or biotic change.

A major advance this year is that we have nearly completed a release of a DW application model, “Ripple,” that uses topographic data, field empiricism, and theory to relate digital topographic data to habitat carrying capacity and to population dynamics of coho salmon. The model is a collaborative effort with Stillwater Sciences and has an easy-to-use interface. Presentations to various government agencies have generated great interest in the model, so much so that we expect to see it applied outside of ACRR in the year to come.

Significant progress has also been achieved over the past year in exploring how the unprecedented topography and vegetation resolution afforded by Light Detection and Ranging (LIDAR) data (provided for ACRR in cooperation with the NSF National Center for Airborne Laser Mapping, NCALM) can: (a) inform feature extraction at the hillslope to the river network scale, (b) guide fieldwork by identifying physically distinct regimes from the statistically distinct signatures different processes leave on the landscape, (c) provide guidance for sediment transport model development and validation especially at the hillslope scale, (d) refine hypotheses related to the emergence of scaling in the hydrologic response (storm hydrographs and flood peaks) in view of documented scaling at hillslope flow paths and river network structures, and (e) pose hypotheses related to vegetation organization driven by topographic attributes and river network organization.

We completed a unique and extensive set of spatially explicit measurements of nutrient spiraling and stream metabolism across the Eel River stream network. We have also finished research to understand the role of invertebrate grazers and consumer-resource stoichiometry on nutrient cycling. Our work at the ACRR has revealed physiographic controls of stream nutrient sources and sinks at the watershed scale. One example is for dissolved oxygen (DO) flux and denitrification hot spots. DO in aquatic sediments inhibits the activity of denitrifying bacteria in ecosystems, while carbon, nitrate, and nitrite supplies stimulate them. Our work linked DO measurements across a range of scales including laboratory flume, large open channel setup (StreamLab), and the field (ACRR). The results were explained by a similarity model for describing DO flux to sediments controlled by large-scale fluid motions.

Researchers in the DW collaboration are iterating between maps, experimental data, and theory to generate dynamic mosaics of prediction across landscapes, with scaling empiricisms that predict responses of interest over finite regions but break down where thresholds in environmental conditions tip landscape dynamics or food web interactions and ecosystem responses into new regimes. Discovering the fundamental processes underlying both the regularities and deviations remains a central motivation for this work.

Subsurface Architecture

As discussed earlier, the SA IP has undergone a major transformation; bringing this about has been a major focus of the SA team this year. The revised SA goal is *to develop methods to extract quantitative information on structure and dynamics of depositional systems from stratigraphic records and apply this information to landscape prediction and restoration.* This section summarizes SA research including that conducted under the previous version of the SIP.

A new study of the construction of leveed channels and overbank surfaces by depositional turbidity currents linked measurements of submarine levees and stratigraphy from the offshore Borneo with a laboratory experiment that resolves the processes controlling submarine levee growth. We found that levee taper rapidly increased during early levee growth then transitioned to a slower taper growth rate at a channel relief exceeding approximately 30 m. Results from laboratory experiments indicate that the degree of channel confinement and vertical structure of the sediment concentration profile are the most important parameters controlling levee growth. Using these observations, we developed a levee growth model based on an advection-settling scheme coupled to a sediment concentration profile described by the Rouse profile. We identified a reasonable set of flow conditions that produced a levee taper growth history similar to observations. The measurements and associated model of the morphodynamics of levee growth in aggrading channel settings can also be applied to terrestrial levee dynamics.

The main XES activity this year was completion of a long-planned experiment on interaction of multiple sediment sources in an asymmetrically subsiding basin modeled after the Rio Grande rift. This work contributes to the SA IP via its theme on tectonic steering of channel systems. The experiment had four sediment/water sources: two on the footwall side, one on the hanging-wall side, and one axial. Thus far, the main finding has been that the relative sizes of the domains controlled by the four sediment sources is almost entirely controlled by the ratio of sediment supply to subsidence; water supply does not seem to play a major role. In a sense, the boundaries between the tranverse and axial domains can be thought of analogous to a shoreline with strong alongshore transport.

In addition, we carried out a series of experiments with colleagues at ExxonMobil to demonstrate that a new cohesive-sediment simulant mix they have developed can indeed capture the spatial structure of fine-grained deltas like the Mississippi Delta. The shoreline of such fine-grained deltas is much more irregular than for the non-cohesive case, which we believe will influence the distribution of biota sensitive to the total length of the land-water interface. To help clarify the distribution of habitat types, we developed what we believe is the first quantitatively based method to distinguish channel edges from true shoreline. We also developed prototype cellular channel-avulsion models that we have implemented in various forms (ie, different sediment transport dynamics, including or excluding backwater effects) to determine their affects on delta dynamics.

Finally, we have been working intensively, with input from NSF, on a new initiative in delta restoration that will extend the SA IP to a larger group of colleagues.

Stream Restoration

The SR goal is *to advance the science and practice of stream restoration by conducting and coordinating research and by working with agency and industry partners to identify information needs, develop improved tools, and transfer this knowledge into practice.* This year, work in the SR IP balanced research, partner interactions, tool development, and training. The stream restoration context of NCED research can be broadly organized into three categories: placing stream restoration projects in their watershed context, predicting the physical and biological response of stream channels to changes in driving conditions, and developing predictive links between stream restoration preferences, objectives, and actions. Watershed context is an essential area of overlap with the DW IP. Advances made in identifying regime thresholds and the effect of watershed location are essential for identifying favorable locations for management actions. The emergence of dynamic DW models, together with the increasing availability of digital archives, will support development of landscape history at specific locations, allowing past and future trends at proposed restoration sites to be more accurately predicted and interpreted. Watershed context is also a dominant factor in the new SA focus on restoration of the Mississippi Delta. A particular focus of NCED watershed research is routing of sediment through reaches and channel networks. We seek to extract essential grain-scale mechanisms for application to the reach and network scale, while also developing geochemical analyses (sediment fingerprinting) for integral summary of sediment sources. Progress on sediment modeling has been made at the flume to the reach scale, including the studies of the movement of fine sand through coarse-grained systems and the development of sediment routing models that incorporate sediment storage in pools, eddies, and floodplains.

Predictive stream restoration requires an ability to predict the physical and biological response of stream channels to changes in initial and boundary conditions. We have made important progress in developing predictive relations for streambed composition as a function of water and sediment supply, including model studies of vertical and lateral grain sorting, advances on a general model for streambed sorting, tests of models of gravel augmentation and sediment pulses, and the transport of fine sediments over coarse beds. At the section scale, we continue our exceptional success in producing realistic dynamic scale channels with vegetation, we have developed additional relations for stream channel geometry, and we are applying channel/floodplain exchange models to field applications. Watershed position, channel configuration, and flow regime strongly control ecosystem response. We have demonstrated the concept of field-scale controlled experiments with high-resolution instrumentation in a major collaborative effort intended to support development and testing of predictive eco-physical models of the connection between structures, disturbance, and ecosystem response. We have also made important progress in scaling physical/biological interactions from lab to field, which is essential if we are to take full advantage of the possibilities offered by controlled laboratory experimentation.

Prediction of cause and effect incorporating the watershed context is a necessary, but not sufficient, condition for transforming stream restoration to a predictive practice. Implementation requires an explicit connection to stream restoration policy, decision-making, and implementation. We work to understand quantitatively how to link project goals to public preference, regulatory and policy guidelines, and management actions. We establish the link between stakeholder preferences and restoration options by determining stakeholder preference regarding stream restoration objectives and actions and the willingness to pay for restoration benefits. We have developed economic models of the role of uncertainty in restoration outcomes and are using survey methods to evaluate their affect on public preference. Because restoration objectives typically conflict, and alternative locations and methods are commonly possible, implementing improved prediction in restoration decision-making requires a consistent basis for evaluating the tradeoffs. We have evaluated the conditions for implementing decision analysis tools in the restoration context and are developing both stochastic and deterministic decision models, which will be implemented in a collaborative field effort with NCED research identifying sediment and nutrient sources.

We made significant progress in Year 5 in developing new initiatives that focus multi-disciplinary collaboration in projects that require a center mode of operation. We initiated an experimental program, StreamLab, of full-scale experiments on linked physical/chemical/biological processes. Its essential features include an explicit multi-disciplinary focus, experimental control at the field scale, and the use of advanced technology to support detailed observations typical of small-scale lab experiments. A sound understanding of both local mechanisms and broader interactions is needed to develop predictive models in river science. The solution is to conduct experiments at full scale while maintaining experimental control and using instrumentation that can resolve both local and full-scale processes. These experiments address a general need in river science; the immediate motivation within the SR IP is to better predict the ecosystem response to intentional modifications to the stream system. We believe that we demonstrated the StreamLab concept successfully in Year 5 and are now developing an expanded version—Outdoor StreamLab. A multi-scale, multi-disciplinary experiment is necessarily a large collaborative venture. StreamLab06 involved a 40 member research team of engineers, geologists, and ecologists, which included nine NCED faculty, as well as postdoctoral research associates, graduate students, visiting scientists, environmental consultants, undergraduate assistants, and research staff. This collaborative work would be difficult to achieve outside of the organization, support, and commitment of a center.

An important step forward in center-mode collaborative research was also achieved in the initiation of an integrated project on sediment and nutrient loading in the Minnesota River Basin. This new project, largely funded from outside NCED, provides two things that NCED evaluators have urged us to pursue: a demonstration site for stream restoration and a field site in the Midwest. With leveraged funding from the Minnesota Pollution Control Agency, we will develop a sediment budget for the Le Sueur River watershed, Minnesota, one of the main contributors to sediment and nutrient loading in the Minnesota River Basin. At the same time, we are using surveys to determine public preference and willingness-to-pay for management practices that will reduce sediment and nutrient loading. We are also developing decision analysis models to support evaluation of tradeoffs and the incorporation of improved scientific information in the decision-making process. Locating management actions for reducing river loading is an advantageous problem for a collaborative physical/social decision-making research project. This project will involve at least six NCED PIs including both NCED and leveraged funds; the development of new approaches and trans-disciplinary integration requires a center-mode of support.

Research Synthesis

NCED uses several metrics to monitor research synthesis and added value (discussed more in the Management section). One simple measure is the fraction of PIs who are actively contributing to more than one IP; this year that number has dropped slightly to 78%, which reflects changes in the PI group and the magnitude of our commitment to delta restoration. Another method is quantitative diagrams showing connections among the PIs. The present state of these connections, relative to the initial state when NCED started, is shown in Figure 1 below. The outcome is satisfying and reflects both the maturity of the center and the strong commitment of the PIs to collaborate to achieve our goal of Earth-surface prediction.

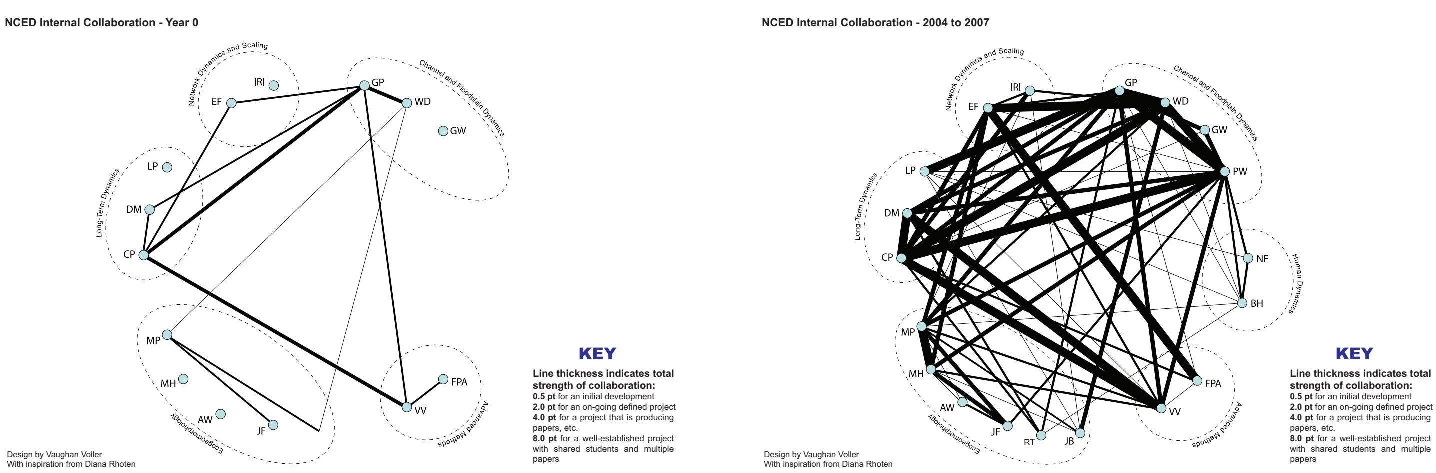

Figure 1: *Connections amoung NCED PIs*

Another major indicator of research integration is published papers that provide clear evidence of center-mode research. This includes research syntheses, papers involving multiple PIs (especially PIs at different institutions), and papers that reflect new collaborations attributed to the center. Listed here are papers for 2006-2007 that fall in these categories (NCED PIs are in bold):

Barnes, E., **M.E. Power**, **E. Foufoula-Georgiou** and **M. Hondzo** (in review), Predicting and upscaling Nostoc biomass in a gravel-bedrock river: combining local predictors with hydrogeomorphic scaling laws, *Geophysical Research Letters*.

Cantelli, A.; Wong, M.; **Parker, G.**; **Paola, C.**(in review), Numerical model linking bed and bank evolution of incisional channel created by dam removal, Water Resources Research

Cui, Y.; **Parker, G.**; Braudrick, C.; **Dietrich, W. E.**; Cluer, B.(2006), Dam removal express assessment models (DREAM). Part 1: Model development and validation, Journal of Hydraulic Research

Cui, Y.; **Parker, G.**; Braudrick, C.; **Dietrich, W. E.**; Cluer, B.(2006), Dam removal express assessment models (DREAM). Part 2: Sample runs/sensitivity tests, Journal of Hydraulic Research

Kim, W.; **Paola, C.**; Swenson, J. B.; **Voller, V. R.**(2006), Shoreline response to autogenic processes of sediment storage and release in the fluvial system, Journal of Geophysical Research- Earth Surface

Lashermes, B., **E. Foufoula-Georgiou**, and **W.E. Dietrich** (in review), River network extraction from LIDAR using wavelets, Geophysical Research Letters

Lauer, J. W.; **Parker, G.**; **Dietrich, B.**(in press), Response of the Strickland and Fly River confluence to post-glacial sea-level rise, Journal of Geophysical Research Earth Surface

McNeely, F. C.; **J. C. Finlay**; **M. E. Power**(in press), Grazer traits, competition, and carbon sources to a headwater stream food web, Ecology

O'Connor, B. L.; **M. Hondzo**; D. Dobraca; T. M. LaPara; **J. C. Finlay**; P. L. Brezonik(2006), Quantity-activity relationship of denitrifying bacteria and environmental scaling in streams of a forested watershed, Journal of Geophysical Research

Parker, G. P.; **Wilcock, P. R.**; **Paola, C.**; **Dietrich, W. E.**; Pitlick, J.(in press), Quasi-universal relations for bankfull hydraulic geometry of single-thread gravel-bed rivers, Journal of Geophysical Research

Parker, G.; Muto, H.; Akamatsu, Y.; **Dietrich, B.**; Lauer, J. W.(in review), Unraveling the conundrum of river response to rising sea level: from laboratory to field. Part II. The Fly-Strickland River System, Papua New Guinea, Sedimentology

Parker, G.; Muto, T.; Akamatsu, Y.; **Dietrich, B.**; Lauer, J. W.(in review), Unraveling the conundrum of river response to rising sea level: from laboratory to field. Part I. Laboratory experiments, Sedimentology

Power, M. E.; Parker, M. S.; **Dietrich, W. E.**(in review), Seasonal reassembly of river food webs under a Mediterranean hydrologic regime: Floods, droughts, and impacts of fish, Ecological Monographs

Toniolo, H.; **G. Parker**; **V. Voller**(in press), Role of ponded turbidity currents in reservoir trap efficiency, Journal of Hydraulic Engineering

Tornqvist, T. E.; **Paola, C.**; **Parker, G.**; Liu, K.; **Mohrig, D.**; Holbrook, J. M.; Twilley, R. R.(in press), Comment on "Wetland Sedimentation from Hurricanes Katrina and Rita", Science

Voller, V. R.; Swenson, J. B.; Kim, W.; **Paola, C.**(2006), An enthalpy method for moving boundary problems on the earth's surface, International Journal of Numerical Methods for Heat and Fluid Flow

Finally, another indicator of center-added value in research is the increasing number of graduate students and postdoctoral research associates who are co-advised or co-supervised by multiple PIs within and across NCED institutions. Current examples are given in the table below.

Postdoctoral research associates	
Nancy Brown	Wilcock and Mohrig
Karen Gran	Voller and Paola
Ion Iorulescu	Foufoula-Georgiou and Dietrich
Doug Jerolmack	Mohrig and Paola
Wonsuck Kim	Parker, Paola, and Mohrig
Bruno Lashermes	Foufoula-Georgiou and Dietrich
Cailin Orr	Wilcock and Finlay
Wendy Palen	Power and Foufoula-Georgiou
Michael Puma	Rodriguez-Iturbe and Paola
Jane Staiger	Perk and Parker
Matt Wolinsky	Voller and Paola
Graduate students	
Phairot Chatanantavet	Parker, Foufoula-Georgiou, and Porté-Agel
Ted Fuller	Paola and Perg
Amy Hanson	Hondzo and Finlay
Mike Limm	Power, Dietrich, and Hondzo
John Martin	Paola and Mohrig
Paola Passalacqua	Porté-Agel, Foufoula-Georgiou, and Paola
Rebecca Stark	Hondzo and Finlay
Michal Tal	Paola and Foufoula-Georgiou

As discussed earlier, the three IPs focused the application areas of NCED's core science: the dynamics of channels and channel networks. This common scientific core, across scales and environments, is a primary vehicle for integration and synthesis of NCED research. This common core provides a network of pathways for cross-fertilization and application of theoretical ideas, observational techniques, and research findings across apparently disparate fields. Many can be used to link education and research as well. A second integrating mechanism is direct incorporation of results from one IP into other IPs. What follows are examples from this year's initiatives:

StreamLab06. Collection of high-quality data, sensor testing and calibration, and improvement of routing laws were all part of the StreamLab06 effort, and this work is ongoing. We have now enhanced this effort with our new "Virtual StreamLab" by bringing together NCED PI Fernando Porte-Agel with our newest NCED PI, Fotis Sotiropoulos, to apply advanced methods of computational fluid dynamics to study the interaction of turbulence, large particles and structures, and fish. The StreamLab project is "headquartered" in SR, but the results are critical to DW, where they will be used in sediment routing, estimation of local channel properties in watersheds, prediction of biological activity, and prediction of fish dynamics. Advances in coupling fluid flow, particles, and biology will eventually also have an impact on delta restoration, where the emphasis shifts to fine particles and plants.

Flow, microbes, and nutrient dynamics. We note that nearly all of our current research in ecology, microbial geochemistry, and nutrient dynamics is equally relevant to DW and SR, and for reporting purposes would have been equally at home in either section. We are looking forward to exploring potential applications of microbial dynamics in delta restoration as well. Ongoing ACRR-based work on how channel processes control denitrification opens the way to predicting nitrate from digital watershed data (DW), to designing channels to optimize the flow of nitrate and other nutrients in stream restoration projects (SR), and to the potential side benefit of wetland restoration in deltas in reducing nitrate flux to the ocean (SA). The field-based results are enhanced by results from StreamLab06, which included study of connections between water, sediment, and solute flux and fundamental ecological processes such as nutrient uptake.

Vegetation and channels. NCED experimental work over the last three years has revealed the extent to which vegetation interacts with physical channel processes to set channel geometry (cross section and planform) and migration kinematics. In Year 5, we added new analysis of how a floodplain can assemble through aggregation of vegetated patches. These results are important to designing channels with vegetated banks (SR), development of vegetated islands in deltas (SA), and predicting where vegetation is expected to stabilize bars in a watershed (DW).

Channel extension into standing water. There is a fundamental question about how channels extend themselves into standing water. Field evidence shows that this is possible by extension of the channel tip and construction of levees, but how it works mechanistically is not understood, and therefore it has not been modeled. NCED work in this area involves a collaboration between NCED PIs William Dietrich and David Mohrig and their students. The process is critical to deposition on floodplains, and to channel development in deltas, so it is fundamental to SA and SR. SA partner ExxonMobil, for example, has invested a good deal of research money in understanding depositional processes associated with this type of channel development. But since streams and floodplains are intimately connected, both physically and ecologically, floodplain restoration is often a vital (though sometimes overlooked) aspect of SR as well. The dynamics of small channels on floodplains and building into floodplain lakes is central to understanding how floodplains maintain themselves.

Scaling and statistics. NCED's expertise in scaling comes primarily from our hydrologist (NCED PI Efi Foufoula-Georgiou), who has applied scaling methods extensively in analyzing environmental variables such as rainfall, streamflow, and drainage-network structure. Through NCED, we are extending application of these methods to new areas such as grain-size variation in tributary basins (DW), uncertainty in stream restoration (SR), and spatial statistics of deltaic networks (SA).

Education

The Education Initiative's goal is *to bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED's key mission areas of land, resource, and ecosystem management.* This year, NCED Education Initiative efforts focused on deepening the impact of existing successful programs while at the same time broadening the audiences reached. Our successful integration of research with public education, which began with the Earthscapes and Big Back Yard (BBY) initiatives at the Science Museum of Minnesota (SMM), flourished as we began intense development work on a 5,000 square-foot, nationally traveling exhibition about water. This project increased in size and scope when the SMM and the American Museum of Natural History (AMNH) both learned that the other was producing an exhibition about water and decided to merge their efforts. The water exhibition now will be 7,000 square feet, and two versions will be produced—one to tour North America and the other to tour overseas venues. Use of our table-top dam removal experiment, based on visitor research, continued to expand to new audiences in formal and informal education, and its success led us to develop a second model, the Delta Box, which has already met with similar enthusiasm nationally and is helping us expand our impact on undergraduate education. Our Earthscapes Teacher Institute and River Restoration Residency programs continued to be active, with resulting talks and posters at professional conferences. Development work on our research-grade visualizations was concentrated in the area of public education but testing of the educational effectiveness of visualizations continued. A new undergraduate geology textbook, featuring many of these visualizations, will be published in June 2007. Many of our methods and materials were featured in two very well-attended NCED-sponsored workshops, a one day Hands-On Inquiry Based workshop for teachers of grades 4-16 at the fall 2006 meeting of the American Geophysical Union (AGU) and the On The Cutting Edge - Professional Development for Geoscience Faculty Teaching Sedimentary Geology in the 21st Century workshop held July, 2006, at the University of Utah. Finally, our Graduate Student program flourished with students participating broadly in all aspects of NCED research, as well as planning another graduate-students-only retreat, presenting many of NCED's weekly videoconferences, and conducting international research through our NSF-funded International Research Experience Program (IREP).

Diversity

The Diversity Initiative's goal is *to increase participation by underrepresented groups in NCED scientific disciplines until minority representation is continuously reflective of the US national population. This includes an immediate improvement in participation by members of all underrepresented groups in NCED itself, and a specific focus on improvement in representation of Native Americans in NCED-related disciplines.* NCED continues to make strides towards achieving this goal. Diversity among our researchers increased this year across the board: graduate, postdoctoral, IP leadership, and an associated PI. The addition of these researchers to NCED has increased the fraction of researchers from underrepresented groups from 13% of our total research group in Year 4 to 19% in Year 5, bringing us closer to parity with the US population. Two NCED graduates from underrepresented groups took up faculty positions this year: NCED graduate student Aric Shafran and NCED Postdoctoral Research Associate Juan Fedele. Shafran, advised by NCED PI Nicholas Flores, received a PhD from the University of Colorado at Boulder and will become a tenure-track assistant professor at California Polytechnic State University in San Luis Obispo, California. Fedele, advised by NCED Director Chris Paola, is now a tenure-track assistant professor at St Cloud State University.

NCED's Faculty-to-Faculty Program, initiated in Year 4, brought two faculty members to SAFL in Year 5 and involved a third faculty member in NCED research. Visiting faculty gave seminar talks, toured our research facilities, and met with NCED faculty and research staff. We are negotiating plans for joint research with one faculty member now, another faculty member is advising an NCED undergraduate student in the field this summer, and the third faculty member is doing research with NCED PI Peter Wilcock this summer on a project that will also involve students from our Undergraduate Summer Internship Program (USIP).

In Year 5, NCED's *gidakiimanaaniwigamig* (Our Earth Lodge) and *ando-giikendaasowin* (Seek To Know) programs brought over 200 middle- and high-school students to Native American Math and Science Camps and to participate in other hands-on science activities related to NCED research. New partnerships brought scientists from the University of Minnesota, from tribal entities, and from other institutions across the country to lead activities at our camps. Camp activities included geology of the local area, lake core sampling of a wild rice and nonwild rice lake on a reservation, and dam removal on a salmon river. We were especially excited to have the University of Minnesota's Limnological Research Center staff come to our winter camp and core two lakes on the Fond du Lac Reservation and then examine the cores with the youths in our camps. Students in our programs have shown increases in their math and science grades and school attendance since the inception of the program. In addition, a number of students are now enrolled in advanced math and science courses. NCED is serving as a model for other groups by presenting workshops at professional conferences (Society for the Advancement of Chicanos and Native Americans in Science (SACNAS), American Indian Science and Engineering Society (AISES), STC Director's Meeting) on creating math and science programs for Native American youths. Students' enthusiasm can also be seen by their participation in the NCED/ Fond du Lac Tribal and Community College -sponsored American Indian Regional Science Fair, which had 240 middle- and high-school student exhibitors in its first three years. From this group, NCED collaborated with the Fond du Lac Tribal and Community College and the Ojibwe School to send 40 students, between 2005-2007, to Albuquerque to attend the AISES NAISEF. In 2007, 16 of our students attended and brought home 20 medals and awards, including special engineering awards from IBM and a women in science award from the Association for Women Geoscientists (AWG). Five of our students took medals in the National American Indian Science and Engineering Fair (NAISEF) math competition this year. One *gidakiimanaaniwigamig* participant, who took her science project to the Minnesota State Science Fair, was chosen to represent Minnesota at the Intel International Science and Engineering Fair (ISEF).

Knowledge Transfer

The Knowledge Transfer Initiative's goal is *to create and maintain two-way communication and exchange among our applied science stakeholders, the broader research community, and NCED participants, in order to ensure that NCED research is informed by societal needs and to ensure that NCED results are disseminated*. Because each of the three IPs was designed around a set of applications in addition to basic science, we have incorporated our knowledge activities directly into the IPs themselves in the body of this Annual Report. Knowledge transfer begins with relationships and activities with the partners groups for each IP. Of the three IPs, SR has the largest and best developed partner group, a natural consequence of the applied nature of restoration and of the need for better science to produce better outcomes. This year, the DW Partners Group is increasingly energetic with completion of the initial version of the DW computer application and planned field application with Stillwater Science and other partners.

This year, we improved the Visitor Program by organizing it around a major collaborative, multi-investigator research experiment (StreamLab06) in the Main Channel facility at St Anthony Falls Laboratory (SAFL). Year 5 brought to a close the first of NCED's innovative multi-investigator collaborative research experiments, StreamLab06. StreamLab06 involved a total of 40 researchers, including members of the Stream Restoration Partners Group (SRPG) and one Visitor Program researcher. Represented were six academic institutions outside NCED, three Federal agencies, two consulting firms, and four NCED institutions. All data from the experiments, including detailed bed topography information and photographs, was archived on NCED servers for community use.

We also co-sponsored the International Bedload Surrogates Monitoring Workshop (IBSMW) with the Bedload Research International Cooperative (BRIC) April 11-14, 2007, at SAFL. Organized by NCED partner John R Gray (United States Geological Survey or USGS), Jonathan B Laronne of Ben Gurion University of the Negev, Israel and SR IP Manager Jeff Marr, the workshop was attended by 47 people from 11 countries. Attendees were a mix of university and agency researchers; many had participated in StreamLab06. A unique feature of the workshop was the use of the Macromedia's Breeze technology, which allowed slides and a live image of the presenter to be broadcast to additional attendees around the world, who could then submit typed questions for inclusion in the discussion periods. Abundant new NCED partner collaborations are emerging from this workshop.

In addition to StreamLab06, in Year 5 NCED provided leadership to the broader research community through short courses and special sessions at professional meetings.

Short courses

- *Morphodynamics of Sand-bed Rivers*. Two-day short course sponsored by NCED, May 27-28, 2006, Baltimore, MD. NCED PIs, students, and collaborators (William Dietrich, Marcelo Garcia, J Wesley Lauer, David Mohrig, Chris Paola, Gary Parker, Robert Twilley) led the course.

- *The principles and practice of stream restoration*. Two-week short course convened by JC Schmidt, Utah State University, May 30 – June 8, 2006. NCED PI Peter Wilcock primary instructor.

- *Ecological and geomorphic principles of stream restoration*. One-week short course co-convened by NCED PI Peter Wilcock and External Advisory Board member Margaret Palmer, University of Maryland, June 12-16, 2006.

- *River restoration: Application of fluvial geomorphology*. One-week short course convened by GM Kondolf, University of California, Berkeley, Truckee, CA, August 10-14, 2006. NCED PI Peter Wilcock primary instructor with NCED PI Mary Power also on faculty.

- *Sediment transport in stream channel design*. One-day short course, Northwest Environmental Training Center, September 27, 2006, Missoula, MT. Led by NCED PI Peter Wilcock.

We have begun, in Year 5, to share our successful Working Group initiative with the University of Minnesota's new Institute on the Environment, of which NCED PI Efi Foufoula-Georgiou was an Advisory Committee member and NCED Director Chris Paola a Founding Fellow 5. Partnering with this high-profile University-wide effort will help ensure sustainability of NCED's Working Group model.

The Subsurface Architecture Partner Group (SAPG) comes from the oil industry; in Year 6, we expect to begin enlarging this partner group to include other organizations interested in restoring the Mississippi Delta. SAPG relationships continue to be strong and included an annual meeting (August 2006), two new short courses, an internship, joint research with several graduate students, ongoing communication via a dedicated website, and our online data repository. An ongoing challenge in monitoring SAPG relations is that the oil industry is traditionally secretive about specific research applications, so we cannot provide detailed case studies of how our work is being used. Instead, we rely on indirect measures. These measures include sustained levels of research funding; student internships; joint experiments; expansion of our short course program; last summer's joint International Association of Sedimentologists (IAS) short course with Japan Oil, Gas and Metals National Corporation; a new program of joint experiments with ExxonMobil, including access to their proprietary cohesive-sediment simulant mix; and a joint NCED-ExxonMobil special session at the American Association of Petroleum Geologists (AAPG).

Management

The major management accomplishment of the current reporting year was the successful conclusion of the renewal process. Now, as mentioned above, we have turned our attention to tuning up our SIP. We held an intensive PI retreat at the Louisiana Marine Consortium (LUMCON) in the Mississippi Delta in January 2007, at which time we discussed the implementation strategy for the Mississippi Delta SA intiative and updated the sub-projects around which our research in all IPs is organized. To effect a switch from PI-based funding to project-based funding, we introduced a new proposal system: structure PI proposed work around IP sub-projects. By meeting together shortly before proposals were submitted, we were able to obtain reasonably good coverage of our priority research areas by PI effort. Where gaps remain, we are working to cover them through a combination of PI negotiation, outside collaborations (this is especially the case in SA), and strategic postdoctoral research associate hires.

Presented here are the additional highlights of management accomplishments for the past year:

EAB. We avoided major turnover in the EAB during our renewal year and have since thanked a number of our long-serving EAB members and refreshed the board with new members. The most recent additions are Russell Stands-Over-Bull, a stratigrapher with Anadarko Petroleum, and Rudy Slingerland of Pennsylvania State University, a world leader in numerical modeling of surface processes. Slingerland will be the new Chair of the EAB, and will provide an additional strong link to Community Surface Dynamics Modeling System (CSDMS) as well. We continue to benefit greatly from the input of the EAB. Their report for this year, and our response to it, are presented in the body of the Annual Report.

PI changes. Robert Twilley, an ecologist with Louisiana State University and head of their Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program for delta restoration, was added as a PI in 2006. Twilley and the CLEAR program add tremendous strength in pragmatic ecological prediction and nicely complement NCED's growing effort in predicting land building in deltaic environments. We also added Fotis Sotiropoulos, a world leader in computational fluid dynamics, who will work on extending the StreamLab experimental approach via advanced numerical simulations. Finally, with regret we report that this year we accepted the resignation of one of NCED's founding PIs, Ignacio Rodriguez-Iturbe of Princeton University.

Community service. Community participation in StreamLab06 was one of our major community efforts in Year 5, along with related activities such as the IBSMW, which we hosted at SAFL this spring. Last year, we noted that, apart from these activities, we had led two additional events: the "preflight" workshop meeting in December 2005 for the CSDMS proposal; and an exploratory initiative to build a long-term partnership with CUAHSI and Critical Zone Exploration Network (CZEN), two major organizations representing the hydrology and soil-geochemistry communities respectively. Outcomes related to these (funded CSDMS and CZO initiatives) were discussed above. Overall, our goal has been to lay the groundwork for initiatives in predictive Earth-surface dynamics on the scale of the whole research community. This remains a key step towards a future in which NCED evolves into a self-sustaining community-based organization.

IIa. Desktop Watersheds Integrated Project

Project Team

Lead PI: William E. Dietrich

Project Manager: Collin Bode

Contributing PIs: Jill Banfield, Jacques Finlay, Efi Foufoula-Georgiou, Miki Hondzo, Gary Parker, Lesley Perg, Fernando Porte-Agel, Mary Power, Andrew Wold, Ignacio Rodriguez-Iturbe

Executive Summary

This year the Desktop Watersheds Integrated Project (DWIP) has identified 11 Projects with 33 milestones, and progress has been made by NCED collaborators on most of these milestones. Our focus field site is the Angelo Coast Range Reserve (ACRR) and extensive improvements in our monitoring capability there were made this year. The wireless network is up and running and will be expanded further this year. In Year 5, DW Project Manager Collin Bode and ACRR Steward Peter Steel moved out of the design phase to install the first operational stage of the system. This brought internet connectivity to the reserve headquarters and allowed us to switch from a slow satellite internet connection (64kbps) to our new wireless network (currently 2mbps, 8mbps once optimized). Sensors for a variety of environmental variables and biotic responses (including acoustic and video recordings) are being deployed according to sampling designs guided by hypotheses about landscape effects.

Significant progress has been made in understanding sediment transport, channel incision, and sediment routing processes. We have: 1) developed a new model for landslide size; 2) obtained dates and rates of erosion and channel incision in the ACRR that suggest variations that may be driven by climate; 3) dated past movement on a large deep-seated landslide at the ACRR; 4) developed a model for stochastic production and transport of soil by tree throw; 5) documented for the first time that granular flow incision into rock can be scaled by inertial stresses of the flow; 6) advanced new theory for coverage effects and suspension wear on fluvial incision into bedrock; 7) explained the slope dependency in critical shear stress in steep shallow flows (typically over boulders); and 8) developed models of the transport of sand across gravel beds.

At the ACRR we have been mapping ecosystem processes (e.g. denitrification, stream metabolism), as well as distributions, abundances, performances, and interactions of key organisms through the drainage network, and investigating environmental controls of these patterns and processes. We are attempting prediction through two routes. One is empirical, to use engineering approaches (e.g., statistical upscaling and dimensionless analysis) to discover scale-free predictors of biomass or process intensity that can be read or inferred from topographic maps. The other approach uses targeted experiments to determine why changes in ecological regimes or ecosystem processes occur along environmental gradients (e.g. down drainage networks or across valleys), then combines process-based understanding with modeling to predict how thresholds between these regimes would shift with land-use, climate, or biotic change.

Significant progress has also been achieved over the past year in exploring how the unprecedented topography and vegetation resolution afforded by LIDAR data (provided for ACRR in cooperation with the NSF-funded National Center for Airborne Laser Mapping, (NCALM) can inform: a) feature extraction at the hillslope to the river network scale; b) guide fieldwork by identifying physically distinct regimes from the statistically distinct signatures different processes leave on the landscape; c) provide guidance for sediment transport model development and validation especially at the hillslope scale; d) refine hypotheses related to the emergence of scaling in the hydrologic response (storm hydrographs and flood peaks) in view of documented scaling at hillslope flow paths and river network structures; and e) pose hypotheses related to vegetation organization driven by topographic attributes and river network organization.

In Year 5, we completed a unique and extensive set of spatially explicit measurements of nutrient spiraling and stream metabolism across the Eel River stream network. We have also finished research to understand the role of invertebrate grazers and consumer-resource stoichiometry on nutrient cycling. Our work at the ACRR has revealed physiographic controls of stream nutrient sources and sinks at the watershed scale. One example is for dissolved oxygen (DO) flux and

denitrification hot spots. DO in aquatic sediments inhibits the activity of denitrifying bacteria in ecosystems, while carbon and nitrate and nitrite supplies stimulate them. Our work linked DO measurements across a range of scales including laboratory flume, large open channel setup (StreamLab), and the field (ACRR). The results were explained by a similarity model for describing DO flux to sediments controlled by large-scale fluid motions.

Researchers in the DW collaboration are iterating between maps, experimental data, and theory to generate dynamic mosaics of prediction across landscapes, with scaling empiricisms that predict responses of interest over finite regions, but that break down where thresholds in environmental conditions tip landscape dynamics or food web interactions and ecosystem responses into new regimes. Discovering the fundamental processes underlying both the regularities and deviations remains a central motivation for this work.

Finally, we have nearly completed a release of a DW application model, “Ripple,” that uses topographic data, field empiricism, and theory to relate digital topographic data to habitat carrying capacity and to population dynamics of Coho salmon. The model is a collaborative effort with Stillwater Sciences and has an easy-to-use interface. Presentations to various government agencies has generated great interest in the model.

Goal

The goal of DWIP is to discover and advance the fundamental relations needed to predict landscape evolution and to model the coupling of ecosystem, landscape, and land-use dynamics. Combining digital environmental data (topography, vegetation, precipitation, runoff, etc.) with research showing how local properties are controlled by drainage basin structure, we propose to make spatially explicit predictions about resource attributes (landslide locations, river bed grain size, algal abundance, etc.). Such predictions then become null hypotheses that guide fieldwork, transforming it from simple data gathering or monitoring to hypothesis-testing.

Digital topographic data also offer the possibility of building watershed-scale numerical models of real landscapes to explore problems ranging from the long time-scale controls on landscape evolution to short time-scale response of aquatic ecosystems to land-use change. Such modeling efforts are inhibited, however, by a lack of knowledge and quantitative expressions for many of the fundamental geomorphic and biotic processes. Closure of this knowledge gap and introduction of new theories and approaches by NCED and collaborators is leading to discoveries about landscape evolution, and to the construction of practical numerical models that will revolutionize land-use management and environmental forecasting. NCED’s unique breadth of researchers, experimental facilities, and field programs has enabled it to assume this leadership role.

Approach

High-resolution digital topography provides the template for Desktop Watersheds modeling. To unlock the potential of digital topography, we introduce new theories, propose new analytical approaches, conduct innovative experimental studies, and perform intensive field studies to discover, parameterize, and evaluate the fundamental driving equations. Our findings are made available to others to improve watershed-scale numerical modeling being developed across the community. We use our current digital-terrain based models (prototype Desktop Watersheds), to guide prioritization of research and maintain a tight coupling between modeling and observation. In their simplest form, in which the topography is used to estimate such features as biological productivity, probable landslide location, channel morphology or bed grain size, Desktop Watersheds models can provide a relatively parameter-free prediction of landscape attributes useful in guiding field work and in applications such as planning timber harvests and stream restoration projects. Advances from this new research will set the stage for models of cumulative watershed effects, controls on total maximum daily load levels of sediment, and “game” management scenarios so that users can optimize land-use activities for ecosystem protection and restoration.

Accomplishments and Plans: Angelo Coast Range Reserve

NCED’s two field sites are located in erosional and depositional watersheds. The Angelo Coast Range Reserve (ACRR) is the erosional field site. The ACRR is located on the South Fork of the Eel River, about 3.5 hours by car from the University of California- Berkeley (UCB) campus. The entire study area is protected from unrestricted public access by a gated road, which provides easy transportation of material and equipment to field sites. NCED PI Mary Power is the faculty manager of this University of California Natural Reserve System Preserve. Various buildings and outbuildings on the reserve are available for year-round housing, laboratory use, and equipment storage. A Science Center includes two large laboratories (with ovens, muffle furnace, fume hood, and extensive workspace), a computer lab and DSL connectivity to all rooms where sensors can be calibrated etc., a herbarium, and a canopy-access facility spanning old growth redwood and Douglas fir trees along a river-to-ridgeline gradient.

Wireless monitoring and communications network at the Angelo Coast Range Reserve

At present, in collaboration with our sister NSF Science and Technology Center (STC), the Center for Embedded Network Sensing (CENS), we are constructing a wireless network at ACRR. The network will support automated environmental sensors of light, temperature, and soil moisture, plus imaging for algal blooms and acoustic detection of bats. In the years to come we will add new sensing capability (e.g. nitrate). Recently acquired LIDAR data also supports analysis of relations between network structure and habitat, local channel properties, and vegetation, as discussed above under the DW IP Executive Summary.

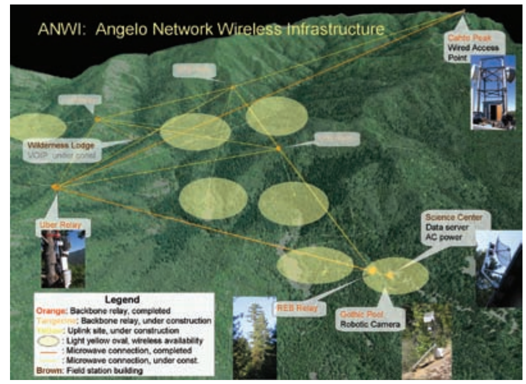

Figure 1: *Angelo Network Wireless Infrastructure*

As part of the development of the ACRR as one of NCED's two primary field sites, we have developed a wireless network infrastructure to create a sensor observatory. In 2006, DW Project Manager Bode and ACRR Steward Steel moved out of the design phase to install the first operational stage of the system. This brought internet connectivity to the reserve headquarters and allowed us to switch from a slow satellite internet connection (64kbps) to our new wireless network (currently 2mbps, 8mbps once optimized).

This network is constructed using commercial packet radios instead of consumer wifi. This gives us the flexibility to develop an extensive hierarchical network of radios with built-in routing redundancy to ensure that any one point of failure does not take down the system. We used trees (redwoods and Douglas firs) as radio towers, which reduces the impact on the reserve and cuts the total system cost from $300K to $100K.

We have the ACRR weather station online (http://angelo.berkeley.edu/sensors/met/) and a live robotic camera (http://angelo.berkeley.edu/sensors/webcam/) and have developed automated hourly health monitoring for every radio and router on the system (http://angelo.berkeley.edu/sensors/net/) . The robotic camera has taken six daily photographs for one year of Gothic Pool to record the algal life-cycle in the South Fork Eel River. We also recorded an additional eight photos every hour over the peak months of spring-summer growth. This was done to estimate the value of triggered or timed increased sampling. The daily recording is now in the second year and will continue.

Summer 2007 will also include Stage Three build-out of the wireless network, which will add three more towers to the system and connect Wilderness Lodge and Fox Creek Pavilion to the network. Fox Creek lodge will have a voice over internet protocol (VOIP) phone installed as a safety measure. The Keck Foundation HydroWatch project will attach 60-90 mesh network wireless "motes" (sensors) to the NCED network in July-August, 2007. We will expand our image sampling to other areas along the South Fork Eel River and Elder Creek by installing two-to-four fixed view digital cameras to wireless uplink sites (Figure 1).

We have also begun a collaboration with the Keck HydroWatch group at UCB, of which NCED DW Project Leader Bill Dietrich is a member, which is committed to developing reliable, inexpensive wireless technology for environmental monitoring of water through the entire hydrologic cycle. One of the group's field sites is Elder Creek, a tributary of the South Fork Eel within the ACRR, so NCED's work to install a wireless backbone will be put to immediate use. We hope this collaboration will attract wider collaborations that will bring in additional funding for legacy programs that continue beyond NCED's scheduled end date of 2012.

Accomplishments and Plans: SIP Project Plan

Year 5 saw further integration of DW with the other three NCED Integrated Projects, though the main focus of the DW effort remains unchanged. Project numbers have been reordered and two new projects have been introduced: DW10: DW Model code development, and DW11: Use of DW models in land-use management decisions. DW10 was added in recognition that we have a significant amount of programming to be done to achieve a base set of tools for performing DW style modeling. DW11 was added in synergy with SR IP work to emphasize the interaction between the research and its social impacts on management and communities.

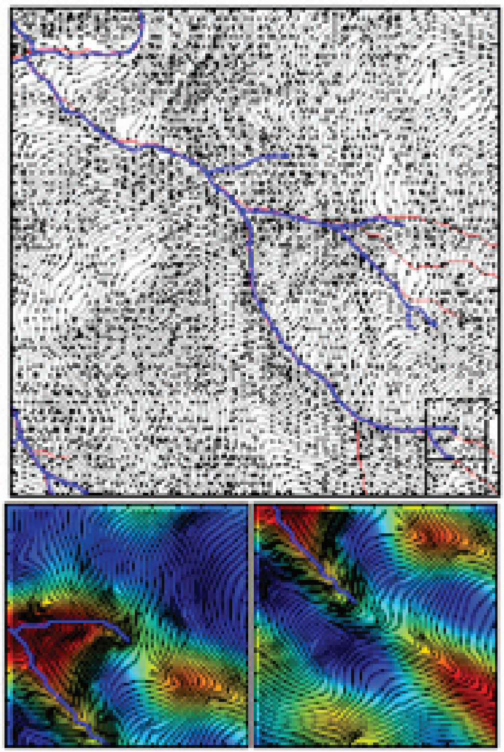

Figure 2: *Demonstration of the difference between a threshold-type criterion for channel initiation versus the objective extraction of channels using the proposed wavelet-based methodology. The proposed methodology correctly depicts a disruption or termination of the channel, whereas the other methodologies do not.*

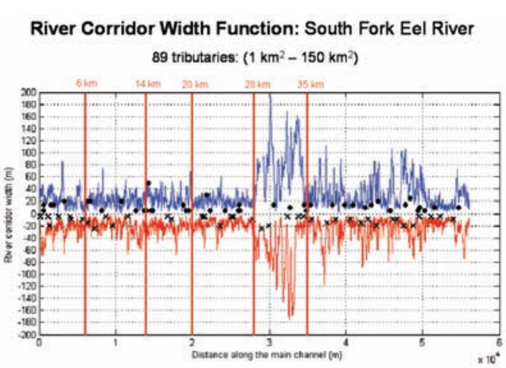

Figure 3: *The river corridor width (RCW) series at the right (top) and left (bottom) side of the main stream of the South Fork Eel river basin.*

► DW01: Numerical techniques for feature extraction

The acquisition of high resolution airborne laser altimetry presents large challenges and opportunities. One major challenge is that, for the first time, many landscape features like channels now have topographic expression in the data field. Therefore, traditional methods of assigning channels to a cell based on drainage area and slope are no longer appropriate.

To address the issue of channel initiation, we have developed a wavelet-based methodology for computing local slope and curvature from LIDAR data across a range of scales. We have subsequently explored how multi-scale statistical analysis of local curvature in conjunction with a new quantity, namely the derivative of the steepest slope direction, can provide a robust means for extracting river networks and for defining the point of channel initiation (Lashermes et al., 2007). The algorithm does not require any *a priori* information, such as threshold area or the combined slope-area relationship, for defining the channel head; rather the fine-scale geomorphic features analyzed with appropriate image processing techniques define the presence or absence of a channel (see Figure 2). The details of the algorithm can be found in Lashermes et al. (2007). A short paper for a special Geophysical Research Letters issue on LIDAR data is also currently under preparation.

We have recently introduced a new way of looking at the 3D dissection of landscapes by examining the valley organization via the so-called "river corridor width" (RCW) series. RCW is the lateral distance from the centerline of the river to the left and right valley walls at a fixed height above the channel water surface. The RCW series carries information about the "roughness" of the valleys (see Figure 3) as created by several interacting processes such as hillslope transport, mass wasting, terraces, debris flow landsliding, and interaction with stream tributaries. We have established that RCW series extracted from LIDAR data of the South Fork Eel River basin along the mainstream exhibit a rich multiscale statistical structure (anomalous scaling) which varies distinctly across physical boundaries, e.g., bedrock versus alluvial valleys (Gangodagamage et al., 2007; see Figure 3). We postulate that such an analysis, in conjunction with field observations and physical modeling, has the potential to quantitatively relate valley forming mechanistic laws with the statistical signature they leave on the landscape and thus can be useful in guiding field work and advancing process understanding and hypothesis testing.

Note: numbers below refer to the list given in NCED's Strategic and Implementation Plan (SIP). If the Milestone is not listed, then no progress in the past year has been made.

Progress on deliverables

Milestone/Deliverable	Progress
1) Channel head location and detection.	Successful algorithm created and published. Refinement will continue.
5) Automated mapping of deep-seated landslide features.	Josh Roering and Ben Mackay of the University of Oregon are collaborating at the ACRR on testing Roering's procedure for landslide detection. The method was also used to explore a LIDAR dataset in Humboldt County, CA.
7) Exploit water penetrating LIDAR for channel topography mapping.	We are waiting for the completion of the NCALM experimental LIDAR, which is scheduled to be completed in 2007.

Plans

The proposed multiscale statistical analysis of topographic attributes can be further explored for the extraction of other geomorphic features of interest, such as channel widths, landslides, etc. This will be investigated in Year 6. Also, further documentation of the accuracy of the proposed river network extraction algorithm, not only for steep terrains such as the South Fork Eel River basin but for lower relief basins, is planned to be performed in the coming year. We intend to relate the statistical structure of RCW series to the underlying processes forming the valley. Summer 2007 field work is planned to explore the relationship between the channel network and landsliding processes at the ACRR.

► DW02: Exploit topographic signatures to estimate properties of and processes in the environment

Shallow landslides on steep slopes often mobilize as debris flows. The size of the landslide controls the initial size of the debris flows, defines the sediment discharge to channel network, affects rates and scales of landform development, and influences the relative hazard potential. In collaboration with partner Jim McKean of the US Forest Service (USFS), we have developed a multidimensional landslide model, using a search algorithm to investigate possible shapes and sizes. The work supports our hypothesis that it is the spatial structure of soil depth, topography and root strength that sets landslide size (Dietrich et al., submitted). Given the importance of soil depth, we have also developed a stochastic soil production and transport model that simulates tree throw processes. This is our first attempt to model directly the effects of biotic processes rather than reflect these processes as specific coefficients in physical relationships.

A new subject for DW02, not specifically listed in our SIP milestones, but one of great promise, is the exploration of high resolution topographic data to examine scaling properties of landscapes. High resolution topographic data provides the ability to examine basin characteristics from the hillslope scale to the channel to the whole river network scale. The width function of a river basin W(x) (number of channelized pixels at distance x from the outlet) is a 1D function that summarizes the 2D branching structure of a river network. It has been studied extensively in the geomorphologic and hydrologic literature because of its significance for discerning the shape of the instantaneous unit hydrograph (IUH) from readily available topographic data. More recently, the multiscaling properties of W(x), and of the area function A(x) which considers all flow paths (channelized or not) at distance x to the outlet, have been studied by several authors. Multifractal (MF) analysis of A(x) and W(x) presents challenges and several examples of "wrong-doings" exist in the literature. In Lashermes et al. (2007b), we demonstrate the shortcomings of current analysis methodologies and propose a robust framework of analysis. We also pose and examine the following questions: 1) Does the topology of river networks leave a unique signature on the multifractal properties of area and width functions? 2) How different are the multifractal properties of commonly used simulated trees and those of real river networks? and 3) Are there differences between the multifractal properties of width and area functions, and what can these tell us about the topology of hillslope versus channelized drainage patterns in a river basin?

Our analysis so far has preliminary answers for these questions. Specifically, we have documented discrepancies between the statistical scaling of the area functions of real networks (found to be multifractal with a considerable spread of local singularities and the most prevailing singularity ranging from 0.4 to 0.8) and that of several commonly used stochastic self-similar networks (found monofractal with a single singularity exponent in the range of 0.5 to 0.65). Moreover, differences were found between the multifractal properties of width and area functions of the same basin, interpreted as depicting the different branching topologies in the hillslopes versus channelized drainage paths.

Progress on deliverables

Milestone/Deliverable	Progress
2) Shallow landslide size and location model.	Paper submitted in collaboration with McKean on a model that searches for the least stable area in a landscape.
4) Estimate spatially explicit soil properties.	An initial model has been completed that represents the effects of stochastic production of soil and down slope transport by tree throw, leading to highly variable soil depth.
6) Relate landscape features to environmental regimes with improved stream temperature model; use canopy cover from LIDAR.	In progress.

Plans

We plan to: 1) analyze more basins in terms of the statistical structure of their area and width functions as well as the structure of their RCWs. The implications of these findings for hydrologic response and sediment transport laws will be explored. Examples include exploration of a scale-dependent IUH convolution theory, regionalizing basins according to the statistical nature of the high frequency component of their area and width functions, and development of hillslope sediment transport laws that respect the observed scaling in RCW series.

In addition, we plan to focus on a new area, that of investigating the multiscale variability of rainfall as a driver of geomorphic extremes. This work is in conjunction with National Aeronautics and Space Administration/Japan Aerospace Exploration Agency (NASA/JAXA) and their multi-satellite Global Precipitation Mission (GPM). GPM can be used to advance our understanding of rainfall-induced landslide hazards in mountainous areas for the purpose of forecasting and development of early warning systems. Landslides are often triggered by significant (in terms of intensity and/or duration) rainfalls. The magnitude and temporal scale of critical rainfall events that causes a high probability of failure by a given hillslope depends on site characteristics that are increasingly detectable with high resolution remote sensing. Work will continue to devise efficient search algorithms to locate the least stable areas for shallow landsliding across a landscape. Our current hypothesis is that landslide size is set by combinations of local soil depth, root density, and topographically-controlled pore pressure development. Therefor, we plan to further develop our model for predicting the spatial variation in soil-depth across a landscape.

► DW03: Predictive mapping of key biotic populations: relationships to habitats

Year 5 saw an extensive push to analyze environmental controls on food web interactions and ecosystem fluxes at different network positions within the ACRR. The positions represent a gradient of basin sizes with different slope gradients, light flux, nutrient availability, and ecological communities or food webs. Species respond differentially, so outcomes of species interactions change across the landscape, with potentially significant consequences for ecosystems. We are investigating various key species interactions down river networks, focusing on why changes occur at certain landscape positions. The hypothesis is that mechanistic understanding of 'regime thresholds' at these sites will improve our ability to forecast ecological responses to altered future conditions driven by land-use, climate, or biotic change.

We are continuing to study the changing interactions of algae and heterotrophic bacteria down a gradient of light and nutrient availability down a channel network at the ACRR. Last year, we documented downstream-increasing availabilities of light and nutrients. We are testing hypotheses that algal-bacterial interactions shift from neutral to competitive to parasitic under different combinations of light and nutrient limitation. To test these, both nutrient and carbon supply (in diffusing substrates deployed in the river) are manipulated. We are also trying to differentially exclude algae or heterotrophic bacteria with selective biocides. In Summer 2006, we experimented with delivery of selective biocide-diffusing substrate designs and deployed a set along a drainage area gradient at the ACRR. Nutrient-diffusing substrates were deployed along the same gradient to assess the effect of nutrient availability on biofilm composition at each site. We also collected baseline samples for biofilm composition and membership from natural substrates at the same suite of sites.

We investigated several mechanisms for algal accrual. We examined how bed surface microtopography controls periphyton accrual. In 2006 we conducted field experiments in the South Fork of the Eel River (Figure 4) and laboratory research at St. Anthony Falls Laboratory (SAFL). When river beds are "embedded", or filled with fine deposited sediments (a common impact of land-use on western US rivers), their surface roughness is diminished. This smoothing may alter boundary layer conditions that regulate nutrient availability to periphyton. Embedded bed surfaces may also indirectly affect periphyton accrual by altering grazer abundance or activity. To study both direct and indirect effects, we manipulated fine sediment concentrations in experimental channels and quantified periphyton accrual, metabolism, and nutrient uptake under both natural and reduced grazer conditions. We followed up this field work with experiments in a SAFL flume. NCED graduate student Mike Limm and colleagues manipulated bed surface roughness with natural cobbles, pebbles, gravels, and sand in the field, and unglazed ceramic tiles in the flume, and quantified the resulting hydraulic conditions, periphyton metabolism, and periphyton accrual.

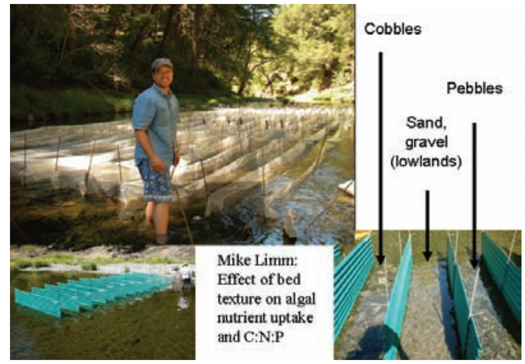

Figure 4: *Field experiments conducted in the South Fork of the Eel river in Mendocina, CA.*

We surveyed a five km reach of the South Fork mainstem by kayak and mapped the sites of all major algal blooms at their summer peak. We will complete our third year of this survey in 2007. We will analyze bloom locations relative to light regime and nutrient loading from watersheds, which we will attempt to predict from LIDAR maps of basin topography and vegetation height. Year to year consistency or shifts of locations in channels will give us insight into the importance of a third possible control, sediment flux, in determining spatial positions and extent of algal blooms. In the South Fork Eel (and many temperate rivers worldwide) blooms are dominated by the filamentous green alga *Cladophora glomerata*, which is sensitive to scour and substrate stability.

Another approach we are taking is to look broadly at a number of abiotic controls in relation to metabolism for peryphyton. Dimensional analysis, a technique widely used in the field of fluid mechanics, was used to investigate functional dependencies between biotic and abiotic variables. Nondimensional groups of variables were formulated and evaluated with the field measurements. Periphyton biomass was controlled by: $B^{9/5}$, exposure to light $PAR^{1/5}$, nutrient concentration $N^{5/6}$, inverse stream depth $H^{-5/6}$ and discharge velocity $U^{-1/2}$. The autotrophic-heterotrophic balance, quantified by the gross primary productivity (P) to ecosystem respiration rate (R), scaled with the stream aspect ratio $\left(\frac{B}{H}\right)^{3/5}$ and Peclet number $P_e = \left(\frac{UB}{u_* H}\right)^{3/10}$, where u_* is the shear stress velocity (Figure 5). The functional relationships were validated against reported field measurements from other geographical areas. The scaling relations show non-linear dependencies among periphyton biomass, stream metabolism and abiotic variables. These non-linear relationships point to a need for detailed quantification of biotic and abiotic variables over a range of scales in the field.

Finally, at a higher position in the food web (i.e. trophic level, we conducted a series of complimentary experiments in 2006 with Pacific lamprey, *Lampetra tridentata*. These build upon our prior work estimating the impact of deposited fine sediments on juvenile salmon (Suttle et al., 2004) and will support SR efforts to address sedimentation impacts and management decisions. Pacific lamprey share with Pacific salmon both an anadromous (and adromous species primarily inhabit salt water but breed in fresh water) life history as well as dramatic population declines over the last century. We have been interested in understanding the impact of deposited fine sediments on both juvenile salmon and larval lamprey, as increased fine sediment loading and deposition result from a variety of both natural and anthropogenic watershed disturbances (road density, landslides, forestry). In Year 5, we experimentally determined that increased substrate embeddedness with fine sediment enhances larval lamprey summer growth rates in direct contrast to the response of juvenile salmon. Additional experiments from 2006 have allowed us to begin teasing apart the influence of deposited fines on the distribution and movement of larval lamprey across substrate-types, both necessary steps for 'up-scaling' the potential impacts of increasing fine sediments to lamprey populations in the South Fork Eel river.

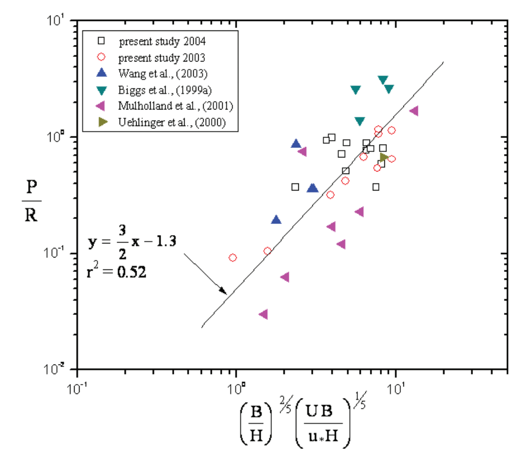

Figure 5: *Comparison of present study with studies of net ecosystem production quantified by P to R ratio (gross primary productivity/ecosystem respiration) versus dimensionless abiotic groups.*

Progress on deliverables

Milestone/Deliverable	Progress
1) Steady state models estimate of spatially explicit salmon populations.	In progress with the Ripple model described further in DW11.
2) Steady state models of frog reproduction patterns.	Most effort currently is focused on dynamic hydrologic limitations.
3) Steady state model spatial distributions SR03, SR09.	In planning for upcoming year is a spatial distribution model of periphyton.
4) Steady state model of aquatic insect abundance and emergence rates.	In planning for upcoming year is a grazer model.

Plans

A steady-state model of periphyton spatial distribution driven by local geomorphological and large-scale watershed abiotic signatures will be developed. A steady-state model of grazer spatial distribution driven by local geomorphological and fluid-flow properties will be developed. Additional laboratory measurements at SAFL and field measurements at ACRR will be conducted. Grazer orientation and accumulation driven by local fluid-flow characteristics will be systematically investigated. This work is a continuation of previous NCED research. A steady-state model of stream gross primary productivity (P) to ecosystem respiration (R), P/R ratio, will be developed. Additional field work will be conducted in Minnehaha Creek (MN) and at the ACRR. Steady-state model of microbial biomass and metabolism spatial distributions mediated by soil moisture and carbon concentration will be developed. This effort will require additional laboratory measurements at SAFL and field work at ACRR.

We will use a new Large Eddy Simulation (LES) code as a ‘Virtual StreamLab’ to study the effects of channel topography on turbulent transport and ecosystem habitat. A new Computational Fluid Dynamics (CFD) tool will be used to study the effect of natural channel topography and river restoration structures (see next section) on the heterogeneity of the turbulent flow. This information will guide the development of numerical models to account for the effects of turbulence on stream ecology. We plan to study the role of surface shear stress heterogeneity around boulders on the presence and activity of grazers. Special attention will also be placed on predicting and characterizing low-turbulence regions, which have been recently identified as preferred habitats for many fish species.

Our first DW model application, “Ripple”, described below, will be released and further developed (to include barriers).

► DW04: Understand linkages among solutes, soil production and biota

Stoichiometry & Nutrient Spiraling

Research at the ACRR has increased our knowledge of basic river ecology in key areas important for elucidating the poorly understood interactions between river biology, hydrology and geomorphology. We are investigating spiraling lengths at different drainage network positions by measuring nutrient uptake lengths from headwaters down to the mainstem with field pulse enrichment experiments.

The impact of biota (grazers, algae, detritus and detritivores and decomposers) on uptake rates was investigated in small chambers where current is maintained with magnetic stirrers. The research program addresses how spiral length (an index of watershed retentiveness for nutrients, and the efficiency of ecosystem production for given nutrient fluxes) responds to the three way coupling of:

- food web structure (as it affects grazer and algal abundance),
- stoichiometry (the match between the elemental composition of consumers and their resources, affecting consumer production efficiency, excretion of elements, and their downstream fluxes), and
- landscape position (which affects food webs and resource stoichiometry because of the gradients of light, nutrients, and hydraulic conditions described above).

Our research is focused on understanding how measurable gradients in physical forces affect ecological interactions, and in particular, uncovering the mechanisms and spatial-temporal thresholds over which they occur. In Year 5 we completed a unique and extensive set of spatially explicit measurements of nutrient spiraling and stream metabolism across the Eel River stream network. We have also finished research to understand the role of invertebrate grazers and consumer-resource stoichiometry on nutrient cycling. Our work at the ACRR has revealed physiographic controls of stream nutrient sources and sinks at the watershed scale. One exciting result in this area is a newly observed transition between nitrogen to phosphorous limitation in the basin that appears to be driven by increases in light availability, nitrogen fixing plant species, and changes in water flow through riparian zones.

NCED has supported synthetic activities, such as coauthorship on a conceptual manuscript on links between ecology and geomorphology (Post et al. in press), and lead authorship with a senior scientist at the U.S. Geological Survey (USGS) on a review of stable isotope tracing of organic matter in rivers (Finlay and Kendall, in press). In addition, work on two other NSF funded projects is contributing to NCED goals. In the NSF-Ecology project: "Food-Chain Length in Streams: Testing the Role of Ecosystem Size, Resource Availability and Disturbance", we are working to understand the interaction of hydrology, geomorphology, and organic matter dynamics in affecting the structure of river food webs. Our preliminary results show an important role for geomorphic conditions, independent of productivity, in structuring river food webs.

In an NSF-Polar programs project "A Measurement Program in Siberia to Assess Disturbance-Driven Changes in Arctic Carbon Fluxes", we are working to understand how destabilization of permafrost will affect terrestrial and aquatic ecosystems in at high latitudes. With our collaborators, we published two papers last year in Geophysical Research Letters on work to understand the source and controls of organic carbon fluxes from northern watershed. We have observed seasonal dependence on export of Pleistocene aged carbon in a rapidly warming basin in northern Russia.

During the last two years NCED researchers have sampled north shore tributaries to Lake Superior to determine the effects of groundwater input on these streams. Groundwater effects on macroinvertebrate assemblages and nutrient cycling in these streams were also investigated. Several Fond du Lac Tribal and Community College (FDLTCC) students have been involved in this research and some have presented posters at NCED site visits.

Soil geochemistry, microbiology, and landscape evolution

The development of integrated predictive watershed science requires understanding of how physical, chemical, and biological factors interact to generate soils, sediments, and solutes. The explicit goal of this research is to develop new understanding of how two important environmental variables – water abundance and seasonality of rainfall - change nutrient fluxes and biological productivity in a river network. We investigated the coupling between climate change-induced rainfall change, soil microbial community structure, physical and chemical properties of the soil, above ground vegetation, and microbial activity in the ACRR.

Soil moisture is a controlling variable for carbon cycling, soil physical and chemical characteristics, and rates of soil (and thus sediment) formation. "Hot spots" characterized by high microbial cell numbers and/or high activity levels can be identified in the field by sampling across scales from microns to meters. NCED work on hot spots in soils provides interesting bases for comparisons with hot spots in streams (e.g., as documented for denitrification in ACRR channels by O'Connor et al. ,2006) and may be extrapolated to other landscape positions, based on maps of watershed properties.

For the first time, it has been possible to comprehensively and quantitatively evaluate how microbial richness and abundance in soil respond to changes in climate, specifically the abundance and seasonality of rainfall. Results demonstrate that soil microorganisms change in abundance and communities change to some extent in richness on the time scale of months. Some effects can be correlated with physical, chemical, and biological factors. We detect changes in the diversity structure because distinct groups of microorganisms respond (increase in abundance) to availability of specific resources and ambient conditions. The research takes advantage of a well-replicated six-year (and ongoing) climate change simulation experiment in the ACRR for which extensive information about above ground (plant and invertebrate) responses is available. We analyze how soil microbial diversity is altered by two climate change manipulations that differ in the seasonality of increased precipitation. These manipulations simulate the two major climate change predictions for northern CA in the next 50-100 years: Winter addition plots receive an additional 44 cm of precipitation from January 3 to April 1. Spring addition plots receive an identical amount from April 2 to June 20. Control plots receive no precipitation over ambient precipitation.

We use 16S rRNA gene microarrays to document species richness of samples from multiple treatment plots and over time. Multivariate analysis is used to identify correlations between microbial abundance patterns (relative to the control). Systematic and significant changes in the abundance of specific lineages can be detected. For example, by July, three groups (Actinobacteria, Bacteriodetes, Planctomycetacia) increased in abundance and Methanomicrobia decreased in abundance.

Ongoing work will test predictions of the factors responsible for these changes. Relative to the control, the winter rain addition showed no effect on above ground plant diversity (also true for all six years), but a strong effect on below ground in terms of microbial abundances (which decreased) and a strong effect in richness if December 2006 is included in the analyses (see below). The uncorrelated effects above and below ground are somewhat unexpected.

Relative to the control, the spring addition had huge effects in decreasing the above ground richness of plants and invertebrates but only weak effects in abundance and richness of the microbial consortia (cumulative richness increased). Again, lack of correlation of above and below ground responses to altered water abundance and seasonal distribution is striking. In April, the alpha- and betaproteobacteria increased in abundance relative to the control, whereas in May, the deltaproteobacteria, Flavobacteria, and Sphingobacteria increased in abundance, and betaproteobacteria showed a small increase. In July, the Nitrospira, Clostridia, Acidobacteria, Verrucomicrobiae increased in abundance whereas Actinobacteria, Planctomycetacia decreased in abundance. Many of these groups have identifiable physiological traits. These traits generate predictions that form the foundations for future work to test causes and effects (e.g., Nitrospria are often involved in nitrogen cycling).

The treatments changed numerous aspects of the biotic and abiotic environment experienced by soil microorganisms. Based on these changes, we have identified predictors of soil microbial diversity. These predictors are somewhat seasonally specific, and include soil moisture and pH. There are correlations with moss biomass in April and moss and litter biomass in December 2006 (strong). In July, there is a correlation between microbial abundances and soil nitrate and ammonium levels. The only time point where microbial diversity strongly correlates with aspects of the biotic and abiotic environment is May, with a less strong correlation in July. The key factors in May are pH, soil moisture, and litter biomass at the previous sampling time, and in July, soil moisture and to a lesser extent, pH. When considering *cumulative* richness across the entire year, primary production shows a strong positive correlation with microbial diversity. This is the only case where there is a strong relationship between above and below ground biology.

Progress on deliverables

Milestone/Deliverable	Progress
1) Document how microbial community in soil responds to changes in seasonal water loading.	Climate-driven changes in the diversity structures of plant and soil microbial communities are found to be essentially uncorrelated.

Plans

Ecological and biogeochemical relationships in stream networks: Research proposed for Year 6 is focused in the general areas of predicting ecological and biogeochemical relationships in stream networks and applications toward restoration of stream ecosystems. Ecosystem research will focus on gaining the information to interpret emerging patterns and to facilitate modeling of biogeochemical processes in watersheds. For example, an area of focus will be in linking physical conditions to biological processes governing nutrient cycling.

Soil geochemistry, microbiology, and landscape evolution: The focus of this work in the upcoming year will be to use a combination of *directed* field-based experimental manipulations, microarray technology, and geochemical/mineralogical analyses to test the following hypotheses: 1) over the time-scale of the project, altered amount and seasonality of rainfall will lead primarily to changes in the abundance distribution patterns of soil microbial communities rather than changes in total soil species richness and 2) specific sub-families of organisms will change in abundance for reasons that can be predicted based on multivariate analysis and confirmed by directed *in situ* manipulations.

► DW05: Controls on rate of landslide transport to channels

Shallow landslides often mobilize as debris flows. We presently lack a theory for landslide size and for linking prediction of size and location to characteristics of rainfall (such that a reliable landslide warning system could be built). Collaborations are underway with McKean (USFS) and NCED alumnus Taylor Perron (currently at Harvard University). We have developed a multi-dimensional cell-based slope stability model which is used in a search for the size and shape of all cells that are likely to fail. A manuscript has been submitted on our findings. We have begun discussions to see how to link the rainfall drivers with the landslide theory.

Deep-seated landslides may dominate uplands erosion in many hill and mountainous areas, but we lack any theory to predict landslide dynamics and sediment discharge to rivers. The ACRR, thanks to the LIDAR survey supported by NCED, has become a focal field site for studies. We are collaborating with Josh Roering and graduate student Ben MacKay (University of Oregon), who have used various techniques to identify deep-seated landslide dominated terrain and have obtained radiocarbon dates in the toes of some of the landslides to document activity. Our work on cosmogenic radionuclide dating of erosion rates at ACRR has provided the first data on erosion rates (order 0.4 mm/yr), which places an important constraint on landslide activity.

Year 5 also saw the completion of research that made important contributions to documenting and explaining the spatial evolution of soil and saprolite across a hillslope. The Earth's surface is modified by chemical reactions that weather primary minerals, precipitate secondary minerals, and generate solutes. Mineral weathering is a vital step in mass removal from landscapes as it alters the physical properties, making soil formation and erosion possible. In the past year, we completed an NCED-initiated study of geochemical and microbiological controls on hillslope erosion and landscape evolution. We investigated the importance of biogeochemical versus physical weathering in soil formation and mass removal from soil-mantled hillslopes, as well as how landscape position affects the relative contributions of chemical weathering, microbial activity, and physical erosion to these processes. Findings from this (now complete) work are applicable in the general sense, as watershed models require quantitative information about processes and fluxes.

Two field sites, separated by three km across an escarpment in southern New South Wales, Australia, were used to determine how physical erosion rates influence chemical weathering. At the slowly eroding Brown Mountain site, chemical weathering removes five times more mass than physical erosion. At the more quickly eroding Nunnock River site, chemical weathering removes only 0.6 times the mass of physical erosion. In addition, small variations in the form of soil humic compounds have large influences on the distribution of some elements within the soil profiles.

By combining erosion rates previously derived from cosmogenic radionuclide analysis at the Nunnock River site and bulk geochemical measurements, it was possible to quantify chemical fluxes. It was shown that chemical weathering rates increase then decrease as soil transport distance increases across a hillslope. Mapping of the geometry of the soil-saprolite boundary in a trench incised into the hillslope revealed considerable sub-meter-scale topography, yet a consistent thickness trend with transport distance at the tens- to hundreds-of-meters scale. Mapping of microbial abundance distribution patterns showed that community structure depends primarily on depth below the soil surface. Differences in microbial abundance and nutrient supply lead to variations in geochemistry and phosphate mineralogy, and thus nutrient geochemistry, as a function of landscape position.

A new type of laboratory reactor was designed to quantify mineral weathering rates under fluctuating moisture conditions found in soil environments. Experiments indicate that heterogeneous flow paths influence primary mineral dissolution and secondary mineral precipitation, resulting in dissolution rates that are orders of magnitude slower than those measured in more conventional reactors. In combination, the work provided new insights into how interconnected physical, chemical, and microbial processes contribute to soil formation and landscape evolution.

Progress on deliverables

Milestone/Deliverable	Progress
1) Develop a shallow landslide flux "law".	Active collaboration on shallow landslides modeling with McKean (USFS).
2) Develop a deep seated landslide flux "law".	Collaboration continuing on deep seated landslides with Roering (University of Oregon).

Plans

The shallow landslide research will continue with a new focus on quantifying how the multi-scale variability of precipitation modulates the initiation and multiscale variability of landslide sizes. For example, we hypothesize that it may be possible to characterize the statistical properties of the material properties of slope stability controls and the pore pressure dynamics (as driven by precipitation but buffered and amplified by subsurface flow) to make predictions about probable size distributions of landslides. We will continue to pursue the challenging problem of building a search algorithm that efficiently finds the likely landslide size across a variable landscape. Size and frequency of occurrence are the drivers of sediment flux, so this problem needs to be solved. Work on deep-seated landsliding will continue, largely through the collaboration with Roering.

We anticipate in the next two years that the Keck HydroWatch group will instrument and model the hydrologic and geochemical dynamics of Elder Creek. The work on DW04 on soils in the Eel should be important in defining the role of biota in weathering processes and geochemical losses and cycling. Though the geobiology is complicated, we will move further towards what might be called a "chemical erosion law."

► DW06: Sediment routing: coarse sediment transport in shallow flow; fine sediment interaction with coarse bed

Considerable progress has been made this year on bedload transport rates and size mixtures. Hillslope sediment entering streams is often weathered and experiences rapid breakdown as it is transported downstream. In this past year a series of meetings resulted in a paper, now published in Water Resources Research (Sklar et al., 2006) exploring the influence of gravel abrasion on downstream grain size evolution. Much to our surprise, as long as a channel is replenished with sediment from hillslopes, abrasion has essentially no effect on grain size distributions. We also found that the bedload transport rate will become constant, that is, independent of drainage area. This occurs where abrasion (to silt) is balanced by replacement from hillslope sources.

In Year 5, we have been engaged in four projects on this crucial issue. The first one is the prediction of bedload transport of mobile gravel over rarely mobile boulders in steep shallow streams (one paper submitted to Water Resources Research). We found that by using NCED PI Gary Parker's surface transport model with boundary shear stress corrected for form drag on the boulders, bedload width (or area) set by the proportion of the bed area covered in mobile sediment, and bed size specified by the mobile fraction, we could predict reasonably well the bedload transport in a steep shallow river.

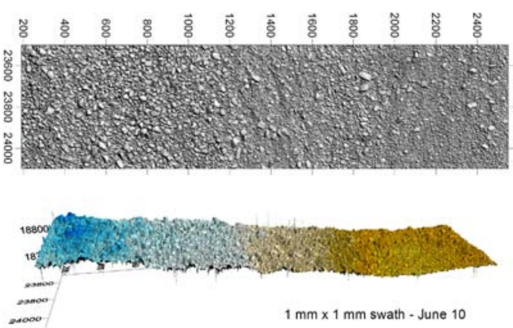

Figure 6: *Shaded relief image and colored elevation map of a bar surface during the StreamLab06 experiments. Note the patchy nature of the bed sorting.*

We are also looking at what controls surface bed patchiness. This is partly motivated by the problem of gravel augmentation, and the design of load and grain size additions. In Year 5, we conducted flume experiments exploring the hypothesis that fine gravel can mobilize coarser armor, thus fining the bed surface (a desirable outcome for augmentation projects for salmon). This hypothesis was supported both in 1D low width to depth ratio flume experiments conduced at UCB's Richmond Field Station (RFS) (using an NCED designed instrument cart) and in 2D experiments associated with the StreamLab06 project (see the SR section and Appendix G: StreamLab Laboratory Experiments of this report for a full description of StreamLab06). One of the more striking findings is the strong dependence of bar amplitude on sediment supply (virtually disappearing when supply is shut down). The StreamLab06 experiments also allowed us to collect extraordinarily high resolution topographic images of the bed, which visibly display the surface patchiness (Figure 6). New collaborative research was also initiated (Foufoula-Georgiou's group with NCED post-doc Douglas Jerolmack) to investigate the statistical scaling structure of the sediment flux series as a function of flow rate and bedload material and relate it to statistical scaling structure of bedform morphodynamics. The results were presented at the International Bedload Surrogate Monitoring Workshop (see the StreamLab and Knowledge Transfer sections of this Report for more information on this meeting). The implications of these results for bedload sediment transport measuring technologies are currently under development.

Rebecca Leonardson (UCB Civil Engineering graduate student) through encouragement from NCED SR Project Leader Peter Wilcock and Project Manager Jeff Marr, also participated in the StreamLab06. The experiments were done in collaboration with Aleks Wydzga (University of California-Santa Barbara graduate student who collaborated with UCB researchers at the RFS). This experience motivated her current dissertation proposal, which is on the processes leading to co-deposition of sand in gravel bed streams (as compared to infiltration from over passing sand during relatively static bed states).

NCED partially supported post-doctoral research by Daniele Tonina in collaboration with partner McKean (USFS). The project focuses on the in-stream effects of chronic and acute sand loading on bed texture, river morphology and habitat in salmon-supporting streams. The goal is to develop numerical models of channel response to chronic loading of fines on river beds. The study takes advantage of a unique high-resolution water-penetrating LIDAR survey of gravel bedded rivers in Idaho. In this first year Daniele has:

- collected data from 24 mountain streams in Idaho [*King et al.,* 2004] characterized by bimodal streambed material (sand and gravel), and low discharges, which sustains bedload transport of fine sediment over an immobile coarse sediment bed;

- examined the performance of the seven available bedload transport models by comparing predicted with observed sediment transport;

- developed several models to estimate the relationship between streambed material and available volume for fine sediment deposition among the large particles; and

- implemented the bedload transport model with fine sediment surface storage effects within a USGS hydrodynamic numerical model, Multi-Dimensional Surface-Water Modeling System (MD-SWMS).

Progress on deliverables

Milestone/Deliverable	Progress
1) Theory for gravel over boulder transport.	Prediction of bedload transport of mobile gravel over rarely mobile boulders in steep shallow streams (Yager et al., in press).
2) Theory for boulder transport.	Draft of paper on boundary shear stress needed to transport large rocks in shallow flows in steep channels completed (Lamb and Dietrich).
4) Theory for fines interaction with the bed SR07.	In progress: numerical models of channel response to chronic loading of fines on river beds.

Plans

In Year 6, we will explore various modeling strategies, ranging from particle dynamic models to more typical continuum models of sediment transport to predict the evolution of surface patchiness. We anticipate conducting experiments to explore the problem of distrainment, as it seems the stopping of mobile particles plays a critical role in patch development. We think we may be able to build upon work by Parker and Seminara in which they rewrote the bedload flux- shear stress relationship in terms of entrainment and deposition. Over the next two years we will develop theory, process the massive data collected (including the StreamLab06 data) and conduct flume experiments at the RFS on distrainment. We will continue to study the problem of the transport of sand over gravels and the numerical modeling of such. The findings and modeling tools could find application in many practical problems.

We hope to use the new LES code (see DW03) to study the impact of river restoration strategies on turbulence and, in turn, on fish habitat. The new CFD technique (see also DW03) will be used as a virtual laboratory in the design and evaluation of river restoration strategies. This will provide a much needed systematic approach to river restoration design, which has been traditionally driven by empiricism.

► DW07: Develop predictive models for channel incision

Debris flow scour drives valley channel incision in steep landscapes. NCED supported work established from field observation that debris flows appear to be the dominant process in bedrock scour in steep channels, and led to a proposal that debris flow incision varies with the inertial stress of flow. We have built two vertically rotating drums to test this hypothesis and, thereby, advance a general relationship to predict debris flow incision. The initial drum was 56 cm in diameter. We completed numerous experiments in the drum and have recently submitted a paper to JGR-Earth Surface that shows evidence for the first time that: 1) debris flows do scour rock; 2) the wear rate varies with grain size, shear rate; and water content, and 3) strong wall effects cause the circulation in channeled flows to be strongly 3D.

In Year 5, our 4m diameter vertically rotating drum (Figure 7) has been outfitted with custom load-cell and laser-topography systems and we have begun to explore the dynamics and erosion of a range of debris flow materials and speeds. For example, we observed varying normal stresses on the bed including high excursions in the bouldery front and fluid body of the debris flows (Figure 8*:* x-axis is the drum angle where 0 degrees is the 6 o'clock position). Much of this past year has

Figure 7: *The 4 m diameter vertically rotating drum at the Richmond Field Station.*

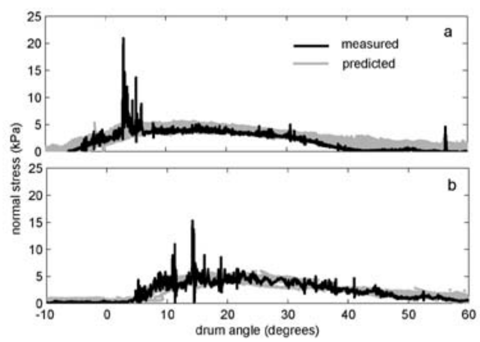

Figure 8: *Normal stress measurements and static load calculations from topography for experiments in the large rotating drum.*

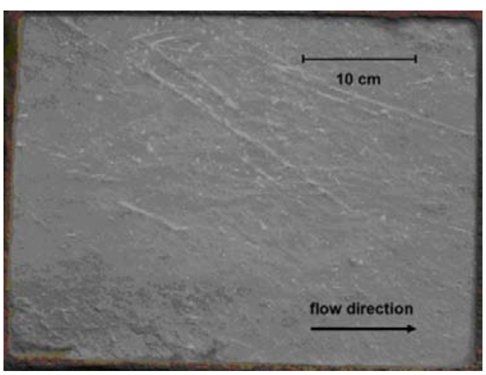

Figure 9: *Fine scale scratches in a limestone slab due to passage of a debris flow. Note that the grooves are oblique to the flow direction, indicating a near bed cross circulation.*

been a learning process of how to roughen the bed (to prevent sliding), what kinds of materials to use, and what properties can be measured.

As part of the debris flow project, we initiated a field project in the Illgraben Torrent, Switzerland, through the NSF-International Research Experience Program (IREP) program and in collaboration with Brian McArdell (WSL, Zurich). McArdell has instrumented a channel that annually experiences debris flows and is making measurements comparable to our flume work. In order to make comparisons, we have installed two natural bedrock slabs (granite and limestone) in the Illgraben channel bed which are recording erosion by frequent (multiple per year) debris flows (Figure 9). Initial findings showed the softer rock to be much more strongly scoured, but it also revealed strong cross-channel drag direction, like that which we see in our drum due to wall effects. Results of these studies were reported in a Fall American Geophysical Union (AGU) poster and a conference paper submitted to the 4th International Debris Flow Hazards and Mitigation Meeting (IDFH&MM).

Progress on deliverables

Milestone/Deliverable	Progress
1) Observation and theory for river incision by fluvial sediment wear.	Improvement on Sklar model completed by Chatanantavet and Parker. Successful testing of revised model in rivers in the Olympic Peninsula of Washington.
2) Observation and theory for debris flow incision.	Completed observations on debris scouring and wear rates. Paper submitted JGR-Earth Surface. Fall AGU poster. Conference paper 4th IDFH&MM.

Plans

We have developed a suite of drum experiments and field observations to document bedrock wear by debris flows. One goal is to make comparable measurements in the field and the drum, something we should be able to accomplish with through our collaboration with MacArdell. The central hypothesis is that the wear varies with inertial stress, which is scaled by the square of the product of the shear rate and the representative grain size. Grain sizes, flow speed and depth will all be varied, as well as water content and fines content. Importantly, we can put in full scale particles for representative modest size natural flows. But our initial observations suggest that this hypothesis for linking inertial stress to bulk flow properties may be too simple. We see a rich dynamical complexity in heterogeneous mixtures put into the drum.

We are in the process of planning how best to conceptualize the mechanics of debris motion and how to measure particle dynamics related to bedrock wear. To explore particle dynamics more directly, we have initiated collaboration with DK Arvind from the School of Informatics at the University of Edinburgh (now a frequent visitor to Berkeley). He is Director and PI of the Research Consortium in Speckled Computing (http://www.specknet.org/) a multidisciplinary grouping of computer scientists, electronic engineers, electrochemists and physicists drawn from five universities, to research the next generation of miniature 5mm cube specks. One of his staff visited Berkeley in the Fall of 2006 to install in a fist size ball a system of accelerometers, magnetometers, and gyroscopes in order to track the ball at high frequency as it participated in the debris flow. Initial results look very promising, and we hope to build about ten such balls of varying dimension to document grain size dependent dynamics. We think this may reveal a new way to view grain dynamics, flow and boundary stress generation.

The large drum is an NCED facility and besides reaching out to grain flow mechanicians, we are seeking collaborations with others for experiments with different goals that exploit the scale and instrumentation capability of the drum. MacArdell rurposes to study landslides associated with snow avalanches and ice rich landslides. He specifically proposed to do experiments in the drum in which he will use a mixture of rock and ice. We have also initiated research collaboration with Kimberly Hill (Civil Engineering, UMN) who will perform discrete particle models to compare with our physical model experiments.

► **DW08: Upscaling transport laws and biotic processes**

We surveyed algal abundance and metabolism at a large number of sites distributed over the South Fork Eel mainstem and several tributaries. We then developed dimensionless scaling relationships from these data, which also fit algal surveys conducted in other, very different watersheds (Warnaars et al., in revision).

Based on an 18 year dataset of seasonal (summer base flow) monitoring of attached periphyton in the South Fork Eel River, we demonstrate that the biomass of a cyanobacterium (*Nostoc*, an important nitrogen fixer in many ecosystems) can be predicted with a dimensionless model composed of local hydraulic and geomorphic variables. For example, *Nostoc* biomass at a point along the river can be predicted by a nonlinear relationship that involves average cross-sectional depth, maximum width, average velocity and maximum velocity, grouped in dimensionless quantities (Barnes et al., 2007). We are developing a framework for "geomorphic upscaling" of such local (at-a-point) biotic predictive relationships, using known geomorphologic scaling laws, e.g., between discharge and channel properties (hydraulic geometry), between flow and upstream drainage area, etc. We hope to be able to demonstrate that, due to nonlinearities and inhomogeneities, the stream-reach average periphyton biomass can be estimated to greater accuracy using the proposed geomorphic upscaling of local predictors, rather than evaluating the local predictive relationship using stream-average quantities.

Progress on deliverables

Milestone/Deliverable	Progress
2) How do we translate local knowledge of biotic production and fluxes to watershed scale interactions?	Upscaling of Nostoc biomass completed.

Plans

We will explore the implications of this work for sampling design and for interpreting sparse local observations in the context of reach average quantities. Predictions made from the dimensionless relationships derived from the transects sampled in the 18-year survey will be tested against measurements made at new transect sites. We will compare stream reaches where relationships break down, and attempt to elucidate new controls not captured in the empiricism, using experimental methods. In this way we can assemble a mosaic of prediction across the landscape, with empiricisms that work over finite regions, but break down where thresholds in environmental conditions tip food web interactions or ecosystem responses into new regimes. We are also developing these predictive dimensionless tools for algae, and for lamprey larvae, which depend on specific sediment textures and hydraulic conditions that favor delivery of organic silts.

► **DW09: Link food webs and channel networks, including dynamic response**

We approached dynamic responses from two directions this year. First, we analyzed population dynamics of algae and frogs in response to hydrologic regimes. Second, we examined nutrient and oxygen flux at varying scales.

Dynamic food web response to hydrologic regimes

Food web and hydrologic controls on algal accrual. An 18-year dataset from the South Fork Eel River in the ACRR was analyzed to investigate food web and hydrologic controls on algal blooms during the summer food-web reassembly. The controlling aspect of the Mediterranean hydrologic regime proved to be whether a flood of (estimated) bankfull magnitude had scoured the bed in the mainstem study reach over the preceding winter (Power et al., in revision, Ecological Monographs). This released algae from grazing by a predator-resistant grazer, the large armored caddisfly *Dicosmoecus*. This work supports policies that allow enough flow to rivers like the Eel to cause bed scouring floods, which rejuvenate food webs that better support salmonids and other predators (this research), and also cleanse and replenish spawning gravels, and favor native over many invasive, exotic river and riparian species.

Another area of active research progress includes the continuation of population-level studies of the California state-listed Foothills yellow legged frog, *Rana boylii* in collaboration with NCED partner, Sarah Kupferberg. Building upon expertise and prior work with *R. boylii*, Kupferberg and NCED investigators have continued an annual survey of *R. boylii* breeding timing and egg mass distribution along a 5.2 km reach of the South Fork Eel river within the ACRR. Additional new data collection in 2006 included a population mark-recapture effort to estimate the population size and overwinter survival of newly metamorphosed *R. boylii*, data that are otherwise lacking for this and many amphibian species, but potentially critical to understanding their population dynamics. Additionally, we are using the 16-year time series of *R. boylii* breeding from the South Fork Eel as a basis for retrospectively evaluating the efficacy of different monitoring strategies that are currently being considered in the context of hydroelectric dam relicensing (abstract, W. Palen et al., Ecological Society of America, August 2007). In the next 15 years over 150 hydroelectric dams will be carefully scrutinized for their environmental impact, especially on focal taxa of particular conservation interest (e.g. Pacific salmon *Oncorhynchus* spp., *R. boylii*). The majority of the proposed monitoring plans to evaluate the status of *R. boylii* populations during adaptive dam management are lacking a quantitative basis.

In 2007, the *R. boylii* population monitoring will continue, including egg mass surveys and further mark-recapture estimates of newly metamorphosed tadpoles. These data, along with information gathered from other locations and from the literature will allow us to parameterize a preliminary population projection model, with which we hope to explore the consequences of altered hydrology on *R. boylii* population dynamics. This will be relevant to NCED Stream Restoration efforts that involve how regulated flows need to be managed for species of special concern.

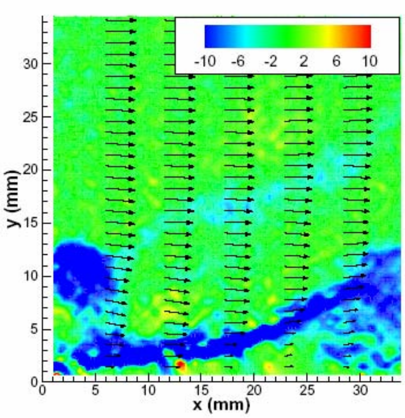

Figure 10: *Particle image velocimetry vorticity in the spanwise direction, ω_z (in color) with velocity magnitude and direction vectors (arrows) at the sediment-water interface (y=0).*

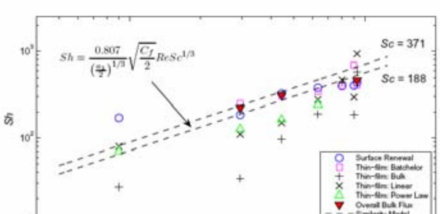

Figure 11: *Dimensionless Sherwood-Reynolds number relationship. Experimental data was used to estimate of the mass transfer coefficient (k) using thin-film and surface renewal theories, which was made dimensionless, where L is the characteristic length scale (equal to H for flume channel and R for open channel experiments), and D is the molecular diffusion coefficient.*

DO flux and denitrification hot spots in aquatic sediments

The second area of inquiry was in DO flux and denitrification hot spots. DO in aquatic sediments inhibits the activity of denitrifying bacteria in ecosystems, while carbon and nitrate and nitrite supplies stimulate them. Our objective was to unify DO measurements across the range of scales including laboratory flume, large open channel setup (StreamLab), and the field (ACRR). The results were explained by a similarity model for describing DO flux to sediments controlled by large-scale fluid motions (Figure 10). Results demonstrated that bursting events dominated the Reynolds stresses responsible for momentum and mass fluctuations at the sediment-water interface. Independent methods for detecting bursting events using both DO concentration and velocity data were applied. The average time between bursting events scaled with wall variables and was incorporated into a similarity model to describe the dimensionless mass transfer coefficient (Sherwood number, Sh) in terms of the Reynolds number, Re, and Schmidt number, *Sc*, which describe transport conditions in the flow. This scaling of bursting events was employed in conjunction with the Sh-Re-Sc similarity model to quantify DO flux to sediments and showed good agreement with experimental data (Figure 11).

Enhanced mass transport to bacterial and microalgal cells in a turbulent flow.

Microorganisms, including bacteria and microalgae, are embedded in aquatic ecosystems with ambient fluid being in continuous transition from laminar to turbulent fluid flow regimes. Theoretical studies imply that fluid motion including turbulence do not significantly increase in the molecular diffusive mass flux toward and away from organisms of $1\ \mu m < L < 100\ \mu m$ equivalent linear dimension. Laboratory experiments were conducted to quantify the effect of small-scale fluid motion on the *E. coli* and *Selenastrum capricornutum* growth rates, and nutrient uptake in a turbulent flow. The specific growth of microorganisms was up to five times larger in a turbulent flow in comparison to the control conditions, not including fluid motion (Figure 12). The dissipation of turbulent kinetic energy, ε, estimated directly from measured velocity gradients, was within the reported range in aquatic ecosystems.

Using the technique of inner and outer expansions, a model for nutrient uptake by microorganisms was developed. The theoretical model in the form of the Sherwood (Sh)-Péclet (Pe) number relationship $Sh = \left(1 + Pe^{1/2} + Pe\right)$ agreed with the measurements well (Figure 12). The Péclet number is defined by $Pe = \left(\frac{E_{zz}\eta_K L_c}{D}\right)$ where Ezz is the root-mean-square of fluid extension in the direction of local vorticity, ηK is the Kolmogorov length scale, and Lc is the length scale of microorganisms. An alternative formulation for Pe is given by $Pe = \left(\frac{\tilde{u}_K L_c}{D}\right)$ where $\tilde{u}_K = 0.5(\varepsilon v)^{1/4}$ is the Kolmogorov velocity averaged over the Kolmogorov length scale, and ν is the kinematic viscosity of fluid.

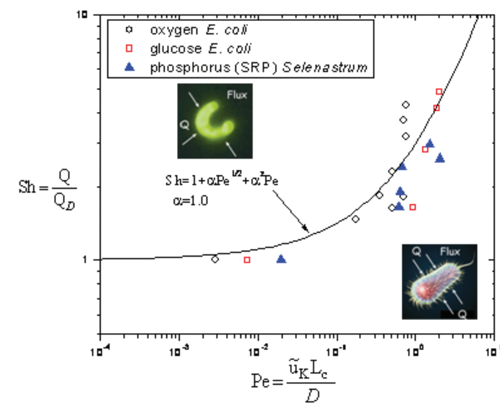

Figure 12: *The ratio of total mass flux to microorganisms cells in a turbulent fluid (Q) normalized by the total mass flux to the cell by molecular diffusion (Q_D) as a function of the Péclet number. There are not parameters in the prediction model that require specific calibration. Energy dissipation level, ε, is a unifying physical scaling parameter which integrates large scale fluid motions and the metabolism of microscopic organisms.*

Progress on deliverables

Milestone/Deliverable	Progress
3) Dynamic algae bloom model.	Significant progress in hydrologic controls. Paper in press.
5) Dynamic frog population model.	Significant progress in hydrologic controls on egg mass survival rate. Abstract Ecological Society of America (ESA), 2007, partners work bearing on dam relicensing.

Plans

We will continue to investigate environmental controls (conditions and resources limiting persistence and abundance) of key species (cyanobacteria, algae, lamprey, frogs, and fish) using empirical and mechanistic approaches. Coupling what we learn about the needs and tolerances of focal organisms with highly resolved environmental data should move us closer to understanding the relative importance of individualistic species niche requirements versus species interactions and landscape (e.g. source-sink) scale movements in explaining distributions, abundances, performances, and persistence of species in watersheds.

► DW10: DW Model code development

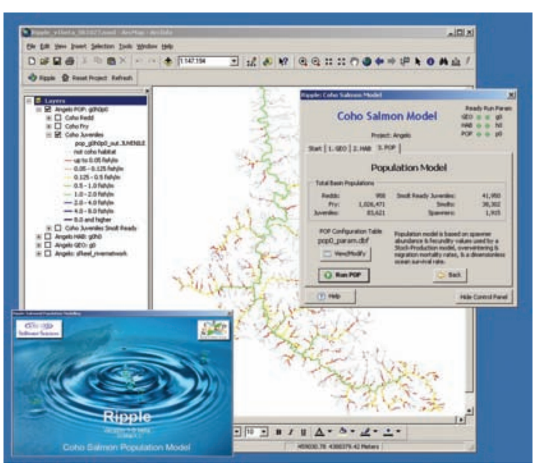

Figure 13: *Ripple Graphical User Interface*

In Year 5, a large effort was made to assemble a first-cut static modeling linking topographic, channel habitat and Coho populations. It has been named Ripple and will be released in 2007. Some important programming work remains to be done, but it is on schedule. We plan to release not just the executable program, but also source code (not-for-profit only).

The effort is an extensive collaboration between NCED researchers and Stillwater Sciences, with some assistance from NCALM. We are also examining the University of Washington's SHIRAZ, the closest existing salmon population model to Ripple, and assessing their relative strengths. Users of Ripple will need good data on channel gradients. Common procedures (involving delineating maximum fall lines and calculating slope for individual cell pairs) generate huge noise. Part of our effort will be to write up tools we have developed that give a much better slope data. We assembled the model in time for a demonstration during NCED's 2006 NSF Site Visit. Since then we have been working on improving the interface and improving the stability of the model (Figure 13).

Progress on deliverables

Milestone/Deliverable	Progress
1) Steady state model for linking topography to populations of critical organisms.	Ripple Coho Salmon model release date summer, 2007. Work on expanding and generalizing after that.
2) Dynamic model for linking topography, climate change, and landuse to populations of critical organisms.	Investigating appropriate 2D hydraulic flow model to serve as basis for flow routing.

Plans

In the next two years we expect to improve Ripple in several ways: 1) introduce dynamic hydrology by linking it to a watershed rainfall-runoff model and channel routing program—which in turn would start us on the path of sediment routing; 2) adding a temperature model; 3) adding barriers and large woody debris; and 4) directing the model approach at organisms other than Coho, namely algae, frogs, and aquatic insects.

► DW11: Use of Desktop watershed models in land-use management decisions

Due to changes in the SIP, we have added this project for the coming years. We have initiated discussions with social scientists in NCED to explore how DW gaming scenarios might inform societal decisions about watershed resources.

IIb. Subsurface Architecture Integrated Project

Project Team

Lead PI: David Mohrig
Project Manager: James Buttles
Contributing PIs: Chris Paola, Gary Parker, Robert Twilley, Vaughan Voller, Efi Foufoula-Georgiou, Nick Flores, Ben Hobbs

Executive Summary

The Subsurface Architecture (SA) Integrated Project (IP) underwent a fundamental restructuring during 2006-2007. We decided to focus the whole SA IP effort on developing methods for predicting delta evolution in support of sustainable delta restoration, with a particular emphasis on integrating predictive models with information from subsurface and experimental studies of delta lobe development, channel network self-organization, and ecogeomorphology. Building on the "surface to subsurface" SA IP theme, we are developing methods to use subsurface records to understand how the delta maintained itself naturally (ie, before human influence) during the Quaternary, with the aim of using these natural self-maintenance processes to guide the design of a sustainable delta-restoration program. As channels evolve under conditions of net deposition, they leave records of the natural variability of the surface and of its response to imposed changes. "Reverse engineering" the stratigraphic record to extract this information requires that we understand the complex, nonlinear processes by which surface dynamics are encoded into 3D stratal geometry. Stratigraphically controlled variations in porosity and permeability also set the spatial patterns of mechanical compaction that control land subsidence and influence the ecology of lowland settings. A byproduct of this work is insight that can improve prediction of variations in the distribution of porosity and permeability that control the flow and accumulation of water, oil, and gas in the subsurface.

A new study of the construction of leveed channels and overbank surfaces by depositional turbidity currents linked measurements of submarine levees and stratigraphy from the offshore Borneo with a laboratory experiment that resolves the processes controlling submarine levee growth. We found that levee taper rapidly increased during early levee growth then transitioned to a slower taper growth rate at a channel relief exceeding approximately 30 m. Results from laboratory experiments indicate that the degree of channel confinement and vertical structure of the sediment concentration profile are the most important parameters controlling levee growth. Using our observations, we developed a levee growth model based on an advection-settling scheme coupled to a sediment concentration profile described by the Rouse suspended sediment profile. We identified a reasonable set of flow conditions that produced a levee taper growth history similar to observations. The measurements and associated model of the morphodynamics of levee growth in aggrading channel settings can also be applied to terrestrial levee dynamics.

The main eXperimental EarthScapes facilitiy (XES) activity this year was completion of a long-planned experiment on interaction of multiple sediment sources in an asymmetrically subsiding basin modeled after the Rio Grande rift. This work contributes to the SA IP via its theme on tectonic steering of channel systems. The experiment had four sediment/water sources: two on the footwall side, one on the hanging-wall side, and one axial. Thus far, the main finding has been that the relative sizes of the domains controlled by the four sediment sources is almost entirely controlled by the ratio of sediment supply to subsidence; water supply does not seem to play a major role. In a sense, the boundaries between the transverse and axial domains can be thought of as analogous to a shoreline with strong alongshore transport.

In addition, we carried out a series of experiments with colleagues at ExxonMobil to demonstrate that a new cohesive-sediment simulant mix they have developed can indeed capture the spatial structure of fine-grained deltas like the Mississippi Delta. The shoreline of such fine-grained deltas is much more irregular than for the noncohesive case, which we believe will influence the distribution of biota sensitive to the total length of the land-water interface. To help clarify the distribution of habitat types, we developed what we believe is the first quantitatively based method to distinguish channel edges from true shoreline. We also developed prototype cellular channel-avulsion models that we have implemented in various forms (ie, different sediment transport dynamics, including or excluding backwater effects) to determine their affects on delta dynamics.

Finally, we have been working intensively, with input from the National Science Foundation (NSF), on a new initiative in delta restoration that will extend the SA IP to a larger group of colleagues.

Goal

The revised goal of the SA IP is to develop methods to extract quantitative information on the structure and dynamics of depositional systems from stratigraphic records and apply this information to landscape prediction and restoration.

Approach

The SA IP applies the National Center for Earth-surface Dynamic's (NCED) integrated, predictive approach to extracting information from subsurface stratigraphy to infer rates, spatial patterns, and mechanisms of natural (prehuman) delta building processes. The data base for this is primarily seismic imaging, well logs, and cores. This data is extremely costly to obtain and is mostly privately held in the oil industry, so we seek to maintain industrial connections that will give us access to data. In parallel, we perform experiments and field studies in the modern delta to develop predictive models of the processes by which deltas build land and maintain themselves and their associated ecosystems against subsidence and sea-level rise. These processes are strongly influenced by biota such that deltaic land-building must be seen as a bio-physical process and collaboration among ecologists, Earth scientists, and engineers is essential. Our approach involves understanding internally generated (autogenic) deltaic dynamics as well as delta response to external controls like subsidence, climate, and sea level. To provide additional focus and connect the SA IP with stream restoration, we are developing a depositional field site, the Wax Lake Delta (WLD), an active sublobe within the Mississippi Delta system. This will be done in collaboration with the NCED Stream Restoration (SR) IP group and outside Principal Investigators (PI). The end result will be predictive tools for delta restoration. To make the final step to restoring the Delta requires collaboration between natural and social scientists to understand and optimize the interaction of scientific input and human decision making.

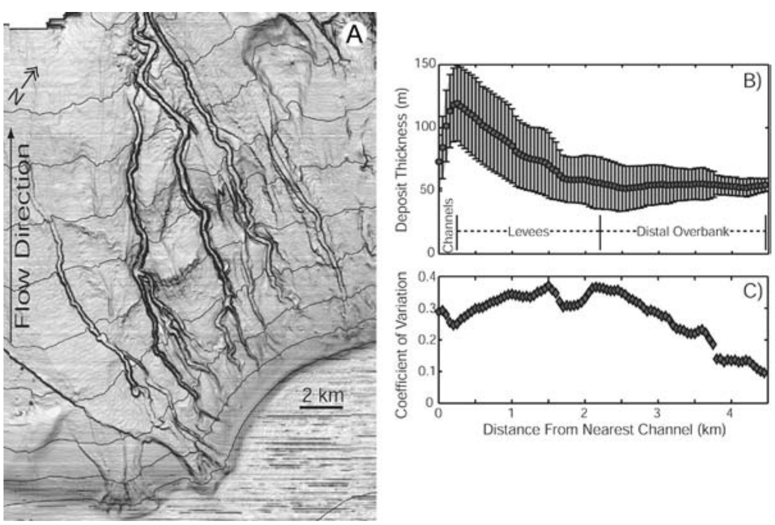

Figure 1. *Recent sedimentation within a tributary network of submarine channels. A) Dip map of study region, offshore Borneo, highlighting the network of leveed submarine channels. High values of surface slope (dark shading) define channel side-walls and detachment scarps associated with submarine landslides. Contour lines mark 100 m bathymetric intervals. B) Mean thickness of Holocene/latest Pleistocene sediment deposited within the network shown in (A) as a function of distance from the nearest channel thalweg. Error bars represent +/- one standard deviation in deposit thickness. Thickness data was assembled on a 25 m × 25 m grid. B) Coefficient of variation (CV) for deposit thickness. The transition from a roughly constant CV to a continuously decreasing value defines the boundary between the levee and background overbank surface. We expect a greater variation in depositional thickness to be associated with focused levee deposition versus the background sedimentation building the regional overbank surface.*

Accomplishments and Plans: Major Initiatives

Accomplishments, 2006-2007: work predating the revised SA plan

In our study of the construction of leveed channels and overbank surfaces by depositional turbidity currents, we linked geometrical measurements of submarine levees and stratigraphy from the continental margin offshore Borneo with results from a laboratory experiment that resolves, at a reduced scale, the processes controlling submarine levee growth (Figure 1; Straub et al, in review). These measurements aid in the development of a quantitative model that captures some of the morphodynamics of levee growth in aggrading channel settings and may therefore aid our conceptual understanding of terrestrial levee dynamics. The thickness of natural levee and regional overbank deposits that resulted in the construction of a tributary network of submarine channels offshore Brunei were measured using an industry 3D seismic volume. Channel relief in this system is tied to the growth of prominent levees. Levee taper was measured for channels of varying relief. We found that levee taper rapidly increased during early levee growth and then transitioned to a slower taper growth rate at a channel relief exceeding approximately 30 m. Results from the reduced scale laboratory experiment indicate that the degree of channel confinement and vertical structure of the sediment concentration profile are the most important parameters controlling levee growth. The rate of levee taper growth was high for all laboratory cases where turbidity current thickness was three times greater than the local channel relief (depth). For these flows, a fraction of the highly stratified portion of the suspended-sediment concentration profile was located above the levee-crest and free to spread onto the channel margins, promoting the rapid increase in levee taper. Using our observations from the laboratory experiment, we developed a levee growth model based on an advection-settling scheme coupled to a sediment concentration profile described by the Rouse suspended sediment profile. We identified a reasonable set of flow conditions that produced a levee taper growth history similar to that observed from offshore Borneo (Figure 1). The results of this model demonstrated that a roll-over to a lower rate of levee taper growth occurred following confinement of the highly stratified portion of the sediment concentration profile within the channel-bounding levees. This data can be used to estimate a characteristic thickness of channel forming turbidity currents by hypothesizing that the measured roll-over in a plot of levee taper vs channel relief is the result of the confinement of the lower 30% of the turbidity current. The ability to estimate turbidity current heights for modern and paleo-channel systems will aid in forward and inverse modeling of channel evolution. This work has benefited from interactions with NCED PI Gary Parker and was motivated by the former SA priority, Comparative Dynamics of Submarine Versus River Channel*s*. Ideas generated via this analysis will be used in developing current SA priority area SA01.

XES facility

The main XES activity this year was completion of a long-planned experiment on interaction of multiple sediment sources in an asymmetrically subsiding basin modeled after the Rio Grande rift. This work contributes to the SA IP via its theme on tectonic steering of channel systems. However, this experiment was done to fulfill, and was partially supported by, a non-NCED NSF grant with colleagues from the University of New Mexico (G Smith, S Connell) who provided expertise on Rio Grande rift sedimentation. The lead NCED personnel were graduate students Wonsuck Kim and John Martin along with staff members Dick Christopher, Jim Mullin, and Chris Ellis. The experiment had four sediment/water sources: two on the footwall side, one on the hanging-wall side, and one axial. A pair of images of the experimental surface at two different times is shown in Figure 2. The experiment lasted about 210 run hours and was completed this fall. As of the submission of this proposal, the deposit was still being sectioned. Thus far, the main finding has been that the relative sizes of the domains controlled by the four sediment sources is almost entirely controlled by the ratio of sediment supply to subsidence; water supply does not seem to play a major role. In a sense, the boundaries between the transverse and axial domains can be thought of as analogous to a shoreline with strong alongshore transport. NCED PIs Chris Paola and VaughanVoller are working to adapt existing moving-boundary theory to model this problem (however, further work on this will be done outside of NCED). No publications have resulted from this experiment yet, though we have produced a number of XES related publications from previous experiments (eg, Kim et al, 2006a,b; Strong and Paola, 2006).

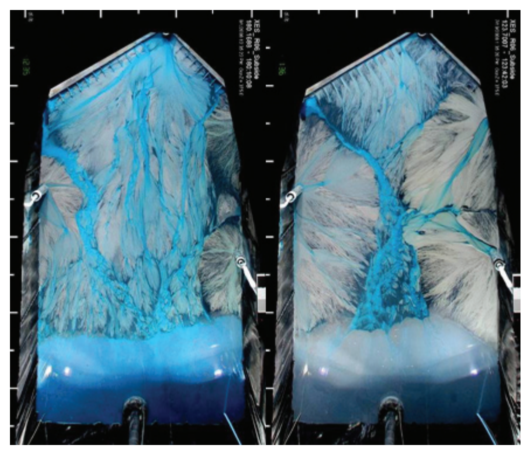

Figure 2. *Channel patterns and domain boundaries in the XES 06 rift-sedimentation experiment. Left: axial dominated condition; right: footwall-dominated condition.*

Rationale for the new SA focus: Delta restoration science and engineering

Coastal landscapes of Louisiana have withstood repeated hurricane events over the past 5,000 years, but the current, highly-engineered watersheds and floodplains have made these wetlands more susceptible to the destructive forces of climate change. Ecosystem restoration efforts seek to provide freshwater and sediment resources to develop extensive wetland landscapes. An important factor to consider: restoration plans effectively determine limitations of the coastal processes necessary to develop resilient wetland landscapes. And, these resources must be supplied at rates that effectively change the trajectory of landscape fragmentation to a stable, or enhanced, wetland area. Even with the occurrence of sea level rise, subsidence, and hurricanes, adequate river resources, consisting of freshwater and sediments, sustained the Louisiana coast for several thousand years. Yet with the impacts of land-use practices and public works projects, the future of coastal resources are fragile since we are not sure what thresholds of sea level rise will result in their collapse.

Restoration goals focus on building extensive coastal landscapes of habitat mosaics that by modifying environmental drivers and conditions that will allow self-design of an ecological footprint. If provided the requisite resources, coastal wetlands are able to sustain themselves over hundreds of years, even where the land is subsiding or the sea level is rising. It is important that restoration plans account for the presently observed subsidence rates and the anticipated acceleration of sea level rise to calibrate the amount of resources needed to maintain rehabilitated landscapes through the 21st century. This result can only be achieved with large-scale, strategic, and scientifically informed restoration investments (NRC 2005, CERP 2004).

Accomplishments and Plans: SIP Project Plan

Much of this year's SA research was structured by the previous Stategic Implementation Plan (SIP) and is discussed above. In this section, we focus on plans for Mississippi Delta restoration research and initial results.

► Project SA01: Current sediment budget and subsidence distribution in Mississippi Delta

Accurate measures of the amount of sediment moving through the lower Mississippi River are essential to all plans that include diverting some fraction of these solids onto the delta top in order to counteract ongoing subsidence and land loss. NCED graduate student Jeff Nittrouer, working with Meade Allison of Tulane University, has collected sequential bathymetric maps from a key section on the lower river that allows them to track bedforms and estimate the bed-material flux as a function of river stage and/or discharge. These measured values for the volume of the coarsest sediment moving through the channel (Nittrouer et al, in review) provide an important constraint on the amount of sand available for possible land-building strategies. Examples of the channel-bottom bathymetry used to calculate the bed-material flow are shown in Figure 3 and point out the dramatic change in river bottom topography associated with variation in sediment transporting conditions.

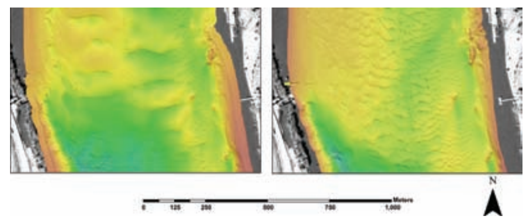

Figure 3. *Dramatic change in Mississippi River bottom topography at Audubon Park (river km 165) associated with variation in sediment transporting conditions. Cool colors represent relatively deep water. (Left) January 2005, river discharge of 34,300 m3/s. (Right) March 2006, river discharge of 8.900 m3/s.*

Swath maps of river-bottom topography similar to those in Figure 3 have been collected for the lower 150 km of the Mississippi River. These data reveal that a fraction of the river bottom is not covered by actively moving sediment. Stratigraphic layering of the stable exposed substrate, assumed to be Pleistocene or younger in age, is easily recognized on the bathymetric maps (Figure 4). Why hasn't the large relative rise in sea level forced sediment deposition on the channel bed of the lower river? Is it possible that bed sedimentation upstream of New Orleans is sufficient to remove enough bed material from the system that the lower river bed is somewhat starved of material?

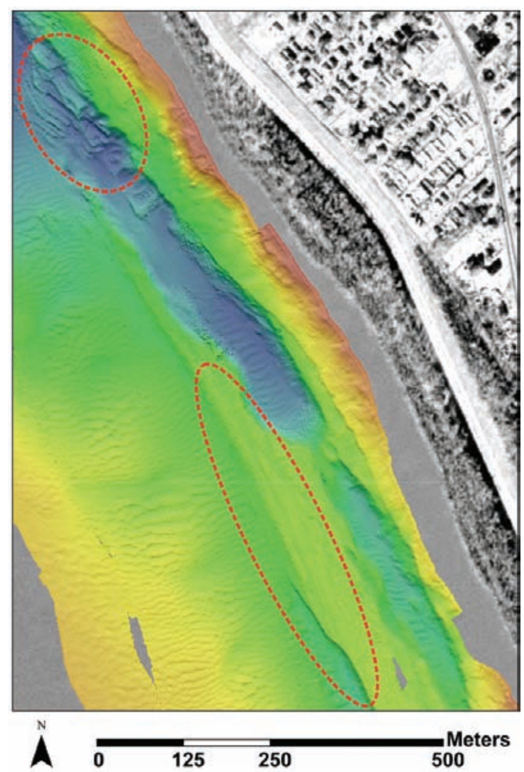

Figure 4. *Image of Mississippi River bottom topography at English Turn (river km 135). Ellipsoids mark prominent exposures of resistant stratified substrate on the river bottom. Cool colors represent relatively deep water. November 2003, river discharge of 6,300 m^3/s.*

There have been few studies in sandy rivers that specifically identify how much of the sand is being transported as bedload, suspended load, or in a transitional mode, despite its importance in interpreting estimates of bed-material load from bedform tracking and in constraining the amount and type of sand available to build the surrounding floodplain. Members of NCED PI David Mohrig's research group have been collecting this type of data from the lower Niobrara River, NE. The group has developed a methodology for estimating local transport conditions, by determining the single local shear velocity that produced a suite of Rouse profiles for different particle sizes, that best fits the suite of concentration profiles measured in the field. Fraction of particles moving completely in bedload or suspended load at each location can then be estimated using the following ratios of settling velocity (w_s) to shear velocity (u_*): fully suspended when $w_s / u_* \leq 1$ and moving only as bedload when $w_s / u_* > 3$ (Nino et al, 2003). Application of these criteria to sediment moving through the Niobrara River shows that ~80% of the sediment is traveling as suspended load, ~ 20% is traveling in a transitional mode between bedload and suspended load, and less than 1% is traveling as pure bedload. This work highlights the importance of the transitional transport mode in natural sandy rivers, a transport scenario thought to be equally important in the lower Mississippi River. Insight from the analysis of the shallow river is being used to guide development of a suspended sediment sampling scheme for the larger Mississippi River that focuses on resolving the structure of the sediment concentration profiles in the lowermost 10 m of water column. NCED graduate student Jeff Nittrouer, graduate student Meade Allison of Tulane University, and PI Mohrig and are presently developing a methodology to do this using a P-63 suspended sediment sampler system.

Progress on deliverables

Milestone/Deliverable	Progress
Develop quantitative measures of bedload, suspended load, and wash load supply near Baton Rouge	As discussed above, we have initial estimates of sediment delivery to the Mississippi Delta based on analysis of topography in the main Mississippi channel, and these estimates indicate that sediment losses along the channel may be substantial. A major advance this year was to secure access to a seismic volume through WesternGeco (see report under project SA04 below).
Determine net loss to in-channel deposition downstream of Baton Rouge.	
Determine regional spatial distribution of subsidence from seismic records.	

Plans

NCED graduate student Jeff Nittrouer and colleague Meade Allison of Tulane University collected the first set of suspended sediment profiles for the lower Mississippi River using a P-63 suspended sediment sampler system. We are now in position to start defining the fraction and sand sizes moving as bedload vs suspended load and defining floc concentrations over the range of river discharge to quantify the spatial and temporal variability of bed-material transport in the Mississippi River from Baton Rouge to the river mouth.

Of particular importance is determining the structure of the concentration profiles for suspended sand as a function of river discharge. Improving our understanding of sand transport in the lower river is important to reducing the uncertainty associated with the quantity of sediment available for possible Mississippi Delta restoration projects.

Sub-bottom profiles for the river between Baton Rouge (roughly) and Venice, LA will be carried out to determine the thickness of the Holocene sand deposit on the channel bed. An understanding of where sediment is being naturally sequestered within the lower river system is also necessary in order to refine our understanding of potential amounts of sediment available for restoration projects.

► Project SA02: Behavior and deposition of cohesive sediment

This is a new priority research area associated with the new focus on the Mississippi Delta. No work has been done on it yet. During the coming year, we will investigate the extent to which traditional sediment-flux equations can be applied to the transport of cohesive sediment, accounting for their effective (flocculated) diameter and density. This work will begin with planned field work at Wax Lake Delta in May, 2007, to establish the state of transport of the fine sediment load.

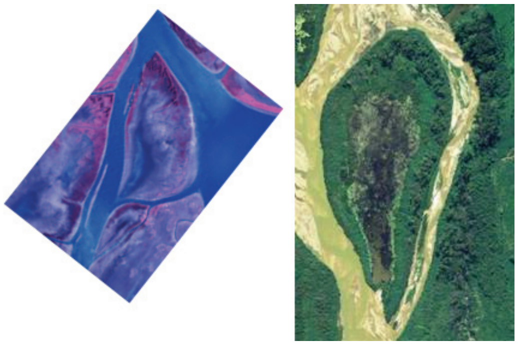

Figure 5. *Bar/island vegetation in aggrading channels–Niobrara River, NE (right). Bar/island topography in aggrading channels–Wax Lake Delta (left). Islands approximately 1 km in length.*

► Project SA03: Vegetation-sedimentation interaction in island and marsh development and maintenance

Vegetation plays a role in inducing and stabilizing sedimentation and in the evolution of bed elevation in aggrading channels. Figure 5 shows an example of bar/island vegetation in aggrading channels of the Niobrara River, NE, where we have been doing field work for the past several years, and an example of bar/island topography in aggrading channels of the Wax Lake Delta.

We have been carrying out experiments on vegetation-channel interaction for the past three years. A principal finding has been that a simple two-discharge cycle (prolonged low flow with short (one hour) episodes of high flow at regular intervals accompanied by seeding with a constant areal density of alfalfa) leads to self-organization of a dynamic single-thread channel (with occasional splits and islands) in which the rate of production of a newly vegetated area balances the rate of loss of area to erosion (Tal and Paola, 2007). We parameterize the vegetation-channel interaction in terms of a time-scale ratio T_{veg}/T_{chan} where T_{veg} is the time needed for vegetation to establish itself and T_{chan} is a channel mobility time scale, eg, the time needed for channels to displace themselves laterally by some fixed fraction of their width. The velocity and depth characteristics of the single channel are comparable to those of the active threads of the initial braided river from which the channel develops. The channel dimensions are adjusted to be just sufficient, to slightly undersized, to carry the flood (high) discharge, so that (unlike the initial braided state) the single channel has well defined edges and a floodplain. We also analyzed the development of the floodplain and found that it self-assembles by aggregation of initial isolated vegetated areas (bar tops and other high areas in the initial braided river; Figure 6). This work has been done in the context of restoration and management of relatively coarse-grained braided channels, but we believe the basic principles can be adapted to fine-grained deltaic systems as well.

Figure 6. *Formation of a floodplain (green) by coalescence of individual vegetation patches on high areas of an initial braided river (yellow). Floods 2 and 9 of SAFL veg-braiding run #1, with interflood (growing) time = 6 days, 1 hr flood, and high/low discharge ratio = 5.*

Progress on deliverables

Milestone/Deliverable	Progress
Determine role of growing plants in inducing and stabilizing sedimentation	The experiments described above clearly indicate the central role of vegetation in controlling channel morphology. This year we will work to extend these ideas to bar and island stabilization in fine-grained, low-gradient systems. We have also initiated a modeling effort to describe and predict the aggregation process of island coalescence by which the experimental flood plain formed.
Determine correlation between bed elevation and plant community and physical plant properties.	

Plans

We are working with NCED PI Efi Foufoula-Georgiou, synthesis Postdoctoral Research Associate Doug Jerolmack, and others to explore theoretical models for the aggregation of initial isolated vegetated areas. We will also investigate the feasibility and affect of using the alfalfa methods on our experimental deltas. We have also worked with collaborators at the US Department of the Interior, Bureau of Reclamation (USBR), NIWA New Zealand, and NCED PI Peter Wilcock on applications of this work to the SR IP, given that revegetating and devegetating channels and bars are often central issues in stream restoration. This year, we will work with PIs Robert Twilley and Mary Power to try to incorporate more realistic ecological effects in this effort.

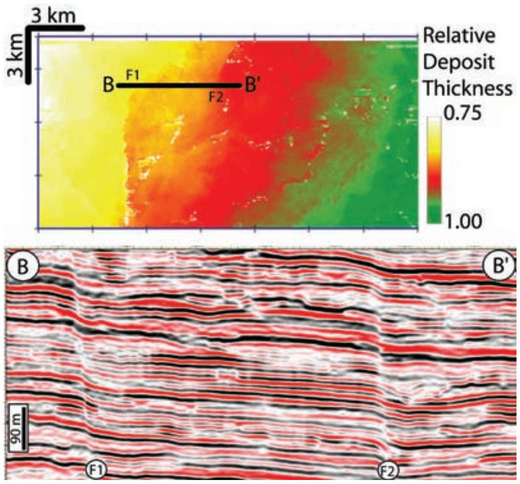

Figure 7. *Local map and cross-section from Breton Sound, LA, highlighting variability in Quaternary sedimentation associated with internal structural deformation of the Mississippi delta. Seismic imaging of Quaternary sedimentary deposits constructing the Mississippi delta shows significant spatial and temporal variability in deposit thickness, and therefore deposition rate, associated with growth faulting. Two growth faults, labeled F1 and F2 are marked on the seismic cross section B – B'. Seismic data is provided by WesternGeco.*

► Project SA04: Reconstructing delta dynamics from seismic records

Regional seismic records, mostly obtained from industry, are used to determine geometry, spatial arrangement, and variability of deltaic depositional units. Growth faults have been recognized as having an important role in surface displacement on the delta, but there is very little information characterizing their magnitude as a function of space and time. These records also reserve spatial patterns of subsidence associated with faulting and differential compaction. Access to a seismic volume has been provided by WesternGeco with substantial help from collaborator David McCormick of Schlumberger-Doll Research (Figure 7). Intensive mapping of faults and key stratigraphic horizons in the Quaternary section of the seismic volume will provide a framework for understanding these vertical displacements and their influence on the depositional system.

Progress on deliverables

Milestone/Deliverable	Progress
Map fault location and offset.	As mentioned above, the major advance this year was to secure access to a substantial seismic volume through WesternGeco. We estimate the cost of obtaining this data at roughly $10M. We are grateful for substantial help from collaborator David McCormick of Schlumberger-Doll Research.
Map interaction of active faults and channels.	
Measure geometry, spatial arrangement, and variability of deltaic depositional units as a function of relative sea level rise and fall.	

Plans

Research emphasis this year will be on analysis of the seismic data we have to define the roles of small- and large-scale normal faulting in controlling delta-top subsidence. We will also be seeking additional data for analysis.

► Project SA05: Reconstructing delta dynamics from cores and other records

Mechanical compaction of the underlying sediment column is recognized to be one of, if not the largest, contributor to the relative sea level rise presently experienced by the Mississippi Delta. This compaction is a function of the deposit porosity, which in turn is a function of composition of the detritus, burial depth, and other factors. In the academic community, it is generally assumed that deposit compaction important to delta land loss is restricted the thin Holocene section. While consolidation of Holocene deposits plays a role in land subsidence, focused withdrawal of interstitial fluids from deposits at greater depth provide evidence for high porosities throughout the delta volume. Thus a long-term goal is to characterize the porosity state for the uppermost kilometer of strata in the Breton Sound area through well log analysis combined with direct detection via seismic inversion. This analysis will provide necessary information for evaluating the potential contributions of a larger portion of the sedimentary section to land subsidence via compaction with results directly relevant to Louisiana State University's CLEAR (Coastal Louisiana Ecosystem Assessment and Restoration) model project.

Progress on deliverables

Milestone/Deliverable	Progress
Collect core and basic data analysis (grain size, C14), initial focus on Barataria Bay and the Wax Lake Delta.	This is a new project, and we have not yet begun work on it. We note that significant progress on this sub-project will require outside collaboration. There is no one within NCED who has primary expertise in this area. However, it is included here because we consider it critical to the overall success of the Mississippi Delta restoration initiative.
Use core data to constrain bulk spatial distribution of grain size and sedimentation rate for La Fourche lobe (40-8ka).	
Use sedimentary structure and textures, for the Wax Lake Delta, to constrain depositional conditions from the SA06 numerical model.	

Plans

As discussed previously, we are hard at work putting together a new initiative to support an expanded program in the Mississippi Delta. If successful, this initiative will fund the coring work required for this sub-project. Our next task within the existing NCED framework is to characterize the porosity state for the uppermost kilometer of strata between the Breton Sound area through well log analysis combined with direct detection via seismic inversion.

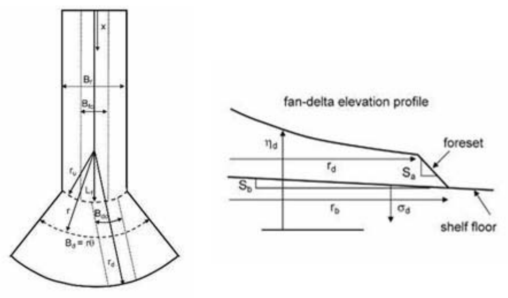

Figure 8. *Morphodynamic model of the Wax Lake Fan Delta and the fluvial reach immediately upstream.*

► Project SA06: Modeling land building; integration with Louisiana State University's CLEAR project

A first version of a laterally averaged numerical land-building model (Figure 8) has been developed and applied to the Wax Lake Delta (Figure 9; Parker et al, Proceedings, River Flow 2006, Lisbon, October). The model assumes a single sand grain size and applies time-averaged Exner equations of sediment continuity on the fluvial and fan-delta reaches. Water and sediment route through the seven major distributary channels of the Wax Lake Delta (Figure 9). Published maps of the Wax Lake Delta show that sedimentation is not evenly distributed between the seven existing channels and that the sedimentation associated with each channel varies from year to year. The maps suggest a dynamic routing of water and sediment across the Wax Lake Delta that is important to understand in order to generate accurate numerical models of land construction using the current numerical model and the LSU CLEAR model.

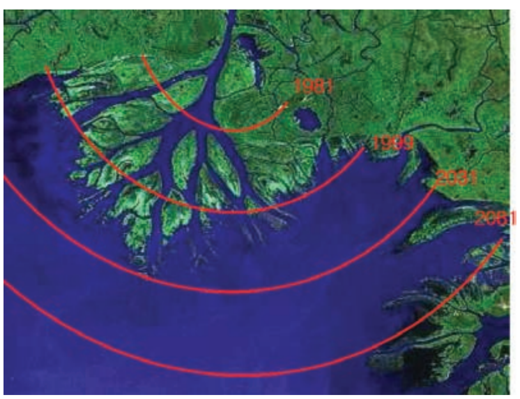

Figure 9. *Initial morphodynamic model predictions of the evolution of Wax Lake Delta. Concentric red lines show the projected evolution of the shoreline of the delta out to 2081 overlain onto a satellite image from January 1999.*

The basic idea in a numerical solution is to cover the solution domain with a field of discrete nodes, and use the appropriate governing partial differential equations, to develop algebraic equations that relate values of the dependent variables at a given node point to the values at neighboring nodes. However, there is an emerging class of problems that is not so amenable to these basic methods. These problems, referred to as multi-scale—multi-physics problems, are characterized by a process that occurs across a very wide range of length scales involving interacting of physical phenomena that have dissimilar mechanics. It is theoretically feasible to build so-called direct simulations of multi-scale—multi physics problems that resolve all the length scales and physical phenomena. In practice, however, a wide scale application of such models is severely limited in the choice of domain size. A small river reach that resolves the major geomorphology features and accounts for the larger flow eddies is possible. On the other hand, a delta size domain that resolves down to the bed ripples is beyond current computer power.

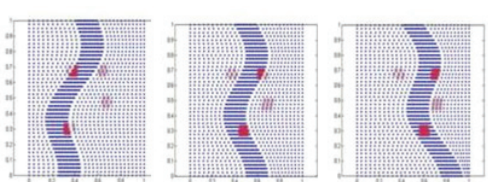

Figure 10. *Schematic of a channel avulsing across its floodplain indicating how a "particle cloud" method could adapt to resolve the channel.*

On a structured grid, the location of a node is uniquely defined by an index address. In this approach, it is easy to generate appropriate algebraic discrete equations and devise efficient solution techniques. A critical drawback is a severe restriction in the shape of domain that can be discretized. The restriction on the ability to discretize the domain can be overcome by using a data structure of mesh of elements (triangle elements will tessellate any 2D domain). In this case, however, the data structure can be cumbersome, and it is particularity difficult to adapt the mesh as the solution proceeds, e.g., imagine a crack forming or a channel avulsing. This adaptive drawback is overcome by using so called "meshless methods." These emerging methods use a data structure that can be described as "cloud of particles"—a particle (a surrogate for a node point) of interest surrounded by its nearest

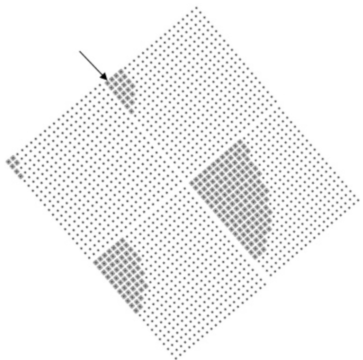

Figure 11. *Cloud Particle solution of enthalpy model of delta. Delta formation: Constant dimensionless flux of q = 2 applies at corner of basin-anisotropic channelization pronounced in x-direction.*

neighbors. Obtaining accurate, efficient, and robust discrete equations with this data structure is an active area of research in the computational mechanics community. The consequences of arriving at a sound scheme are dramatic since it allows for amazing flexibility in dealing with problems where adaptive meshing is required. The classic example is tracking the growth of a crack in a solid mechanics problem. In the context of a delta formation, a possible application would be tracking a channel as it avulses across the floodplain, as shown in Figure 10.

Preliminary work with the Cloud Particle method has been able to numerically resolve the enthalpy model of a delta prograding into an ocean basin. Figure 11 shows some predictions (four time snap shots of a developing delta) for the case of an anisotropic channelization mimicked by a directional diffusivity.

Progress on deliverables

Milestone/Deliverable	Progress
Develop laterally averaged lobe-construction model	Development of the laterally averaged lobe-construction model is progressing well; a first version is running and compares well with the known evolution of WLD as indicated above. We also added NCED PhD Wonsuck Kim as lead postdoctoral research associate to help accelerate model development. As indicated in the report for project SA07, we have also begun experiments that should help provide the data support for development of a new set of channel resolving models to couple to the averaged model.
Use results of network analysis, field data, and experiments to estimate fine-scale properties and variability of evolving delta lobes.	

Plans

Successive measurements of water and sediment discharge in the primary passes of the Wax Lake Delta, and associated changes in channel bottom and bank topography, will be undertaken this year. It is expected that considerable spatial and temporal variability in sedimentation will exist within the distributary network. These variations will be compared to those already studied in the aggrading Niobrara River, NE. Measurements will be used to refine the evolving numerical models of land construction beginning with the current numerical model and models being developed with Louisiana State University's CLEAR project.

We will also explore combining the new methods described above with our existing self-organization models, discussed in the next section, to provide new channel-resolving models.

► Project SA07: Self-organization of distributary systems including elevation statistics

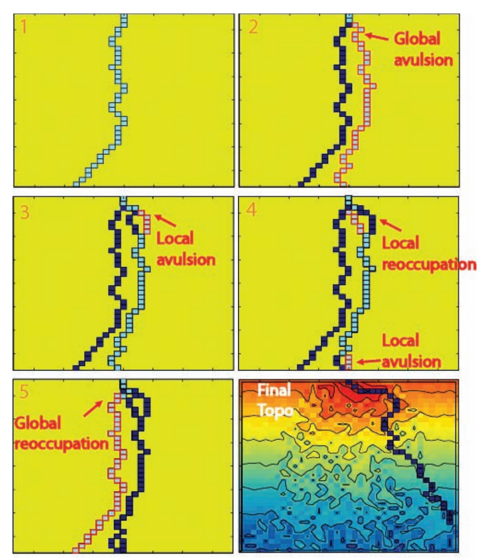

Figure 12. *Styles of avulsion in a cellular channel-avulsion model by Jerolmack and Paola (2007 in press). Active channel path is indicated by light blue cells, and red borders indicate cells involved in an avulsion. A large scale (global) avulsion (2) creates a new channel, then further (local) avulsions create smaller new channel segments (3–4) before a large avulsion returns flow to the previous channel path (5). Panel 6 shows the contoured relative topography at the end of a typical model run with uniform floodplain sedimentation.*

Intensive work on modeling and experimentation on deltas, focusing on autogenic dynamics and pattern formation, is underway. This work, which involves NCED Director Chris Paola, NCED PIs Vaughan Voller and David Mohrig, and Postdoctoral Research Associates Doug Jerolmack, Michael Puma, and Matt Wolinsky, is aimed at the Mississippi Delta and focuses on developing self-organization models for the fine structure of the delta top: channels, branching patterns, distribution of topographic elevation, and shoreline pattern. Figure 12 illustrates styles of avulsion in a cellular channel-avulsion model. An advantage of cellular models is that they can be readily adapted to include vegetation and coastal-marsh modeling. Our intent is that this work will fit into

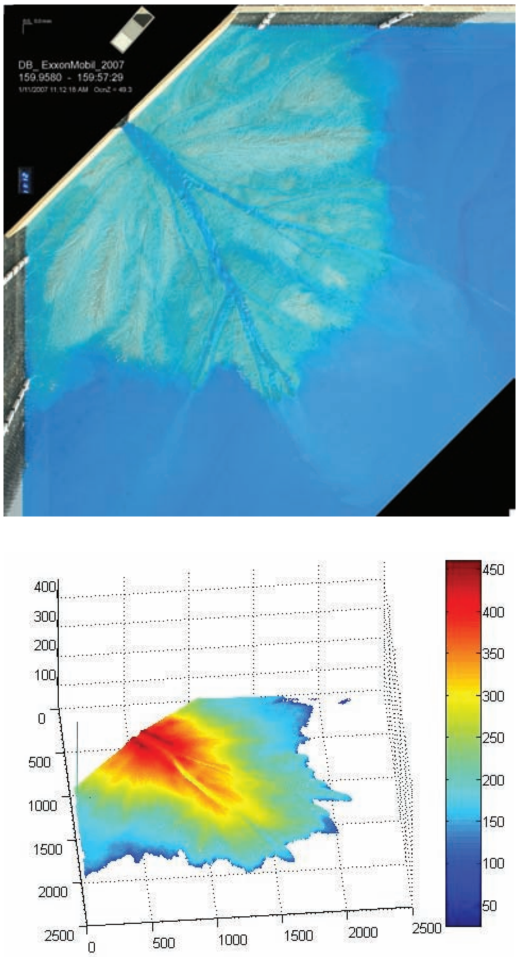

Figure 13. top: *Delta channel pattern produced in a basin with steadily rising sea level using the new proprietary ExxonMobil weakly cohesive sediment mix. Lead experimenter: John Martin.* bottom: *experimental delta topography.*

and complement the laterally averaged delta-lobe model being developed by NCED PI Gary Parker with new NCED Postdoctoral Research Associate Wonsuck Kim. NCED PI Vaughan Voller is working on adapting newly developed numerical methods to couple the deterministic PDE-based, laterally-averaged models with cellular models that can capture the self-organized channel pattern on the delta top.

Finally, we began working intensively on modeling and experimenting on deltas, focusing on autogenic dynamics and pattern formation. This work is aimed at the Mississippi Delta research focus for the SA IP. The intent is that this work will fit into and complement the laterally averaged delta-lobe model being developed by NCED PIs Gary Parker and Chris Paola with new NCED Postdoctoral Research Associate Wonsuck Kim. As discussed in the previous section, NCED PIs Vaughan Voller, Paola, and Parker are working on adapting advanced numerical methods to couple the deterministic PDE-based, laterally-averaged models with cellular models that can capture the self-organized channel pattern on the delta top.

Both the theoretical and experimental work are motivated, in part, by the need from the ecological side (NCED PI Robert Twilley) for information on the total length or area on the delta top with specific habitat parameters for fish as a delta lobe evolves and increases in size. For example, we might guess that the total delta top channel edge length l_{edge} or shoreline length l_{shore} scales with total top area A_{top} as $l \sim A_{top}^{\ b}$ where the reference value for b would be 0.5. We expect that b would be sensitive to sediment properties, especially degree of cohesion, wave climate, and perhaps vegetation effects. The plan is to investigate this through a combination of numerical models and experiments. Although the experiments are not intended to be precise scale models, we have been working on developing methods that allow us to create experimental deltas that have branching structures comparable to those of natural fine-grained deltas like the Mississippi Delta. To this end, one of the major advances this year was to secure transfer of a new proprietary sediment mix developed at NCED partner ExxonMobil that produces much more natural delta channel patterns and shorelines than our standard noncohesive coal-sand mixture (Figure 13).

Progress on deliverables

<table>
<tr><th>Milestone/Deliverable</th><th>Progress</th></tr>
<tr><td>Adapt existing network analysis tools to (static) distributary networks.</td><td rowspan="2">We have had limited success adapting network analysis techniques from tributary to distributary networks due to the much greater variability of the latter. This work will receive less emphasis in the coming year. The main progress in space-time statistics of evolving distributary systems involved collection of the experimental dataset sketched above, which we are just beginning to analyze now. Within a year, we will have a good intitial picture of how distributary network organization influences the space-time distribution of deposition in an experimental system. This information will provide an initial hypothesis to guide field observations (subsurface and Wax Lake Delta).</td></tr>
<tr><td>Develop methods for quantifying space-time statistics of active, evolving distributary systems to forecast distribution of elevation, grain size, and rate of deposition.</td></tr>
</table>

Plans

We will investigate statistics of length (channel, edge, shoreline) and area on the delta top with the aim of estimating specific habitat parameters for fish as a delta lobe evolves and increases in size. The initial focus will be experiments, calibrated with field data from WLD, and then numerical models. We also expect to make major headway on developing methods for quantifying space-time statistics of active, evolving distributary systems with the eventual goal of forecasting distribution of elevation, grain size, and rate of deposition.

► Project SA08: Upscaling short-term rates and small-scale geometries

The idea here is to improve our methods for relating small-scale laboratory experiments quantitatively to field scales and also to investigate how local, short-term flux laws (eg, sediment flux) change as space and time scale increase. Comparison of Wax Lake and experimental delta processes and patterns will guide development of appropriate scaling methods in these distributary systems. In particular, we are interested in the extent to which short-term transport and sedimentation rates (and, in some areas, subsidence rates) can be reliably extrapolated to predict delta evolution over decadal time scales. Some progress has already been made in characterizing the multiscaling structure of sediment fluxes and bed elevations for gravel and sand river beds. In addition, we are interested in the extent to which similarity measures can be used as a guide to scaling delta dynamics and geometry observed at laboratory (i.e., m) scales up to field (i.ei, > km) scales.

Progress on deliverables

Milestone/Deliverable	Progress
Develop methodology for upscaling laboratory delta data to natural scales for use in numerical models	This is a new project. The only direct work we have done on this project so far is an initial comparison of distributary patterns in the experiment described above with those of the Wax Lake Delta. The results are promising; work this year will focus on specific quantitative comparison of the experimental deltas with Wax Lake. In a previous project, we explored application of techniques from turbulence to analyzing scale dependence in landscapes (Passalacqua et al, 2006). In addition, promising initial work by NCED PI Efi Foufoula-Georgiou on scaling of fluctuations in sediment flux is reported in the StreamLab section (Appendix G: StreamLab Laboratory Experiments).
Develop physical theory to explain spatial distribution of deposition rate as a function of time scale	

Plans

We will work on methodology for upscaling laboratory delta data to natural scales for use in numerical models. This will be coupled to physical theory to predict spatial distribution of deposition rate as a function of time scale.

► Project SA09: Coastal system response to rising relative sea level

Current experiments are not intended to be precise natural scale models, but we have been working on developing methods that allow us to create experimental deltas that have branching structures comparable to those of natural, fine-grained deltas like the Mississippi Delta. To this end, one of the major advances this year was to secure transfer of a new proprietary sediment mix developed at NCED partner ExxonMobil; this mix produces much more natural delta channel patterns and shorelines than standard noncohesive coal-sand mixture (Figure 12). Knowledge of the patterns of sedimentation induced by relative sea-level rise will be compared against predictive models under development by NCED PIs GaryParker, Vaughan Voller, and Chris Paola.

We have made progress this year on analyzing depositional system response to rising sea level. NCED PI Gary Parker has led an extensive analysis of how low-gradient rivers deposit in response to rising sea level (Lauer et al, 2007; Parker et al, 2007a,b). Synthesis NCED Postdoctoral Research Associate Matt Wolinsky has developed a new long-profile model (LPM) of linked onshore-offshore depositional systems that can be applied to the sea-level rise case; the model uses some of the

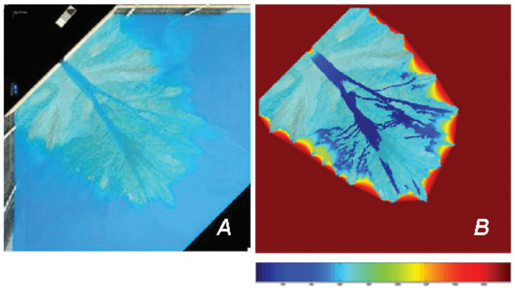

Figure 14. *Automated mapping of complex shorelines: A) Overhead photo of experimental delta. The coast is complex, with channel mouths and "marshy" areas. B) Map showing the swath angle (0o-180o) of "open ocean" seen by each image pixel. The shoreline can be mapped using by contouring the visibility angle (e.g. the 70o shoreline is the boundary between cyan and green in the angle image).*

methodology developed by NCED Postdoctoral Research Associate Juan Fedele and NCED Director Chris Paola (2007). The majority of work in the LPM over the past year has focused on the interactions between the fluvial surface and shallow marine and in particular shoreline dynamics. Advances have been made in understanding how storage and release of sediment provide an autogenic signal on shoreline movements. Through model interpretation of the XES measurements, ordered importance of the various controls on shoreline migration were established. A novel, fixed-grid method for tracking the development of an ocean basin in response to sediment input and base level change has been developed, and a computational method for identifying the location of the shoreline from satellite mapping has been developed (Figure 14).

Progress on deliverables

Milestone/Deliverable	Progress
Develop and calibrate a suite of numerical models for rivers that forecast lowland sediment accumulation and shoreline advance/retreat under conditions of relative sea-level rise.	Through the work reported above, particularly that of NCED PI Gary Parker's group, we now have a usable suite of 1D models to predict delta response to sea-level rise.

Plans

The next step is to use a combination of experiments and model refinements to move from 1D to 2D prediction, including the response of the distributary pattern to sea-level rise. Eventually, these predictions will be compared with the reconstructed history of the response of the Mississippi Delta to Holocene sea-level rise but this is three to four years off.

► Project SA10: Social tradeoffs in Mississippi Delta restoration

Project SA10 is a new project aimed at providing a means of developing and applying tools developed in our social science program under the SR IP. Initial implementation will begin in Year 6. What follows is an explanation of the rationale and plan for our social science effort in the SA IP.

Based on review of the decision analysis procedures proposed by the US Army Corps of Engineers (USACE) (the "Risk Informed Decision Framework"), there is a need for decision analytic methods to evaluate adaptive strategies. These strategies take advantage of what is learned from demonstration restoration projects and trade off the value of information from such projects with the costs of delaying the implementation of flood and surge protection plans.

The development of best decision practices will provide those interested in restoration a generalized set of tools that they could use to improve the way in which decisions are made so that the outcome of the restoration will more likely meet the objectives. Second, the application of the best practices to the case studies will provide excellent examples of how NCED is able to successfully integrate best practices into its comprehensive projects and provide a model for ways in which restoration decision-making can be effectively executed.

The NCED vision is to develop predictive scientific models that advance the science and application of landscape modeling. Current models were developed specifically to address uncertainty over restoration outcomes (supply-side uncertainty) and time of implementation. Both of these issues have received very little attention by economists, yet are fundamentally important research topics for economic analysis.

The basic idea is to develop models of social responses to landscape changes. These models of social responses fall into two categories: social responses that have market-based observations and social responses that have non market-based responses. Falling into the first category are things such as residential location and relocation, commercial fishing activities, and tourism-related activities. These responses can be integrated into a larger, general equilibrium model of the regional economy. Falling into the second category are things such as recreational fishing, hunting, and benefits to the public for nonusers that value restoration in order to preserve or restore nature even though they may not directly use the affected restoration areas. The framework will use predictions from the physical landscape models as inputs into the predictive economic models. Social responses predicted from the economic models can then be translated into economic benefits and general social changes. The resulting framework will be general enough to accommodate a broad range of economic and landscape models, but at the same time sufficient detail will be developed to apply specifically to Louisiana State University's CLEAR model. Restoration in the Mississippi Delta area will be one of the largest and most costly restoration projects ever undertaken. Integration of economic and predictive landscape models will lead to valuable insights for restoration planning and implementation in this area.

Progress on deliverables

This is a new project. Work on it has not yet begun. Please see the annual report under project SR09 for information on progress in the NCED social science program in the past year.

Plans

Our initial tentative focus will be on integrating several broad classes of predictive economic models into predictive models of landscape change, such as Louisiana State University's CLEAR model. We will also consider conflicts between marsh restoration, business and society, and apply risk and uncertainty analyses. We stress, however, that it is not realistic to expect our present modest social-science effort to address these issues in depth. Thus, a major emphasis in our plan to develop and secure additional funding for a larger Mississippi Delta restoration initiative will be to add more social scientists to the group.

Executive Summary-Plans

Each of the ten sub-projects within SA will move forward as described in the preceding text. The following scientific questions will be addressed:

1. What are the biasing and filtering properties of the sedimentary recording process, ie, how well do preserved strata represent the processes and structures that produced them?

2. How can we extract quantitative information on the rates, spatial pattern, and variability of transport and depositional processes from preserved strata?

3. How do low-lying depositional systems respond to external changes, such as changes in sediment supply, channelization, differential subsidence, and rising relative sea level?

4. How do depositional channel networks self-organize, and what information can be extracted from observed spatial patterns?

5. How does life (microbes, plants, and/or animals) influence depositional processes and depositional environments?

6. How can stratigraphic information on natural variability and channel-system response to change be used to inform environmental management?

Status of the larger Mississippi Delta Restoration Initiative

The Mississippi Delta Restoration Initiative, the general name for the new SA IP focus, draws on everything we have learned over the past five years about how surface dynamics are recorded in subsurface strata and also on our extensive collaboration with the oil industry, whose cooperation we will need to obtain critical subsurface data. The Mississippi Delta initiative will be, to our knowledge, the first-ever, large-scale attempt to "reverse engineer" a natural system from the sedimentary record. To carry it off, we need a bigger team than NCED can support. Hence, with NCED PIs and funds serving as a nucleus, we have formed a new, larger group that will develop the Mississippi Delta restoration program. We began making our case with the National Science Foundation (NSF) in June 2006 at a meeting with then-Assistant Director Margaret Leinen, her associate Marge Cavanaugh, NCED NSF managers Rich Lane and Mike Ellis, and many other NSF officials. A major accomplishment of this still-developing group was publication of a (fully refereed) comment on depositional processes in the Mississippi Delta in *Science* (April issue) of this year (Tornqvist et al, 2007).

Partner interactions

The Subsurface Architecture Partner Group (SAPG) is currently made up of researchers from the oil industry. At this time, confidentiality agreements prevent us from releasing the details of their application of NCED research. However, we can report that our emphasis on moving from analogy to analysis, as the basis for prediction, with its core experimental base, is being met with great enthusiasm by our partners. As in past years, we collaborate with partners on short courses involving deep-water and terrestrial depositional systems and NCED graduate students and alumni continue to serve as key leaders in these courses. A major development this year was expansion of our shallow-water short course program from one company to three companies. We also continue to conduct joint research with partners. A major partner activity during this year has been the release to NCED of a proprietary sediment simulator developed at ExxonMobil, which is allowing for more realistic experiments on fine-grained deltas. This contribution is a critical development in support of the Mississippi Delta Restoration Initiative, since it allows us to study the dynamics and evolution of distributary channel networks that closely match those of the WLD, the only naturally growing lobe in the modern Mississippi River. A second major partner activity has been the release of a 3D seismic survey from the Mississippi Delta transition zone (present-day shoreline zone) to analyze Pleistocene-to-Recent strata and faulting in order to improve our understanding of delta construction for purposes of improving delta maintenance. This seismic data has been made available to NCED by WesternGeco. In the coming year, we anticipate that the SAPG will expand to include active participants from the USACE, the US Geological Survey (USGS), and Louisiana state agencies as work on the Mississippi Delta becomes the central focus of the project.

IIc. Stream Restoration Integrated Project

Project Team

Lead PI: Peter Wilcock

Project Manager: Jeff Marr

Contributing PIs: Bill Dietrich, Jacques Finlay, Efi Foufoula-Georgou, Nicholas Flores, Benjamin Hobbs, Miki Hondzo, Chris Paola, Gary Parker, Lesley Perg, Mary Power, Vaughan Voller, Greg Wilkerson

Executive Summary

Year 5 work in the Stream Restoration Integrated project (SRIP) balances research, partner interactions, tool development and training. Here, we summarize partner interactions and focus primarily on SRIP research. Training initiatives are discussed in the Knowledge Transfer section of this report.

The stream restoration context of NCED research can be broadly organized into three categories: placing stream restoration projects in their watershed context, predicting the physical and biological response of stream channels to changes in driving conditions, and developing predictive links between stream restoration preferences, objectives, and actions.

Watershed context is an essential area of overlap with the Desktops Watershed IP (DWIP). Advances made in identifying regime thresholds and the effect of watershed location are essential for identifying favorable locations for management actions. These advances are largely described in the DW section of this report. The emergence of dynamic DW models, together with the increasing availability of digital archives, will support development of landscape history at specific locations, allowing past and future trends at proposed restoration sites to be more accurately predicted and interpreted. Watershed context is also a dominant factor in the Subsurface Architecture (SA) focus on restoration of the Mississippi Delta. A particular focus of NCED watershed research is routing of sediment through reaches and channel networks. We seek to extract essential grain-scale mechanisms for application to the reach and network scale, while also developing geochemical analyses (sediment fingerprinting) for integral summary of sediment sources. Progress on sediment modeling has been made at the flume to the reach scale, including the studies of the movement of fine sand through coarse-grained systems and the development of sediment routing models that incorporate sediment storage in pools, eddies, and floodplains. Substantial progress is reported under SR02, SR03, SR07, and SR08.

Predictive stream restoration requires an ability to predict the physical and biological response of stream channels to changes in initial and boundary conditions. We have made important progress in developing predictive relations for streambed composition as a function of water and sediment supply, including model studies of vertical and lateral grain sorting, advances on a general model for streambed sorting, tests of models of gravel augmentation and sediment pulses, and the transport of fine sediments over coarse beds, reported in SR02 and DW06. At the section scale, we continue our exceptional success in producing realistic dynamic scale channels with vegetation, we have developed additional relations for stream channel geometry, and we are applying channel/floodplain exchange models to field applications, reported in SR01 and SR03. Watershed position, channel configuration, and flow regime strongly control ecosystem response. We have demonstrated the concept of field-scale controlled experiments with high-resolution instrumentation in a major collaborative effort intended to support development and testing of predictive eco-physical models of the connection between structures, disturbance, and ecosystem response. We have also made important progress in scaling physical/biological interactions from lab to field, reported in SR04, SR05, and SR06.

Prediction of cause and effect incorporating the watershed context is a necessary, but not sufficient condition, for transforming stream restoration to a predictive practice. Implementation requires an explicit connection to stream restoration policy, decision-making, and implementation. We work to understand how to quantitatively link project goals to public preference, regulatory and policy guidelines, and management actions. We establish the link between stakeholder preferences and restoration options by determining stakeholder preference regarding stream restoration objectives and actions and the willingness to pay for restoration benefits. We have developed economic models of the role of uncertainty in restoration outcomes and are using survey methods to evaluate their effect on public preference. Because restoration objectives typically conflict and alternative locations and methods are commonly possible, implementing improved prediction in restoration decision requires a consistent basis for evaluating the tradeoffs. We have evaluated the conditions for implementing decision analysis tools in the restoration context and are developing both stochastic and deterministic decision models which will be implemented in a collaborative field effort with NCED research identifying sediment and nutrient sources.

In Year 5 we developed three new initiatives that focus multi-disciplinary collaboration in projects that require a center mode of operation:

StreamLab. We initiated an experimental program, StreamLab, of full-scale experiments on linked physical/chemical/ biological processes. Its essential features are an explicit multi-disciplinary focus, experimental control at the field scale, and the use of advanced technology to support detailed observations typical of small-scale lab experiments. We pursue full scale experiments for the simple reason that important features of natural systems (especially organisms) are difficult or impossible to scale. A sound understanding of both local mechanisms and broader interactions is needed to develop predictive models in river science (Paola et al., 2006). The solution is to conduct experiments at full scale while maintaining experimental control and using instrumentation that can resolve both local and full-scale processes. These experiments address a general need in river science; the immediate motivation within the SR IP is to better predict the ecosystem response to intentional modifications to the stream system. We believe that we demonstrated the StreamLab concept successfully in Year 5; we are now developing an expanded version – Outdoor StreamLab (OSL). A multiscale, multidisciplinary experiment is necessarily a large collaborative venture. Our first collaborative "run", StreamLab06, involved a 40 member research team of engineers, geologists, and ecologists, which included nine NCED faculty, as well as post-doctoral associates and graduate students, visiting scientists, environmental consultants, undergraduate assistants, and research staff. This collaborative work would be difficult to achieve outside of the organization, support, and commitment of a Center.

Minnesota River Basin. An important step forward in center-mode collaborative research was also achieved in the initiation of an integrated project on sediment and nutrient loading in the Minnesota River Basin. Eutrophication in Lake Pepin, which is downstream from the Mississippi River-Minnesota River confluence, has led to development restrictions and a focused push to define loading sources in contributing watersheds. With leveraged funding from the Minnesota Pollution Control Agency, we will develop a sediment budget for the Le Sueur River watershed, Minnesota, one of the main contributors to sediment and nutrient loading in the Minnesota River Basin. At the same time, we are using surveys to determine public preference and willingness-to-pay for management practices to reduce sediment and nutrient loading. We are also developing decision analysis models to support evaluation of tradeoffs and the incorporation of improved scientific information in the decision-making process. Locating management actions for reducing river loading is an advantageous problem for a collaborative physical/social decision-making research project to tackle. The objective – reducing sediment and nutrient discharge at the watershed outlet – is simple and well posed, providing an unambiguous basis for evaluating alternatives. At the same time, the sources of sediment and nutrients and the effectiveness of different management options are poorly known, providing the opportunity to explore how improved knowledge and reduced uncertainty may influence public preference and the effectiveness of different decision-making tools. This project will involve at least six NCED PIs, and include both NCED and leveraged funds. The development of new approaches and trans-disciplinary integration necessary to undertake such a project requires a center-mode of support.

Angelo Coast Range Reserve (ACRR). The long-running collaborative efforts at the NCED field site at ACRR continue to provide insight on the interaction between watershed location, physical condition, and ecosystem response. Work identifying regime boundaries and the physical and locational controls of primary production, nutrient processing, and organism dynamics will play directly into improved ability to identify locations in the watershed where restoration would be most needed or effective. Work there also provides field verification of laboratory relations developed for nutrient processing and mass transfer to organisms.

IP Goal

The goal of the Stream Restoration Integrated Project is to advance the science and practice of stream restoration by conducting and coordinating research and by working with agency and industry partners to identify information needs, develop improved tools, and transfer this knowledge into practice. We aim to promote a transition in restoration practice from an approach based on single-discipline analogy to one based on multidisciplinary quantitative prediction.

Approach

Our approach has two key elements:

1. Stream restoration problems are inherently multi-scale and multi-disciplinary. By combining expertise in biology, physical, and social sciences with a research focus spanning the space and time scales needed to characterize stream disturbances, NCED is well positioned to develop the integrated knowledge needed to improve the practice of stream restoration.
2. To effectively advance restoration practice, we must move beyond a researcher's perspective to that of the practitioner. This is all the more important because the state of restoration practice is ill-defined, sometimes contentious, and highly varied in terms of training, practice, and the perceived need for the application of new research findings. Improved methods will be communicated and changes in practice will be affected only if we have some understanding of the needs and attitudes of those in practice. We strive to understand the issues facing those engaged in the industry and to use this knowledge to inform our research agenda and guide our Knowledge Transfer program.

Accomplishments and Plans: Major Initiatives

StreamLab06

StreamLab is a multi-investigator, multi-disciplinary experimental approach to problems of stream dynamics. It fills a pressing need for field-scale research, under laboratory conditions, of inherently cross-disciplinary topics that combine sediment transport, channel morphology, eco-hydraulics, biogeochemistry, and aquatic ecosystems. Key elements of StreamLab include (1) experiments conducted at field scale with laboratory control; (2) close cross-disciplinary collaboration; and (3) testing and application of new technologies, particularly environmental sensors. The inaugural StreamLab experiments (StreamLab06) were a major focus of the SRIP in 2006/2007. Individual research topics will be mentioned under different projects below. A broader overview of the project is given here.

StreamLab06 was conducted in the main channel at NCED's St. Anthony Falls Laboratory (SAFL) headquarters. It was a collaboration among more than 40 researchers, practitioners and students from across North America. The project began with upgrading flow controls and the sediment recirculation system in SAFL's Main Channel. A state-of-the-art sediment flux measurement system, designed by NCED engineers, was installed as part of this upgrade. Renovation of the flume's sediment recirculation system began in Fall 2005 and was completed in January 2006. The flume is large (9 ft wide, 6 ft deep, and 275 ft long) and capable of flows up to 300 cubic feet per second.

StreamLab06 experiments were divided into two categories. The first was ground-truth testing of bedload measurement methods and technologies, including innovative uses of acoustic Doppler velocimeters. This addressed a strong Partner interest in developing improved field methods for measuring transport rates in coarse-grained streams. This research was completed in March 2006 and was reported in detail in NCED's Year 4 Annual Report.

The second category consisted of a suite of experiments involving the interaction among flow, transport, sediment sorting, bed topography, hyporheic exchange, nutrient uptake, and periphyton distribution and abundance. These experiments nicely illustrate the motivation for StreamLab. The experiments began in May 2007 and continued for approximately six months. They used four basic bed conditions, composed of two sediment types: clean gravel and sandy gravel; each under two bed configurations: plane-bed and alternating bar. Working with our Partners at Stillwater Science/CALFED, we conducted experiments involving bed armoring, gravel augmentation, and sand infiltration. The physical, chemical, and biological processes investigated were interdependent: the physical configuration controls the transformation and flux of nutrients, which together determine the distribution and abundance of periphyton, which influence the mobility and hydraulics of the riverbed. One cannot understand one piece without the others. The StreamLab06 initiative was conducted by a team of researchers from different disciplines, working closely together under conditions with laboratory control and field scale, with innovative measurement technology. More detailed information on StreamLab06 is available on our website at: http://www.nced.umn.edu/streamlab.html/ and in Appendix G: StreamLab Laboratory Experiments.

StreamLab is a concept that fills an important need in ecogeomorphic research. Controlled experiments at field-scale with instrumentation capable of mm-scale measurements are expensive and time-consuming and coordination across projects is clearly warranted. A project like this can be supported only by a center with a combination of 1) in-house facilities and expertise, 2) a commitment to learning and improving the approach over repeated experimental cycles, and 3) an ability to provide partial support to leverage additional funding and host outside investigators. We will continue to host and work to more broadly coordinate implementation of field-scale experiments in ecogeomorphology. To carry the concept to true field scale, NCED and SAFL are building two outdoor channels that will be used for field-scale experiments and will be wide enough to incorporate riparian zones (OSL).

Outdoor StreamLab

In Year 4, we reported on a joint venture by NCED and SAFL to acquire and convert two abandoned flood-bypass channels for St. Anthony Falls on the Mississippi River (adjacent to SAFL) into an outdoor laboratory for trans-disciplinary research on interactions among flow, transport, channel and floodplain dynamics, biogeochemical processing, aquatic ecosystems, and riparian vegetation (Figure 1). In Year 5, efforts to gain legal access to the property were successful, paving the way for the development of this research facility for stream restoration and land-use dynamics. With a field-scale outdoor flume, we can conduct the controlled experiments needed to develop and test models of ecosystem dynamics. We demonstrated the power of the StreamLab model in the SAFL Main Channel experiments (StreamLab06) and are excited to expand the StreamLab concept to the outdoor channels. The first of the outdoor channels will be developed in the summer of 2007 and available for research in 2008.

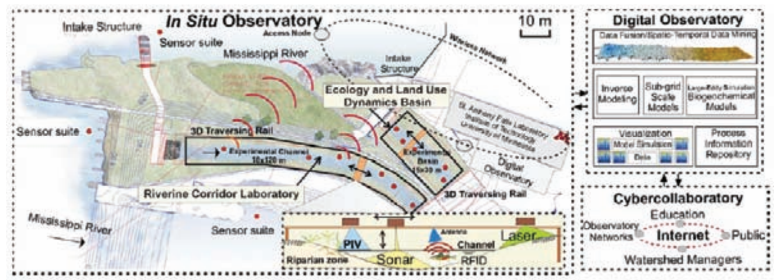

Figure 1. *The NCED/SAFL Outdoor StreamLab*

Partner Interactions

A critical component to NCED's SRIP is our interaction with our Stream Restoration Partners Group. This year we modified the structure and nomenclature of our Partners. The Partners Group is now called the Stream Restoration Community Partners Group. The name change is designed to communicate that partnership is open to anyone. Whether a consultant, academic, federal or state agency, all who are interested in improving the field of stream restoration are welcome to become SR Community Partners. These changes in name were also accompanied by an update in our website (http://www.streamrestoration.net), including a page for Community Partners to formally register as Partners.

The 2006 NCED Stream Restoration Community Partners Group held its annual meeting at a joint workshop with the Stillwater Sciences meeting on physical model research in river restoration. The first day of the workshop focused on modeling studies in support of improved stream restoration design. This included presentations of experimental research conducted by Stillwater Sciences, UC-Berkeley, San Francisco State University, and NCED, as well as presentations of other experimental research being conducted in support of stream restoration. The second day of the workshop featured a full-day field trip to examine urban and rural stream restoration projects in northern California. The last day of the workshop served as the annual meeting of the NCED Stream Restoration Partners Group and included presentation and discussion of stream restoration training, project assessment and evaluation, post-project monitoring, and public preference and selection of stream restoration Best Management Practicess.

In addition to the Community Partners Groups, NCED has three focused SR Partner Work Groups. These are subgroups of our larger community partner group that have specific focus, expertise and desire to work with NCED on special issues. The three groups are (1) Training Work Group, (2) Dam Removal and Sediment Remobilization Work Group, (3) Sediment Monitoring Technologies Work Group. Members of these groups come from federal and local agencies, consulting and academia. The SR Training Working Group held its first formal meeting in March of 2006, which was reported fully in NCED's Year 4 Annual Report. In Year 5 this group continued to work on a white paper produced from the workshop, which is submitted for peer review. The main priorities of this group are to (1) help identify and coordinate stream restoration training initiatives, (2) provide assessment of state of stream restoration training in the US and provide recommendations for training, (3) explore issues of professional licensure or certification for the practice of stream restoration, and (4) explore the concept of common field/research/training sites for stream restoration. The Dam Removal and Sediment Remobilization Work Group held its first meeting in March 2005, which was reported in NCED's Year 3 Annual Report. Ongoing interactions with Partners include a range of training and research projects. PI Wilcock and NCED Partner Jack Schmidt conducted a two-day training session for NCED Partner US Bureau of Reclamation (USBR) in March, 2007. With NCED parter US Forest Service (USFS), we have initiated a new model study of the removal of Marmot Dam on the Sandy River, Oregon, and associate remobilization of reservoir sediments. The model study and associated film production are underway at SAFL. PI Wilcock and NCED PhD student Chuck Podolak will initiate a field research program in Summer 2007 to document downstream adjustments to the sediment discharge from the dam removal scheduled for Fall of 2007. We have also initiated an experimental study with SR Partners at the USBR, to develop a bedload monitoring technology capable of continuous monitoring gravel and sand transport that will be deployed on the Elwha River in Washington, downstream of two major dam removal sites. In all of these projects, NCED investigators are collaborating with SR Partners on issues related to dam removal, sediment remobilization and sediment routing downstream of the dam sites.

The Bedload Monitoring Working Group is the newest subgroup of the SR Community Partners. The focus of this group fills an important need in the US and internationally to improve our ability to estimate and predict the flux of bedload sediment via rivers and streams. Current technologies lack temporal and spatial accuracy, are difficult and often dangerous to deploy, and produce unreliable data. Estimation of sediment loads is a key component to many stream restoration designs – especially projects that take into consideration the watershed scale sources and sinks of sediment. The topics of dam removal and gravel augmentation (in which pulses of coarse sediment are introduced into a river) necessitate the need for better monitoring technologies. Both are popular stream restoration practices but practitioners lack sufficient understanding of implementation and the consequences of these mediations. The Bedload Monitoring Work Group first met in December 2005 (see NCED's Year 4 Annual Report). Some of the members of this group participated in the early phases of Streamlab06 in which we conducted flume experiments to calibrate and ground-truth conventional (bedload traps) and surrogate bedload monitoring technologies. NCED co-sponsored a second meeting of this working group by organizing the International Bedload Surrogate Monitoring Workshop in April 2007. The workshop was held at SAFL and involved nearly 50 participants representing 12 countries including Canada, Europe, and Asia. The majority of the meeting was webcast using Adobe Breeze 5.1, which allowed anyone to participate in the workshop. Over 50 people took advantage of this service. The workshop developed new international collaborations, produced a workshop proceedings volume containing 24 technical papers on surrogate technologies, and developed recommendations for establishment of a small number of continuously monitored bedload transport sites that would allow ground-truthing of bedload technologies and generation of long-term sets of bedload transport and hydraulics data.

Accomplishments and Plans: SIP Project Plan

Update of SIP SR Projects Areas

Following the NCED PI retreat in February 2007, the list of SR Project Areas was revised in March 2007 (SIP version 3). These revisions primarily represent rewording to better describe the scope and purpose of each project area. The largest change was in the area of ecogeomorphology. In Year 5, research in this area was organized under SR02: *Determine how physical channel attributes affect structure and function of stream ecosystems*. A draft revision developed at the February 2007 PI retreat provided finer resolution to distinguish among ecological components cited in restoration design. This resulted in three projects:

SR04 – *Design stream restoration projects to optimize net primary productivity;*

SR05 – *Define physical channel attributes and flows that control nutrient processing; and*

SR06 – *Specify structure, inputs, and disturbance regime for species recovery*.

A summary of the ten project areas and their genesis is given below. The current listing of project areas is used to organize the discussion of Year 5 research, although in the case of the ecogeomorphology topics, the discussion is combined to reflect the organization in place during most of Year 5.

SR01 – Channel geometry, including variability in space and time – Channel size and shape are fundamental attributes of any stream restoration design. An ability to predict these features and their variability lies at the heart of improved restoration practice. [Project is a rewording of SIPv2.3, SR01.]

SR02 – Mixed-size sediment dynamics - Streambed materials that provide the basic organism-scale template for the stream ecosystem and bed material transport drives channel change. The goal of this project is to develop predictive relations for the sorting and transport of coarse bed material. [Project is a rewording and renumbering of SIPv2.3, SR07.]

SR03 – Channel-floodplain interaction - Floodplain deposition is a key part of riparian ecosystems and also sets channel bank height. Channel-floodplain sediment exchange and bank erosion are key gaps in developing a predictive understanding of sediment budgets and evaluating the benefits of streambank stabilization projects. [Project is a rewording of SIPv2.3, SR04 to include both channel and floodplain dynamics.]

SR04 – Design stream restoration projects to optimize net primary productivity - Improving net primary productivity is a common objective in restoration design. [Project is newly defined and is derived from SIPv2.3, SR02, SR03.]

SR05 – Define physical channel attributes and flows that control nutrient processing - Restoration projects frequently cite nutrient removal as an objective. An ability to predict the effect of channel alterations on changes in bed/bank/channel exchange and nutrient processing is needed to support or evaluate this objective. [Project is a focused rewording of SIPv2.3, SR02]

SR06 – Specify structure, inputs, and disturbance regime for species recovery - Many restoration projects are driven by the goal of individual species recovery, which depends on the interplay among a wide range of factors. Building adequate structure without necessary inputs and disturbance will not promote species recovery. [Project is newly defined.]

SR07 – Develop improved sediment storage and sediment routing models - The performance of stream restoration projects depends essentially on the supply of both water and sediment. An inability to predict sediment supply is a leading barrier to development of predictive stream restoration design. [Project is a focused rewording of SIPv2.3, SR06 and SR10.]

SR08 – Sediment source and yield - Restoration projects are often proposed for the purpose of reducing sediment and nutrient loading to receiving waters. There is little basis for connecting local bank stabilization measures with watershed sediment yield. [Project is a focused rewording of SIPv2.3, SR06 and SR10.]

SR09 – Stream restoration objectives, tradeoffs, and decision-making under uncertainty - As the ability to predict landscape and restoration dynamics improves, we must also anticipate the challenges to putting these tools to work. How does predictive understanding best inform management actions? Can management requirements guide more effective model development? How should uncertainty be incorporated in the decision-making process? [Project is renumbered from SIPv2.3, SR08.]

SR10 – Dam removal, dam management - Dam re-operation and dam removal represent major restoration opportunities, but the effect on the downstream channel of dam-released flows and sediment injections requires improved understanding of how large volumes of sediment move through rivers. [Project is reworded and renumbered from SIPv2.3, SR05.]

SIP Projects

► SR01 – Channel geometry, including variability in space and time

The width, depth, and shape of a stream channel are vital components of stream restoration design and are the main parameters by which the fluvial system self-organizes and maintains a dynamic equilibrium. We are still limited, however, in our understanding and ability to predict channel geometry for particular systems. Current stream restoration practice relies heavily on specification of a “stable channel geometry”, yet our understanding of the fundamental controls on channel geometry are incomplete. This research area focuses on the mechanics of channel geometry, its relation to channel planform, and the influence of vegetation and cohesive sediment on bank stability, channel planform, and flow dynamics.

NCED research is addressing channel planform and hydraulic geometry at a range of scales. At the watershed scale our research is developing state-of-the-art approaches for processing high resolution datasets to reveal important characteristics of channel network structure and channel geometry. This work is described in greater detail in the DWIP under DW02 and is therefore only briefly covered here. The research is motivated by a need to understand the processes of self-organization and internal linkages within landscapes. This year, efforts have lead to the development of a robust methodology (wave-let based) for extracting local slope and curvature information using LIDAR high resolution elevation data. This paves the way for extracting other important geomorphic characteristics, such as channel width and channel-floodplain connectivity from the data. This research is a critical contribution to stream restoration as it provides much needed methodologies for analyzing high resolution elevation data and also provides a more complete understanding of how rivers at the reach scale: the scale most often addressed in stream restoration are interconnected with the broader watershed scale.

We continue our research on channel planform and geometry through physical modeling experiments that incorporate vegetation (alfalfa). Our goal for these projects is to provide better conceptual understanding of channel planform dynamics by investigating the role of sediment grainsize, bank strength, reach-scale sediment routing and sediment sorting, the influence of vegetation on lateral migration, and avulsion processes. Research in a 6 by 16 meter flume at the UCB Richmond Field Station (RFS) has been developed to explore channel planform dynamics for single-thread meandering rivers. This work is also reference in SR03 – Channel and Floodplain Interaction. This year was largely spent exploring various mixtures of water, fine and coarse sediment, and surrogate vegetation needed to generate realistic channel processes. We are proud to report that, for the first time, single-thread meander growth and cutoff processes were modeled in the laboratory, paving the way for informative experiments in the years ahead.

Figure 2. *Image of a self-formed, laboratory scale meandering stream. The channel is approximately 15 cm wide.*

Our research on braided river morphodynamics continues with a fourth and final flume experiment initiated in early 2007 at SAFL. This experiment builds on a series of experiments by graduate student Tal and PI Paola that are aimed at investigating the dynamic interactions within the flow-vegetation-sediment system. Previous experiments showed that continuous cycling of high and low discharge and vegetation seeding resulted in the change from a braided morphology to a single-thread channel with a vegetated floodplain. This result was consistent in the past three experiments. A key parameter in these interactions is the time vegetation has to establish relative to a flood discharge. Therefore, the goal of this last experiment is to investigate whether a longer flood duration (4 hours instead of 1 hour in all the previous runs) removes enough vegetation during each flood cycle to maintain braiding. The ability to maintain braiding with adequate timing and duration of floods has important consequences for rivers with managed flow regimes. Results of previous experiments were published this year (Tal and Paola, 2007).

Stream Restoration design and management often rely on determining the bankfull discharge for a given system. We continue to conduct research on issues related to the bankfull discharge. Specifically, we are investigating means of quantifying/predicting the bankfull discharge, Q_b, as well as the hydraulic channel geometry associated with bankfull discharge. This year we completed research focused on improving design approaches for determining Q_b from regional regression equations.

The research indicates that the precision of regional regression equations (regionalized equations for predicting bankfull discharge, Q_b, as a function of drainage area, A_{da}) can be increased by using estimates of the two-year return period discharge. A manuscript on this research was submitted to the Journal of the American Water Resources Association.

We are also putting research effort into better understanding reach-scale issues essential to hydraulic geometry. In Year 4, we reported ongoing research on bank stability in two studies. In the first study, experiments and a model were in development on the use of willow planting to stabilize stream banks. In Year 5, results of this research were accepted for publication. In this paper we present model results for predicting velocity distributions in trapezoidal and rectangular channels. The model was developed using data from the physical model study, the continuity equation, and wake theory. The effect of varying the cylinder configuration (i.e., the density, diameter, height, and location) was demonstrated. The research has been used to develop a new cast in the form of an NCED SR Tool (Beta-version). A final version of this tool will be made available to the public in 2007.

In the second study of bank stability, we reported in Year 4 ongoing investigation of procedures for proper scaling of streambank strength through detailed measurements of cohesive streambank erosivity in prototype streams. Overarching objectives include 1) developing a method for measuring the erodibility of cohesive stream banks in natural rivers and scaled river models, and 2) identifying quantifiable parameters for scaling erodibility. We are currently collaborating with several stream restoration partners at the US Agricultural Research Service (USARS), who have extensive field and laboratory experience in quantifying cohesive bed and bank strength. The collaboration will likely involve developing joint proposals for experiments in the Outdoor StreamLab facility.

We recently completed efforts to develop quasi-universal relationships for bankfull hydraulic geometry relationships for gravel-bed rivers. This work has been accepted for publication in the Journal of Geophysical Research. Research is now underway to develop quasi-universal relationships for bankfull hydraulic geometry in sand-bed rivers. This study is an attempt to establish relationships for bankfull channel hydraulics and geometry (discharge, width, depth, and slope) using physical relationships that describe resistance to flow, sediment transport, a sediment yield relationship, and a dimensionless channel forming shear stress.

Finally, NCED's SR Toolbox contains several tools with application to channel geometry issues. The Gravel River Bankfull Discharge Estimator and the Gravel River Bankfull Channel Estimator, were both updated this past year.

Progress toward milestones/deliverables for years 3-5.

Milestone/Deliverable	Progress
Develop generalizable conceptual, physical, and numerical models for the influence of vegetation on channel geometry.	Experiments on channel morphology as a function of vegetation density and flood regime. Achieved realistic meander migration dynamics. Developed experimental channels sized to flood magnitude.
Develop conceptual approaches, analytical relationships, and numerical models/tools for predication of hydraulic geometry of sand-bed and gravel-bed rivers.	Updated versions of Gravel River Bankfull Discharge Estimator and the Gravel River Bankfull Channel Estimator. Improved determination of Bankfull Discharge from regional regression equations. Completed hydraulic geometry relations for gravel-bed streams and began development of relations for sand-bed rivers.
Develop techniques for scaling bank strength and vegetation effects between laboratory scale and field scale.	Developing collaborative relationships with Partner USDA-ARS.

Plans

We will continue to conduct physical experiments and numerical modeling of channel hydraulic geometry at various scales. We will further our development of wavelet-based analysis of LIDAR data to extract other important channel characteristics such as slope, channel width and channel-floodplain connectivity. Physical model studies on single-thread meandering rivers with vegetated banks will turn focus from preliminary experiments toward quantification of natural morphodynamic processes. We will complete the final multi-channel flume experiments as well as complete data analysis of this large body of work. To address the difficult issues around modeling channel systems in which cohesive sediment plays a role, we are developing collaboration with our Partners who have relevant expertise. In the next year, we hope to formalize collaboration with USARS. NCED researchers will continue development of empirical relations with quasi-uniform relationship for hydraulic geometry in sand-bedded rivers.

► SR02 – Dynamics of mixed-size sediment

The transport of streambed material has direct impact on surface and subsurface bed composition, the morphology of the channel, and surface and subsurface fluid flow. The details of the channel planform, the composition of the bed surface, and hyporheic flow constitute the essential, organism-scale template for the stream ecosystem. This project focuses on developing our understanding of the transport and sorting of coarse bed material. Our goal is the development of predictive capabilities for modeling sediment dynamics under a range of conditions, and extension of these capabilities into models and tools that can support stream restoration design. We organize our research on sediment transport dynamics around gravel, sand, and mix-sized transport. This project area includes significant interactions and collaborations with the DW and SA Integrated Projects.

A focus of Year 5 research was the dynamics of gravel transport under varying hydrographs. Flume experiments and modeling were completed and a paper published on reach-scale response of gravel-bed rivers to a cycled flood hydrograph (Wong and Parker, 2006). The research shows that, in situations where the time-scale of flood events is short compared to a morphologic time-scale, gravel-bed rivers will adjust to variable water discharge through changes in sediment transport rate versus changes in river gradient. In similar research, we collaborated with researchers at the University of British Columbia on joint flume experiments comparing gravel-bed morphology and armoring under various hydrologic regimes: desert ephemeral hydrographs and humid or snow melt hydrographs. The experiments explored 13 different experimental flume runs involving various durations of flood hydrograph. The results of the work were published this past year (Hassan et al, 2006) and reveal important linkages between sediment supply, flood hydrograph duration, and vertical and surface grain sorting. Work by NCED PhD graduate Miguel Wong also included a re-evaluation of the bedload data of Meyer-Peter and Müller (Wong and Parker, 2006).

NCED PhD graduate Elowyn Yaeger developed a predictive model for the transport of mobile gravel over immobile boulders in steep shallow streams (submitted to Water Resources Research). The model uses surface-based transport models (developed by NCED PIs) with the boundary shear stress corrected for form drag on the boulders, the active bedload width set by the proportion of the bed area covered in mobile sediment, and bed size specified by the mobile fraction. In a related study, NCED PhD graduate Paul Grams completed a study of the transport of fine-to-medium sand over immobile boulders. A sand entrainment function based on the sand bed elevation relative to the boulder bed was developed and tested in the SAFL Main Channel and then implemented in a sand routing model developed for the Colorado River in the Grand Canyon (discussed under SR07).

The influence of sand supply on transport and bed dynamics is also a focus of an NCED supported project conducted in collaboration with NCED partner USFS in Boise, Idaho. This project is motivated by chronic and acute sand loading in Idaho streams and is using field and LIDAR data to examine the effect of sand loading on bed texture, river morphology, and habitat in salmon-supporting streams. The work is described under DW06.

Transport of mixed sand-gravel sediment lay at the heart of the StreamLab06 experiments. The experiments used two different sediments, one with negligible sand content and the other with 20% sand, and included both plane-bed and alternate bar configurations. Taking advantage of the transition from the clean to the sandy gravel, additional experiments, discussed under DW06, examined the propagation of a sand pulse over a coarse immobile bed and the locations and depth of sand infiltration. Prior to the sand infiltration runs, bed armoring experiments were conducted and followed by the introduction of a fine gravel to investigate the ability of gravel augmentations to mobilize an armored bed. Both the sand infiltration and gravel augmentation experiments were extensions of experiments at the RFS at large scale with variable bed topography, providing an opportunity to introduce field-scale complexity under controlled laboratory conditions with detailed measurement of transport, topography, and bed grain size. The sand infiltration experiments show a strong correlation between the spatial and vertical pattern of sand infiltration and the non-uniform topography and fluid exchange between the water column and the bed. Research on surface bed patchiness at the RFS was also extended to the large-scale spatial variability achieved in StreamLab06. This work focuses on the formation and location of coarse and fine surface patches and how they are driven by entrainment and distrainment within each patch.

The high spatial and temporal resolution of the Streamlab06 transport and topography observations motivated a supplementary investigation by PI Foufoula and NCED Post-Doc Jerolmack of the statistical connection between the self-organized bed morphology and the resulting sediment transport rates. This work, which will continue in Year 6, looks for scalable patterns that allow high-resolution topography to be used to understand and predict transport and streambed dynamics. The StreamLab06 data is also providing predictive target for modeling the evolution of mixed-size streambeds. A mixed-size morphodynamic model developed by PI Parker has been modified to include stratigraphy and is being tested against StreamLab06 results and additional experiments at University of Illinois at Urbana-Champaign (UIUC). Testing this model at larger scale with spatial nonuniform transport is an important step in developing a predictive model.

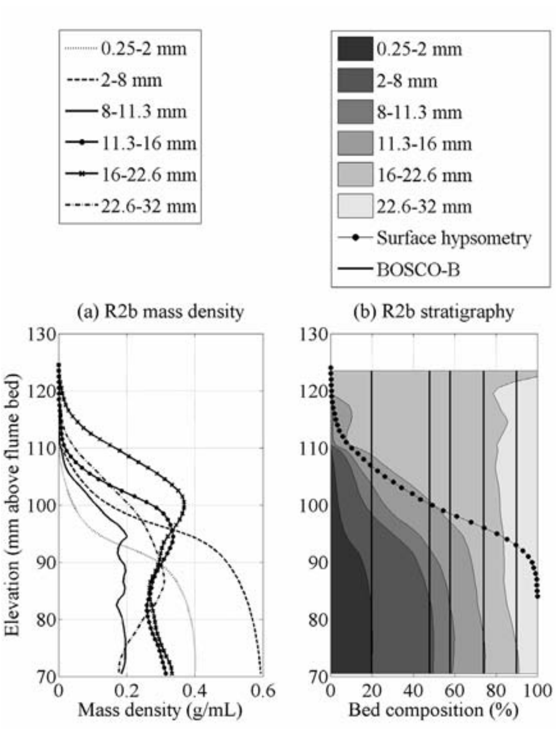

Figure 3. *Mass density and percent composition at 1mm resolution for gravel bed following active transport in a recirculating flume.*

A continuing area of research is the development of vertical sorting algorithms that, together with a surface-based transport model and a continuous form of the sediment mass balance equation developed by NCED PIs Parker and Paola, will constitute a complete formulation for the prediction of gravel-bed morphodynamics, including armoring. NCED PhD graduate Miguel Wong completed a study of the dispersal of tracer grains that included definition of the vertical variation of erosion and deposition rates in a single-sized sediment. NCED PhD student DeTemple has completed a series of flume experiments using two widely sorted sediments and is developing constitutive relations for vertical variation of erosion and deposition rates for mixed-size sediment bed. The key to this work is mm-scale vertical mass density observations developed from grain-by-grain excavation of the bed (Figure 3).

A significant milestone for SRIP and our KT activities is the incorporation of the Wilcock/Crowe mixed-size transport model into the most recent update to the US Army Corps of Engineers' Hydrologic Engineering Center's River Analysis System (HEC-RAS), the industry standard model for 1D hydraulic modeling and (now) sediment transport calculations.

Work in the SA Integrated Project focuses on sand transport and has elements in common with work in DW and SR. One shared focus is the distinction between bedload and suspended load in systems with large roughness. David Mohrig and colleagues have completed field research on the lower Niobrara River, Nebraska and focusing on sampling bedload and suspended load using vertically stacked, miniature Helley-Smith bedload samplers at various elevations over the bed. Processing of the data revealed that, in the study river, 20% of the sediment load was moving in a transitional layer and 80% as suspended load. Results from this research will be published in the coming year. On the Mississippi River, estimates of sediment supply to the Mississippi Delta rely on a better understanding of the various regimes of sand-transport. This year, NCED and collaborators at Tulane University collected the first dataset of suspended sediment profiles for the lower Mississippi River using a P-63 suspended sampling system. This will allow estimation of fraction of the sand load moving as suspended load versus bedload.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Models for predicting vertical sorting and armoring.	Vertical sorting model developed for unisize sediment. Experiments with mm-scale vertical stratigraphy completed for mixed-size sediment.

Milestone/Deliverable	Progress
Management guidelines for gravel augmentation and sand infiltration.	Completed plane-bed (small-scale) and alternate bar (large-scale) flume experiments on gravel augmentation and sand infiltration. Guidelines under development by NCED partner Stillwater Sciences.
Validation model for mixed-size morphodynamics for homogeneous beds.	StreamLab06 transport and bed evolution model used to test morphodynamic model.
Strategy for capturing and scaling up local variability.	Collected observations of spatially and temporally variable transport, bed sorting, and topography at field scale with unprecedented resolution (StreamLab 06). Initiated study of the joint statistics of transport and bed morphology.
Predictive models of fine sediment transport over coarse beds.	Completed two transport models for bed of coarse, immobile boulders, one for fine gravel and the other for suspendable sand.

Plans

Analysis and dissemination of the voluminous StreamLab06 dataset will continue in Year 6. Derivative projects, including the dynamics of bed surface grain patches, effect of gravel augmentation, distribution of sand infiltration, multiscale transport/topography relations, and testing of morphodynamic models will move forward. Development and testing of a coupled transport and stochastic vertical sorting model will continue, extending existing models for uni-size sediment and for dunes to the case of quasi plane-bed mixed-size sediment. Our goal is to have a robust predictor for homogeneous mixed-size beds and then move on to the difficult question of spatial variability (patchiness) in surface grain size.

► SR03 – Channel-floodplain interaction

The channel and floodplain are intimately connected to one another through physical channel dynamics, fluid and sediment exchange, and ecological interactions. This research project focuses on improving our understanding of the connections between channel and floodplain. In particular we are interested in the physical connections (hydraulics, bank erosion, bar growth, and overbank deposition) and ecological connections (nutrient spiraling, riparian vegetation, carbon sequestration, sediment fingerprinting).

Research on lateral channel dynamics of vegetated coarse bedded channels was addressed through two physical flume studies this past year. As reported in NCED's Year 4 Annual Report, we have completed a multi-year set of experiments at SAFL on the effect of vegetation on channel evolution and morphology. Analysis of these experiments was conducted this year. The principal finding so far is that simple cycling of a two-stage discharge (prolonged low flow with short (1-hr) episodes of high flow) leads to self-organization of a dynamic single-thread channel in which the rate of production of new vegetated area balances the rate of loss of area to erosion. The channel dimensions of the single-thread are self-adjusted to be slightly undersized to carry the flood (high) discharge, so that, unlike the initial braided state, the single channel has well defined edges and a floodplain. We analyzed the development of the floodplain and found that it self-assembles by aggregation of initial isolated vegetated areas (bar tops and other high areas in the initial braided river) (Figure 4). We are now exploring theoretical models for this aggregation process.

Part of successful restoration is promoting the natural process of channel migration across the floodplain. There remain large gaps in our understanding of the linkages between the discharge distribution, stable channel geometry, and rates of lateral migration. An important constraint on building and testing theoretical models for these processes has been the lack of a methodology for creating laboratory-scale channels of the most common channel forms in nature: single-thread channels with stable widths and migrating meanders. Model channels composed of non-cohesive sediment (sand, gravel) do not build bars and banks on the inside of migrating bends and consequently widen and subdivide, leading to a

Figure 4. *Formation of a floodplain (green) by coalescence of individual vegetation patches on high areas of an initial braided river (yellow).*

braided pattern. NCED has successfully shown that such channels can be experimentally developed using sand, vegetation (alfalfa), and variable water flow, and that the channels reproduce many of the behaviors of natural single-thread rivers. With the methods in place we are able to move towards investigating the effects of hydrology, sediment supply, and sediment size distribution on channel geometry (channel width and depth) and lateral migration. In NCED's Year 4 Annual Report, we reported on the construction of a new flume (6.1 by 16 m) at RFS that is sufficiently wide for high amplitude meanders to form and for channels to migrate freely without encountering side walls. Research experiments conducted in this facility this year focused on fine-tuning the variables required for making a bedload dominated, lateral migrating, meandering river in a flume. Our findings indicate the following are key: 1) adequate bank strength to slow outer bank migration rate and allow point bar growth to keep up, 2) a variable hydrograph to get occasional high flows over the tops of bars, and 3) fine (suspended load) sediment to deposit at the downstream end of point bars. Bank strength in the experiments is provided by the alfalfa roots. The experiments exhibit realistic single-thread morphodynamics (Figure 5) including lateral migration, chute and neck cutoffs, and oxbow lakes. Using this year's results, we will proceed with studying further channel-floodplain processes with focus on river response to altered inputs (hydrology, sediment supplies, colonization by vegetation).

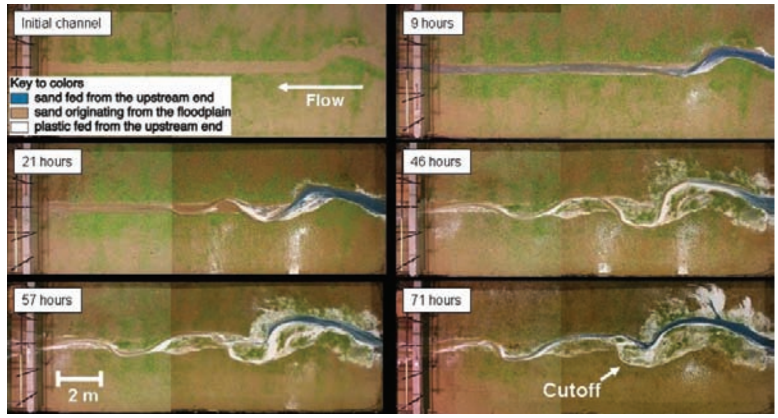

Figure 5. *Overhead pictures of the Richmond flume through time. The fed sediment (blue) does not extend past the first bar until the cutoff shown at 71.3 hours.*

Tie channels connect mainstem and floodplain water bodies and are thus of great ecological importance, but the processes controlling their formation remain poorly understood. They also turn out to be difficult to reproduce at fine scale in the laboratory. In the past year NCED PhD student Joel Rowland focused on obtaining detailed velocity and suspended sediment measurements of a jet entering a basin of standing water and creating levees from a flat, nonerodible bed. The relative width of sedimentation along the margins of the jet appears to be inversely proportional to the square root of settling velocity of the particles in the flow. A paper providing a geographical overview of tie occurrence, and proposing what controls their occurrence has been submitted for publication.

Work completed in Year 5 to develop a floodplain sediment balance associated with migration of a meandering stream has been submitted for publication. This work has also been cast in the form of two Stream Restoration Tools that are available for download from the SR Toolbox (Bank Stabilization Diagnosis Tool and the Planform Statistics Tool). We completed work on the application of NCED research on channel-floodplain sediment budgets through a study of deposition, storage, and removal of sediment on a river floodplain associated with the Milltown Dam removal off the Clark Fork River, Montana, USA. This work was also submitted for publication in Year 5.

The hydraulics of channel-floodplain under overbank flows is a key area of research for standard channel hydraulics and for improving our understanding of floodplain deposition and nutrient distribution. We have begun analytical research focused on developing generalized expressions for predicting the distribution of depth-averaged velocities in compound trapezoidal channels (channel-floodplain) and will continue this work in the Year 6.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Develop methodologies for conducting scaled experiments of channel-floodplain processes.	Developed methodologies for conducting scaled single-thread meandering rivers.
Develop conceptual and predictive models for lateral channel movement including point bar growth and bank erosion.	Submitted paper on floodplain sediment balance research. Submitted paper on application of floodplains sediment balance applied to Milltown Dam, Missoula, MT.

Milestone/Deliverable	Progress
Develop concepts, modeling capabilities, and tools for the hydraulics for straight and sinuous compound channels.	Initial steps taken to develop generalized expressions for depth averaged velocity in compound channels.
Develop qualitative and quantitative understanding for physical-chemical-ecological linkages for nutrient flux and retention in the channel-floodplain system.	Initial discussion will occur in year 6.

Plans

We will continue to conduct physical model studies on single-thread channel-floodplain dynamics. Work will continue on the effect of vegetation at the RFS meandering flume and channel-floodplain interactions will play a central role in the design of experiments in the OSL facility. We will continue to develop improved analytical methods for the hydraulics of compound channels. We will continue to move from model development to model testing and application, including development of a sediment routing model with floodplain storage and bank erosion for the purpose of identifying sediment sources in the Le Sueur River watershed (SR08).

► Ecogeomorphological Research

Stream restoration projects almost always cite ecological improvements (e.g. increased habitat, improved water quality, and recovery of target species) among their objectives. Typically, the ecological outcomes are not predicted, but drawn from analogy or narrative. NCED research seeks to develop the understanding and tools that will allow practice to be based on prediction, in which the outcome of a management action is predicted with specified uncertainty. In particular, we seek predictive links between physical channel structure and disturbance regime and a hierarchy of ecological response: primary productivity, nutrient processing, and species recovery. In Year 5, research in this area was organized under SR02: *Determine how physical channel attributes affect structure and function of stream ecosystems*. A draft revision was developed in Year 5 to provide finer resolution to distinguish among ecological components cited in restoration design. This resulted in three project areas in the current SIP:

SR04 – *Design stream restoration projects to optimize net primary productivity;*

SR05 – *Define physical channel attributes and flows that control nutrient processing; and*

SR06 – *Specify structure, inputs, and disturbance regime for species recovery.*

However, since ecogeomorphological research in Year 5 was conducted under the old SR02 project, we maintain a single section in describing the work here.

A primary focus of SRIP ecogeomorphological research in Year 5 was StreamLab06. The ecogeomorphologic studies in StreamLab06 were led by NCED PIs Finlay and Hondzo with students Ben O'Connor, Becky Stark, Alyxis Feltus, synthesis post doc Cailin Orr and NCED collaborator Jeff Clark.

The experimental goal of StreamLab06 was to evaluate the effect of topographic and sorting complexity on sediment and solute transport and their interaction with periphyton biomass and spatial distribution. Real streams typically include channel-scale features such as bars and pools which introduce spatial variability in topography and bed composition that control local flow, transport, and near-bed ecohydraulic processes. This complexity is typically excluded in small-scale experiments in order to focus on particular mechanisms. StreamLab06 included experiments with a simple, plane-bed configuration as well as more complex alternate bar topography and local sediment sorting. High-resolution observations of bed topography and composition, flow, and transport were combined with integral measures of water chemistry, to evaluate the effect of channel complexity on sediment transport and sorting, hyporheic exchange, and nutrient processing. Two periods of periphyton growth were included to support observations of the interaction among bed configuration, periphyton biomass, transport, hyporheic exchange, and nutrient processing.

To investigate the effect of pore-filling fine sediment, two sediments were used in the experiments, one with a size range between 2mm and 32mm and a median size of 12mm, and a second formed by adding sand to the bed until total sand concentration is 20%. Discharge and flow depth were adjusted to produce different transport rates for quasi-plane-bed and alternate bar conditions with each sediment. These experiments thus provided a template to examine the effect of bed composition (sandy or clean gravel), bed topography (plane or alternate bar), and transport rate (moderate or high), on surface and subsurface grain sorting, surface and subsurface water storage and flow paths, autotrophic and heterotrophic biomass accumulation, metabolic rates, and the uptake and retention of ecologically important nutrients.

The motivation of the ecogeomorphology work in StreamLab06 was to determine how physical conditions commonly altered by stream restoration impact basic ecosystem functions. At the reach-scale we investigated interactions between sediment transport, bed morphology, nutrient cycling and respiration. At the sub-reach scale the focus was on fluid flow, heterotrophic biomass with time and depth, and dissolved oxygen profiles across the sediment water interface. Paired infrared-visible light cameras mounted on a moving cart were used to periodically photograph the entire flume allowing us to assess algae accumulation at multiple scales.

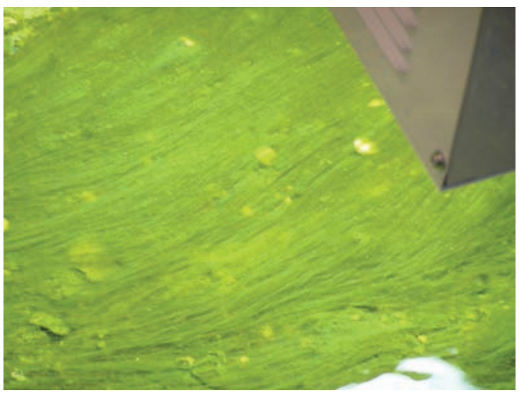

Figure 6. *Image of streambed showing the growth of periphyton and biofilms on the gravel surface. Reflection in the upper right corner is from growth light on the water surface. Periphyton abundance diminishes with distance from the light. The width of the image is approximately 1 m and stream flow is from left to right.*

Using a combination of conservative tracer and non-conservative nutrient additions, we compared the bed morphologies and sediment mixtures to determine the relative influence of bed porosity and morphology on nutrient cycling. It was possible to determine surface and hyporheic flow paths and measure retention of nitrogen and phosphorus individually and together along these flow paths. Following the dark configurations, 18 high-power grow lights were evenly spaced along the length of the flume. A two week growing period produced complete bed coverage of filamentous algae in the vicinity of the lights (Figure 6). The growth period was followed by a large flood intended to fully disturb the bed, followed by a second, ten-day growing period.

While bed porosity was important in determining the volume of the transient storage zone, adding bars had a stronger influence on surface water-hyporheic exchange rates than the change from clean gravel to sandy gravel. Nitrogen concentrations were consistently high in the Mississippi River water used in the experiment and uptake was generally not measurable. However, uptake of phosphorus varied widely across treatments. In the dark runs, highest uptake rates were measured in both clean gravel configurations suggesting uptake occurred in gravel interstices. The importance of near surface hyporheic flow paths to metabolism was corroborated by a measured increase in microbial respiration rates at shallow depths and at mid-channel.

Algal growth responded strongly to light availability, generating a patchy distribution of diatom dominated periphyton. Measurements of dissolved oxygen (DO) in the boundary layer of the flow were made using a microDO probe with and without Photosynthetically Available Radiation (PAR). Results from these measurements show a dynamic response by the autotrophs suggesting that light is a limiting resource. The periphyton accumulation virtually shut off hyporheic exchange and shifted the location of nutrient uptake from the hyporheic zone to the benthic surface. Phosphorus uptake rates increased very strongly with the addition of lights. This indicates that autotrophic biofilms play a more important role than bedforms in regulating stream nutrient uptake and hydrologic exchange. These results are significant because they point to the fundamental importance of factors that control algal biomass (limiting nutrients, light, grazers) in regulating nutrient removal and hydrologic exchange in streams, two key parameters for the ecology of streams, and for their restoration.

Solute transfer between the water column and the bed was also investigated using numerical models developed by Voller and Stefan. Solute uptake by a bed is significantly enhanced by the pressure field induced by standing waves or bed forms. In this situation, the transport of the solute into the bed is controlled by an advection diffusion process and the penetration of solute into an initially clean bed is dramatically larger than that controlled by hydrodynamic dispersion alone (Figure 7). This work has successfully identified a characteristic dispersion coefficient that can be used in a one-dimensional analysis to calculate the solute penetration. This work can inform important stream restoration questions such as the placement of flow devices to increase (dissolved oxygen for fish eggs) or decrease (organic carbon) exchange between the stream and its bed. An important component in arriving at this one-dimensional transport model required a careful and accurate treatment for the solution of the two-dimensional advective-dispersion equation (Qian et al., 2007; Qian et al., in press).

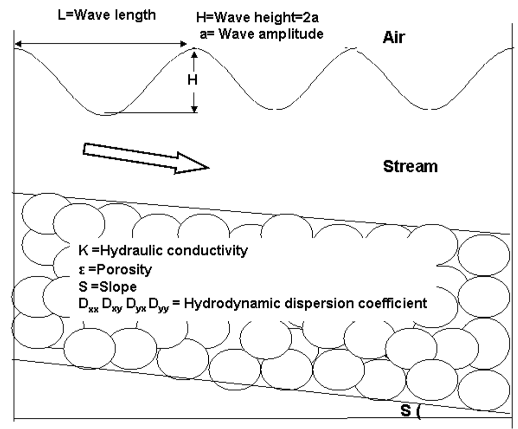

Figure 7. *Solute transport into a gravel stream bed under a standing surface wave.*

Physical channel conditions and turbulence exert strong controls on rates of primary productivity and nutrient uptake. Restoration actions taken to control nutrient processing will not be predictive unless we can scale up generalized models for processes that happen at the organism scale. The work by NCED PI Hondzo and students is playing a central role in establishing and quantifying the organism-scale connection between physical channel conditions, primary productivity, and nutrient uptake. NCED PhD graduate Benjamin O'Connor and undergraduate student Dina Dobraca evaluated controls of DO concentration (which controls denitrification), with the objective of unifying DO measurements across the range of scales including a small laboratory flume, the large open channel setup (StreamLab), and field measurements. The effect of turbulence on mass transport to bacterial and microalgal cells has been studied by former graduate student Tanya Warnaars, and was continued by graduated student Amer-Alhomoud using laboratory experiments to quantify the effect of small-scale fluid motion on the bacterial growth rates, and nutrient uptake in a turbulent flow. Nondimensional relations suitable for scaling have been developed for DO and mass transfer and are described in DW09.

Our ability to connect organism scale mechanisms with channel-scale properties has taken an important step forward with the development of advanced fluid dynamics tools. NCED PI Porte-Agel and his research group have been actively involved in developing a new generation of Large Eddy Simulation (LES) dynamic subgrid-scale models with application to turbulent boundary layer flows. The new models are tuning free and able to dynamically adjust to the flow anisotropy and inhomogeneity associated with near-surface turbulence and surface heterogeneity effects. NCED also welcomes new PI Sotiropoulos who uses advanced Computational Fluid Dynamics (CFD) techniques involving flexible gridding to predict unsteady turbulent fluctuations over a range of spatial scales. Both sediment transport and flow/organism interactions are likely driven by extremes in the near-wall flow, such that resolving unsteady fluctuations at the small scale will be essential for ecogeomorphological prediction.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
.Inaugurate field-scale ecogeomorphology experiments using high-resolution instrumentation.	StreamLab06 successfully completed, including update of SAFL Main Channel, deployment of 3m high-resolution cart, collaborative studies of hyporheic exchange, nutrient processing, and biomass accumulation.
Develop predictive relations for physical controls on primary productivity and nutrient processing.	Scaling relations developed for DO concentration and mass transfer to micro-organisms. Substrate solute transfer model developed.

Plans

StreamLab will continue to be a primary focus of the ecogeomorphological research in the SRIP. Year 7 will be a transition year for StreamLab, including analysis of data collected in StreamLab06 and preparation for the first year of OSL experiments in 2008. We are designing collaborative experiments in the OSL channel that combine stability testing of in-stream rock structures (an interest of NCED SR partners USBR and USACE), the response of benthos (invertebrates and algae) to spatial variation in light and substrate and temporal variation in flow, and the measurement of nutrient processing. We are developing a design using parallel channels in the OSL 12x30m Ecology and Land Use Dynamics basin, two with rock structures and two without in order to provide Before, After, Control, Impact (BACI) for both flood and topographic variability treatments. The rock structures will provide a favorable spatial variation in depth, velocity, and light. Porte-Agel and Sotiropoulos will be collaborating on developing a calibration-free "numerical flume" that will be tested at field scale in the Outdoor StreamLab.

► SR07 – Develop improved sediment storage and sediment routing models

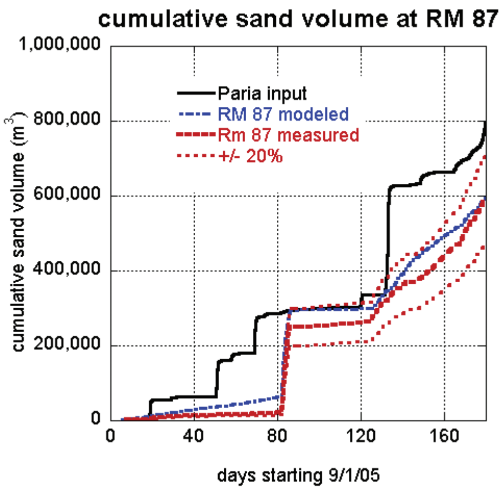

Figure 8. *Results from uncalibrated sand routing model for 87 miles of the Colorado River in Grand Canyon. Results agree within measurement error for cumulative sediment discharge at the downstream end of model reach (Wiele et al., in press).*

The performance of stream restoration projects depends essentially on the supply of both water and sediment. An inability to predict sediment supply is a leading barrier to development of predictive stream restoration design. This project is substantially shared with DW06. In particular, the work by NCED PI Dietrich and NCED PhD graduate Yaeger on bedload transport of mobile gravel over rarely mobile boulders in steep shallow streams and NCED Postdoc Tonini on chronic and acute sand loading on Idaho gravel-bed streams are closely aligned with work in this project. In addition, this project strongly overlaps with SR03 in the study of sediment exchange and storage on the floodplain and with SA01 regarding the supply of sand to the Mississippi Delta.

NCED PI Wilcock and NCED PhD graduate Paul Grams completed a reach-averaged sediment transport model for 87 miles of the Colorado River in Grand Canyon (Wiele et al., in press). This work was performed with collaborator Stephen Wiele of the US Geological Survey. We believe this is the first model that has successfully coupled sediment source and sink relations to a 1D hydraulic routing model using a prismatic channel. We argue that this is a favorable approach for systems in which changes of sediment storage occur predominantly in multi-dimensional local flow and transport fields, but a 1D model is the only practical or possible modeling alternative, especially for longer river reaches of practical concern in river management or landscape modeling. Our Grand Canyon model addresses this problem by reach averaging the channel properties and predicting changes in sand storage using separate source and sink functions coupled to the sand routing model. The model incorporates results from the application of a 2D model of flow, sand transport, and bed evolution.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Fine sediment routing through steep and low gradient systems.	- Completed routing model for sand through Grand Canyon. - Developed transport model for fine gravel in boulder streams.
Development of reach-averaged sediment routing models with explicit sediment storage functions for both sand and gravel rivers.	- Demonstrated reach-averaged model with coupled storage functions for Colorado River in Grand Canyon.

Plans

Beyond plans listed under DW06 and SA01, a primary focus of our efforts will be in developing strategies for reach-averaged transport in different kinds of systems. Parker will be developing a sand routing model for the Le Sueur River that includes sediment storage on floodplains. Wilcock will be developing a gravel transport and storage model for the Sandy River including sediment storage in pools and bars. In both cases, field observations of transport and sediment storage will be used to test the underlying concepts and model predictions. We will also be conducting further experiments with and without bed topography in the SAFL Main Channel.

► SR08 – Sediment source and yield

This project overlaps with DW05, DW06, DW07 and SA01. The work discussed here focuses on sediment yield from landscapes intermediate between the steep headwater conditions of ACRR and the deposition conditions of the Mississippi Delta.

Graduate student Sean Smith has completed three years of flow and suspended sediment monitoring in the headwaters of the Upper Patuxent River watershed in Maryland. This provides information that supports evaluation of the relative roles of hillslopes and first order gullies in producing sediment yield from first order watersheds. Most available sediment data have been obtained from alluvial channels at the outlets from third order or higher watersheds. This has hindered prediction of sediment yield in large basins, such as the Chesapeake Bay watershed. Our measurements include three primary land uses: cropped land, forest, and suburban in a region with similar lithology and slope, providing a new opportunity to evaluate mass flux of sediment within a region undergoing rapid land-use transitions. The results have implications to watershed management strategies including storm water management, erosion control, and water quality modeling in the suburbanizing region between Washington D.C. and Baltimore, MD. This project complements NCED efforts on sediment production conducted in the more tectonically active California Coast Range.

We secured external leveraged support for initiating a sediment budget for the Le Sueur River watershed, a primary source of sediment to the Minnesota River. The ultimate goal of this research is to support efforts currently underway by the Minnesota Pollution Control Agency (MPCA) to develop Total Maximum Daily Load (TMDL) allocations for reaches along the Minnesota River, tributary watersheds, and Lake Pepin. The budget will be based on two parallel approaches: 1) a cosmogenic and fallout radionuclide budget to apportion sediment by sources, and 2) a physical sediment budget utilizing in-field measurements, sediment gaging stations, and air photo analyses to determine sediment flux from the uplands through the watershed, including flux into and out of storage. Radionuclide tracers provide an estimate of the proportional contribution from different sources and land uses, integrated over a large area, which is crucial for examining non-point source pollutants. The physical budget provides information on location and rates of sediment erosion and supply, allowing targeting of the most impaired areas. The two approaches apply different principles and methods and provide independent corroboration. Future work will link the sediment budget to a network routing model, routing sand, gravel, and fines through the basin.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Establish sediment fingerprinting methods for sediment source and history.	Established sediment budget project for the Le Sueur River (MN) watershed.
Evaluate geochemical fingerprinting and physical sediment budgets for same time scale in same watershed.	Established sediment budget project for the Le Sueur River (MN) watershed.
Incorporate valley bottom sediment storage and streambank erosion in network routing models.	Channel-floodplain exchange model completed (SR03). To be incorporated in Le Sueuer River (MN) sediment budget.

Plans

Outside of relevant plans discussed in DW05, DW06, DW07 and SA01, the primary focus of this work is to develop a sediment budget and sediment fingerprinting record for the Le Sueur River Watershed. This project began in April 2007 and will be completed in three years.

► SR09 – Stream restoration objectives, tradeoffs, and decision-making under uncertainty

Stream restoration design reports typically provide a list of project objectives but little explicit connection to either stakeholder desires or predicted outcomes. NCED research seeks to transform practice such that project goals are predictive targets quantitatively linked to public preference, regulatory and policy guidelines, and management actions. The other SRIP research topics are collectively aimed at moving restoration science toward prediction, but prediction alone will not transform stream restoration policy, decision-making, or implementation. This project seeks to develop predictive links between restoration preferences, objectives, and actions.

One focus area involves determining stakeholder preference regarding stream restoration objectives and actions and the willingness to pay for restoration benefits. This establishes the link between stakeholder preferences and restoration options. Uncertainty is a key issue in accurately evaluating preference in the context of a complex natural system. Although the economic literature has traditionally focused on demand uncertainty, NCED PI Flores and NCED PhD students Aric Shafran and Andy Meyers have demonstrated that supply uncertainty is more representative of restoration projects and requires a different modeling approach. They have developed economic models for the option price of a restoration project and are implementing a survey, to be administered to Minnesota residents, to evaluate the option price for different restoration options (project location, type, and timing) to reduce sediment and nutrient loading to the Minnesota River. This is part of the collaborative effort in which NCED PIs Perg, Parker, and Wilcock will be developing a sediment budget model with the goal of reducing scientific uncertainty in the outcome of different restoration approaches.

A second focus area in this project is developing decision analysis methods for the systematic evaluation of tradeoffs and risk. Restoration objectives typically conflict, and alternative locations and methods are commonly possible, each with different costs, benefits, and risk. A consistent basis for evaluating the resulting tradeoffs is needed to not only support decision making, but to develop a framework for incorporating improved scientific predictions. NCED PI Hobbs and NCED PhD students Hope Corsair and Jennifer Bassman conducted a study evaluating how risks and multiple objectives are considered in stream restoration practice, and demonstrating the potential contribution of explicit multicriteria risk analysis. They are now developing two multi-criteria decision-analysis models for a particular case-study: sediment and nutrient control in the Minnesota River Basin as part of the broader collaborative study on sediment sources, supply and management options. A deterministic decision analysis model weighs tradeoffs among options to evaluate which solutions are efficient, leading to alternative portfolios of mitigation measures that emphasize different objectives. A second modeling approach relaxes the assumption that sediment sources are known and uses Bayesian-based stochastic methods for characterizing uncertainty and developing optimal hedging strategies in nonpoint source reduction under multiple objectives. The method can be used to identify optimal mitigation measures and information gathering activities (such as cosmogenic radionuclide identification of the sources of nutrients). This model would take advantage of the inventory of sediment reduction measures developed as part of the deterministic analysis.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Develop framework for incorporating uncertainty in the evaluation of public preference and multi-criteria decision analyses of stream restoration alternatives.	Option price and discount price models developed for incorporating supply uncertainty. Deterministic and stochastic MCDA models defined.
Implement case studies to demonstrate effectiveness of valuation and tradeoff analyses.	Implementation of preference survey and MCDA models underway.

Plans

The immediate plan in Year 6 is for NCED PIs Flores and Hobbs to execute the valuation survey and multicriteria decision models for stream restoration and Best Management Practice (BMP) options in the LeSeuer/Maple River basin. This work will be done in collaboration with NCED PIs Perg and Wilcock and with NCED partners at the Minnesota Geological Survey and MPCA in order to evaluate the interaction between increasing scientific knowledge and decreasing uncertainty. Flores will develop a market experiment (willingness to accept incentives to adopt recommended BMPs) to evaluate proportion of farmers that will adopt at different levels of economic incentives in the Minnesota River Basin. Both Flores and Hobbs will be working to expand valuation and decision analysis methods to DW and SA applications, particularly in the area of Mississippi Delta Restoration in connection with the CLEAR project of NCED PI Twilley and building on Hobbs' role on the External Peer Review panel for the USACE's Risk Informed Decision Framework for Louisiana Coastal Protection and Restoration. We are recruiting an NCED synthesis postdoc to help carry forward connections with the DW and SA IPs.

► SR10 – Dam removal, dam management

Dam sites are commonly the focal point for river restoration projects and represent a unique subset of the stream restoration field. In this research area, we focus on conducting research on the important areas associated with dams and rivers with the goal of producing new knowledge, models, and tools that will help better address dam-related restoration issues.

NCED seeks to improve understanding of how rivers respond and adapt to altered flow and sediment regimes (often from dams) through field and laboratory research. Laboratory experiments underway at the RFS successfully produced self-formed, single-thread meandering rivers by using alfalfa as a surrogate for riparian vegetation. These results constitute a milestone in laboratory modeling of single-thread channels and are the results of significant effort in testing various combinations of experimental conditions. This work sets the stage for further research of single-thread system response to changes in water supply, flood frequency and magnitude, vegetation density, and sediment supply, such as in settings downstream of dams.

Ongoing laboratory experiments at SAFL, in which alfalfa is used to simulate vegetation, model the dynamics of braided multi-thread river systems. Our research explores the linkages between the establishment of vegetation and the magnitude and frequency of flooding events. We have started to quantify the conditions by which a braided system will be maintained or will be overtaken by vegetation and undergo a change in planform. This research has important application to stream restoration and the management of flow regimes downstream of dams. This year we have been in direct collaboration with two groups: the USBR and National Institute for Water and Atmospheric Research (NIWA) in New Zealand. Our work with the USBR is focused on the Platte River in Nebraska. The Platte River is a sand bed river that less than a century ago flowed across a wide unconstrained braidplain. Today however the braided morphology is drastically changed and is continuing to change due to a reduction of water to the system because of dams and water extraction. The reduction in the frequency and magnitude of flood events as well as a reduction in the mean flow has given vegetation more opportunity to establish in time and space resulting in widespread colonization by vegetation of previously bare sand bars. The immediate ecological consequence of this is the degradation of critical habitat for Sand Hill cranes, which rely on the wide open braidplain as a staging ground before their northward migration. The restoration of the Platte River to its natural braided state is a major restoration project, motivated largely by the ecological goal of habitat restoration, and intimately tied to NCED research. Our partners at NIWA are also working to understand the mechanisms associated with vegetation encroachment through comparative studies of managed and unmanaged rivers. The collaboration is an excellent example of how laboratory experiments and field work can be used together to investigate a problem.

NCED is involved in several large restoration projects in which restoration managers are working with dam operators to adapt operational protocols that are more favorable for the downstream river in terms of restoring more natural geomorphologic and ecologic functionality. We are working with the USBR's Trinity River Restoration Program (TRPP) on determining base-line sediment budgets for this system and issues related to designing gravel augmentation for the project. NCED is also working with the US Geological Survey's Grand Canyon Monitoring and Research Center (GCMRC) on similar issues of managing and operation for positive geomorphic and ecologic results (for more information see SR07).

Our Stream Restoration Partners have identified the design and implementation of gravel augmentation as an area of critical research need. Questions include how often and how much gravel, what size of gravel, and how to distribute in the channel. In StreamLab06 we investigated the use of a fine-grained augmentation to, in essence, jump-start the river back into a mobile bed regime. We hypothesized that a fine grained augmentation would serve to "smooth" the coarse bed by filling in pore spaces between the immobile armor, thus reducing the roughness of the bed and increasing near-bed shear stress to a level that would break up the surface armor layer and provide access to finer grains in the subsurface. The experiments involved simulation of pre-dam conditions with mobile bed conditions, simulation of dam closure in which all sediment was cutoff to the test section, and finally addition of fine-grained augmentation. Initial results from these experiments indicate that the fine-gravel augmentation does indeed lead to an increase in bed stress, break up the bed armor and increase the total flux of the gravel in the system. This work is a major step toward providing knowledge and tools for the application of gravel augmentation in the field.

Dam removal is an important area of stream restoration. NCED research is focused on providing knowledge, models, and tools that will improve the ability of our Partners and dam removal stakeholders to forecast spatial and temporal adjustment of the system post-removal leading to safe and effective dam removal restoration. Our research is organized into upstream problems and downstream problems. In the upstream reaches, our research utilizes physical and numerical models to study processes for reservoir filling and emptying of sediment. From its inception NCED has been conducting state-of-the-art physical experiments on the processes of reservoir filling including the resulting stratigraphy and grain sorting processes that occur. This year we continue to improve our modeling capabilities and completed experiments in Jurassic Tank and the NCED Delta Basin located at SAFL. In Year 4, we reported completion of a numerical model of the morphodynamics of dam removal by Cantelli and Parker for the case of uniform sediment. This year we began preparation for a set of experiments that will expand upon this work by examining reservoir filling and emptying processes with sediment mixtures.

In Year 5, we were successful in leveraging funds to conduct a model study of the Marmot Dam Removal. The Marmot Dam is located on the Sandy River east of Portland, Oregon and is a 15 meter high concrete structure owned and operated by Portland General Electric (PGE). The research project started in April 2007 and will be done in collaboration with SR Partner Gordon Grant (USFS). The reservoir upstream of Marmot is completely filled will a layered deposit of coarse gravel underlain by sand. The Marmot dam removal will begin in the summer of 2007 and, as one of the first large dam removals in the country, provides a unique opportunity for both field and laboratory examination of the physical and ecological response to a major dam removal on a popular salmon fishery. The primary goals of the research are to examine processes by which sediment mixtures are sorted and deposited in the basin, processes of remobilization and erosion, the influence of delta stratigraphy, routing of sediment downstream of the dam site, and the impact of hydrology (discharge and duration) on sediment remobilization. The project with PGE includes both a physical model study and filming for a documentary film covering the Marmot Dam removal (Figure 9). The model at NCED-SAFL will be a major component to the film, which will depict the physical, ecological, historical and social issues of the Marmot Dam and its removal. There is a field component to the project as well: NCED will lead pre- and post-removal field studies on the Sandy River using local surveys and sediment sampling to detect sediment storage associated with sediment released by the dam removal. A broader goal of the work will be to test reach-averaged models of sediment transport over the 60 km reach below the dam.

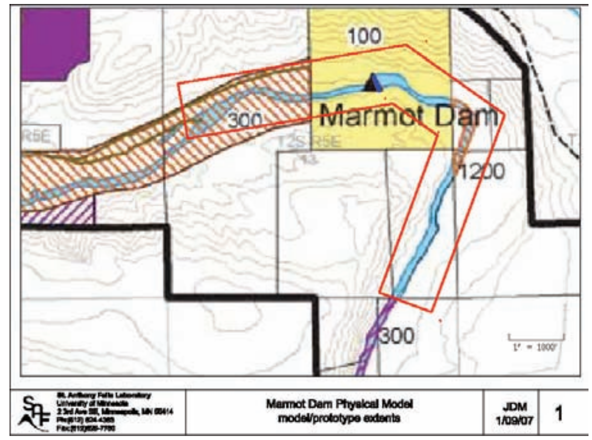

Figure 9. *Sand River, Oregon and the Marmot Dam site including limits of NCED physical model.*

NCED downstream research involves numerical modeling, physical model studies, field research, and technology development leading toward a capability for routing (models) remobilized reservoir sediment as well as predicting biochemical and ecological impacts post-removal. As described in SR07, NCED has furthered our sediment routing capabilities. Laboratory work by PI Dietrich and graduate student Leonardson examined the dispersion of a fine grained sediment pulse over time as validation of ongoing numerical work. At the ACRR, work was conducted in Summer 2006 on the impacts of embeddedness (extend of gravel matrix filled with fines) on primary productivity and nutrient retention. This research was also carried out in a flume setting at SAFL. These efforts to link fine sediment transport, fines infiltration into the interstices of gravel bedded rivers, and impacts on primary productivity and nutrient retention are the first steps toward our goal of developing predictive capabilities of ecohydraulic processes. This work will have direct benefit to dam removal restoration of rivers and streams.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Gravel Augmentation: develop predictive capability, included model, tools, and/or methodologies, for sizing, estimating volumes, placement, and routing of augmented gravel.	StreamLab06 laboratory experiments on gravel augmentation. Richmond field station experiments on gravel augmentation.
General Dams: Downstream – develop predictive capability for river response to dams including vegetation encroachment, bed degradation and armoring, ecological regime-shifts, and morphological changes.	Laboratory experiments underway on natural single-thread river processes using vegetation. Continue laboratory experiments relating vegetation density and flood frequency and duration on channel morphology. StreamLab experiments on armoring in alternate bar, gravel bed river.
Dam Removal: Upstream – develop quantitative and predictive capability (models) for reservoir filling and emptying for the case of a) single grain size and b) mixed-grain size coarse sediment load.	Conducting multiple flume study of mixed grainsize reservoir filling. Conducting physical model study of Marmot Dam filling and removal on Sandy River, OR.
Dam Removal: Downstream – develop conceptual and predictive capability for impact of fine sediment infiltration into coarse bed (embeddedness) on primary productivity and food webs.	Conducted field and laboratory study investigating effect of embeddedness on periphyton. StreamLab06 experiments included study of sand infiltration into a clean gravel bed.

Plans

We will continue our research in dam-related issues on a number of fronts. Physical modeling of upstream reservoir filling and deposition with sediment mixtures will be conducted, the data from which will be used to validate numerical models. The model study of Marmot Dam removal will be completed and will produce information on reservoir filling and remobilization. Data analysis from the gravel augmentation and sand pulse components of StreamLab06 will be completed and we will focus on publishing these results. We will continue to work with our Partners at TRRP, USBR and GCMRS on issues of river restoration downstream of regulated dams. Finally, we will continue our multi-disciplinary work through field work at the ACRR in the summer of 07 and in the laboratory at SAFL in the fall of 2007 on the issues of river sediment embeddedness and linkages to primary productivity and nutrient uptake.

III. Education Initiative

Project team

Education Director: Karen Campbell
Staff: Karen Gran, Paul Morin
Contributing PIs: all

Executive Summary

In Year 5, NCED Education Initiative efforts focused on deepening the impact of existing successful programs while at the same time broadening the audiences reached. Our successful integration of research with public education, which began with the Earthscapes and Big Back Yard (BBY) initiatives at the Science Museum of Minnesota (SMM), flourished as we began intense development work on a 5,000 square-foot nationally traveling exhibition about water. This project increased in size and scope when SMM and the American Museum of Natural History (AMNH) both learned that the other was producing an exhibition about water and decided to merge their efforts. The water exhibition now will be 7,000 square feet and two versions will be produced – one to tour North America and the other overseas venues. Use of our table-top dam removal experiment, based on the Visitor research, continued to expand to new audiences in formal and informal education and its success led us to develop a second model, the Delta Box, which has already met with similar enthusiasm nationally and is helping us expand our impact on undergraduate education. Our Earthscapes Teacher Institute and River Restoration Residency continued to be active programs, with resulting talks and posters at professional conferences. Development work on our research-grade visualizations was concentrated in the area of public education but testing of the educational effectiveness of visualizations continued. A new undergraduate geology textbook, featuring many of these visualizations, will be published in June, 2007. Many of our methods and materials were featured in two very well-attended NCED sponsored workshops, a one day "Hands-On Inquiry Based" workshop for teachers of grades 4-16 at the Fall 2006 meeting of the American Geophysical Union (AGU) and the On The Cutting Edge - Professional Development for Geoscience Faculty Teaching Sedimentary Geology in the 21st Century, held in July, 2006 at the University of Utah. Finally, our Graduate Student program flourished, with students participating broadly in all aspects of NCED research, as well as planning another graduate students only retreat, presenting many of NCED's weekly videoconferences, and conducting international research through our NSF-funded International Research Experience Program.

Goal

The overall goal of NCED's Education Initiative is to bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED's key mission areas of land, resource and ecosystem management.

Approach

NCED adopts a broad-band approach to education, emphasizing informal as well as formal learners, and strong connections between its research and education programs. Our Education Initiative includes the following key elements:

Graduate education: (a) Enhancing the education of NCED student participants by providing unique opportunities and an extended, cross-disciplinary peer and mentor network, and (b) developing a new, practice-oriented program in Stream Restoration that will help advance training in restoration as well as attract a broader student population into NCED areas, including students who are not intent on research careers.

Grades 4-16 education: (a) Adapting research tools such as 3D visualization, wireless sensors, and laboratory experiments to provide novel 4-16 educational tools; and (b) designing programs to engage science teachers in NCED research in ways that allow them to bring this knowledge to their students in practical ways, and sharing the products of this work via the NCED website.

Public education: Working intensively with the SMM and other science museums to develop engaging new methods for informal education centered on Earth-surface dynamics and environmental awareness.

Achievements and Plans

► Project ED01: Bring surface dynamics to informal education with SMM

Traveling Water Exhibition: In January 2005, SMM submitted a grant proposal to Informal Science Education at NSF in support of a 5,000 square-foot traveling exhibition tentatively titled WaterPlanet. In September 2005, NSF informed SMM that the grant was approved. At about the same time, NOAA formally informed SMM that its grant proposal for Science-on-a-Sphere (a scientific visualization system that will be incorporated into the WaterPlanet exhibition) was approved. While exhibit development is overseen by NCED PI Pat Hamilton and assisted by NCED Visualization Specialist Paul Morin, NCED Director Chris Paola and Education Director Karen Campbell are also intimately involved in the exhibit development. WaterPlanet is broadly informed by all the work NCED has done with SMM to develop the Earthscapes exhibits and programs and it will also include several specific components taken directly from this work, for example the large Dam Removal interactive exhibit developed for the BBY and many visualizations and visualization tools developed through that collaboration. WaterPlanet will enable these products of NCED's research-education integration to reach new and broader audiences.

A major development in Year 5 has been the merging of SMM's NCED-developed WaterPlanet exhibition project with a water exhibition being developed by the AMNH. This unprecedented partnership, initiated when staff from SMM and AMNH realized each museum was developing a traveling exhibit on water, will create a 7,000 square-foot traveling exhibition rather than a 5,000 square-foot show that SMM initially was planning and will result in two copies of the exhibition – one that will tour North America (the original touring territory envisioned for WaterPlanet) and one for overseas venues. This SMM/AMNH collaboration not only enhances the scope and reach of this new water exhibition but also the quality of the exhibition. SMM is a leader in design and fabrication of hands-on interactive exhibits and scientific visualizations. AMNH is a leader in natural history collections and multimedia and diorama development; it is also the only museum in the world to offer a PhD program. The exhibit design teams for the water exhibition (title still to be determined) have now joined forces and meet regularly in St. Paul and Manhattan, to combine their strengths and learn from one another. The water exhibition will open in New York in fall 2007. It closes at AMNH in May 2008 and goes to the San Diego Natural History Museum for summer 2008. The water exhibition will come to SMM in fall 2008 and then resume its North American tour in late spring 2009. The overseas version of the water exhibition currently is planned to be fabricated in early 2008 in order to begin its tour, which is tentatively scheduled to begin in summer 2008.

Earthscapes in the BBY: Having been open to the public for three summers, the SMM's BBY has matured into a well-known and well-loved museum destination. Attendance figures in summer 2006 were 34,500, bringing park visitation totals to 136,500 since the park opened in June 2004. The park's native landscape plantings, prairie maze, turtle effigy garden and three sisters garden are fully established, greatly enhancing the appearance of the BBY. Originally installed Earthscapes Mini-Golf and interactive exhibit components are holding up to visitors and Minnesota's harsh climate admirably; little re-engineering has been necessary.

Notable BBY developments in Year 5 include:

- Design and construction of exhibit components, to be installed in summer 2007, involving visitors in the puzzle of the park's natural artesian well. The hydraulic pressure fueling flow of water from this well is greatly reduced during the summer months, due to drawdown from a nearby city well, which creates a cone of depression in the aquifer. Visitors will be able to explore this phenomenon through an above-ground model; use a hand pump to draw drinkable water from the museum's well, and experiment with the porosity and permeability of various rock samples which typically serve as aquifers in our region.

- Acquisition and installation of a "camera obscura" in the park, which will engage visitors in the simple but intriguing physical optics of this device and offer them a new perspective on the park.

- Development of additional educational opportunities and an instructor's manual for the Youth Science Center (YSC) Park Crew (see also Diversity and ED05 sections of this report) by NCED Graduate Museum Assistant (GMA) Emily Horth. In Summer 2006, the Park Crew were trained in use of NCED's Dam Removal model and began using it to engage visitors to the Park. The Park Crew's summer experience culminated in hosting a private reception in the BBY for University staff and senior administrators, arranged by GMA Horth, at which the Crew introduced these special visitors to the BBY, showcasing the activities they developed during the summer.

- Completion of a fossil exploration program and Park Crew-visitor activity, designed with assistance from two NCED GMAs, Ted Fuller and Emily Horth.

- Major interior renovation of the BBY's Science House. This model energy-producing structure had previously served largely as an example of environmentally sustainable building design and headquarters for the YSC Park Crew. With assistance from the 3M Foundation, SMM has, in Year 5, converted the building to the TRC. The building is currently being stocked with materials, models, and experiments for classroom and field use by science teachers, as well as a large format color printer and other resources for science teaching that may not be available in every school. The TRC will serve as a resource for area teachers and science coordinators during the school year, offering programming and materials for check-out to enhance science teaching. Many initial resources in the TRC were developed and/or made possible through NCED, including a set of the Dam Removal models, multiple sets of the AAAS Atlas of Science Literacy, 3D maps, and water quality testing kits.

NCED's Year 4 report included two BBY plans which have not been completed. Given public Hurricane-Katrina-related awareness of an NCED's involvement in the issue of subsidence in the Mississippi, we had planned an exhibit for the Park on subsidence. This plan has not been pursued; however, there will be related material in the traveling Water exhibits. Secondly, we have continued to experience operational design challenges with one of the original BBY components, the Erosional Landscapes component. Work to resolve these challenges is ongoing.

Earthscapes Indoors: In Year 4, Science-on-a-Sphere (SOS), a NOAA-developed spherical projection system, was installed at SMM, through a NOAA grant. Year 5 saw development of many new visualizations for this system, through the efforts of NCED Visualization Specialist Paul Morin, in collaboration with SMM staff. Newly developed content, including Earth's topography, surficial processes on Titan, seasonal global vegetation, rivers of the world, world wide distribution of dams, and sedimentary basins of the world, were incorporated into a special NCED "play-list", narrated by NCED Director Chris Paola, which plays regularly in the exhibit gallery. In addition, NCED 3D maps have been mounted nearby, and the large Dam Removal interactive exhibit from the BBY now resides indoors, near SOS. Evaluation of the Earthscapes Indoors gallery indicated that in some family groups with small children, the attention of the younger members lapsed before that of older children and parents. Accordingly, a floor map puzzle, aimed at young children, was devised and placed in a corner of the gallery, near a bench with a good line of sight to SOS. This allows the younger family members to remain engaged while others continue to observe SOS.

In SMM's Mississippi River Gallery, major improvements were made, in consultation with NCED staff and students at St. Anthony Falls Laboratory, to the gallery's popular meandering stream table.

Finally, a newly developed 420 square foot "floor map' has been installed in the public lobby of the museum, immediately visible to all who enter the building, whether to visit the exhibits or simply stop at SMM's store or coffee shop or the (free) National Park Service's Mississippi River Visitor Center, also located in the lobby. This shaded relief map of world topography and bathymetry includes two separate projections centered on the Arctic and Antarctic.

Wider Audiences: SMM's Science Buzz online community with related modular museum interactives (http://www.smm.org/buzz) began receiving national attention in Year 5, through collaboration with NCED. NCED's Visualization Specialist Paul Morin became a contributing scientist during his 2007 visit to Antarctica to participate in mapping in the Dry Valleys. Science Buzz was featured in an Education session at the national meeting of the Geological Society of America. In addition, Science Buzz was a popular feature of the 2006 STC Directors' Meeting, which was hosted by NCED and held jointly at the University of Minnesota (UMN) and SMM.

Large format map installations: The Liberty Science Center, in Jersey City, NJ, is using two NCED maps. One is a geomophological/LANDSAT map of the entire Hudson River Valley. It will be installed as a 30'x40' floor in a gallery in their new museum to open in mid 2007. A second 30'x20' map of the Hudson River, illustrating how humans have engineered the southern portion, was produced and will be installed on the windows of the same gallery.

NCED's Dam Removal model: Developed from the research of Visitor Chris Bromley, continued to appear at events around the country in Year 5. Three notable examples are:

- NCED Education Director Karen Campbell, PI Ben Hobbs, and graduate student Jennifer Bassman, joined SAHRA staff at the 12th Annual Reception and Exhibition on Capitol Hill on June 7, 2006. This annual event, sponsored by the Coalition for National Science Funding, showcases research made possible by the National Science Foundation. The event draws a large number of Congressional staff, Members of Congress, and White House leaders each year. All exhibitors are sponsored by a CNSF member society, university, or corporation; NCED and SAHRA were invited as a team, due to our exceptional outreach materials, by the American Geophysical Institute, Ameican Geological Institute and Geological Society of America. Senior Staff from each organization shared the booth with NCED and SAHRA and AGU staff arranged visits for Campbell to the offices of Minnesota's Congressional delegation on June 8 (see: http://www.cnsfweb.org/exhibition.html for more details).

- NCED supplied one of the Dam Removal models to the National Park Service's Olympic National Park, site of the Elwha River's Glines Canyon Dam, featured in the model. The model was used by park staff in many events in the Elwha watershed throughout the summer of 2006 and received local media attention (see Appendix D: Publicity). We are especially pleased that NCED has been able to supply this proven teaching tool to educators working with the stakeholders and students who will be affected by removal of the dams on the Elwha River.

- The model and the research it represented served as the focal point for an invited talk and exhibit at the International Conference on Rivers and Civilization in June, 2006.

Documentaries: NCED Director Chris Paola is leading a group of NCED and SAFL staff working with a National Geographic film crew to develop and film a series of models and experiments of various Earth surface processes, such as hurricanes, for National Geographic documentaries. NCED Education Director Karen Campbell and Stream Restoration IP Manager Jeff Marr are collaborating with Portland General Electric (PGE) and NCED Partner Gordon Grant of the U.S. Forest Service to design and build a physical model of an upcoming dam removal. The model will serve both as a scientific study and an opportunity for a documentary filmmaker, contracted by PGE, to add critical footage to his film about this 2007 event. This latter activity has been the main development in our River on the Road initiative, described in NCED's 2006 Annual Report.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
BBY exhibits fully functioning; at least one new component added.	All original exhibits fully functional; new components ("fossils", "artesian well") developed and/or installed.
Functioning Youth Science Center –NCED docent program for BBY.	YSC Park Crew worked with visitors to the BBY throughout summer 2006 to further engage them in the "science behind the golf/exhibits"; GMAs Ted Fuller and Emily Horth contributed to fossil exhibit/activity. Horth worked with SMM and NCED staff to provide the 2006 Park Crew with instruction and multiple fieldtrips to enhance their understanding of BBY concepts. NCED ESTREAM intern Kate Poulter Rosok will work with 2007 Park Crew and has begun planning.

Milestone/Deliverable	Progress
BBY visitor target of 150,000 reached or surpassed.	Attendance through Year 5: 136,500
Develop initial NCED components for WaterPlanet.	25+ new visualizations developed for SOS, floor map technique developed, groundwater, dam removal, GeoWall, hydrous minerals and RainTable components prototyped.
Develop 3D film outlines with SMM.	Experimentation with HD 3D cameras in Antarctica, exploration of possible sites and collaborations ongoing.
Reach national audiences .	Collaborative AMNH/SMM water exhibition opens at AMNH in fall 2007; international show tentatively scheduled to begin touring in summer 2008; national/international show to open 2007. Work with film documentary crews ongoing; national exposure for Dam Removal model.

Plans

1. Carry NCED research to national audiences by:

   a. Combining NCED's physical modeling expertise with SMM's growing experience in HD 3D formats to produce 3D visualizations on landscape evolution and channel dynamics.
   b. Collaborating with SMM in adapting NCED-developed BBY components to the AMNH/SMM water exhibition.

2. Collaborating with SMM the Center for Future Earth (CFE), a 3,500 square-foot exhibition, web site, and public policy programs at SMM that will enable public and professional audiences (e.g. policy-makers) to: 1) Better understand how humans are influencing large-scale planetary processes; 2) Learn how modeling can describe past planetary conditions and help predict future ones, and 3) Explore how the new fields of sustainability science and sustainability design are seeking to address the balance between nature and society. NSF recently approved SMM's preliminary proposal for CFE. The full proposal is due June 21, 2007.

► Project ED02: Provide unique center-based experience for graduate students

Internal Activities: NCED's graduate students continued to participate actively in the life of the Center in Year 5. Seven graduate students gave presentations at NCED's weekly research videoconference (see Appendix M: Activity Tables), two students (one from outside NCED) served as GMAs, and three made international research visits under NCED's International Research Experience Program (IREP), an STC-wide program.

Two students participated in our **GMA** program in Year 5:

1. Ted Fuller completed work, begun in Year 4, to develop a new activity for the BBY, collecting fossiliferous rock from a local quarry and developing interpretive materials to incorporate a fossil-collecting activity/exhibit into the park.

2. Emily Horth, a recent graduate of the University of St. Thomas, worked with the SMM YSC Park Crew in the summer of 2006 to develop science enrichment experiences for them, such as field trips to local rivers and SAFL. She also guided these high school youth in developing experiences for visitors and assisting in development of the fossil exhibit. Emily developed a permanent manual for future Park Crew leaders and planned a private event in the BBY at which the youth presented their work to visitors from the UMN. Finally, she joined in much of the work done by the ESTREAM intern team, described under ED05.

NCED's **International Research Experience Program (IREP)** sent three graduate students and two undergraduates on international research trips during Year 5. This competitive STC-wide program provides funding for international educational and research travel by graduate students, with the goal of strengthening international research partnerships and two-way technology transfer. Leslie Hsu, University of California-Berkeley (UCB) with undergraduate Roman Dibiase, Robert Haydel, University of Illinois at Urbana-Champaign (UIUC), and Michal Tal, UMN with Brown University undergraduate and former NCED Undergraduate Summer Intern Program (USIP) intern Edith Moreno, participated and presented their research at NCED videoconferences:

- Hsu - Channel erosion in the Illgraben torrent (international advisor: Brian McArdell, Swiss Federal Institute for Forest, Snow and Landscape Research, Switzerland)
- Haydel - Morphology and flow structure downstream: Two bar-confluences in a large river (international advisor: Mario Amsler, Universidad Nacional del Litoral, Santa Fe, Argentina)
- Tal - Untangling the management practices of New Zealand's Canterbury rivers (international advisor: Murray Hicks, NIWA (National Institute of Water and Atmospheric Research), New Zealand).

Graduate students Peter Nelson (UCB), Sara Johnson (UMN), and Amy Hansen (UMN) will participate in the IREP, and present their research to the NCED community, in summer 2007.

NCED's **Graduate Student Council (GSC)**, continued to be active. NCED graduate students developed and presented 15 posters at NCED's Annual Site Visit in May 2006. The students also used the Site Visit event as a time to meet with one another and formally elect a new GSC President, Brandon McElroy. The students also served in NCED's booth on the Exhibits floor at the Fall 2006 AGU meeting and participated with post-docs in developing a proposal to Meeting of Young Researchers in Earth Sciences (MYRES, details below). Finally, McElroy began plans for another Graduate-Students-only retreat, to be held in conjunction with NCED's June 2007 Site Visit.

NCED graduate students continued to work closely with NCED Partners throughout Year 5. Notable examples include collaborations with Stillwater Sciences at UCB's Richmond Field Station, and UMN student John Martin's collaborative experiments with Chevron-Texaco. Martin is now serving as an intern at Exxon-Mobil Research; upon completion of his PhD, he will become a full-time researcher there. In addition to his experiences managing NCED's consortium of Stratigraphic Partners, Martin took a leadership role in the development of NCED's latest teaching model, the Delta Box. This is described in more detail under ED05. NCED's SAFL-based collaborative research initiative, StreamLab 06, provided students rich and varied opportunities to interact and collaborate with visiting researchers from academic and agency Partner institutions. StreamLab06 is described in greater detail in Appendix G: StreamLab Laboratory Experiment of this report.

NCED had an active team of Integrative Post-docs in Year 5. In addition to their important research efforts across NCED IPs, these recent graduates, some NCED alumni and some from institutions outside NCED, serve as important near-peer advisors for NCED graduate students. One notable example of this relationship is their joint effort to propose an NSF and European Science Foundation funded MYRES conference. At a Town Hall Meeting at the Fall 2006 AGU meeting, the NCED-led draft proposal for MYRES III, to be held May, 2008, entitled: Dynamic Interactions Of Life And Its Landscape was presented. Voting on all MYRES proposals will occur in May 2007.

By Year 5, a substantial number of PhD and post-doc alumni had moved into teaching positions. Several of them wished to stay involved in NCED research but found themselves at primarily undergraduate institutions with heavy teaching loads and no formal REU programs to provide support for undergraduate research. Therefore, NCED piloted in summer 2006, and will continue in summer 2007, an informal program of funding a small number of undergraduates associated with NCED alumni to participate in NCED research. To date, the program is focused on research at the ACRR. Dr. Jill Welter Shade, now at the College of St. Catherine (CSC), a women's college in St. Paul, MN, was assisted in her summer research by two female undergraduates. NCED EAB Member Dr. Tony Murphy, who teaches Science Education at the same institution, was able to make a site visit to ACRR, about which he prepared a brief report for the NCED EAB.

NCED-led Graduate Experiences for Wider Audiences: NCED's NSF-funded Integrative Graduate Education and Research Traineeship (IGERT) program (Non-equilibrium Dynamics Across Space and Time: A Common Approach for Engineers, Earth Scientists and Ecologists), taught by PIs from NCED as well as faculty from four departments and two schools across the UMN, admitted five students to the second year of this program in fall 2006, for a program total of 11 students. Three students are advised by NCED PI Miki Hondzo; one by PI Lesley Perg. NCED PIs Chris Paola, Vaughan Voller, Hondzo, Jacques Finlay and postdoc Matt Wolinsky are contributing lecturers to the program. Eight special seminars were held at SAFL during the 2006/7 academic year:

NCED PIs, including, Bill Dietrich, J. Wesley Lauer, David Mohrig, Chris Paola,, Gary Parker, Lesley Perg, Peter Wilcock, and colleagues Jorge Abad and Victor Rivera designed and delivered a two-day short course on the physical and ecological dynamics of low-slope sand-bedded rivers to 40 graduates students from within and outside NCED in Baltimore, MD, May, 2006. PI Peter Wilcock developed and taught a new course at Johns Hopkins University, entitled Geomorphic and Ecologic Foundations of Stream Restoration, to 23 students.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Strong graduate student participation in cross-disciplinary research & seminars, GSC, videoconferences, NCED retreats, site visits, partner research, internships.	15 student posters presented at 2006 Site Visit (each with multiple student authors), 7 students presented center-wide videoconferences, 4 students conducted joint research with NCED Partners.
Thriving GMA program.	2 students completed GMAs during Year 5; another has been identified for summer 2007.
Promote national models for graduate education.	Monitor and document progress/successes of IGERT: Non-equilibrium Dynamics Across Space and Time: A Common Approach for Engineers, Earth Scientists and Ecologists.

Plans

We will continue all activities discussed above, and ensure participation by NCED students in new shared depositional field site in the Mississippi Delta.

► Project ED03: Establish Stream Restoration certificate program

NCED's Stream Restoration Engineering and Science Certificate program (SRES) admitted its first 13 students for classes beginning in September 2006. A newly developed, full semester class was led by NCED Director Chris Paola and post-doc Karen Gran. Additional NCED staff participated in teaching the class, including PI Jacques Finlay and post-doc Cailin Orr. Guest lecturers included Dr. Omid Mohseni of SAFL, Bruce von Dracek of the USGS and UMN and Marty Melcher of NCED Partner Interfluve, Inc. In addition to lectures, students participated in field trips and laboratory experiments. Additional stream restoration practitioners participated by working with small groups of students on post project assessments at restoration sites in Minnesota. The program can be completed in one year or two, allowing flexibility for those students who are employed full-time. In between the NCED developed introductory course and the Capstone experience, students select amongst a designated set of existing courses at UMN. So a subset of the first cohort of students will participate in the May Term 2007 Capstone experience, as some have elected to take two years to complete the certificate. While admissions are still open as of submission of this report, a similarly-sized cohort has indicated interest in being admitted to the program beginning September 2007. The Capstone experience will involve work with a real restoration site; ideally on a long-term basis. Final site selection was not complete at the time of this report.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Functioning certificate program in Stream Restoration.	First 13 students enter the program, complete fall introductory course; Capstone course in preparation, recruitment ongoing.

Plans

We will complete design of the Capstone experience and teach and evaluate the Foundations and Capstone courses on an ongoing basis. We will also track student placement and recruit for/promote program nationally.

► Project ED04: NCED enhancements to undergraduate education

Visualization: NCED's 3D visualizations continue to attract national attention in Year 5, particularly in the area of undergraduate instruction. More detail on specific activities is available in section ED06 of this report.

Models and Experiments: NCED's table-top model of dam removal,developed from Visitor Chris Bromley and Partner Gordon Grant's research experiment at SAFL, continued to be used in undergraduate settings, including Macalester College, the CSC, and two University of Wisconsin campuses. A new model, christened the "Delta Box," was developed and introduced at the NSF-funded On The Cutting Edge - Professional Development for Geoscience Faculty Teaching Sedimentary Geology in the 21st Century workshop, held at the University of Utah in July, 2006. See ED05 for more details on the model and the workshop.

Instruction: Finally, while NCED has made slow progress on developing complete undergraduate courses, NCED PIs and alumni have been very active in advising undergraduate interns and preparing individual lectures for undergraduate courses. This activity is detailed in the Diversity section of this report, as well as in Appendix M: Activity Tables.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Non-NCED participation in summer research surpasses 20 total (shared with Diversity).	17 undergraduate interns
At least 3 NCED-inspired undergraduate courses developed and taught.	No progress in Year 5; two have been developed during NCED's first 5 years.
NCED research-based course materials available on web with documented use.	NCED's 3D maps continue to be downloaded regularly from our website

Plans

We will continue to refine design of the Delta Box and monitor its use by faculty members nationally who have built their own Delta Boxes. We have begun developing more online resources aimed at undergraduate instruction and hope to increase this collection in NCED's renewal period. NCED models and 3D maps have met with considerable enthusiasm from undergraduate instructors; we anticipate the same response in relation to the new textbook *Exploring Geology* (see section ED 06). Given this experience, and our relative lack of progress in developing full undergraduate courses during Years 1-5, we will re-evaluate that goal during year 6. Finally, we began, in Year 4, plans to incorporate undergraduate instruction into SMM exhibits, as a model for other museums to follow. As of submission of this report, we will re-evaluate our ability to meet that goal, given current commitments.

► Project ED05: Professional Development For 4-16 Teachers

SMM-based Earthscapes Programs. Education Director Karen Campbell and SMM staff delivered NCED's third field-, laboratory- and museum-based Earthscapes Teacher Institute to 16 teachers who used their Institute experience to design new field- and lab-based river studies for their students. At this year's institute, staff and teachers tested several new products for water-quality sampling, ranging from very simple all-in-one kits to very accurate electronic methods. The most usable of these were then purchased in greater numbers for inclusion in SMM's new TRC, described in section ED01.

A set of seven NCED-designed dam removal models, along with their accompanying curriculum, continued visiting schools (45 classrooms, 1213 students, 3939 contact hours in Year 6) as part of SMM's River Restoration Residency program. (Please note: this program was referred to in some earlier NCED reports as the "School Contact Program".) These models, based on the study of NCED Visitor Chris Bromley of the potential impact on the Elwha River of the removal of the Glines Canyon Dam, are also in use elsewhere in NCED and colleague programming, as discussed throughout this report. In Year 5, SMM staff completed a formal evaluation of the Residency Program (see Appendix H: Program Evaluation) and built an additional set of the models, be available in the SMM's new TRC for check-out by classroom teachers.

NCED's Year 5 saw the conversion of Science House, in SMM's BBY, to a TRC. While this project was funded outside of NCED, many of the initial materials available to teachers in the TRC will be NCED-developed or inspired. See Section ED01 of this report for more details on the TRC.

ESTREAM teacher interns: ESTREAM, NCED's intern program for in-service and pre-service teachers, was very active in Year 5. Two women with undergraduate degrees in Geology, Amy Chen and Kate Poulter Rosok, worked part-time for much of the year. Chen was deciding between continued educations in Education versus Geology while working as an intern. Rosok began a Graduate Teacher Education Initial Licensure Program in middle and high school earth and space science teaching which she will complete in 2008. In summer 2006, they were joined by NCED GMA Emily Horth (see sections ED01 and ED02), a recent environmental studies graduate and Jon Fults, in his final year of an undergraduate Earth Science teaching degree at St. Cloud State University. Accomplishments of this very vibrant group include:

- Designing, conducting and documenting a full suite of field trips and museum-based experiences for the SMM YSC Park Crew
- Regularly planning and delivering NCED activities for NCED Diversity programs such as the *gidakiimanaaniwigamig* camps
- Planning and delivering portions of the Earthscapes Teacher Institute and follow-up workshop
- Presenting NCED educational material in posters and sessions at local and national meetings
- Developing instructional material for NCED's web-based resource collection
- Working with graduate student John Martin, Karen Campbell, Chris Paola and NCED collaborator Dr. Tom Hickson to develop NCED's Delta Box model (see workshop section below)
- Developing and testing a classroom-sized version of NCED's research experiment on the determinative impact of vegetation on stream morphology
- Working with John Martin to conduct, document and film a sequence-stratigraphy experiment for his graduate research in a full-sized SAFL flume which will be added to NCED's web resources as both a stand-alone resource for undergraduate instruction and an enhancement for the Delta Box.
- Intern Rosok secured a Knowles Science Teaching Foundation Fellowship (http://www.kstf.org) teaching fellowship; Chen was admitted to a graduate program in Geology, Horth secured a full time position doing science enrichment for high school students through the I Have a Dream Foundation, and Fults completed his student teaching.

NCED-led workshops: For the second consecutive year, Campbell and Dr. Katherine Pound of St. Cloud State University proposed, organized and delivered a day-long oral and poster session at Fall 2006 AGU. The session, "Hands-on, Inquiry-Based Classroom and Laboratory Assignments: Bringing Research in Earth-Surface Processes and Hydrology to K-12 and Undergraduate Students," included six oral and 13 poster sessions, as well as activity demonstrations in the AGU Exhibit hall. NCED ESTREAM interns Amy Chen and Katherine Poulter Rosok co-led the session, presenting posters and facilitating group discussion in the oral session.

In July 2006, NCED co-sponsored the NSF-funded On The Cutting Edge - Professional Development for Geoscience Faculty Teaching Sedimentary Geology in the 21st Century at the University of Utah. This workshop, also sponsored by the National Association for Geoscience Teachers, was co-convened by NCED Director Chris Paola and Drs. Kathleen Benison (Central Michigan University), Marjorie Chan (University of Utah), Tom Hickson (University of St. Thomas), and Heather Macdonald (College of William and Mary). This five-day workshop, whose purpose was to enhance the teaching of sedimentary geology at the undergraduate level, included sharing of exemplary laboratory and classroom activities, discussion of course content and curriculum, and exploration of field trips as a catalyst for integrating field and in-class material, attracted 45 faculty from public and private universities and colleges around the United States. Education Director Karen Campbell joined Paola and Hickson to lead one full day of the workshop, entitled: Using Physical Models in Sedimentary Geology Courses: Exploring Ideas and Examples from the National Center for Earth-surface Dynamics. Participants worked in 4 small groups to explore NCED's Dam Removal and Delta Box models and discuss their effectiveness for undergraduate teaching. A manual for building the Delta Box was prepared for the workshop and posted on NCED's website; several participants have built or are building their own delta boxes using this manual. Given workshop participants' enthusiasm for the new Delta Box model, we went on to distribute the manual on cd at the fall meetings of the Geological Society of America (GSA) and the AGU , as well as featuring the Delta Box in our booth, shared with SAHRA, at AGU. More details on the workshop are available at: http://serc.carleton.edu/NAGTWorkshops/sedimentary/workshop06/index.html.

NCED sponsored a customized American Association for the Advnacement of Science (AAAS) Project 2061 Professional Development Workshop for Educators at SMM in January, 2007, attended by NCED and SMM staff, ESTREAM intern Kate Rosok and area teachers and science coordinators. This three-day workshop gives participants perspective on standards-based education reform and tools, including the *Atlas* for Science Literacy and other AAAS Project 2061 resources for understanding and working with standards. The workshop's goal is to enhance participants' understanding of science literacy and to improve curricula, instruction, and assessment. This customized workshop also gave AAAS staff an opportunity to learn how this approach may be tailored to inform informal as well as formal science education. SMM and NCED staff now regularly consult the Atlas in developing activities and experiences and found the workshop and accompanying material to be a valuable shared resource.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Functioning ESTREAM and Earthscapes Summer Institute summer teacher programs, with commensurate participation in Earthscapes School Residencies.	3 Earthscapes Teacher Institutes have been presented, in August 2004, August 2005 and June 2006. In Year 5, residencies were presented to 45 classrooms, (1213 students; 3939 contact hours). (Cumulative figures: 61 classrooms, 7939 contact hours).
Materials developed through above programs made available for broad use over the web, and promoted at local and national conferences.	Presentations or posters were given at 3 national professional meetings and one national workshop, as well as on Capitol Hill. Materials are available on the NCED website; many are also available through the SERC website http://nagt.org/nagt/programs/activities_collection.html.

Plans

We will continue to promote and support use of our Dam Removal and Delta Box models to partners across the country, for use in teacher education and undergraduate settings. While our Professional Development programs for middle to high school Earth science teachers, the Earthscapes Teacher Institute and ESTREAMs internships have been very rewarding for the participants, both are small programs with largely local impact. The advent of the new teacher professional development venue at SMM, the Teacher Resource Center, along with our success with workshops for undergraduate faculty, offers NCED the opportunity to reassess where and how we focus our efforts in Teacher Professional Development. Therefore, in Year 6, we will explore a possible shift in programming emphasis, evaluating whether to continue with the teacher institute and intern format or focus on developing more workshops to serve new audiences.

► Project ED06: Visualization tools to enhance Earth-science education

As reported in ED01 and ED04, a great deal of progress was made in this area in Year 5. In addition to those described in detail below, Visualization Specialist Paul Morin worked with colleagues at SMM to produce many visualizations and develop new vehicles for displaying these visualizations to students and the public (see ED01 for details).

3D Paper Maps: Paul Morin and Karen Campbell, working with NCED's pre-service teacher interns, external colleagues and classroom teachers, continued to develop, test, and nationally promote new course materials for grade 4-16 teachers based on NCED's research visualizations. 15,000 copies of two Morin-designed 3D maps were printed and sold or given to geology departments, professional geological organizations, and museums throughout the U.S. One of these, the "Four Corners" map of Arizona, New Mexico, Colorado and Utah, was developed in partnership with SAHRA and featured at the joint NCED-SAHRA booth at the Fall 2006 meeting of the GSA. This map was also distributed by the National Association of Geology Teachers through their journal, aimed at 4-16 instructors A second map, showing the entire Mississippi River, was widely distributed by NCED and will shortly be commercially produced for distribution by NCED, the National Park Service and the McKnight Foundation.

Testing the effectiveness of 3D visualization in undergraduate instruction continued in the Department of Geology and Geophysics at the UMN. A new 3D visualization tool, RainTable, developed for SMM exhibits to help people understand the flow of surface water through drainage basins, has met with great interest from undergraduate instructors.

Textbook publication: The final drafts of the Mc-Graw Hill Earth science textbook, Exploring Geology, of which NCED Visualization Specialist Paul Morin is a co-author, were completed http://www.mhhe.com/earthsci/geology/Reynolds1e/ReviewSite/). This 650 page textbook offers a uniquely visual approach to teaching introductory geology and draws on cognitive and Earth science research and data developed by NCED and collaborators. Text and figures, presented as 320 two-page spreads, are much more tightly integrated than in traditional textbooks. Highly influenced by current pedagogical research and theory, the entire textbook is designed to encourage inquiry and a critical-thinking approach to geologic problem-solving, all framed within a learning-cycle approach. The textbook will be available for adoption by undergraduate instructors beginning in Fall 2007 and has already met with extremely enthusiastic pre-press response from reviewers and faculty nationally. Exploring Geology is projected to be used by 15% of all non-major Physical Geology students in the U.S. in the first year.

Science-on-a-Sphere (SOS) Evaluation: SMM continued to perform considerable audience evaluation of SOS with both general museum audiences and formal education classes from nearby colleges and universities. SOS is a very new scientific visualization technology and thus had undergone minimal testing and evaluation with audiences. SMM's work has been invaluable not only to informing itself about how to make SOS work more effectively as a learning experience but to all institutions in the U.S. that currently have SOS installations.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Research-grade 3D surface visualization and anaglyph map tools widely and successfully used in 4-16 education	35,000 3D maps distributed nationally, 2 new maps developed/under development; ongoing testing in undergraduate instruction at the UMN.

Plans

Continue development of research-grade 3D visualizations for 4-16 education.

Executive Summary - Plans

In Year 6, NCED Education efforts will continue to:

- focus heavily on development of AMNH/SMM water exhibition materials and exhibits, visualization products for education, and plans for 3D visualizations about landscape processes;
- explore ways to expand our impact on K-16 education, locally and nationwide, through hands-on workshops and development of additional models and experiments;
- support the unique Center-based activities of our graduate students, through the GSC and our IREP, and
- support the development of our IGERT and SRES graduate programs and begin promoting them as national models.

- New education efforts we will explore include:
- possible development of a new SMM exhibit initiative focused on human impacts on Earth's surface
- taking a leadership role at the UMN in connecting University researchers to public education through SMM
- active involvement in the NSF Geoscience Directorate's efforts to forge a unified vision for Geoscience Education and Outreach
- building a robust collection of research videos for undergraduate use through NCED's website
- establishing an ongoing restoration monitoring site for research, public education and SRES purposes.

Evaluation and Performance Indicators

	MEASUREMENT	
	Description	Value
NCED Students		
1. Graduate student participation in NCED Center-wide activities	Number of participating students	22
2. Graduate student application and graduation rates, and job placement	Number graduated	11
	Number placed:	11
	in Academic positions	7
	in Government/Industry	4
	in Other	0
3. New seminars and course materials developed for undergraduate education	Number of courses affected	50+
	Number of institutions	50+
Earth Science Teachers and Students		
1. Participation in NCED programs	Number of teachers	20 in Year 5 49 cumulative
	Number of students	1385
2. Classroom tools developed and utilized	Number of tools developed	3
	Number of web hits	3773 (Year 5) 10883 (cumulative)
	Data downloaded	250433 Kb (Year 5) 497584 Kb (Cumulative)
Public		
1. Attendance statistics and feedback from the BBY	Attendance	34,500 (2006) 136,500 (cumulative)
	Feedback	SMM internal evaluation completed summer 2006; see appendix H

IV. Knowledge Transfer Initiative

Project Team

Knowledge Transfer Director: Jeff Marr
Contributing PIs: all

Executive Summary

Knowledge Transfer activities and goals are aligned closely with each of NCED's Integrated Projects (IP). These activities and goals generally fall into two groups: 1) formal partner activities, such as meetings, web portals, and short courses and 2) research collaborations that include participants from within and outside NCED and include activities such as field, experimental, or modeling work. Year 5 saw exciting developments in both areas as our Stream Restoration (SR) partner activities became increasingly well established and meaningful collaborations with researchers from outside NCED flourished in all three IPs. Because each of the three IPs was designed around a set of applications in addition to basic science, we have incorporated our knowledge activities directly into the IPs themselves in the body of this Annual Report. Knowledge transfer begins with relationships and activities with the partners groups for each IP. Of the three IPs, SR has the largest and best developed partner group, a natural consequence of the applied nature of restoration and of the need for better science to produce better outcomes. This year, the DW Partners Group is increasingly energetic with completion of the initial version of the DW computer application and planned field application with Stillwater Science and other partners.

This year, we improved the Visitor Program by organizing it around a major collaborative, multi-investigator research experiment (StreamLab06) in the Main Channel facility at St Anthony Falls Laboratory (SAFL). Year 5 brought to a close the first of NCED's innovative multi-investigator collaborative research experiments, StreamLab06. StreamLab06 involved a total of 40 researchers, including members of the Stream Restoration Partners Group (SRPG) and one Visitor Program researcher. Represented were six academic institutions outside NCED, three Federal agencies, two consulting firms, and four NCED institutions. All data from the experiments, including detailed bed topography information and photographs, was archived on NCED servers for community use.

We also co-sponsored the International Bedload Surrogates Monitoring Workshop (IBSMW) with the Bedload Research International Cooperative (BRIC) April 11-14, 2007, at SAFL. Organized by NCED partner John R Gray (United States Geological Survey or USGS), Jonathan B Laronne of Ben Gurion University of the Negev, Israel and SR IP Manager Jeff Marr, the workshop was attended by 47 people from 11 countries. Attendees were a mix of university and agency researchers; many had participated in StreamLab06. A unique feature of the workshop was the use of the Macromedia's Breeze technology, which allowed slides and a live image of the presenter to be broadcast to additional attendees around the world, who could then submit typed questions for inclusion in the discussion periods. Abundant new NCED partner collaborations are emerging from this workshop.

In addition to StreamLab06, in Year 5 NCED provided leadership to the broader research community through short courses and special sessions at professional meetings.

Goal

Create and maintain two-way communication and exchange among our applied science stakeholders (partners), the broader research community, and NCED participants in order to ensure that NCED research is informed by societal needs and to ensure that NCED results are disseminated quickly and effectively.

Approach

Note: In Year 5, NCED updated its Strategic and Implementation Plan (SIP). This report refers to the projects in the updated SIP (dated March 2007).

Knowledge transfer programs are incorporated into NCED's research IPs. Each research IP has specific knowledge transfer activities designed to support the goal of establishing two-way exchange between research and practice. The following elements are common to our approach to knowledge transfer across the IPs:

1. Establish regular communication between NCED and NCED partners for each IP area.
2. Develop website content for each IP including recent research products (articles, data, technologies, and software), links, and future directions.
3. Conduct application-oriented short courses and workshops both at NCED facilities and at other meetings.
4. Provide opportunity for collaborative research between NCED and non-NCED researchers within each IP through joint research, the Working Group Program, the Faculty-to-Faculty Program, and the Visitor Program.

The SR IP has a particularly wide range of applications. NCED's goal is to explicitly link restoration practice, research, methods, and training. Much of current stream restoration practice is based on research that is 50 years old and does not fully connect cause and effect in stream channel dynamics. NCED works with a variety of partners to improve training and provide broad distribution of methods and models within an organized, open-source framework. To achieve this, the SR IP has three unique knowledge transfer implementation components:

1. Develop a SR newsletter that highlights issues important to the stream restoration community.
2. Produce a stream restoration "toolbox" containing helpful numerical models, equations, and information derived directly from NCED research efforts.
3. Support the development of education and training programs in stream restoration.

Achievements and Plans – Major Initiatives

Visitor Program

NCED hosted three individual projects under the Visitor Program in 2006. Each visit was significant in some way. Elizabeth Hagen and Noah Finnegan were our first visitors to be hosted at an NCED facility other than at the St Anthony Falls Laboratory (SAFL). SAFL visitor Collin Rennie's proposed work inspired the project that became the large multidisciplinary effort, StreamLab06. He also was an active participant in the International Bedload Surrogates Monitoring Workshop (IBSMW) co-sponsored by NCED (see below for more on StreamLab and IBSMW). A complete summary report of the Visitor Program is available on the NCED website at www.nced.umn.edu/Visitor_Program_Summary_Report.html.

Rennie (Assistant Professor and Director of the Hydraulics Laboratory at the University of Ottawa) tested the viability of using an Acoustic Doppler Current Profiler (ADCP) as a surrogate method for measuring bedload transport in a stream by conducting a series of experiments in SAFL's Main Channel. This technique is proposed as an alternative to traditional physical samplers, which can be both time-consuming and dangerous to use in high flow settings in the field. Traditional samplers also typically incorporate a large margin of error. Preliminary results showed a good fit between ADCP data and data from the Main Channel's weigh-pans for sand bed runs and, with recently available video data, there may be promising results from the gravel bed runs as well.

Hagen (graduate student, School of Life Sciences Arizona State University) visited the Angelo Coast Range Reserve (ACRR) where she performed experiments on how bat foraging activities relate to stream morphology. She monitored numbers of bats feeding in stream settings with various degrees of open space and vegetation. Following a four-month field study, Hagen was able to correlate foraging behavior to season (temperature and period in the life cycle) as well as physical location. She noted that bats tend to feed where insects are concentrated, and that their echolocation abilities were not obstructed by dense vegetation.

Finnegan (graduate student, Earth and Space Sciences, University of Washington) conducted his physical experiments at the University of California, Berkeley's, Richmond Field Station. He examined incision rates in bedrock channels and their feedback effects on sediment load supplies and channel morphology. Finnegan found that a delicate balance exists among these phenomena and that both negative and positive feedbacks on rate of incision change follow sediment supply perturbations. He also noted an intriguing relationship in which removal of bedrock scaled with sediment supply when the bed was exposed and showed that incision is limited by the availability of erosive sediment.

StreamLab06 (See also Appendix G: StreamLab Laboratory Experiment)

Year 5 brought to a close the first of NCED's innovative multi-investigator collaborative research experiments, StreamLab06. StreamLab06 involved a total of 40 researchers: 19 members of the Stream Restoration Partner Group (SRPG) and one member of the Visitor Program (see also Visitor Program Section above). Represented were six academic institutions outside NCED, three Federal agencies, two consulting firms, and four NCED institutions. All data from the experiments, including detailed bed topography information and photographs, was archived on NCED servers for community use. From a knowledge transfer perspective, the real value of this initiative is three-fold:

- the opportunity for researchers from outside the primary NCED Principal Investigator/postdoctoral research associate/graduate student community to fully participate in NCED activities;

- the opportunity to combine theoretical and applied research in the same project; and

- the robust dataset it yielded, which will be available for analysis for years to come.

IBSMW

NCED co-sponsored this workshop with the Bedload Research International Cooperative (BRIC), April 11-14, 2007, at SAFL. Organized by NCED partner John R. Gray (United States Geological Survey or USGS), Jonathan B. Laronne of Ben Gurion University of the Negev, Israel, and SR IP Manager Jeff Marr, the workshop was attended by 47 people from 11 countries. Attendees were a mix of university and agency researchers; many had participated in StreamLab06. A unique feature of the workshop was the use of Macromedia's Breeze technology, which allowed slides and a live image of the presenter to be broadcast to additional attendees around the world, who could then submit typed questions for inclusion in the discussion periods. Workshop sessions included these topics:

- Bedload flux: modeling and monitoring
- Passive acoustics I: lab calibration
- Passive acoustics II: field calibration
- Passive acoustics II and in-situ samplers I: field monitoring
- Impact methods and passive acoustics III: field monitoring
- Active acoustics
- Prototype bedload monitoring
- Bedload monitoring in sand bedded rivers
- Principles of acoustics and signal processing
- Piezoelectric and magnetic methods
- Special topics in bedload monitoring

A wrap-up session focused on defining the next steps necessary to develop operational-scale bedload surrogate monitoring techniques and enumeration of major workshop findings and recommendations to be presented to workshop sponsors (see also: http://www.nced.umn.edu/BRIC_2007.html).

Involvement with broader research community

In addition to StreamLab06, in Year 5 NCED provided leadership to the broader research community through short courses and special sessions at professional meetings.

Short courses

- *Morphodynamics of Sand-bed Rivers*. Two-day short course sponsored by NCED, May 27-28, 2006, Baltimore, MD. NCED PIs, students, and collaborators (William Dietrich, Marcelo Garcia, J Wesley Lauer, David Mohrig, Chris Paola, Gary Parker, Robert Twilley) led the course.

- *The principles and practice of stream restoration*. Two-week short course convened by JC Schmidt, Utah State University, May 30 – June 8, 2006. NCED PI Peter Wilcock primary instructor.

- *Ecological and geomorphic principles of stream restoration*. One-week short course co-convened by NCED PI Peter Wilcock and External Advisory Board member Margaret Palmer, University of Maryland, June 12-16, 2006.
- *River restoration: Application of fluvial geomorphology*. One-week short course convened by GM Kondolf, University of California, Berkeley, Truckee, CA, August 10-14, 2006. NCED PI Peter Wilcock primary instructor with NCED PI Mary Power also on faculty.
- *Sediment transport in stream channel design*. One-day short course, Northwest Environmental Training Center, September 27, 2006, Missoula, MT. Led by NCED PI Peter Wilcock.

Special sessions

- Earth Surface Processes and Landscapes. Co-convened by NCED PI Peter Wilcock and James Pizzuto.
- Stochastic Geomorphology: The Role of Variability and Uncertainty in Prediction. Co-convened by NCED PIs Peter Wilcock and Efi Foufoula-Georgiou, spring 2006 Joint Assembly, Baltimore, MD.
- Flow and Sedimentation Processes That Construct Floodplains. Co-convened by NCED PI Bill Dietrich and Tom Dunne, fall 2006 American Geophysical Union (AGU), San Francisco, CA.
- Autogenic Dynamics in Landscape Evolution and the Geologic Record. Co-convened by NCED Postdoctoral Research Associate Doug Jerolmack and John Swenson, fall 2006 AGU, San Francisco, CA.

An effort was also begun to share leadership of our successful working group initiative with the University of Minnesota's new Institute on the Environment, of which NCED PI Efi Foufoula-Georgiou was an Advisory Committee member and NCED Director Chris Paola a Founding Fellow during Year 5. Partnering with this high-profile University-wide effort will help ensure sustainability of NCED's working groups.

Achievements and Plans – SIP Project Plan

In Year 5, NCED updated its SIP. This report refers to the projects in the updated SIP (dated March 2007):

Desktop Watersheds (DW) IP

KT01 Desktop Watersheds Partner Group (DWPG)
KT02 Make components of the DW available to practitioners and the public
KT03 Collaborative DW research with non-NCED researchers

Stream restoration (SR) IP

KT04 NCED SRPG
KT05 SR website
KT06 SR newsletter
KT07 SR "toolbox" containing useful numerical models, equations, and guidance for practitioners
KT08 Education and training programs in SR

Subsurface Architecture (SA) IP

KT09 Establish regular communication between NCED and Subsurface Architecture Partner Group (SAPG)
KT10 Develop website content for Subsurface Architecture (SA) goals, current progress, and future direction
KT11 Conduct short courses and workshops

► Project KT01: DWPG

Priority knowledge transfer activities in the DW IP in Year 5 were concentrated in the areas of model development and collaborative research. See KT02 and KT03 below.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Identify and formally adopt partners into the DWPG.	Stillwater Sciences is NCED's primary DW partner.
Hold initial meeting.	Stillwater Sciences co-sponsored NCEDs Annual SRPG meeting in California, July, 2006.

Plans

As NCED moves into its second five years, we will reassess the need for a formal DWPG. There is a great deal of research activity with partners in this IP, as well as the potential for greater interaction once the DW Ripple Coho Salmon model (see KT02 below) is in public release; a formal partners group distinct from that of the SR IP may not be the most effective mechanism for partner interaction for this IP.

► Project KT02: Make components of DW available to practitioners and the public

In Year 5, a substantial effort was made to assemble a first-cut static model linking topographic, channel habitat, and coho salmon populations. DW Project Manager Collin Bode developed a user interface for code written by Peter Baker (Stillwater Sciences). Postdoctoral Research Associate Wendy Palen, graduate student Douglas Allen, and Rafael De Asousa (Stillwater Sciences) consulted on design. NCED partner Frank Ligon (Stillwater Sciences) played a central role in structure of the model and provided financial support from Stillwater for model development. Some contributions were also provided by Dino Bellugi (University of California, Berkeley) and Ionut Iordache (National Center for Airborne Laser Mapping analyst). The model was assembled in time for a demonstration during the May 2006 NCED site visit. Subsequent work focuses on improving the interface and stability of the model. This generation of the model has been named Ripple (Coho Salmon model).

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Initial results available through website and publication including DW webportal on the NCED website.	User interface in development. Release date set.

Plans

We anticipate a first public release of the Ripple Coho Salmon model by June 2007. In the next two years we expect to improve the Ripple model in several ways: 1) introduce dynamic hydrology by linking it to a watershed rainfall-runoff model and channel routing program, which in turn would start us on the path of sediment routing, 2) add a temperature model, 3) add barriers and large woody debris, and 4) direct the model approach at other organisms (other than coho), namely algae, frogs and aquatic insects. In addition, the ecology group, led by NCED PI Mary Power, providing feedback on the structure of the salmon population dynamics module will continue to make progress in the evaluation and testing phase in 2007. This work is expected to culminate in a peer-reviewed paper comparing the estimated limiting factors for coho salmon populations in a number of watersheds in Northern California (5-15 watersheds).

► Project KT03: Collaborative DW research with non-NCED researchers

Year 5 DW IP research involved a number of non-NCED researchers from agencies, consulting firms, and academia. Highlights include:

Shallow landslides: Shallow landslides often mobilize as debris flows.We presently lack a theory for landslide size and for linking prediction of size and location to characteristics of rainfall (such that a reliable landslide warning system could be built). Collaborations are underway with Jim McKean (US Forest Service), Taylor Perron (currently at Harvard University), Dino Bellugi, and Efi Foufoula-Georgiou. We have developed a multi-dimensional cell-based slope stability model, which is used in a search for the size and shape of all cells that will fail. A manuscript on this work has been submitted for publication.

In-stream effects of sand loading in salmon-supporting streams: In Year 5, NCED provided partial support for the postdoctoral research by Daniele Tonina (a former NCED visitor) in collaboration with Jim McKean (US Forest Service). The project focuses on the in-stream effects of chronic and acute sand loading on bed texture, river morphology, and habitat in salmon-supporting streams. The goal is to develop numerical models of channel response to chronic loading of fines on river beds. The study takes advantage of the unique high-resolution water-penetrating Light Detection and Ranging (LIDAR) survey of gravel bedded rivers in Idaho.

Particle dynamics: To explore particle dynamics more directly, collaboration with DK Arvind, from the School of Informatics at the University of Edinburgh, was initiated in Year 5. Arvind is the founding Director and Principal Investigator of the Research Consortium in Speckled Computing (www.specknet.org), a multidisciplinary grouping of computer scientists, electronic engineers, electrochemists, and physicists drawn from five universities, to research the next generation of miniature 5 mm cube specks. In consultation with this group, NCED staff installed, in a fist-sized ball, a system of accelerometers, magnetometers, and gyroscopes in order to track the ball at high frequency as it participated in a debris flow. Initial results look very promising. See plans below for next steps.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
DW Working Group Program established.	No progress.
1-2 Visitor Program participants complete DW projects.	While not official participants in the NCED Visitor Program, the collaborative work with US Forest Service's McKean and projects in the large drum are both vibrant examples of outside researchers successfully collaborating with NCED. Visitor Noah Finnegan conducted flume experiments on incision rates of bedrock channels.

Plans

Shallow landslides: The shallow landslide work in collaboration with Jim McKean, Dino Bellug,i and Efi Foufoula-Georgiou will continue with an emphasis on understanding how the space-time variability of precipitation modulates the initiation and size of shallow landslides. A new research proposal was funded this year by the National Aeronautics and Space Administration (NASA) (NCED PI Efi Foufoula-Georgiou in collaboration with NCED PI William Dietrich) to develop orographic precipitation downscaling models and examine the potential for early warnings on landslide initiation. We will also continue to pursue the challenging problem of building a search algorithm that efficiently finds the likely landslide size across a variable landscape. Size and frequency of occurrence are the drivers of sediment flux, so this problem needs to be solved.

Particle dynamics: We hope to build approximately 10 more particle dynamics tracking balls of varying dimension to document grain size dependent dynamics. We think this may reveal a new way to view grain dynamics, flow, and boundary stress generation. In addition to the Research Consortium in Speckled Computing (specknet.org) group, discussions are underway with a number of non-NCED researchers from the USGS and University of Minnesota to participate in this research. Specifically, Assistant Professor Kimberly Hill at the University of Minnesota, with expertise on particle dynamics, has visited the University of California, Berkeley, to initiate discussions for collaboration (a seed grant of $15K has been provided to her from SAFL towards the establishment of this collaboration).

Large rotating drum: We are actively seeking collaborations for experiments in grain flow mechanics, as well as in other areas, to exploit the scale and instrumentation capability of the large rotating drum NCED designed and built at the University of California, Berkeley. Brian McArdell, of the Swiss Federal Institute for Forest, Snow, and Landscape Research, has submitted a proposal to study landslides associated with snow avalanches and ice rich landslides in the drum using a mixture of rock and ice.

► Project KT04: NCED SRPG

NCED SR IP Leader Peter Wilcock co-convened the annual meeting of the SRPG. This group facilitates and coordinates interactions among research, method development, and training in stream restoration. The meeting was held at the University of California, Berkeley, Richmond Field Station in California, July 6-8, 2006. It was jointly convened by NCED and Stillwater Sciences. Part I, led by Stillwater Sciences and colleagues, focused on Physical Modeling Experiments to Guide River Restoration and included field trips to local restoration sites. Part II, led by Wilcock, included presentations and discussion on the following topics:

- Restoration for fish recovery,
- Monitoring and postproject assessment,
- Public preference in the selection and location of projects for water quality improvement,
- Stream restoration tools (routing mixed-size sediment), and
- Stream restoration education and training.

Note: A meeting of the Stream Restoration Training Working Group (SRTWG) occurred March 30-April 1, 2006, and was reported in NCED's 2006 Annual Report. While this group did not meet formally in Year 5, revision continued on the white paper drafted at that meeting, which was also circulated at NCED's May 2006 site visit.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Annual SRPG meetings with report.	Meeting took place July 6-8, 2006.
Subgroup activities to include training, evaluation team, and field meetings.	Revision continued on the white paper drafted by the Stream Restoration Training Team (SRTT).

Plans

Final revisions of the SRTT's white paper will be completed and the document distributed. A meeting of the SRPG will occur sometime in Year 6 and plans for ongoing meetings of other subgroups will be revisited. We hope that the opportunity for pre- and post-restoration monitoring, related to the removal of the Marmot Dam on the Sandy River in Oregon, will provide opportunities for field meetings beginning in Year 6.

► Project KT05: SR website

We added substantial content and completed a major revision of the SR website in Year 5. The website, whose goal is to be a resource for the whole stream restoration community, is accessible directly from the NCED website's front page and includes sections on: Research, Training, Partners, Restoration in Action, and Resources. A major enhancement to the SR website is the addition of an interactive form that enables anyone in the stream restoration community to provide NCED with their contact information, as well as their stream restoration-related activities, for inclusion in a downloadable directory. The new section, Restoration in Action, showcases ongoing restoration projects, which provides a valuable resource for the community to learn from one another. See http://www.nced.umn.edu/Stream_Restoration.html or http://www.streamrestoration.net (both addresses point to the site) for further information.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Website has comprehensive inventory of training opportunities and compiles training materials following the open courseware model.	The Training section of the website is operational and lists training opportunities in both alphabetical and calendar formats. Manuals from two outside organizations are linked.
NCED SR data and results.	StreamLab06 data is currently being inventoried and will be posted to NCED's data repository in accordance with NCED's 2 year confidentiality policy for data.
Newsletter and enhancements.	See KT06 below.
At least 10 tested NCED SR tools available for free download.	See KT07 below.

Plans

We will continue to maintain and revise the SR website to reflect NCED's ongoing leadership role to provide resources and opportunities to the stream restoration community.

► Project KT06: SR newsletter

In Year 5, we revised the SRN in several important ways, all of which we hope will make it a more useful and usable resource for the community. Revisions include:

- the conversion from a paper to an electronic-only (pdf) format,
- the debut of a new one-page e-mail format which summarizes and links to current issue,
- the added ability to track how many recipients view content,
- a new editorial policy enabling community members to provide more content, and
- a streamlined format for web-based content.

See Appendix E: Knowledgge Transfer Publications for sample recent issues of the SRN.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Quarterly newsletter: The Stream Restoration Networker (SRN)	Frequency changed to twice-yearly.
Circulate to agencies and research institutions involved in stream restoration.	E-version currently circulated to 319 recipients.

Plans

We will continue to enhance functionality of web- and e-mail delivery as appropriate and will continue to e-publish newsletter two times per year.

► Project KT07: SR “toolbox” containing useful numerical models, equations, and guidance for practitioners

Toolbox developments in Year 5 are summarized below. A brief description and link to finished toolkit components are available at http://www.nced.umn.edu/Stream_Restoration_Toolbox.html.

iSURF

Stream channels adjust to the water and sediment supplied to them. The channel slope and depth needed to transport the supplied sediment with the available flow can be found using elementary hydraulic relations and an inverse calculation with a sediment transport formula. Such calculations are at the heart of stream channel design and estimates of stream channel adjustment in response to changes in water and sediment supply. When the sediment contains a range of grain sizes, a surface-based transport model is needed to account for streambed armoring and the transport rates of the individual grain sizes in the sediment supply. A new tool, iSURF, performs an inverse calculation with the Wilcock/Crowe transport model to give stream channel slope, depth, and surface grain size as a function of user-specified water and sediment supply. The output includes a channel stability diagram, a key component in stream channel design previously available only for single-size sediments. Also available are river state diagrams (as pioneered by NCED PI Gary Parker), which can be used to evaluate stream adjustments to changes in water and sediment supply. The sediment transport model used in the tool (Wilcock and Crowe, 2003, *Journal of Hydraulic Engineering*) has also been incorporated into the Hydrologic Enginering Centers River Analysis System (HEC-RAS) software, a standard hydraulic model developed by the US Army Corps of Engineers (USACE).

The iSURF tool was completed in Year 5 and will be prepared for public use and posted to the website in Year 6.

DamRemoverMARK1

NCED Postdoctoral Research Associate Alessandro Cantelli and graduate student Miguel Wong completed a numerical model of the morphodynamics of dam removal for the case of uniform sediment. The work was performed in collaboration with NCED Director Chris Paola. The model captures, for the first time erosional narrowing as well as erosional widening. It was successfully applied to experiments performed at SAFL and is available on the SR website as the DamRemoverMARK1 tool.

Presentations of the SR Toolbox

SR IP Leader Peter Wilcock and SR IP Manager Jeff Marr each delivered two half-day presentations to introduce NCED and the SR Toolbox to the 14th National Nonpoint Source Monitoring Workshop in September 2006. This Environmental Protection Agency (EPA)-sponsored meeting was held in Minneapolis, which enabled NCED to offer tours of its SAFL facility, highlighting the StreamLab06 experiments to meeting participants from around the US.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
At least 10 tested NCED SR tools for free download, with guidelines governing access and usage of tools, and supporting documentation available online.	7 tools and one e-book posted.

Plans

Spawning Gravel Refresher: NCED PI Gary Parker performed some experimental applications of the Spawning Gravel Refresher tool to stream restoration on the Trinity River, California, in Year 5. This effort underlined the importance of including stratigraphy storage and will be accomplished by migrating the storage routine in the numerical model of flume evolution to the tool.

New Tools: We hope that proposed work on the Marmot Dam removal on Oregon’s Sandy River will lead to refinements in a number of NCED-related tools, including developing multidimensional models of erosional and depositional dynamics in areas of active storage to evaluate how these storage changes can be captured in a simple algorithm that can be coupled to a 1D hydraulic routing model. In addition, work completed by graduate student

Michal Tal (with NCED partner Murray Hicks during Tal's NCED International Research Experience Program (IREP) trip to New Zealand) is expected to be incorporated into a tool relating stream morphology to floodplain vegetation during Year 6.

► Project KT08: Education and training programs in SR

Please see the Education Section (ED03) of this report for details on Year 5 progress.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Establish certificate program in SR at the University of Minnesota, with collaboration from PIs at other NCED institutions.	Program admitted first 13 students in Year 5. Newly developed introductory course taught fall 2006. Capstone experience under development and to be delivered spring 2007.
Develop and present new training courses in SR.	5 short courses taught by NCED PI Peter Wilcock, with colleagues internal and external to NCED, in Year 5.

Plans

Please see the Education Section (ED03) of this annual report for details on Year 5 progress.

► Project KT09: Establish regular communication between NCED and SAPG

Two exciting developments in Year 5 that hold promise for NCED's new Mississippi Delta research developed out of our well established cooperation with industry partners in the SA IP. The first development involved the acquisition of a new proprietary sediment mix, developed at partner ExxonMobil, that produces much more natural delta channel patterns and shorelines than our standard noncohesive coal-sand mixture. Results from an experiment using this mix in Year 5 suggest that it will allow us to create experimental deltas featuring branching structures comparable to those of natural, fine-grained deltas like the Mississippi. The second development consisted of securing access to a seismic volume provided by WesternGeco, with substantial help from NCED Collaborator David McCormick of Schlumberger-Doll Research. Estimation of spatial and temporal variability in Mississippi delta subsidence using this industry grade 3D seismic volume covering coastal area of Breton Sound will enable us to make progress in defining: 1) the roles of small- and large-scale normal faulting in controlling delta-top subsidence, and 2) the porosity structure for the Quaternary section via well-log analysis and seismic inversion.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Annual meetings with SAPG.	NCED held its annual meeting with the Stratigraphic Partners Group (SPG) in August 2007.

Plans

As discussed in the SA IP section of this report, NCED refocused this IP in substantial ways in Year 5. An important part of Year 6 efforts will, therefore, include reassessing NCED's knowledge transfer efforts in relation to this IP, bringing the SPG's collaborative research and activities in-line with our new emphasis on delta architecture.

► Project KT10: Develop website content for SA goals, current progress, and future direction

While data from NCED's two primary SA experimental facilities has long comprised a much visited section of our data repository, the performance of the repository itself has never fully met our needs. In Year 5, we continued efforts begun in Year 4 to reassess the way we make NCED data publicly available. A decision was made to design a new, more appropriate platform and interface to host and access NCED data, drawing heavily on best practices developed by NSF-funded efforts, such as the Long Term Ecological Research network.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Experimental stratigraphy results available online.	Year 5 data from experiments in 2 of NCED's primary SA experimental facilities is currently being inventoried and will be posted to NCED's data repository in accordance with NCED's 2 year confidentiality policy for data.

Plans

We plan to have our new repository system in operation early in Year 6 and to make substantial progress in populating it with data throughout the year.

► **Project KT11: Conduct short courses and workshops**

Through the leadership of NCED graduate student John Martin and recent alumnus Dr Ben Sheets, NCED conducted one short course for 12 members of ExxonMobil Research in May 2005. NCED Stream Restoration Certificate Program (SRCP) student Craig Hill assisted NCED Director Chris Paola in leading a short course for nine students from Chevron in April 2007.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
2 industrial short courses per year in quantitative sedimentology and stratigraphy.	2 courses conducted at SAFL.

Plans

Another short course is planned for ExxonMobil in May 2007 (see activity tables in Appendix M: Activity Tables). In addition, as described in KT09, we will assess the content of the current short course structure/partners in the SA IP during Year 6.

Executive Summary: Plans

- In Year 6, we will carefully examine our very successful SAPG to ensure that it continues to be in-line with NCED's overall goals, especially its growing emphasis on delta architecture.
- We will continue the NCED Visitor Program. However, focus of the program will be shifted from supporting individual research projects to supporting visits for collaboration in large, multi-investigator projects, such as NCED's StreamLab06.
- We will continue our successful SR short courses and explore ways to make more course content available online. We will continue to deliver the Stream Restoration and Engineering Certificate courses at the University of Minnesota and reconvene the SRPG and subgroups as time and interest allow.
- We will continue to develop a plan for a second round of experiments, with a similar level of participation by non-NCED researchers, in our StreamLab facility and continue our participation in the development of SAFL's Outdoor StreamLab.
- Ongoing information management work will include substantial redevelopment of NCED's data repository, continued development of its successful SR community resources, such as The Stream Restoration Networker and e-Networker, online toolbox and training resource, and continued improvement of website content and functionality across all three NCED IP areas.
- As we enter NCED's second five years, we will broaden our collaboration with outside researchers in all three IPs and continue seeking ways to ensure an NCED legacy through knowledge transfer.

Knowledge Transfer Challenges

Maintaining frequent meaningful contact with three partner groups has proved challenging, as has timely update of web and data repository content; these latter two issues reflect a need for either higher staffing levels, more efficient structure, or greater focus. We need to continually examine this challenge to ensure that we provide NCED and NCED partners the most effective activities, resources, and opportunities possible.

Evaluation and Performance Indicators

	MEASUREMENT	
	Description	Value
All Stakeholders		
1. Website visits and downloads, within and without NCED.	Total visits to NCED homepage.	2005: 12,967
		2006: 19,928
		2007: 26,806
	Total visits to NCED's data archive.	2005: 1,647
		2006: 6,299
		2007: 2393
2. Timely archival of NCED data and documents with appropriate metadata.	Amount of research data archived and made available (in gigabytes).	2005: 900 GB
		2006: 1000 GB
		2007: 3,800 GB
3. Use of NCED-developed visualization and visualization methods.	Downloads of visualizations from website.	2005: 1,459
		2006: 5,889
		2007: 6175
4. Number of special session and journal issues sponsored by NCED.	Special sessions convened.	2005: 1
		2006: 3
		2007: 4
	Special journal issues/proceedings.	2005: 0
		2006: 1
		2007: 1
NCED PIs		
1. PI involvement with working groups, workshops, visiting scientists, community initiatives, joint publications with partners, and partner meetings.	PIs involved in working groups and workshops [total (percent)].	2005: 9 (50%)
		2006: 5 (25%)
		2007: 4 (25%)
	PIs and student involvement with visiting scientists [PIs (students)].	2005: 3 (2)
		2006: 6 (10)
		2007: 6 (6)
	PI involvement with community initiatives [initiatives (% PIs)].	2005: 2 (10%)
		2006: 6 (30%)
		2007: 3 (15%)
	Joint publications with partners.	2005: 2
		2006: 3
		2007: 3
	NCED PIs involved in partner meetings and other joint activities.	2005: 50%
		2006: 32%
		2007: 40%

	MEASUREMENT	
	Description	Value
2. PI contribution to NCED website and other knowledge transfer dissemination venues.	Number of PIs contributing to website and other knowledge venues.	2005: 7
		2006: 7
		2007: 7
	Number of datasets or papers contributed by PIs to website and other venues.	2005: 9
		2006: 12
		2007: 11
NCED partners		
1.Partner participation in NCED activities and events.	Number of partner representatives who attended NCED meetings and workshops.	2005: 9
		2006: 15
		2007: 84
2. Partner adoption of NCED tools, methods, or training materials.	Number of partners adopting tools, methods, or training.	2005: n/a
		2006: 3
		2007: 1
Wider Community		
1. Participation of non-NCED researchers in NCED workshops, working groups, and other research activities.	Number of non-NCED researchers attending workshops and working groups.	2005: 27
		2006: 57
		2007: 51
2. Impact of NCED research or tools on policy and practice in stream restoration and landscape management.	Number of non-NCED researchers using DW knowledge and tools (estimated).	2005: n/a
		2006: <5
		2007: 14
	Number of non-NCED researchers using SA knowledge and tools (estimated).	2005: n/a
		2006: hundreds
		2007: hundreds
	Number of non-NCED researchers using SR knowledge and tools (estimated).	2005: n/a
		2006: dozens
		2007: hundreds

V. External Partnerships

External partnerships and the basic types of interaction are listed in this section. Goals, indicators, challenges, activities and plans are described in the Knowledge Transfer, Education and Diversity sections themselves.

Knowledge Transfer Partners

Stream Restoration Partners Group

Governmental and corporate organizations involved with stream restoration activities.

Types of Interaction	Frequency
Strategy meeting	Annual
Participation in Working Groups	1-3 times per year - varies by partner
Collaborative Research	Ongoing

Organization Name	Organization Type
Barr Engineering Company	Environmental Consulting Firm
Bureau of Land Management, National Science and Technology Center	Government Agency
California Bay-Delta Authority	State Government
Canaan Valley Institute	Non-profit organization
Federal Interagency Sedimentation Project	Federal Interagency
Inter-Fluve, Inc.	Environmental Consulting Firm
Minnesota Department of Transportation	Government Agency
MN Department of Natural Resources	Government Agency
MN Geological Survey	Government Agency
Minnesota Pollution Control Agency	State Agency
NASA, Goddard Space Flight Center, Hydrological Sciences	Government Agency
National Parks Service, Geologic Resources Division	Government Agency
National Parks Service, Water Resources Division	Government Agency
NOAA Fisheries	Government Agency
ONR, Coastal and Geosciences program	Government Agency
R2 Resource Consultants	Environmental consulting firm
Stillwater Science	Environmental consulting firm
US Bureau of Reclamation, Technical Service Center	Government Agency
US Bureau of Reclamation, Sediment and River Hydraulics Group	Government Agency
US Bureau of Reclamation, Trinity River Restoration Program	Government Agency
US Environmental Protection Agency	Government Agency
US Fish and Wildlife Service	Government Agency
USACE, Research and Development Center, Coastal & Hydraulics Laboratory	Government Agency
USACE, Research and Development Center, Environmental Laboratory	Government Agency
USACE, St. Paul District	Government Agency
USDA, Agricultural Research Service, National Sedimentation Laboratory, Water Quality and Ecology	Government Agency
USDA, Agricultural Research Service, National Sedimentation Laboratory, Watershed Physical Processes Research Unit	Government Agency

Organization Name	Organization Type
USDA, Agricultural Research Service, Southwest Watershed Research Center	Government Agency
USDA, Forest Service, Pacific Northwest Station, Corvallis Forestry Science Laboratory	Government Agency
USDA, Forest Service, Pacific Southwest Station, Redwood Sciences Laboratory	Government Agency
USDA, Forest Service, Rocky Mountain Research Station, Boise Aquatic Sciences Laboratory	Government Agency
USDA, Forest Service, Stream Systems Technology Center	Government Agency
USDA, Natural Resources Conservation Service	Government Agency
USGS, Columbia Environmental Research Center	Government Agency
USGS, Grand Canyon Monitoring and Research Center	Government Agency
USGS, Office of Surface Water	Government Agency

Delta Restoration Partners Group

Partners interested in the long-term dynamics of delta systems.

Types of Interaction	Frequency
WesternGeco	Geophysical services company
Schlumberger-Doll Research	Research center
Louisiana Department of Natural Resources	Government agency
U. S. Army Corp of Engineers	Government agency

Stratigraphic Partners Group

Oil companies interested in the long-term dynamics of channel systems.

Types of Interaction	Frequency
Research meeting	Annual
Industrial Short Courses	Bi-annual
Meetings and consultation	As needed
Reporting research results on (private) website	Ongoing

Organization Name	Organization Type
Anadarko Petroleum Corporation	Oil exploration company
Chevron	Oil exploration company
ConocoPhillips	Oil exploration company
ExxonMobil	Oil exploration company
Japan Oil, Gas and Metals Corporation	Oil exploration company
Shell Oil Company	Oil exploration company

Research Partners

Our numerous research relationships to other institutions are normally person-to-person, and are described in the Research Focus Area reports. In addition, the following research partnerships are underway or in development:

Research Partners Group

Non-NCED organizations that partner with NCED to perform joint research

#	Organization Name	Organization Type
	Description of partnership	
1	International Center for Geohazards (ICG)	International Research Center
	Joint research on subaerial and subaqueous debris flows.	
2	Lawrence University	University
	Joint research on stream restoration	
3	Lousianna State University - CLEAR	University
	Collaboration on Delta restoration research	
4	National Academy of Science	Government Agency
	Ongoing coordination of river restoration study.	
5	National Institute for Water and Atmospheric Research in New Zealand	International Research Center
	Collaboration on stream restoration research	
6	National River Restoration Science Synthesis	Project
	Ongoing coordination of river restoration study.	
7	NSF supported Center for Airborne Laser Mapping (NCALM)	NSF Center
	NCED and NCALM work together to develop visualizations from LIDAR survey data of the ACRR and other areas.	
8	San Francisco State University	University
	Various research collaboration in Stream Restoration and Desktop Watersheds	
9	Swiss Federal Research Institute WSL	International Research Center
	Collaboration on debris flow research in DW	
10	Tulane University	University
	Collaboration on Delta restoration research	
11	University of Colorado/INSTAAR	University
	Coordinated development of Community Surface Dynamics Modeling System.	
12	University of Maryland	University
	Collaboration in stream restoration training programs	
13	University of Wyoming	University
	Collaboration on Subsurface Architecture research	
14	Universidad Nacional del Litoral	University
	Joint studies of large river systems and river engineering.	
15	Universidad Central de Venezuela	University
	Joint research on rivers and debris flows.	
16	Utah State University	University
	Collaboration on various stream restoration initiatives	

Education and Diversity Partners

We have many Partners involved in our various Education and Diversity initiatives. They are listed below:

Education & Diversity Partners Group

#	Organization Name / Description of partnership	Organization Type
1	1854 Treaty Authority	Tribal entity
	Collaborates with NCED on gidakiimanaaniwigamig and ando-giikendaasowin camps.	
2	Advanced Materials for Water Purification	NSF STC
	Purpose: Joint development of traveling Water Planet (exhibit) with SMM.	
3	AISES: American Indian Science and Engineering Society	Minority Professional Organization
	NCEDsends Native American students in our programs to AISES science fair. Fond du Lac's Ojibwe School has also joined AISES with sponsorship from NCED. NCED exhibits at annual meeting for recruiting purposes.	
4	AIHEC: American Indian Higher Education Consortium	Consortium of tribal colleges
	NCED participates in their conferences, recruiting students at their career fairs.	
5	AlBrook School	MN School
	Collaborates on programs for teachers and students.	
6	American Museum of Natural History	Non-Profit
	Collaborates with NCED/SMM on exhibit development	
7	American Rivers	Non-Profit
	collaborates with NCED on public outreach related to dam-removal	
8	APEXES--Academic Programs for Excellence in Engineering and Science	University program
	Collaborates with NCED on undergraduate and graduate recruiting and retention.	
9	Association for Women Geoscientists, Minnesota chapter	Professional Association
	Purpose: Connections to local professionals, career development for students, networking events, K-12 activities for children, events at regional conferences; Karen Campbell and Lesley Perg, past presidents.	
10	Center for Compact and Efficient Fluid Power	NSF Center
	Collaborates on K-12 and undergraduate programs for Native youths.	
11	Center for Embedded Network Sensing	NSF Center
	Collaborates on joint recruiting of underrepresented undergraduate and graduate students.	
12	Center of Research Excellence in Science and Technology, Texas A&M Kingsville	University
	Collaborates on joint recruiting of underrepresented undergraduate and graduate students; Faculty-to-Faculty participant.	
13	Center for Space-Weather Modeling	NSF Center
	Partners with gidakiimanaaniwigamig Native American youth science immersion program and provided access to a Sudden Ionospheric Disturbance Monitor for our students to use.	
14	Center for Transportation Studies, University of Minnesota	University
	Collaborates with NCED on gidakiimanaaniwigamig and ando-giikendaasowin camps.	
15	City Technology of New York	Non-Profit
	Collaborates on developing culturally-appropriate science and math curricula	
16	Cloquet Forestry Center, University of Minnesota	University Center
	Partners with gidakiimanaaniwigamig Native American youth science immersion program.	
17	Cloquet School District	MN School
	Collaborates on programs for teachers and students.	
18	Division of Indian Work	Non-Profit
	Collaborates with NCED on grade-school diversity programming.	
19	Florida A&M University	University
	Faculty-to-Faculty Participant.	
20	Fond du Lac Ojibwe School	Public School
	Partners with NCED on gidakiimanaaniwigamig Native American youth science immersion program.	
21	Fond du Lac Reservation Natural Resources	Reservation
	Partners with NCED gidakiimanaaniwigamig Native American youth science immersion program.	

#	Organization Name	Organization Type	Description of partnership
22	Geowall Consortium	Consortium	Purpose: Exchange visualizations, tools and methods with 3-D developers worldwide; Paul Morin, organizer (NCED is a member).
23	Graduate School Outreach Office, University of Minnesota	University	Partners with NCED on recruiting and hosting underrepresented undergraduate students for our Undergraduate Summer Internship Program
24	Jackson State University	University	Faculty-to-Faculty Participant
25	Laurentian Center, Britt, Minnesota	Environmental Learning Center	Hosts NCED’s gidakiimanaanawigamig camps
26	Limnological Research Center, University of Minnesota	Research Center	Partners with the gidakiimanaaniwigamig Native American youth science immersion programs.
27	Louis Stokes Mississippi Alliance for Minority Participation (LSMAMP)	NSF LSAMP	Collaborates to find research internships and graduate opportunities for LSMAMP participant students at NCED, other departments at University of Minnesota, and at other STCs.
28	MAST Lab, Civil Engineering, Univ of MN	NSF Center	Collaborates on teacher and student programs.
29	Minnesota Space-Grant Consortium	University	Partners with NCED on gidakiimanaaniwigamig Native American youth science immersion program.
30	QEM	NSF funded program	Partners with STCs in recruiting underrepresented groups for graduate and post-doc positions
31	SAHRA	NSF Center	Collaborates on joint recruiting of underrepresented undergraduate and graduate students
32	The Science Center at Maltby Preserve	Non-Profit	Co-hosts and co-leads NCED’s Earthscapes Teacher Institute
33	SciTech Hands On	Museum	Purpose: Develop joint proposals, share exhibit and 3-D visualization expertise
34	SERC: The Science Education Resource Center@Carleton College	Non-Profit	Collaborates with NCED on designing/sponsoring/conducting workshops for college faculty
35	St. Louis County Schools	MN School District	Collaborates on programs for teachers and students.
36	Southwestern Indian Polytechnic Institute	Tribal College	Collaborates on programs for K-12 and undergraduate students.
37	Steadfast Television	Educational Television producers	Partners on educational science programming for all ages
38	NAGT: National Association for Geoscience Teachers	Non-Profit	Collaborates with NCED on designing/sponsoring/conducting workshops for college faculty and middle-to-high-school teachers
39	NOAA	Federal Agency	collaborates with NCED/SMM on exhibit development
40	St. Louis Riverwatch	State Agency	Collaborates with NCED on gidakiimanaaniwigamig and ando-giikendaasowin camps.
41	University of Minnesota, Duluth, Department of Engineeirng and Robotics	University	Collaborates with NCED on gidakiimanaaniwigamig and ando-giikendaasowin camps.
42	University of Minnesota, Duluth E-Portfolio	University	Collaborates on developing technology for education programs.
43	University of Minnesota, Duluth School of Medicine	University	Collaborates with NCED on gidakiimanaaniwigamig and ando-giikendaasowin camps.
44	University of Minnesota, Twin Cities, Graduate School Diversity Programs	University	Collaborates with NCED on recruiting diverse graduate students.
45	Utah Museum of Natural History	Museum	Purpose: Pilot use of Earth-surface visualizations in museums nationally.

VI. Diversity Initiative

Project team

Diversity Director: Diana Dalbotten

Faculty and Staff: Andrew Wold, Holly Pellerin, Lowana Greensky, Robby Schreiber

PI's: All

Executive Summary

NCED continues to make strides towards achieving its goal of a diverse science workforce within NCED, and to foster diversity in the sciences as a whole by increasing the pool of underrepresented students who are interested in pursuing careers in science, math, engineering, and technology fields. Diversity among our researchers was increased this year with the addition of a new graduate student, a postdoctoral research associate, an IP leader, and an associated PI. The addition of these researchers to NCED has increased the percentage of researchers from underrepresented groups from 13% of our total research group in Year 4 to 19% in Year 5, bringing us ever closer to parity with the US population. Two NCED graduates from underrepresented groups took up faculty positions this year: NCED graduate student Aric Shafran and NCED Postdoctoral Research Associate Juan Fedele. Shafran, advised by NCED PI Nicholas Flores, received a Ph.D from the University of Colorado at Boulder and will become a tenure-track assistant professor at California Polytechnic State University in San Luis Obispo, California. Fedele, advised by NCED Director Chris Paola, is now a tenure-track assistant professor at St. Cloud State University.

NCED's Faculty-to-Faculty Program, initiated in Year 4, brought two faculty members to SAFL in Year 5 and involved a third faculty member in NCED research. Visiting faculty gave seminar talks, toured our research facilities, and met with NCED faculty and research staff. One faculty member is in the process of submitting a proposal for joint research with NCED, another faculty member is advising an NCED undergraduate student in the field this summer, and the third faculty member is doing research with NCED PI Peter Wilcock this summer on a project that will also involve students from our Undergraduate Summer Internship Program (USIP).

In Year 5, NCED's *gidakiimanaaniwigamig* (Our Earth Lodge) Native American Youth Science Immersion Program brought over 200 middle- and high-school students to Native American Math and Science Camps and to participate in other hands-on science activities related to NCED research. New partnerships brought scientists from the University of Minnesota, from tribal entities, and from other institutions across the country to lead activities at our camps. Camp activities included geology of the local area, lake core sampling of a wild rice and non-wild rice lake on a reservation, and dam removal on a salmon river. We were especially excited to have the University of Minnesota's Limnological Research Center staff come to our winter camp and core two lakes on the Fond du Lac Reservation and then examine the cores with the youths in our camps. Students in our programs have shown improvements in their math and science grades and school attendance since the inception of the program. In addition, a number of students are now enrolled in advanced math and science courses. NCED is serving as a model for other groups by presenting workshops at professional conferences (Society for the Advancement of Chicanos and Native Americans in Science--SACNAS, the American Indian Science and Engineering Society--AISES, and the NSF STC Director's Meeting) on creating math and science programs for Native American youths. Students' enthusiasm can also be seen by their participation in the NCED/Fond du Lac Tribal and Community College (FDLTCC)-sponsored American Indian Regional Science Fair, which had 240 middle- and high-school student exhibitors in its first three years. In the years 2005-2007 NCED collaborated with FDLTCC and the Ojibwe School to send 40 students from this group to Albuquerque to attend the AISES National American Indian Science and Engineering Fair (NAISEF). In 2007, 16 of our students attended and brought home 20 medals and awards, including special engineering awards from IBM and a women in science award from the AWG. Five of our students took medals in the NAISEF math competition this year. One *gidakiimanaaniwigamig* participant, who took her science project to the Minnesota State Science Fair, was chosen to represent Minnesota at the Intel International Science and Engineering Fair (ISEF).

Major liaisons with other programs have been developed that continue to enrich our diversity programs by creating sustainability and leveraging our efforts, as well as establishing NCED's leadership role in defining best practices and pathways for engaging minorities, and especially Native Americans. These partnerships include the National Academy of Sciences, which provides materials for our camps and programs; the Consortium of Independent Colleges, which collaborates with us on joint recruiting for minority summer research opportunities; the Center for Integrated Space-Weather Modeling (an NSF STC), which has installed a Sudden Ionospheric Disturbance (SIDS) Monitor at FDLTCC for our K-12 and undergraduate students to use for research purposes; the Smithsonian Institution, which has invited our *gidakiimanaaniwigamig* students to take part in their Virtual Museum Workshop Program; and the Consortium of Universities for the Advancement of Hydrologic Sciences, Inc. (CUAHSI), which partners with NCED on modeling our *gidakiimanaaniwigamig* Circle of Learning to new communities. Within the University of Minnesota, our partners include the Institute of Technology Women's Program and the APEXES program, which have collaborated with us to submit a Lewis Stokes Alliance for Minority Participation (LSAMP) proposal to NSF and have also contributed funds to enlarge the scope of our Native American diversity programs; the Center for Compact and Efficient Fluid Power (an NSF ERC), which is co-organizing and developing an undergraduate support program at Fond du Lac Tribal and Community College and providing funding for an expansion of our K-12 efforts; the Multi-Axial Subassemblage Testing (MAST) Laboratory, which has started a new teacher initiative with NCED on the natural and built environment; the Limnological Research Center, which sends faculty and graduate students and equipment to NCED's *gidakiimanaaniwigamig* camps to teach students about the natural history of the reservation using lake bed cores; and faculty at the University of Minnesota, Duluth (UMD) who collaborate with *gidakiimanaaniwigamig* to promote the use of technology in our camps and are also collaborating with NCED schools on a GK12 program which will support science teaching in the schools which NCED's *gidakiimanaaniwigamig* students attend. NCED diversity staff Dalbotten and Pellerin will be advising the GK12 graduate students on best practices for educating Native American youths.

Goal

The overall goal of NCED's Diversity Initiative is to increase participation by underrepresented groups in NCED scientific disciplines until minority representation is reflective of the US national population. The specific goals of our initiative include an immediate improvement in participation by members of all underrepresented groups in NCED itself and an improvement in representation of Native Americans in NCED- related disciplines.

Approach

NCED uses the intrinsic appeal of landscapes and surface dynamics to engage diverse communities in the study of Earth-surface science at all levels and to attract diverse participants into its research programs. Key elements in our approach include:

1. Use a vigorous Undergraduate Summer Internship Program (USIP) to bring upper-level students from underrepresented groups to NCED facilities for a summer to do research on NCED topics.
2. Faculty-To Faculty Program: Build research ties to faculty members from schools with large minority enrollments, particularly minority-serving institutions (MSIs). Identify faculty members who work in NCED research areas and bring them with their students to NCED as visiting researchers to participate in conferences and workshops and to speak at seminar series.
3. Work with and support efforts by NCED participating institutions, STC partners, and other broader national efforts, such as the GEM Consortium, to recruit and fund students from underrepresented groups in NCED-related graduate research.
4. Use the now-approved NCED Stream Restoration Certificate Program to provide an additional gateway to NCED graduate programs by encouraging early-career professional engineers from underrepresented backgrounds to consider research careers.
5. Increase the number of potential future recruits by collaborating with local communities, including the Fond du Lac Reservation, to provide Native American youth science enrichment and immersion programs, including seasonal camps and after-school activities.
6. Use the Youth Science Center (YSC) at the Science Museum of Minnesota (SMM), and especially the Big Backyard (BBY) Park Crew, to team underrepresented youths with faculty and graduate student mentors from NCED and create NCED-based hands-on activities.

Achievements and Plans—Major Initiatives

► Project DV01: Faculty-to-Faculty Program: Building durable connections to MSIs and universities with high minority enrollements

By involving faculty from MSIs and institutions with high minority enrollment in NCED research projects, we are fostering long-term relationships that will lead to a natural increase in the flow of underrepresented individuals into graduate and postgraduate positions at NCED and other national research centers.

- Faculty will gain a new level of excitement and interest in NCED research;
- Faculty will also be able to inject some of this excitement into their courses, potentially recruiting an untapped source for future research scientists;
- Faculty will provide a link to students at MSIs, increasing the natural flow of students into NCED research groups and the geoscience community at large;
- Research partnerships will help to build the research infrastructure of the faculty members' home institutions; and
- Junior faculty will be greatly assisted in their professional development.

This year, two new Faculty-to-Faculty Program participants visited NCED and two more are scheduled to visit this summer. The two faculty members who have visited (Assefa Melesse, Florida International University, and Dr Judy Haschenburger, University of Texas at San Antonio) are submitting proposals for participation in NCED research projects. In addition, Haschenburger will be working with an NCED-supported Hispanic undergraduate summer intern in her field work this summer. The intern, who is from the University of Texas at San Antonio, will spend time at SAFL this summer and present at the NCED summer undergraduate poster session. The faculty that have planned visits at NCED are Emad Habib, Civil Engineering, University of Louisiana, Lafayette and Joanna Curran, Department of Geography, Texas State University.

Progress towards deliverables

Milestone/Deliverable	Progress.
Three new faculty introduced to NCED research in Years 3-5 through multiple visits to NCED facilities or participation in conferences and/or workshops.	In Year 4, NCED PIs collaborated on a project on "Removal of Heavy Metals by Alder Trees and Bed Sediments" with a visiting research team from Texas A&M University, Kingsville, led by Dr. Jianhong Ren and two Hispanic graduate students from Texas A&M visited SAFL to carry out this research. In Year 5, two faculty visited NCED and gave seminars (see above). Two additional faculty members are in the process of planning visits to NCED.
New collaborations and recruiting visits by NCED faculty.	Dalbotten visited faculty at the University of New Orleans and the University of Louisiana, Lafayette, to talk to faculty members about the Faculty-to-Faculty Program and potential collaborations for improving diversity in the sciences. Faculty members at the University of New Orleans included Mark Kulp and Denise Reed. Faculty members at the University of Louisiana, Lafayette, include Emad Habib. Habib will visit NCED at the end of this academic year.

Plans

In Year 6, NCED will continue to identify MSI faculty with compatible research interests and invite them to collaborate with NCED. NCED's Collaborative Investigator designation will provide new possibilities for MSI faculty to get involved. NCED will collaborate with Melesse and Haschenburger on both research and education initiatives.

► Project DV02: Direct recruiting of underrepresented students to NCED graduate and postdoctoral programs

Since its inception, NCED has made steady progress in increasing the diversity of our researchers and staff. Participation by members of underrepresented groups in our research program, including graduate students, postdoctoral research associates, and faculty has risen from 8% at NCED's inception to 19% by the end of Year 5. This year, recent NCED alumni from underrepresented backgrounds filled two faculty positions. NCED graduate student Aric Shafran will become a tenure-track assistant professor at California Polytechnic State University in San Luis Obispo, California, and NCED Postdoctoral Research Associate Juan Fedele is now a tenure-track assistant professor at St Cloud State University in St Cloud, Minnesota.

Progress towards deliverables

Milestone/Deliverable	Progress
Bring percentage of graduate students, including participants in the Stream Restoration Certificate Program, from underrepresented groups to approximately 10% of total graduate students and postdoctoral research associates by the end of Year 5.	Percent of NCED graduate students and postdoctoral research associates who are from underrepresented groups has risen from 2% in Year 3 to 7.5% in Year 4 and is now at 14% in Year 5. This percentage surpasses our strategic plan goal for the first five years.

Plans

We will continue our vigorous program of graduate recruiting, including visits to national recruiting venues such as the AISES National Conference, the SACNAS National Conference, the American Indian Higher Education Consortium (AIHEC) National Conference, and the state and regional Louis Stokes Alliance for Minority Participation (LSAMP) conferences. We will continue support of NCED PI recruiting efforts with diversity supplements to their research grants. We will collaborate with the National GEM Consortium through the GEM-STC fellowship program in order to recruit new graduate fellows.

A former undergraduate summer intern has applied to our Stream Restoration Certificate Program. Two new graduate students from underrepresented backgrounds have been accepted into NCED-related graduate programs for next year.

► Project DV03: Undergraduate Summer Internship Program (USIP)

Each year, the USIP brings undergraduate students from underrepresented groups to NCED institutions for a 10-week summer program, and has played an important part in accomplishing our diversity mission. Four students attended the program in summer 2006, with one student returning for his third research experience with NCED. Summer 2006 also represented the first time we had an NCED undergraduate student participant from Fond du Lac Tribal and Community College, our NCED MSI partner. This summer we will support two additional undergraduate interns from Fond du Lac Tribal and Community College. Of the students supported through the USIP, 82% have expressed a desire to continue their education in graduate programs and 35% have been accepted into graduate programs.

Progress towards milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Ongoing participation of 5 undergraduate students (from underrepresented groups) each summer with consistent recruitment of USIP students to NCED-related graduate programs and the majority of USIP students going to graduate school.	- 17 students have been supported: 10 women and 7 men - 4 students are in graduate school, 2 students have been accepted for next year, and 1 student has graduated with an MS degree - 6 more students plan to apply to graduate programs when they finish their undergraduate programs - 1 student has graduated and is currently working in industry - 2 students have no plans for graduate work but are planning to teach K-12 - 1 student is a current NCED graduate student (Robert Haydel) and 1 student is a past NCED graduate student (Crystal Lesmeister—graduated with an MS degree) -2 students are prospective NCED graduate students for 2008 - 2 students have taken part in the NCED IREP, advised by NCED graduate students, and 1 more student will take part in this program in summer 2007

Plans

We will continue to accept more undergraduate interns from Fond du Lac Tribal and Community College. We will develop methods to provide support and mentoring to these students as they transfer to 4-year programs. NCED is collaborating with the Center for Compact and Efficient Fluid Power (University of Minnesota) and IT APEXES to provide mentoring, visiting research talks, research experiences, and travel opportunities to undergraduate students from Fond du Lac Tribal and Community College. This summer NCED PI Lesley Perg and NCED Postdoctoral Research Associate Jane Staiger will mentor two Native American undergraduate students from Fond du Lac Tribal and Community College as they take part in an NCED research project.

► **Project DV04:** *gidakiimanaaniwigamig* **(Our Earth Lodge) Native American Youth Science Immersion Program**

The NCED *gidakiimanaaniwigamig* (Our Earth Lodge) Program offers Native American youths a science immersion experience that provides ongoing opportunities for students in K-12 from the Fond du Lac reservation and other nearby Native American communities to explore and gain knowledge about the Earth sciences. More than 270 students have participated in NCED camps and related activities with 42% attending more than one activity.

Outcomes

1. Students in *gidakiimanaaniwigamig* are showing improvements in math and science grades and test scores.

2. Four of our *gidakiimanaaniwigamig* students are enrolled in college courses. One of our students, currently in the 11th grade, is taking all of her coursework at Fond du Lac Tribal and Community College under the PSEO program, simultaneously finishing her high-school diploma and working on an AA degree in science. Several other *gidakiimanaaniwigamig* students are on track for taking advanced courses next year and have plans to continue on to college.

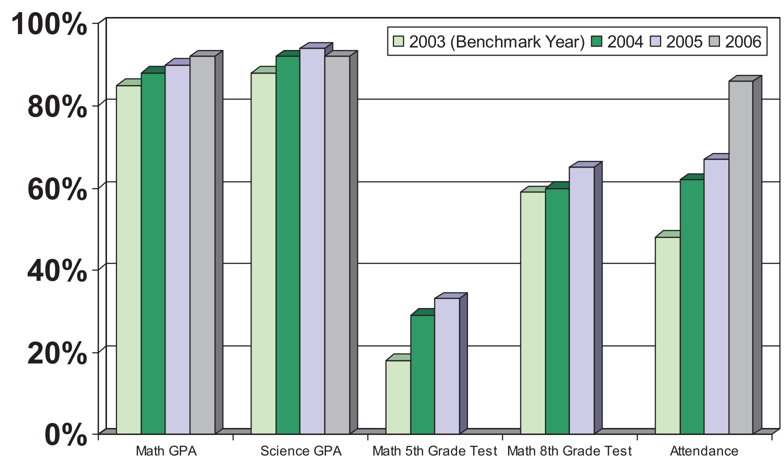

Figure 1. *Math and Science Proficiency. Students in gidakiimanaaniwigamig (Our Earth Lodge) Native American Youth Science Enrichment Program. Note: Changes in the tests for Math in the State of Minnesota mean this year's values are not compatible with previous year, and are not yet available from the schools. We will report these values again in Year 6.*

3. A core group of Fond du Lac Tribal and Community College undergraduate students interested in science are now affiliated with NCED and participating in research activities and academic enrichment. This year NCED supported two of these students to attend an AISES student leadership conference.

4. *gidakiimanaaniwigamig* students began participation in the SMM's new WaterPlanet traveling exhibition. Water Planet brings together the SMM, NEMO, and HSC with the NCED *gidakiimanaaniwigamig* program in a novel outreach program. SMM and NCED are working with *gidakiimanaaniwigamig* affiliated high school students to familiarize them with the visualization tools in the exhibition. Jesse Schomberg, Duluth NEMO Coordinator, met with youth participants to acquaint them with the relationships between land-use and surface- and groundwater quality in preparation for the work youths will carry out this fall. NEMO is a University of Connecticut project that offers workshops to local government officials in 34 states in making better land-use and water-quality decisions.

5. In Year 5, we sent three of our *gidakiimanaaniwigamig* students, who have had multiple camp experiences, to participate in non-NCED science programs and internships.

6. The NCED regional science fair is now drawing student participants from five school districts and from other tribes within northern Minnesota and Wisconsin. Sixty-five students exhibited at the science fair this year and 16 were supported by NCED in collaboration with the Ojibwe School, the Cloquet High School, and Fond du Lac Reservation to attend the AISES NAISEF. Students from the science fair will also present their research at the Minnesota State Fair this summer. Another *gidakiimanaaniwigamig* student attended the Minnesota State Science Fair rather than NAISEF and was chosen to represent the state at the Intel International Science and Engineering Fair.

7. New partnerships have broadened the content of NCED's Native American science camps. This year's winter camp was conducted in partnership with the University of Minnesota's Limnological Research Center.

8. NCED has supported five teachers to participate in teacher professional development activities. One of our former teachers is now teaching outdoor courses at the University of Minnesota, Duluth.

9. Our NCED undergraduate *gidakiimanaaniwigamig* assistant has now applied for graduate school in pharmacology.

Progress towards deliverables

Milestone/Deliverable	Progress
90 students per year participated in the camps and related programs in Years 3, 4, and 5.	172 students participated in the *gidakiimanaaniwigamig* program.
Documented improvement in grades and test scores for students in both programs.	See Chart above and Table below.
Majority of participants attend college, with substantial fraction majoring in science, math, engineering or technology.	None of the students were high school seniors this year; however, 2 students graduated early and are now enrolled at FDLTCC; another student is taking courses at FDLTCC while still in high school through our state Post Secondary Education Option (PSEO) program. Three others of our *gidakiimanaaniwigamig* students are continuing college students.

Plans

This fall, *gidakiimanaaniwigamig* students who are participating in the WaterPlanet exhibition will use visualization tools developed for WaterPlanet to create a culturally appropriate NEMO program that they will present to adult Native American audiences in northern Minnesota. The Headwaters Science Center (HSC) will host programs where *gidakiimanaaniwigamig* students present their NEMO program to adult members of the Red Lake, White Earth, and Leech Lake reservations. In Bemidji, MN, HSC is centrally located among all three of these communities. Native American communities in Minnesota are reclaiming control over their lands by managing land/water interactions. SMM will use its relationship with the Fond du Lac community, HSC, and NEMO in northern Minnesota to test this model for how the science of WaterPlanet might be conveyed to Native American audiences nationwide in culturally meaningful ways.

New collaborations will bring scientists from within and outside the University of Minnesota to our Native American youth programs. The Center for Compact and Efficient Fluid Power, a new ERC headquartered at the University of Minnesota, is taking an active role in funding an expansion of our efforts to include more programs for undergraduate students at Fond du Lac Tribal and Community College and a summer lego camp for our youngest students. The University of Minnesota's MAST Laboratory, one node of the George E. Brown, Jr. NEES, is working with *gidakiimanaaniwigamig* to test new curricula and new methods for supporting teachers. Both groups will be involved in our spring and summer *gidakiimanaaniwigamig* camps this year. The University of Minnesota's Limnological Research Center has worked with our students to understand lakes through lake core samples and will continue to partner with us in Year 6. The Center for Integrated Space Weather Modeling, an STC headquartered at Boston University, has sent us a Sudden Ionospheric Disturbance Monitor and plans to attend our fall camp this year to help students begin a research project involving this technology. Our high-school camp will run in conjunction with the St Louis River-Riverwatch Program. Students in this camp will spend 10 days at Isle Royale where they will learn about the natural history of this important cultural site and be able to connect this information to research that promotes sustainable land and water management.

For the first time, we are going to have our spring camp focus on teacher professional development. Teachers will have a chance to meet researchers, develop curricula for the *gidakiimanaaniwigamig* program working side-by-side with the researchers, and work with NCED program administrators to connect camp curricula to state and national standards.

NCED program administrators will present workshops on Native American science education at professional conferences including the National Research Center Educator's Network, the Society for the Advancement of Chicanos and Native Americans in Science and the American Geophysical Union.

► Project DV05: Earthscapes in the SMM YSC

At the SMM's YSC, students in NCED's Earthscapes Park Crew spent the month of April piloting outreach activities at the Neighborhood House on the west side of St Paul. They worked with groups of elementary students (72 total) on four separate occasions. They also went to an Earth Day clean-up, sponsored by the Minneapolis Park Board, with their stream tables to teach the public about stream dynamics.

Park crew students were mentored throughout the summer by NCED Graduate Museum Assistant Emily Horth. Horth developed six content rich field trips throughout the metro area that supported the youth's earth science learning for the summer. The 12 high-school-aged park crew students assisted visitors in the BBY during summer 2006. The team collectively worked 25 shifts per week, interpreting exhibits and mini-golf holes, providing programming in the Science House, and helping with general visitor needs. They met bi-weekly to continue content learning and to reflect on the effectiveness of the training to their on-the-job experience. The park crew students were particularly helpful in the BBY by involving visitors in the interactive exhibit models in such a way that visitors were able to experiment with different processes—this was particularly true for the braided and meandering river models.

Once the BBY closed for the season, the park crew students took two stream table activities, which they had developed in year 3, and two other watershed science activities to St. Paul Community Education after school programs. The 12 (seven new, five returning) park crew students reached out to 101 youth participants who ranged in grade from pre-kindergarten through sixth grade. The after-school program design included visiting each program site four times over four consecutive weeks. This allowed the youth participants to develop relationships with the park crew students while learning about river systems in a hands-on way. Anecdotal evidence from the program sites has been overwhelmingly positive. The park crew students also participated in college-readiness programming to help them plan for post-high school education.

Progress toward milestones/deliverables for years 3-5

Milestone/Deliverable	Progress
Substantial participation by minority students in YSC park crew and other activities.	20 students participated: 5 males and 15 females with 15 students from underrepresented groups.
Number of youths from community groups taught and demographics.	186 youths taught by YSC park crew, 138 from underrepresented groups.
Number of activities conducted outside SMM by YSC program/hours.	7 activities / 29 program hours per youth.
Number of educational outreach activities conducted outside SMM by YSC program/hours.	28 activities / 84 hours per youth.

Plans

In Year 6, the park crew students will

- serve as docents in the BBY during summer 2007,
- further develop and document challenges and experiments to be used at several places in the BBY and bring stream table activities developed through the community outreach program to visitors in the BBY,
- continue bringing NCED-related stream table and other activities to community centers in the Minneapolis/St Paul metropolitan area, and
- make connections with the new Park Crew students who will be working on the current Science on a Sphere exhibit and the forthcoming WaterPlanet exhibit by sharing their earth science knowledge and activities.

Summary of Plans

In Year 6, we plan to focus the efforts of our Faculty-to-Faculty Program on developing new connections that support our research on the Mississippi Delta area. We will develop relationships with institutions in the state of Louisiana in support of this effort. In addition, we will continue efforts to connect with and visit institutions that are in the Louis Stokes Alliance for Minority Participation and the Alliance for Graduate Education in the Professoriate network.

In collaboration with the Center for Compact and Efficient Fluid Power, we are developing a program to support the FDLTCC AISES club in its efforts to connect with local undergraduate AISES chapters in the AISES regional area. The student chapters will be provided with new opportunities to support each other and provide outreach to K-12 students. The program will provide mentors, science content, opportunities to participate in research projects, and advising to increase the transfer rates from 2-year to 4-year institutions. Every effort will be made to draw students from this group into our USIP.

The *gidakiimanaaniwigamig* Program will continue to connect with science centers and organizations across the country in order to expand and enrich the content in our camps and provide new opportunities for our students. In addition, we are working to develop our camp programs and curricula in connection with the AAAS Atlas for Science Literacy content standards and our state standards. This will help our teachers to integrate their camp experiences into their classrooms. Since teachers and students are both drawn from local schools, integration with the schools is a particular emphasis of our programs. We are also adopting new technologies to facilitate ongoing communication between NCED teachers and researchers.

The *gidakiimanaaniwigamig* Program is also going to help our student participants with their science fair projects. Researchers who introduce new curriculum to the camps will be asked to provide potential science fair projects. Students will be encouraged in camps to begin thinking about their science fair projects and several of the summer camp sessions will be devoted to this effort. In addition, NCED is developing a special Science Fair Planning Event that will bring *gidakiimanaaniwigamig* students to the University of Minnesota, where students will have a chance to brainstorm topics and get connected to graduate students and faculty who can act as mentors for their science projects.

Evaluation and Performance Indicators

	MEASUREMENT	
	Description	Value
NCED Community		
1. Increasing the size of the pool from which under-represented participants are rectuited	Number of applicants for USIP (Year 5)	98
	Number of applicants for USIP (Year 4)	146
2. Increasing the representation of under-represented groups within NCED	**NCED Researchers**	
	Percent of underrepresented researchers in current year	19%
	Percent of underrepresented researchers in previous year	13%
	NCED Participants and Affiliates	
	Percent of underrepresented participants/affiliates in current year	Participant: 22% Affiliate: 6%
	Percent of underrepresented participants/affi liates in previous year	Participant: 21% Affi liate: 5%
3. Enhancing educational and career outcomes for NCED participants from underrepresented groups	List of outcomes	See table below
Native American Students		
1. Number of Native students participating in NCED programs, camps, science fairs, field trips and other activities 2. Repeat contacts with students – camps only	Number of students	289
	Attendance and grades	See Figure 1
	Number of repeat contacts	
	1 camp	54
	2 camps	26
	3 camps	9
	4 camps	5
	5+ camps	23
Youth Science Center		
1. Number of kids enrolled/demographics	Number of students	20
	Male	6
	Female	15
	% from underrepresented groups	75%
2. Number of visitor kids/demographics	Number of visitors	186
	Number from underrepresented groups	138
3. Number of activities conducted outside SMM by YSC programs/hours	Number of activities	28
	Number of program hours	84

Educational Outcomes

The educational outcomes table has been deleted from the public version of this report due to the confidential nature of the information contained therein. Please contact Diana Dalbotten (dalbo001@umn.edu) with any questions pertaining to the educational outcomes of NCED's Diversity initiative.

VII. Management

Management Team

Director: Chris Paola

Co-Director: Efi Foufoula-Georgiou

Deputy Direction, Administration: Rochelle Storfer

Staff: Melanie Lord-Van Slyke (Science Writer), Charles Nguyen (IT Professional), David Olsen (Principal Accountant), Debra Pierzina (Event Coordinator), Adam Recknor (Accountant)

Goal

The overall responsibilities of NCED management are to articulate the Center's vision, to keep the Center moving towards it, and to maximize the Center's added value by ensuring that the whole is greater than the sum of its parts. NCED management does this by: working with center participants to formulate compelling, well focused initiatives; facilitating communication about the Center's goals, initiatives, and expectations among Center participants; and promoting synthesis and synergy across Center initiatives.

Approach

NCED is neither a "top down" nor a "bottom up" organization but rather one that encourages shared goals and rapid, clear communication throughout its network of participants, seeking an optimal balance between consensus and efficiency, and between creative adaptation to changing circumstances and organizational stability. NCED's management is driven by the goals expressed in our statement of purpose and developed in our Strategic and Implementation Plan (SIP). NCED uses an array of metrics to measure progress towards these goals; metrics for management are shown at the end of this section, and at the end of the appropriate report section for each NCED Initiative.

Challenges and Plans

Allocation of Center Resources

NCED's Strategic and Implementation Plan (SIP), adopted in 2005-2006 and undergoing continuous refinements (see Appendix J: Provisional SIP for the latest version), spells out specific goals and deliverables which determine NCED priorities and guide the allocation of NCED resources. The SIP is structured around six primary initiatives, including three research Integrated Projects (IPs): Desktop Watersheds (DW), Stream Restoration (SR), Subsurface Architecture (SA), with cross-links among them and with links to Education (ED), Knowledge Transfer (KT) and Diversity (DV). Until last year, NCED resources were allocated to individual PIs with an oversight by the Directors and the Executive Committee (EC) to ensure that the goals of each IP were met.

Based on feedback from the site visit team and NSF, NCED implemented this year an IP-based (as opposed to PI-based) resource allocation. This was done in two phases. In the first phase, each IP leader presented the achievements, targets, and needs of their IP to the NCED Executive Committee (EC). After discussion and deliberation, the resources available to each IP for the next biannual cycle were determined. The IP priorities were discussed with the PIs at a retreat at the LUMCON center, Louisiana, in February 2007. In the second phase, each PI was requested to submit a proposal summarizing the research performed over the past year and providing proposed plans for the research to be undertaken over the next two years, including contributions to education, knowledge transfer and diversity efforts. The proposals were thoroughly reviewed by the EC (each EC member was assigned 4 proposals to review in detail and present to the EC group; this was accomplished in three two-hour videoconference meetings). The criteria used for proposal evaluation were:

1. The extent to which the proposed research served the goals of one or more IPs;

2. The extent to which the research capitalized on the center mode, i.e. included collaboration among PIs, across institutions and across disciplines;

3. The extent to which the proposed research broadens NCED's educational, knowledge transfer, and diversity activities

Based on the above criteria, recommendations were made by the EC members on the individual PI proposals, including possible adjustments to the requested resources and re-alignment of research to better meet the IP goals. Recommendations have been discussed and approved by the Directors and final decisions are being communicated to each PI. Also written comments are provided for each proposal, mainly focusing on topics to emphasize or de-emphasize to meet the IP goals; synergies that could be further strengthened; and additional activities that the EC thought promising for that PI to undertake over the next two years.

Day-to-day responsibilities for allocated resources are still vested with the PI, but with greater oversight by the IP leader and NCED central administration. Also, annual reporting by PIs is still an expectation and will be followed up with review and comments by the IP leaders and EC.

Changes in Principal Investigators and NCED Management

New Personnel

Professor Robert Twilley has joined the NCED scientific team as a PI. Twilley is an ecologist specializing in coastal wetlands and forests and a leader of the Louisiana State University (LUS)Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) program. He was selected by other PIs and the Executive Committee for his major contributions to ecology of the Mississippi Delta and will play a crucial role in NCED's Mississippi Delta Initiative. Twilley's work will focus primarily on researching wetland development and geomorphic interactions in the Delta. Twilley's biographic sketch and curriculum vitae are provided in Appendix A: Biographic Information of New PIs.

Professor Fotis Sotiropoulos has also joined the NCED scientific team as a PI. Sotiropoulos is an engineer specializing in computational fluid dynamics and Director of St Anthony Falls Laboratory. He was selected by other PIs and the Executive Committee for his leadership in applying sophisticated fluid-dynamical simulations to biological problems and complex natural channels. He will play a crucial role in the SR and DW IPs via the Virtual StreamLab initiative, with PI Porte-Agel. Sotiropoulos's biographic sketch and curriculum vitae are provided in Appendix A: Biographic Information of New PIs.

In addition, Jim Buttles has been appointed the IP manager for the Subsurface Architecture (SA) Integrated Project. Jim has an extensive background in the study of submarine fan channel development, as well as acoustic imaging of experimentally-produced stratigraphy. As such, Jim is a natural fit for overseeing the day-to-day activities of the SA IP.

Partner Institution Changes

Over the course of the past year, PI Mohrig has completed the transition from the Massachusetts Institute of Technology to the University of Texas at Austin; and PI Twilley joins us from Louisiana State University. The list of participating institutions now stands as follows: University of Minnesota (lead institution), Fond du Lac Tribal and Community College, Johns Hopkins University, Louisiana State University, Princeton University, Science Museum of Minnesota, University of California - Berkeley, University of Colorado - Boulder, University of Illinois - Urbana/Champaign, and University of Texas – Austin.

Resignations

The Executive Committee has accepted the resignation of PI Ignacio Rodriguez-Iturbe effective August 1, 2007.

External Advisory Board (EAB)

Several changes to the composition of the EAB have occurred over the past year. First, David Furbish has stepped down as the EAB chair due to other commitments. Members Cacchione, Dhamotharan, Sarg, and Yawakie have also retired from the Board after having served extended terms. Finally, Rudy Slingerland and Russell Stands-Over-Bull have been invited to participate as new members in the EAB. Slingerland will serve as EAB interim chair until the EAB elects a new chair.

NCED wishes to acknowledge Dr. Furbish and the other retiring members for their excellent service to the Board not only with respect to their expert advice, but also for their tireless support and dedication to helping NCED improve. We note that the successful renewal of NCED is in no small part due to the contributions these members have made during their service.

Appendix C: External Advisory Board has a list of current members and the report from the EAB meeting held in Minneapolis, MN from 2006 October 31 to 2006 November 01. The Directors' response to the EAB's comments may also be found there.

Executive Committee

NCED's Executive Committee comprises the following members: Chris Paola (Director), Efi Foufoula-Georgiou (Co-Director), Bill Dietrich (Lead PI for Desktop Watersheds), Peter Wilcock (Lead PI for Stream Restoration), David Mohrig (Lead PI for Subsurface Architecture), Mary Power (member at large, NCED PI), Karen Campbell (Education Director), Diana Dalbotten (Diversity Director), Jeff Marr (Knowledge Transfer Director), and Rochelle Storfer (Deputy Director, Administration). No changes in the composition or function of the NCED Executive Committee have occurred since the last report.

Fostering Center-Mode Research

A major achievement over the past year has been a structural revision to the NCED Strategic and Implementation Plan (SIP) refining the activities in each of NCED's Integrated Projects. These refinements express changes NCED has undertaken to unify the Center across IPs, incorporates a larger role for NCED's social science program, and updates IP projects to include plans for the Mississippi Delta Initiative (MDI). Specific details on these changes are described in more detail in the research sections of this report and in the Context section.

NCED has also continued to make progress on our research integration and synthesis goals. The most visible indicator of this success may be viewed from the number of papers NCED PIs have published together. Of the 60 papers reported in the Center-wide outputs section of this report, 14 papers have reflected collaboration amongst Center PIs bringing the overall value of this measure to approximately 20% since the inception of the Center.

Management and Communications Systems

NCED continues to work on an intranet for researchers, staff, students, and participants to facilitate timely collection, analysis, and evaluation of Center data. During the first several months of Year 6, this site is expected to be available for user acceptance testing. Once revisions are made to correct errors in code and add functionality that may not have been considered at design time, the site is expected to be operational by the January 2008 target.

Resulting from the changes made to how NCED approaches the funding decision-making process, a web-based proposal review system (PRS) was recently incorporated into the design specification of the intranet. The PRS was designed to facilitate communication between EC members, as well as provide a mechanism for both internal and external reviewers to receive and comment on proposals. Preliminary testing of this system shows promise, but was not fully operational for use during the most recent funding cycle.

Beyond these initiatives, NCED continues to use the same management and communication systems that were in place since the previous reporting period.

Legacy and Sustainability

As NCED enters its second five years, we have started thinking about pathways to sustain NCED's position as a center of research, as well as to sustain the technology and knowledge transfer resulting from this research. Discussions among NCED's leadership team and PIs have already begun. We are also seeking advice from more senior STCs. We have begun setting up a "Transition Team" to develop a master plan that prioritizes between alternative possibilities and creates an investment strategy for the next five years of Center operation towards sustainability. In order to start diversifying the Center's sources of support, the transition team will also work with staff at the University of Minnesota and our partner institutions to define networking, visibility, and fundraising objectives.

A formal document stating the guiding principles and goals, as well as the composition of the transition team, will be made available to NSF and site reviewers at the next annual site visit.

Synergy with other centers and partners

The following activities exemplify our community service activities and efforts to foster partnerships with other organizations for intellectual and financial leveraging in the coming years and beyond the STC funding period:

- Liason with the newly formed *Institute on the Environment* at the University of Minnesota (Paola was elected a founding fellow and Foufoula-Georgiou served as a member on the committee responsible for developing the blueprint for the Institute) – NCED is co-funding one working group on earth-surface and environmental processes in the Fall of 2007.
- Exploration of other federal sources of funding – These are discussed in the research sections; for example, Foufoula-Georgiou and Dietrich have received a grant from NASA to investigate rainfall as the driver of geomorphologic extremes and in particular shallow landslides.
- NCED will invest $60,000 for next year for liaison activities (via a postdoc) with the newly funded NSF effort on *Community Surface Dynamics Modeling System* (CSDMS).
- The Berkeley group (Dietrich and Power) has submitted a proposal for a *Critical Zone Observatory* (CZO) following the NSF call for proposal this year.
- One of our PIs (Hondzo) is the recipient of an *NSF Testbed grant* to develop wireless environmental monitoring activities and demonstrate their potential in the Minnesota River.
- Members of the Berkeley group (Dietrich and Power) have received funding from the *Keck Foundation* to enhance the hydrologic and geomorphologic monitoring at ACRR.
- NCED PIs (Foufoula-Georgiou) are involved with the *Consortium of Universities for the Advancement of Hydrologic Sciences (CUAHSI)* such that synergies can be explored in research, education, knowledge transfer and diversity.
- Young researchers from NCED have taken a leadership role in proposing a *MYRES (Multidisciplinary Young Researchers in the Earth Sciences)* conference for next year.
- Several NCED researchers from across institutions are developing, in collaboration with *St. Anthony Falls Laboratory (SAFL),* a strategic plan for the *Outdoors StreamLab* facility to be commenced in 2008.
- Several NCED PIs (Paola, Parker, Dietrich, Twilley, Mohrig, Wilcock) have taken a leadership role in the *Mississippi Delta Initiative* which, as discussed in the SA section, is working to develop a new initiative involving a larger PI group and recently published a refereed comment in *Science*.
- NCED PIs are involved with the research and education activities of other STCs, specifically *SAHRA* and *CENS.*
- NCED PIs are involved with the hydrology and earth-surface sciences activities of the *National Center for Atmospheric Research* (NCAR) for future collaboration and vist exchanges.
- NCED PIs (led by Foufoula-Georgiou) are involved with the NSF funded *Hydrologic Synthesis Activities* led by the University of Illinois.
- NCED PIs are involved with the LSU *CLEAR* program (emphasis on coastal processes and the rebuilding of the Mississippi Delta) via our new PI Robert Twilley.
- NCED PI Peter Wilcock is collaborating with the Stream Restoration synthesis efforts led by EAB member Margaret Palmer; we also would like to acknowledge his energetic leadership in communicating with practitioners via short courses.
- PIs Mohrig, Parker, and Paola have extensive collaborations with the oil industry that have provided, among other things, access to critical data for the Mississippi Delta Initiative.

Metrics

Target	Metric	Done by	Frequency	Current status
PI evaluation	Standard measures (publications etc) + collaboration + contributions to ED, DV, KT	Directors, EC	Annually	Proposals have been evaluated and feedback is being sent to PIs
Project progress	Progress relative to deliverables; see SIP tables	Directors, EC	Semi-annually or as needed	Very Good; see individual IP sections for details
Research integration	collaboration + research synthesis + cross-IP synthesis + co-advised students, postdocs	Directors	Semi-annually or as needed	Continuing to improve, especially with refocusing of SA IP
Research – KT integration	Development of research applications + adoption by Partners	Directors, EC, IP managers	Annually or as needed	Excellent; see KT section for details
Research – ED integration	Use of research results and tools in Education	Directors, EC	Annually or as needed	Excellent; see ED section for details
Research – DV integration	Diversity of participants in research programs	Directors, EC	Annually or as needed	Very Good; see DV section for details
ED – DV integration	Diversity of participants in education programs	Directors, EC	Annually or as needed	Very Good; see DV section for details
Centerwide communication	Participation in centerwide activities: videoconferences, retreats, field sites, joint experiments	Admin staff, Directors	Weekly or per-event	Very Good: Retreats: 19 PIs, 39 students; 25 videoconferences, 32 seminars
Center visibility	Participation in: short courses, working groups, Visitors Program, special sessions; total number of outside professionals supported by NCED programs	Admin staff, Directors	Ongoing	Continuing to improve: highlights include StreamLab06 plus 3 additional visitors, 5 short courses, 4 special sessions
International presence	Number & intensity of international collaborations	Directors, PIs	Ongoing	Improving: Successful IREP participation, to total 7 once completed
External buy-in to center activities	Leveraged funding by NCED PIs	Directors, PIs	Annually	Good; Total for Year 5 = $4,495,062
Research community building	Community buy-in to transdisciplinary surface process science	Directors, EC, PIs	Ongoing	Very Good: CSDMS funded; CZO program launched; CUAHSI collaboration continues
Financial management: review of HQ and subaward accounts	Relevant federal audit standards; rapid, effective communication between HQ and other NCED institutions	Deputy Director, staff	Monthly	Good: HQ-subaward communication improving
Financial management: review of overall Center spending and allocation	Resources used in a timely & effective manner; deployed appropriately relative to project goals & progress	Directors, staff	Quarterly	Very Good: Successful transition to IP-based funds allocation
Staff evaluation	Provide written objectives & performance evaluation for all staff employees	Deputy Director Admin, Directors	Annually	Very Good: need to implement mid-year informal evaluation
External Advisory Board communications	Impact of EAB report & comments on NCED activities	Directors, EC, EAB	Annually	Very Good: Turnover of EAB complete; need to improve meeting format per EAB suggestions
Website effectiveness	Content contribution by NCED participants; website use (hits)	Directors, staff	Ongoing	Very Good: Continue to press for PI data contribution.

VIII. Center-wide Outputs

Center Publications

This list includes all NCED research publications that explicitly acknowledge NCED support either published in the current reporting year, are in the various stages of pre-publication, or were omitted from previous annual reports. They are divided into: 1) journal articles, 2) books, 3) book sections, and 4) proceedings of major conferences. For a comprehensive list of all NCED publications since the inception of the Center, please contact Melanie Lord-Van Slyke (vans0061@umn.edu).

*An asterisk indicates "added value" in research, in that these publications can be attributed only to the Center mode of research and which would not happen otherwise.

JOURNAL ARTICLES

In Press:

Agrawal, A., et al. (in press), Filling key gaps in population and community ecology, *Frontiers in Ecology and Environment*.

Blom, A., et al. (in press), Vertical sorting and the morphodynamics of bedform-dominated rivers: A sorting evolution model, *Journal of Geophysical Research Earth Surface*.

Colosimo, M., and P. R. Wilcock (in press), Alluvial sedimentation and erosion in an urbanizing watershed, Gwynns Falls, Maryland, *Journal of the American Water Resources Association*.

Daly, E., et al. (in press), Ecohydrological significance of the coupled dynamics of photosynthesis, transpiration and soil water balances, *Journal of Hydrometeorology*.

Daly, E., et al. (in press), Modeling photosynthesis, transpiration and soil water balance hourly dynamics during inter-storm periods, *Journal of Hydrometeorology*.

Fedele, J. J., and C. Paola (in press), Similarity solutions for fluvial sediment fining by selective deposition, *Journal of Geophysical Research-Earth Surface*.

Flores, N. E., and A. Strong (in press), Cost credibility and the stated preference analysis of public goods, *Resource and Energy Economics*.

Grams, P. E., et al. (in press), Entrainment of sand from a coarse immobile bed, *Water Resources Research*.

Imran, J., et al. (in press), Helical flow couplets in submarine gravity underflows, *Geology*.

Jerolmack, D. J., and D. Mohrig (in press), The conditions for branching in depositional rivers, *Geology*.

Jerolmack, D. J., and P. Sadler (in press), Transience and persistence in the depositional record of continental margins, *Journal of Geophysical Research-Earth Surface*.

Kim, J., et al. (in press), Analysis of the Sensitivity of Decision Analysis Results to Errors and Simplifications in Problem Structure: Application to Lake Erie Ecosystem Management, *IEEE Transactions on Systems, Man, and Cybernetics, Part A*.

Kim, W., and C. Paola (in press), Long-period cyclic sedimentation with constant tectonic forcing in an experimental relay ramp, *Geology*.

Kostic, S., and G. Parker (in press), Conditions under which a supercritical turbidity current transverses an abrupt transition to vanishing bed slope without a hydraulic jump, *Journal of Fluid Mechanics*.

Lauer, J. W., et al. (in press), Response of the Strickland and Fly River confluence to post-glacial sea-level rise, *Journal of Geophysical Research-Earth Surface*.

McNeely, F. C., et al. (in press), Grazer traits, competition, and carbon sources to a headwater stream food web, *Ecology*.

McNeely, F. C., and M. E. Power (in press), Spatial variation in caddisfly grazing within a Northern California watershed, *Ecology*.

Parker, G., and H. Toniolo (in press), Note on the analysis of plunging of density flows, *Journal of Hydraulic Engineering*.

Parker, G. P., et al. (in press), Quasi-universal relations for bankfull hydraulic geometry of single-thread gravel-bed rivers, *Journal of Geophysical Research-Earth Surface*.

Pasternack, G., et al. (in press), Jet and hydraulic jump near-bed stresses below a horseshoe waterfall, *Water Resources Research*.

Qian, Q., et al. (in press), A physically based flux limiter for QUICK calculations of advective scalar transport, *International Journal of Numerical Methods for Heat and Fluid Flow*.

Qian, Q., et al. (in press), Modeling of solute transport into sub-aqueous sediments, *Applied Mathematical Modelling*, 31, 1461-1478.

Sklar, L., and W. E. Dietrich (in press), Steady-state bedrock channel slope: implications of the saltation-abrasion incision model, *Geomorphology*.

Tal, M., and C. Paola (in press), Dynamic single-thread channels maintained by the interaction of flow and vegetation, *Geology*.

Toniolo, H., et al. (in press), Role of ponded turbidity currents in reservoir trap efficiency, *Journal of Hydraulic Engineering*.

Wiele, S. M., et al. (in press), Reach-averaged sediment routing model of a canyon river, *Water Resources Research*.

Wilkerson, G. V. (in press), Flow through trapezoidal and rectangular channels with rigid cylinders, *Journal of Hydraulic Engineering*, 133.

Yager, E., et al. (in press), Calculating bedload transport in steep, boulder-bed channels, *Water Resources Research*.

<u>In Review:</u>

Barnes, E., M.E. Power, E. Foufoula-Georgiou and M. Hondzo (in review), Predicting and upscaling Nostoc biomass in a gravel-bedrock river: combining local predictors with hydrogeomorphic scaling laws, *Geophysical Research Letters*.

Basu, S., et al. (in review), Estimating intermittency exponent in neutrally stratified atmospheric surface layer flows: A robust framework based on magnitude cumulant and surrogate analyses, *Physics of Fluids*.

Cantelli, A., et al. (in review), Eruption-fed turbidity currents: their thermo-fluid dynamics and sedimentation from explosive subaqueous eruptions, *Journal of Geology*.

Cantelli, A., et al. (in review), Flow and thermal dynamics of sedimentation resulting from turbidity currents caused by explosive submarine volcanic eruptions, *Sedimentology*.

Cantelli, A., et al. (in review), Numerical model linking bed and bank evolution of incisional channel created by dam removal, *Water Resources Research*.

Corsair, H., et al. (in review), Multicriteria decision analysis of stream restoration: Potential and examples, *Group Decisions and Negotiation*.

Francalanci, S., et al. (in review), Effect of seepage-induced non-hydrostatic pressure distribution on bedload transport and bed morphodynamics, *Journal of Hydraulic Research*.

Gangodagamage, C., et al. (in review), Anomalous scaling in river corridor widths reflects localized nonlinearities in valley forming processes, *Journal of Geomorphology*.

Green, E. G., et al. (in review), Chemical weathering across a retreating escarpment, *Geological Society of America Bulletin*.

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Lauer, J. W., and G. Parker (in review), Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meadering river, part I: Theory, *Water Resources Research*.

Lauer, J. W., and G. Parker (in review), Modeling framework for sediment deposition, storage, and evacuation in the floodplain of a meadering river, part II: Application to the Clark Fork River, Montana, *Water Resources Research*.

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Markfort, C. D., and M. Hondzo (in review), Dissolved oxygen measurements in aquatic environments: The effects of changing temperature and pressure on three sensor technologies, *Limnology and Oceanography*.

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Parker, G., et al. (in review), Unraveling the conundrum of river response to rising sea level: from laboratory to field. Part I. Laboratory experiments, *Sedimentology*.

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Power, M. E., et al. (in review), Seasonal reassembly of river food webs under a Mediterranean hydrologic regime: Floods, droughts, and impacts of fish, *Ecological Monographs*.

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Wong, M., et al. (2007), Experiments on dispersion of tracer stones under lower-regime plane-bed equilibrium bedload transport, *Water Resources Research*, 43, doi: 10.1029/2006WR005172.

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*Green, E. G., W. E. Dietrich, and J. F. Banfield (2006), Quantification of chemical weathering rates across an actively eroding hillslope, *Earth and Planetary Science Letters*, *242*, 155-169.

Gupta, R., V. Venugopal, and E. Foufoula-Georgiou (2006), A methodology for merging multisensor precipitation estimates based on expectation-maximation and scale rescursive estimation, *Journal of Geophysical Research*, *111*, D02102, doi:10.1029/2004JD005568.

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CONFERENCE PROCEEDINGS

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Awards and Honors

Recipient	Award Name and Sponsor
Banfield, Jill	Member, National Academy of Sciences
Dietrich, William	David Linton Award from the British Geomorphological Research Group
Foufoula-Georgiou, Efi	Member, University Corporation for Atmospheric Research Board of Trustees
Foufoula-Georgiou, Efi	Fellow of the American Meteorological Society
Foufoula-Georgiou, Efi	Scholars Walk Honoree
Foufoula-Georgiou, Efi	Member, executive council of the Consortium of the Universities for the Advancement of Hydrologic Science

Recipient	Award Name and Sponsor
Kim,Wonsuck	2007 Alvin G. Anderson Award
Paola, Chris	American Geophysical Union Fellow
Paola, Chris	Founding Fellow of the Institute on the Environment
Paola, Chris	Scholars Walk Honoree
Rosok, Katherine	2007 Science Teaching Fellow, Janet H. and C. Harry Knowles Foundation

Graduated Students

Student Name	Advisor	Degree (Year)	Placement
Carper, Matthew	Porte-Agel, Fernando	PhD (2006)	Senior Development Engineer, public sector
Grams, Paul	Wilcock, Peter	PhD (2006)	Research Associate, Department of Aquatic, Watershed, and Earth Resources, Utah State University
Jerolmack, Doug	Mohrig, David	PhD (2006)	Assistant Professor, Department of Earth and Planetary Sciences, University of Pennsylvania (07/07)
Kim, Wonsuck	Paola, Chris and Voller, Vaughan	PhD (2007)	NCED Postdoctoral Associate, University of Illinois at Urbana-Champaign
Lauer, Wesley	Parker, Gary	PhD (2006)	Assistant Professor, College of Science & Engineering, Department of Civil & Environmental Engineering, Seattle University
O'Connor, Ben	Hondzo, Miki	PhD (2006)	NRC Postdoctoral Research Associate, US Geological Survey
Sittoni, Lucca	Paola, Chris and Voller, Vaughan	MS (2006)	Project Engineer, public sector
Strong, Nikki	Paola, Chris	PhD (2006)	NCED Postdoctoral Associate, University of Minnesota, and Postdoctoral Associate, University of Kansas
Theodoratos, Nikos	Foufoula-Georgiou, Efi	MS (2006)	Project Engineer, public sector
Wan, Feng	Porte-Agel, Fernando	MS (2007)	PhD student
Yager, Elowyn	Dietrich, William	PhD (2006)	Postdoctoral Associate, Arizona State University

General Outputs of Knowledge Transfer

Not Applicable

Participants

The NCED participants list has been deleted from the public version of this report due to the confidential nature of the information contained therein. Please contact Diana Dalbotten (dalbo001@umn.edu) with any questions pertaining to NCED participants.

Affiliates

The NCED affiliates list has been deleted from the public version of this report due to the confidential nature of the information contained therein. Please contact Diana Dalbotten (dalbo001@umn.edu) with any questions pertaining to NCED affiliates.

Summary Listing of NCED Partners

Organization Name	Organization Type	Address	Contact Name	Partner Type	160 hr
Advanced Materials for Water Purification	NSF – STC	University of Illionois 3253 Digital Computer Lab 205 N. Mathews Ave. MC-250 Urbana, IL 61801	Susan Herricks	Education & Diversity Knowledge Transfer	N
Anadarko Petroleum Corporation	Oil Exploration Company	1201 Lake Robbins Drive The Woodlands, TX 77380	Todd Green/ James Parr	Knowledge Transfer	N
Association for Women in Geoscience, Minnesota Chapter	Professional Organization for Women	NA	Karen Campbell/ Lesley Perg	Knowledge Transfer	N
Bureau of Land Management	Government Agency	Office of Public Affairs 1849 C Street, Room 406-LS Washington, DC 20240	Jim Fogg	Stream Restoration Partner	N
CALFED – Bay-Delta Program	State Government	605 Capitol Mall, 5th Floor Sacramento, CA 95814	Bill Dietrich	Knowledge Transfer	N
Canaan Valley Institute	Non-profit Organization	P.O. Box 763 Davis, WV 26260	N/A	Stream Restoration Partner	N
Center for Embedded Network Sensing	NSF – STC	UCLA 3731 Hilgard Ave Boelter Hall Los Angeles, CA 90095	Deborah Estrin, Director	Knowledge Transfer	N
Center of Research Excellence in Science and Technology	NSF Center	Department of Environmental Science Texas A&M University—Kingsville Kingsville, TX 78363	Lee Clapp/ Jianhong Ren	Education & Diversity	N
ChevronTexaco	Oil Exploration Company	4800 Fournace Place Bellaire, TX 77401	Martin Perlmutter	Knowledge Transfer	N
CHRONOS	NSF funded research center	Iowa State University Dept of Geol 275 Science I Ames, Iowa 50011-3212	Cinzia Cerbato	Knowledge Transfer	N
ConocoPhillips	Oil Exploration Company	P.O. Box 2197 Houston, TX 77252-2197	Al Shultz	Knowledge Transfer	N
CUAHSI Consortium for the Advancement of Hydrologic Sciences, http:: www.cuahsi.org/	Consortium	2000 Florida Ave, N.W. Washington, DC 20009	Efi Foufoula (board member) Paul Morin (technical advisor)	Knowledge Transfer	N
ExxonMobile Upstream Research Co.	Oil Exploration Company	P.O. Box 2189 Houston, TX 77252-2189	Penny Patterson	Knowledge Transfer	N
Florida A&M University	University	Tallahassee, FL, 32307	NA	Education & Diversity	N
Geowall Consortium	Consortium	http://www.geowall.org	Paul Morin	Knowledge Transfer	N

Organization Name	Organization Type	Address	Contact Name	Partner Type	160 hr
Inter-Fluve, Inc.	Environmental	9594 First Avenue NE St. 615 Seattle, WA 98115	NA	Stream Restoration Partner Group	N
International Center for Geohazards (IGC)	International	P.O. Box 3930 Ullevaal Stadion N-0806 Oslo, Norway	Anders Elverhoi	Partner	N
Japan Oil, Gas, and Metals Corporation	Oil Exploration Company	Fukoku Seimei Bldg. 2-2-2 Tokya 100-8511, Japan	Osamu Takano	Knowledge Transfer	N
Minnesota Geological Survey	State Agency	2641 University Ave. W. St. Paul, MN 55114-1057	Harvey Thorleifson	Knowledge Transfer	N
NASA/Goddard Space Flight Center, Hydrologic Sciences	Government Agency	Code 974, Hydrological Sciences NASA/Goddard Space Flight Center Greenbelt, MD 20771	David Toll	Knowledge Transfer	N
National Academy of Sciences	Government Agency	National Research Council 2101 Constitution Avenue NW Washington, DC 20418	William Logan	Research	N
National Park Service Water Resources Division	Government Agency	1201 Oakridge Drive St. 250 Fort Collins, CO 80525	Several	Stream Restoration Partners Group	N
National River Restoration Science Synthesis (NRRSS)	Project	Plant Sciences, Bldg 4112 University of Maryland College Park, MD 20742	Margaret Palmer	Research	N
NOAA Fisheries Service	Government Agency	1315 East West Highway 9th Floor Silver Spring, MD 20910	Several	Stream Restoraton Partners Group	N
Nova/Mentorn TV	Educational Television Producer	43 Whitfield St London, WIT 4HA	Ben Fox	Education & Diversity	N
NSF Center for Airborne Laser Mapping (NCALM)	NSF Center	365 Weil Hall P.O. Box 116580 University of Florida Gainesville, FL	Bill Dietrich	Research	N
Office of Naval Research, Coastal and Geosciences Program	Government Agency	800 N Quincy Street Arlington, VA 22217	Tom Drake	Knowledge Transfer	N
R2 Resource Consultants	Corporation	15250 NE 95th Street Redmond, WA 98052	Paul DeVries	Knowledge Transfer	N
SAHRA: Sustainability of Semi-Arid Hydrology and Riperian Areas) http://www.sahra.arizona.edu/	NSF – STC	Univ. of Arizona Hydrology & Water Resources College of Engineering and Mines Tucson, AZ 85721	Jim Washburne	Education & Diversity	N
SciTech Hands On http://scitech.mus.il.us/	Museum	18 W Benton Street Aurora, IL 60506	Ronen Mir, Executive Director	Education & Diversity	N

Organization Name	Organization Type	Address	Contact Name	Partner Type	160 hr
Shell International Exploration and Production Company	Oil Exploration Company	3737 Belaire Blvd Houston, TX 77025	Carlos Pirmez	Knowledge Transfer	N
The Science Center at the Maltby Nature Reserve	Non-Profit	Maltby Nature Preserve 789 Sciota Trail East Randolph, MN 55065	Seliesa Pembleton	Education & Diversity	N
Stillwater Sciences	Environmental Consulting Firm	2855 Telegraph Ave., Suite 400 Berkeley, CA 94705	Yantao Cui	Knowledge Transfer	N
US Army Corps of Engineers Rocky Mountain Research Station	Government Agency	Southbend, IN 46628	Meg Jonas	Knowledge Transfer	N
US Department of Agriculture: Forest Service Rocky Mountain Research Station	Government Agency	316 E Myrtle Street Boise, ID 83702	Jim McKean	Knowledge Transfer	N
US Department of Agriculture: Forest Service Pacific Northwest Station	Government Agency	3200 SW Jefferson Way Corvallis, OR 97331	Gordon Grant	Stream Restoration Partners Group	N
US Department of Agriculture: National Sedimentation Laboratory Water Quality and Ecology	Government Agency	Agricultural Research Service National Sedimentation Laboratory PO Box 1157 Oxford, MS 38655	Doug Shields	Knowledge Transfer	N
US Department of Commerce: National Oceanic and Atmospheric Administration: Office of Global Programs: GAPP Program	Government Agency	GAPP Program Manager UCAR/NOAA-OGP 1100 Wayne Ave, Ste 1210 Silver Spring, MD 20910-5603	Richard G. Lawford	Knowledge Transfer	N
US Department of the Interior: Bureau of Reclamation, Sediment and River Hydraulics Group	Government Agency	Sedimentation and River Hydraulics Group (D-8540) US Bureau of Reclamation Technical Service Center	Tim Randle	Knowledge Transfer	N
US Department of the Interior Fish and Wildlife Services	Government Agency	1849 C Street NW Washington, DC 20240	Janine Castro	Stream Restoration Partners Group	N
US Department of the Interior Geological Survey, CERC	Government Agency	4200 New Haven Road Columbia, MO 65201	Robert Jacobson	Knowledge Transfer	N
US Environmental Protection Agency	Government Agency	WW-16J US Environmental Protection Agency 77 West Jackson Boulevard	Tom Davenport	Knowledge Transfer	N

Organization Name	Organization Type	Address	Contact Name	Partner Type	160 hr
Universidad Central de Venezuela	University	Instituto de Mecanica de Fluidos Facultad de Ingenieria Universidad Central de Venezuela	Jose L. Lopez	Research	N
Universidad Nacional del Litoral	University	Department of Eng and Water Universidad Nacional de Litoral Santa Fe, Argentina	Mario Luis Amsler	Research	N
University of Colorado/INSTARR	University	Institute of Arctic and Alpine University of Colorado at Boulder 1560 30th Street, Campus Box 450 Boulder, CO 80309-0450	James P. M. Syvitski	Research	N
Utah Museum of Natural History	Museum	University of Utah 1330 E Presidents Circle Salt Lake City, UT 84112	Rebecca Menlove	Education & Diversity	N

Summary Table

The center-wide outputs summary table has been deleted from the public version of this report due to the confidential nature of the information contained therein. Please contact David Olsen (olse0046@umn.edu) with any questions pertaining to NCED's center-wide outputs.

IX. Indirect/Other Impacts

Not applicable to this Center.

X. Budget

This section has been deleted from the public version of the NCED Annual Report due to the confidential nature of the information contained therein. Please contact David Olsen (olse0046@umn.edu) with any questions pertaining to this section of the report.

Appendix A: Biographic Information of New PIs

Robert R. Twilley
Professor, Department of Oceanography and Coastal Sciences
Louisiana State University

Biographic Sketch

Dr. Twilley is professor in the Department of Oceanography and Coastal Sciences and director of the Wetland Biogeochemistry Institute at Louisiana State University. He is presently serving part-time as Associate Vice Chancellor of Research and Economic Development to develop the 'Coastal Systems and Society' program at LSU. Most of Dr. Twilley's research has focused on coastal wetlands both in the Gulf of Mexico, throughout Latin America, and in the Pacific Islands. Dr. Twilley has published over 90 articles including the 1999 co-edited book The Biogeochemistry of Gulf of Mexico Estuaries, several documents on global climate change, and edited a two-volume report with 63 other authors entitled Coastal Louisiana Ecosytem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. He was recently selected as Distinguished Professor in Louisiana Environmental Studies at LSU; and was the recipient of the 2000 Distinguished Professor Award at the University of Louisiana at Lafayette, where he founded the Center for Ecology and Environmental Technology. Dr. Twilley received his PhD in 1982 in plant and systems ecology from the University of Florida, and performed his post-doc studies at University of Maryland on the Chesapeake Bay. Presently Dr. Twilley is member of the Science and Technology Working Group that is developing a comprehensive restoration plan for the Louisiana Coastal Area. His current focus is developing ecosystem models, coupling natural and social system science with engineering, to forecast the rehabilitation of coastal and wetland ecosystems as director of the Shell Coastal Environmental Modeling Laboratory.

CURRICULUM VITA

Robert Reece Twilley

Wetland Biogeochemistry Institute, Department of Oceanography and Coastal Science, Louisiana State University, Baton Rouge, LA 70803, Telephone: (225) 578 8806; FAX (225) 388 6423; email: rtwilley@lsu.edu

Professional Preparation:

B.S.,	East Carolina University,	1974;	Biology
M.S.,	East Carolina University,	1976;	Biology
Ph.D.,	University of Florida,	1982;	Plant Ecology/Systems Ecology
Postdoc,	University of Maryland,	1982	Horn Point Laboratory, Coastal Oceanography,

Appointments:

Associate Vice Chancellor, Office of Research and Economic Development, LSU, November 2006 to present.
Professor, Department of Oceanography and Coastal Sciences, Louisiana State University, July 2004 to present.
Director, Wetland Biogeochemistry Institute, Louisiana State University, July 2004 to present.
Director, Shell Coastal Environmental Modeling Laboratory, School of the Coast and Environment, LSU, September 2004 to present.
Director and Founder, Center for Ecology and Environmental Technology, University of Louisiana at Lafayette, July 1999 to May 2004.
Professor - Department of Biology, University of Louisiana at Lafayette, August 1995 to present.
Associate Professor - Department of Biology, University of Southwestern Louisiana. August 1988 to July 1995.
Assistant Professor - Department of Biology, University of Southwestern Louisiana. January 1986 to August 1988.

Professional Awards

Distinguished Professor in Louisiana Environmental Studies, LSU, July 2005
Distinguished Professor Award, May 2000, University of Louisiana at Lafayette
Mr. Charles R. Godchaux/BORSF Professor in Coastal Biodiversity, 2002 to 2004

Professional Societies

Ecological Society of America; Estuarine Research Federation; Society of Wetland Science; AAAS

University Initiatives and Leadership

- LSU Coastal Systems and Society Program, $200,000 Grant from Shell Corporation to Organize Systems Approach to Coastal Restoration and Planning
- LSU Breton Sound Study of Post-Hurricane Wetland Restoration, $3.5 Million Grant from Shell Oil Corporation to establish coastal forecasting system.
- LSU Endowed Chair in Wetland and Oceanography Studies, Shell Oil Corporation,
- Chair of the Board of Regents, Post-Hurricanes Conference on Research and Development
- Chair, Science and Engineering Review Team, Integrated Planning Team, CPRA
- Fellow, Northern Gulf Institute, NOAA

Professional Activities (Last five years)

- Ecological Society of America, Rapid Response Team, Gulf Coast
- Framework Development Team, Louisiana Coastal Restoration Comprehensive Plan, 2002-2004
- International Wetland Biogeochemistry Conference, Host and Chair, 2004
- Program Chair, Environmental Research Consortium of Louisiana, 2002 Annual Conference
- Board of Directors, Environmental Research Consortium of Louisiana
- Ecological Society of America, Special Committee – Ecological Sciences in the Next Decade, August 2002
- Estuarine Research Federation/NSF, Steering Committee, Initiative in Biocomplexity; 7-10 April 2002
- NSF Panel, Workshop on Environmental Issues of Bangladesh, 26 January to 2 February 2002.
- NSF Workshop, University of Louisiana at Lafayette, 21-24 March 2002, 'LTER-Based Tropical Coastal research Across the Caribbean Basin'

• Program Chair, Society of Wetland Scientists Annual Meeting, 2003
• Lead Author, ESA/UCS Author team, Gulf Coast Response to Climate Change, 2000-2001
• Invited Presentation, National Academies, Coastal Eutrophication, 2000
• Panel Chair, Govenor's Technical Committee on Brown Marsh, August 2000
• Co-Chair, 15th Biennial International Conference of Estuarine Research Federation, 1999
• Chair, International Chapter, Society of Wetland Scientists, '93-97
• Board of Directors, Society of Wetland Scientists, '93-97
• Editorial Board of *Mangroves and Salt Marshes* '97-present
• Editorial Board of *Environmental Science and Policy*, '97-present
• Editorial Board of *Estuaries,* ''93-95

I. Books and Peer Reviewed Reports:

1 Bianchi, T., J. Pennock, and R.R. Twilley (eds). **1999.** Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons, New York. 428 pp.
2 Twilley, R.R., E. Barron, H.L. Gholz, M.A. Harwell, R.L. Miller, D.J. Reed, J.B. Rose, E. Siemann, R.G. Welzel and R.J. Zimmerman. **2001**. Confronting Climate Change in the Gulf Coast Region: Prospects for Sustaining Our Ecological Heritage. Union of Concerned Scientists, Cambridge, MA and Ecological Society of America, Washington, DC. 82 pp.
3 Kennedy, V.S. R.R. Twilley, J.A. Kleypas, J.H. Cowan, Jr., S.R. Hare. **2002**. *Coastal and marine ecosystems and global climate change: Potential effects on U.S. resources*. Pew Center on Global Climate Change. Arlington, VA. 52 pp.

II. **Journal Articles**

1. Twilley, R.R., M.M. Brinson, and G.J. Davis. **l977**. Phosphorus absorption, translocation and secretion in *Nuphar luteum*. *Limnology and Oceanography* 22:l022-l032.
2. Wheeler, W.B., G.D. Stratton, R.R. Twilley, L.T. Ou, D.A. Carlson, and J.M. Davidson. **l979**. Trifluralin degradation and binding in soil. *Journal of Agricultural and Food Chemistry* 27:702-706.
3. Kemp, W.M., W.R. Boynton, R.R. Twilley, J.C. Stevenson, and J.C. Means. **1983**. The decline of submerged vascular plants in Chesapeake Bay: A summary of results concerning possible causes. *Journal of Marine Technology Series* 17:78-89.
4. Twilley, R.R., L.R. Blanton, Jr., M.M. Brinson, and G.J. Davis. **1985**. Biomass production and nutrient cycling of aquatic macrophyte communities in the Chowan River, North Carolina. *Aquatic Botany* 22:231-252.
5. Twilley, R.R., W.M. Kemp, K.W. Staver, J.C. Stevenson and W.R. Boynton. **1985**. Nutrient enrichment of estuarine submersed vascular plant communities. I. Algal growth and effects on production of plants and associated communities. *Marine Ecology Progress Series* 23:179-191.
6. Twilley, R.R. **1985**. The exchange of organic carbon in basin mangrove forests in a southwest Florida estuary. *Estuarine, Coastal and Shelf Science* 20:543-557.
7. West, P.A., P.R. Brayton, R.R. Twilley, T.N. Bryant and R.R. Colwell. **1985**. Numerical taxonomy of nitrogen-fixing decarboxylase-negative vibrio species isolated from aquatic environments. *International Journal of Systematic Bacteriology* 35: 198-205.
8. Twilley, R.R., A.E. Lugo, and C. Patterson-Zucca. **1986**. Litter production and turnover in basin mangrove forests in southwest Florida. *Ecology* 67:670-683.
9. Twilley, R.R., G. Ejdung, P. Romare, and W.M. Kemp. **1986**. A comparative study of decomposition, oxygen consumption and nutrient release for selected aquatic plants occurring in estuarine environments. *Oikos* 47:190-198.
10. Ward, L.G. and R.R. Twilley. **1986**. Sources and distributions of suspended particulate material and nutrients in a coastal plain estuary. *Estuaries* 9:156-168.
11. Lynch, J.C., J.H. Merriwether, B.A. McKee, F. Vera-Herrera and R.R. Twilley. **1989.** Recent accretion in mangrove ecosystems based on ^{137}Cs and ^{210}Pb methods. *Estuaries* 12: 284-299.
12. Twilley, R.R. and J.W. Barko. **1990**. The growth of submersed macrophytes under experimental salinity and light conditions. *Estuaries* 13: 311-321
13. Twilley, R.R., R.H. Chen, and T. Hargis. **1992**. Carbon sinks in mangroves and their implications to carbon budget of tropical coastal ecosystems. *Water, Air and Soil Pollution* 64: 265-288.

14. Downing, J.P.,M. Meybeck, J.C.Orr, R.R. Twilley,and H.W. Scharpenseel. **1993**. Land and water interface zones. *Water, Air, and Soil Pollution* 70:123-137.
15. Hargis, Thomas G. and Robert R. Twilley **1994**. A multi-depth probe for measuring oxidation-reduction (redox) potential in wetland soils. *Journal of Sedimentary Research* A64: 684-685.
16. Hargis, Thomas G. and Robert Twilley **1994**. Improved coring device for measuring soil bulk density in a Louisiana Deltaic Marsh. *Journal of Sedimentary Research* A64: 681-683.
17. Miller-Way, T., G. Boland, G. Rowe, and R. R. Twilley. **1994**. Sediment oxygen consumption and benthic nutrient fluxes on the Louisiana continental shelf: a methodological comparison. *Estuaries* 17:809-815.
18. Rivera-Monroy, V.H., J.W. Day, R. R. Twilley, F. Vera-Herrera, and C. Coronado-Molina. **1995.** Flux of nitrogen and sediment in a fringe mangrove forest in Terminos Lagoon, Mexico. *Estuarine, Coastal and Shelf Science* 40:139-160.
19. Rivera-Monroy, V.H., R.R. Twilley, R. Boustany, J.W. Day, Jr., F.Vera-Herrera, M. Ramirez. **1995.** Direct denitrification in mangrove sediments in Terminos Lagoon, Mexico. *Marine Ecology Progress Series* 126:97-109
20. Rivera-Monroy, V.H., and R.R. Twilley. **1996.** The relative role of denitrification and immobilization on the fate of inorganic nitrogen in mangrove sediments of Terminos Lagoon, Mexico. *Limnology and Oceanography* 41:284-296.
21. Ellison, A.M., E.J. Farnesworth, and R.R. Twilley. **1996.** Facultative mutualism between red mangroves and root-fouling sponges in Belizean mangal. *Ecology* 77: 2431-2444.
22. Day, J.W., C. Coronado-Molina, F. R. Vera-Herrera, R. R. Twilley, V. H. Rivera-Monroy, H. Alvarez-Guillen, R. Day, and W. Conner. **1996.** A seven-year record of aboveground net primary production in a mangrove forest bordering Terminos Lagoon. *Aquatic Botany* 55:39-60.
23. Cifuentes, L.A., R.B. Coffin, L. Solarzano, W. Cardenas, J. Espinosa and R.R. Twilley. **1996**. Isotopic and elemental variations of carbon and nitrogen in a mangrove estuary. *Estuarine, Coastal and Shelf Science* 43:781-800.
24. Miller-Way, T. and R. R. Twilley. **1996.** A comparison of batch and continuous flow methodologies for determining benthic fluxes. *Marine Ecology Progress Series* 142:257-269.
25. Twilley, R.R., M. Pozo, V.H. Garcia, V.H. Rivera-Monroy, R. Zambrano, and A. Bodero. **1997.** Litter dynamics in riverine mangrove forests in the Guayas River estuary, Ecuador. *Oecologia* 111:109-122.
26. Boustany, R.G., C.R. Crozier, J.M. Rybczyk, and R.R. Twilley. **1997**. Denitrification in a south Louisiana wetland forest receiving treated sewage effluent. *Wetlands Ecology and Management* 4:273-283.
27. Pelegri, S.P., V.H.Rivera-Monroy, and R.R. Twilley. **1997**. A comparison of nitrogen fixation (acetylene reduction) among three species of mangrove litter, sediments, and pneumatophores in south Florida, USA. *Hydrobiologia* 356:73-79.
28. Twilley, R.R., R, R. Gottfried, V.H. Rivera-Monroy, M. M. Armijos, A. Bodero. **1998**. An approach and preliminary model of integrating ecological and economic constraints of environmental quality in the Guayas River estuary, Ecuador. *Environmental Science and Policy* 1:271-288.
29. Twilley, R.R. and R. Chen. A water budget and hydrology model of a basin mangrove forest in Rookery Bay, Florida. **1998.** *Australian Journal of Freshwater and Marine Research*. 49:309-323.
30. Chen, R. And R. R. Twilley. **1998**. A gap dynamic model of mangrove forest development along gradients of soil salinity and nutrient resources. *Journal of Ecology* 86:37-52.
31. Pelegri, S.P. and R.R. Twilley. **1998.** Interactions between nitrogen fixation (acetylene reduction) and leaf litter decomposition of two mangrove species from south Florida, USA: potential inhibitory effects of phenolics. *Marine Biology* 131:53-61.
32. Rivera-Monroy, V.H., C.J. Madden, J.W. Day, Jr., R.R. Twilley, R.Vera-Herrera, H. Alvarez-Guillen. **1998**. Seasonal coupling of a tropical mangrove forest and an estuarine water column: enhancement of aquatic primary productivity. *Hydrobiologia* 379:41-53.
33. Chen, R. and R. R. Twilley. **1999**. A simulation model of organic matter and nutrient accumulation in mangrove wetland soils. *Biogeochemistry* 44:93-118.
34. Ewel, K., R.R. Twilley , and J.E. Ong. **1998.** Different kinds of mangrove forests provide different goods and services. *Global Ecology and Biogeography Letters* 7:83-94

35. Rivera-Monroy, V.H., L.A. Torres, N. Bahamon, F. Newmark, R.R. Twilley. **1999**. The potential use of mangrove forests as nitrogen sinks of shrimp aquaculture pond effluents: the role of denitrification. *Journal of the World Aquaculture Society* 30:12-25.
36. Twilley, R.R., R. Chen, and V. Rivera-Monroy. **1999**. Formulating a succession model of mangrove wetlands in the Caribbean and Gulf of Mexico with emphasis on factors associated with global climate change. *Current Topics in Wetland Biogeochemistry* 3:118-141.
37. Twilley, R.R, Rivera-Monroy, V.H., Chen, R., Botero, L. **1999**. Adapting an ecological mangrove model to simulate trajectories in restoration ecology. *Marine Pollution Bulletin 37:404-419*.
38. Corredor, J.E., Howarth, R.W., Twilley, R.R. And Morel, J. **1999.** Nitrogen cycling and anthropogenic impact in the tropical interamerican seas. *Biogeochemistry 46:163-178*.
39. Downing, J.A., M. McClain, R. Twilley, J.M. Melack, J. Elser, N.N. Rabalais, W.M. Lewis, Jr., G. Turner, J. Corredor, D. Soto, A. Yanez-Arancibia, J.A. Kopaska and R.W. Howarth. **1999.** The impact of accelerating land-use change on the N-cycle of tropical aquatic ecosystems: Current conditions and projected changes. *Biogeochemistry 46:109-148*.
40. Yanez-Arancibia, R. R. Twilley, and A. L. Lara-Dominguez. **1999.** Los ecosistemas de manglar frente al cambio climatico global. *Madera y Bosques* 4:3-19.
41. Chen, R. And R.R. Twilley. **1999**. Patterns of mangrove forest structure associated with soil nutrient dynamics along the Shark River estuary. *Estuaries* 22:1027-1042.
42. Whigham, D.F., R. R. Twilley, I.C. Feller. **1999.** Within-stand nutrient cycling in wetland ecosystems. *Ecology* 80: 2137-2138.
43. Perez, Brian C., John W. Day, Jr., Dubravko Justic, Robert R. Twilley. **2003**. Nitrogen and Phosphorus Transport Between Fourleague Bay, Louisiana and the Gulf of Mexico: The Role of Winter Cold Fronts and Atchafalaya River Discharge. Estuarine, Coastal and Shelf Science Vol 57/56: 1065-1078.
44. Rivera-Monroy, V., R. R. Twilley, E. Medina. **2004**. Spatial variability of soil nutrients in riverine mangrove forests at different stages of regeneration in the San Juan River estuary, Venezuela. Estuaries 27:44-57
45. Rivera-Monroy, V.H., R.R. Twilley, D. Bone, D. Childers, C. Coronodo-Molina, I.C. Feller; J. Herrera-Silveira, R. Jaffe, E. Mancera, E. Rejmankaova, J. Salisbury. **2004.** Conceptual Framework to Develop Long Term Ecological Research and Management Objectives in the Wider Caribbean Region. BIOSCIENCE 54:843-856.
46. Day, J.W. Jr, , J.Y. Ko, J. R. D. Sabins, R. Bean, G. Berthelot, C. Brantley, L. Cardoch, W. Conner, J.N. Day, A.J. Englande, S. Feagley, E. Hyfield, R. Lane, J. Lindsey, J. Mistich, E. Reyes, R. Twilley. **2004**. The use of wetlands in the Mississippi Delta for wastewater assimilation: a review. Ocean & Coastal Management 47: 671–691
47. Twilley, R. R. and V.H. Rivera-Monroy. **2005**. Developing Performance Measures of Mangrove Wetlands Using Simulation Models of Hydrology, Nutrient Biogeochemistry and Community Dynamics. Journal of Coastal Research 40:79-93.
48. Krauss, K.W., Doyle, T.W., Twilley, R.R., Smith, T.J., III, Whelan, R.T.K., and Sullivan, J.K. **2005**. Woody debris in the mangrove forests of South Florida. Biotropica 37: 9-15.
49. Lara-Domınguez, A.L., J.W. Day, Jr,, G. Villalobos Zapata, R.R. Twilley, H.A. Guillen and A. Yanez-Arancibia. **2005**. Structure of a unique inland mangrove forest assemblage in fossil lagoons on the Caribbean Coast of Mexico. Wetlands Ecology and Management 13: 111–122.
50. Krauss, KW, RR Twilley, TW Doyle and ES Gardiner **2005.** Leaf gas exchange characteristics of three neotropical mangrove species in response to varying hydroperiod. Tree Physiology 26:959-968.
51. Jonsson, B., R. R. Twilley, J.E. Mancera, and E. Castaneda. **2006** Turnover-time estimates in a tropical estuary with high spatial and temporal variability. Estuarine Coastal and Shelf Science. XX: 000-000.
52. Cardona-Olarte, P., R. R. Twilley, K.W. Krauss & V. Rivera-Monroy. **2006**. Responses of neotropical mangrove seedlings grown in monoculture and mixed culture under treatments of hydroperiod and salinity. Hydrobiologia 569:325-341.
53. Krauss, K.W., T. W. Doyle, R. R. Twilley, V. H. Rivera-Monroy & J. K. Sullivan. **2006**. Evaluating the relative effects of hydroperiod and soil fertility as growth constraints in south Florida mangroves. Hydrobiologia 569:311-324.

54. Ewe, S.M.L., E. E. Gaiser, D. L. Childers, J. Fourqurean, D. Iwaniec, V. H. Rivera-Monroy, R. R. Twilley. **2006**. Spatial and temporal patterns of aboveground net primary productivity (ANPP) in the Florida Coastal Everglades. Hydrobiologia 569:459-474.
55. Romigh, M.M., S. E. Davis, III, V. H. Rivera-Monroy, and R. R. Twilley. **2006**. Flux of Organic Carbon in a Riverine Mangrove Forest in the Florida Coastal Everglades. Hydrobiologia 569:505-516.
56. Simard, M., K. Zhang, V. H. Rivera-Monroy, M. Ross, P. Ruiz, E. Castañeda-Moya, R.R. Twilley, E. Rodriguez. **2006**. Mapping Height and Biomass of Mangrove Forests in the Everglades National Park with SRTM Elevation Data. Photogrammetric Engineering & Remote Sensing 72:299-311.
57. Rivera-Monroy, V. H. , R. R. Twilley, E. Mancera, A. Alcantara-Eguren, E. Castañeda-Moya1, O.C. Monroy, P. Reyes, J. Restrep-Perdomo, E. Campos, G. Cotes y E. Villoria. **2006**. Aventuras y desventuras en macondo: Rehabilitacion de la Cienaga Grande de Santa Marta, Colombia. Ecotropicos 19:72-93.
58. Krauss, K., J. Chambers, P. Young, R. Twilley. **2007**. Sap flow characteristics of neotropical mangroves in flooded and drained soils. Tree Physiology 27:775-783.
59. Habib, E. W. K. Nuttle, V. H. Rivera-Monroy, S. Gautam, J. Wang, E. Meselhe and R. R. Twilley **2007**. Assessing Effects of Data Limitations on Salinity Forecasting in Barataria Basin, Louisiana, with a Bayesian Analysis. Journal of Coastal Research XX: 000-000.
60. Day, J.W. Jr., D. F. Boesch, E. J. Clairain, G. P. Kemp, S. B. Laska, W. J. Mitsch, K. Orth, H. Mashriqui, D. R. Reed, L. Shabman, C. A. Simenstad, B. J. Streever, R R. Twilley, C C. Watson, J T. Wells, D F. Whigham. **2007**. Restoration of the Mississippi Delta: Lessons From Hurricanes Katrina and Rita. SCIENCE 315:1679-1684.
61. Törnqvist, T. E., C. Paola, G. Parker, K. Liu, D. Mohrig, J. M. Holbrook, R. R. Twilley. **2007**. Comment on "Wetland Sedimentation from Hurricanes Katrina and Rita". SCIENCE 316:000-000.
62. Sundareshwar, P. V., R. Murtugudde, G. Srinivasan, S. Singh, K.J. Ramesh, D. Agarwal, D. Baldocchi, C.K. Baru, K.K. Baruah, G.R. Chowdhury, V.K. Dadhwal, C.B.S. Dutt, J. Fuentes, P.K. Gupta, W.W. Hargrove, M. Howard, C.S. Jha, S. Lal, W.K. Michener, A.P. Mitra, J.T. Morris, R.R. Myneni, M. Naja, R. Nemani, S. Raha, R. Ramesh, S.K. Santhana Vanan, M. Sharma, A. Subramaniam, R. Sukumar, R.R. Twilley, S.B. Verma, P.R. Zimmerman. **2007**. INDOFLUX: A Biogeochemical Monitoring Network for India. SCIENCE 316:204-205.
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III. Book Chapters and Proceedings:

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4. Twilley, R.R. **1988**. Coupling of mangroves to the productivity of estuarine and coastal waters, pp 155-180. In: B.O. Jansson (ed.), Coastal-Offshore Ecosystem Interactions. Springer-Verlag, Germany.
5. Twilley, R.R. **1989**. Impacts of Shrimp Mariculture Practices on the Ecology of Coastal Ecosystems in Ecuador, pp. 91-120. In: Stephen Olsen and Luis Arriaga (eds.), Establishing a Sustainable Shrimp Mariculture Industry in Ecuador. University of Rhode Island, Technical Report Series TR-E-6.
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and B.D. Gold, Food Chains, Yields, Models, and Management of Large Marine Ecosystems. Westview Press, Boulder.
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10. Hargis Thomas G., Patricia S. Rafferty, James C. Lynch and Robert R. Twilley. **1993.** Analysis of Pore Water Nutrients in Marsh Ecosystems Subjected to Alterations in Hydrology. In: Landin, Mary C. (ed). Wetlands: Proceedings of the 13th Annual Conference of the Society of Wetland Scientists, New Orleans, LA. Utica, MS, USA 39175-9351. pp. 852-855.
11. Day, J.W., Jr., C.J. Madden, R.R.Twilley, R.F. Shaw, B.A. McKee, M.J. Dagg, D.L. Childers, R.C. Raynie, and L.J. Rouse. **1994.** The Influence of Atchafalaya River discharge on Fourleague Bay, Louisiana (USA), pp. 151-160. In, K.R. Dyer and R. J. Orth (eds.), Changes in Fluxes in Estuaries. Olsen and Olsen Publishers, Denmark.
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16. Twilley, R.R. **1996**. Ecosystem Analysis of the Louisiana Bight and Adjacent Shelf Environments. Vol. II. Bibliography. OCS study/MMS No. U.S. Dept. of the Interior, Minerals Mgmt. Service, Gulf of Mexico OCS Regional Office, New Orleans, La.
17. Twilley, R.R. and R. Chen. **1996**. The utility of ecological models in the assessment of oil impacts to mangrove ecosystems. In, Proffitt, C.E. (Ed.), Managing oil spills in mangrove ecosystems: Effects, remediation, restoration, and modeling. OCS Study/MMS 96-. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA.
18. Caffrey, J.M., D.E. Hammond, J.S. Kuwabara, L.G. Miller, and R.R. Twilley. **1996**. Benthic processes in south San Francisco Bay: the role of organic inputs and bioturbation, pp. 425-442. In: J.T. Hollibaugh (ed.), San Francisco Bay: The Ecosystem. AAAS Press, San Francisco, CA.
19. Twilley, R.R. **1997**. Mangrove wetlands, pp. 445-473. In, M.Messina and W. Connor (eds.), Southern Forested Wetlands: Ecology and Management, CRC Press, Boca Raton, Florida.
20. Twilley, R.R. **1997.** The diversity of mangrove wetlands and ecosystem management, pp. 31-32. In, S. Wells and C. Young (special editors), Intracoast Network, University of Rhode Island, Coastal Resources Center, Narragansett.
21. Schaeffer-Novelli, Y., Twilley, R. et al. **1997**. Manguezais do Parque Nacional Morrocoy (Estado Falcon, Venezuela): estudo de caso. VII Colacmar, Cogresso Latina-americano sobre Ciencias do Mar. Resumos Expandidos II: 443-444.
22. Twilley, R. R., J. Cowan, T. Miller-Way, and P. Montagna, and B. Mortazavi. **1999**. Benthic fluxes of selected estuaries in the Gulf of Mexico, pp. 163-209. IN, T. Bianchi, J. Pennock and R. Twilley (eds). Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons.

23. Twilley, R.R., M. M. Armijos, J. M. Valdivieso, and A. Bodero. **1999**. The environmental quality of coastal ecosystems in Ecuador: Implications for the development of integrated mangrove and shrimp pond management, p. 199-230. IN: A. Yáñez-Arancibia and A. L. Laura-Domínguez, (eds.), Ecosistemas de Manglar en America Tropical. Insituto de Ecologia, A.C. Mexico, UICN/ORMA, Costa Rica, NOAA/NMFS Siver Spring MD USA. 380 p.
24. Twilley, R.R. and J. W. Day, Jr. **1999.** The productivity and nutrient cycling of mangrove ecosystems, p 127-152. IN: A. Yáñez-Arancibia and A. L. Laura-Domínguez, (eds.), Ecosistemas de Manglar en America Tropical. Insituto de Ecologia, A.C. Mexico, UICN/ORMA, Costa Rica, NOAA/NMFS Siver Spring MD USA. 380 p.
25. Thayer, G.W., R.R. Twilley, S.C. Snedaker, and P.F. Sheridan. **1999**. Research information needes on U.S. Mangroves: Recommendations to the United States National Oceanic and Atmospheric Administration's Coastal Ocean Program from an estuarine habitat program-funded workshop, p. 255-262. IN: A. Yáñez-Arancibia and A. L. Laura-Domínguez, (eds.), Ecosistemas de Manglar en America Tropical. Insituto de Ecologia, A.C. Mexico, UICN/ORMA, Costa Rica, NOAA/NMFS Siver Spring MD USA. 380 p.
26. Bianchi, T., J. Pennock and R. Twilley. **1999**. Biogeochemistry of Gulf of Mexico estuaries: implications to management, pp. 407-421. IN, T. Bianchi, J. Pennock and R. Twilley (eds). Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons.
27. Childers, D.L., S.E. Davis, R.R. Twilley, and V. Rivera-Monroy. **1999.** Wetland-water column interactions and the biogeochemistry of estuary-watershed coupling around the Gulf of Mexico, pp. 211-235. IN, T. Bianchi, J. Pennock and R. Twilley (eds). Biogeochemistry of Gulf of Mexico Estuaries. John Wiley and Sons.
28. Twilley, R.R., Cárdenas, W., Rivera-Monroy, V.H., Espinoza, J., Suescum, R., Armijos, M.M.' and Solórzano, L. **2000**. Ecology of the Gulf of Guayaquil and the Guayas River Estuary, pp. 245-263. IN: U. Seeliger, B.J. Kjerve (eds), Coastal Marine Ecosystems of Latin America. Springer-Verlag. New York. 360 pp.
29. Steyer, G.D., R.R. Twilley and R.C. Raynie. **2006**. An Integrated Monitoring Approach Using Multiple Reference Sites to Assess Sustainable Restoration in Coastal Louisiana. Pages 326 – 333 In Aguirre-Bravo, C., Pellicane, Patrick J., Burns, Denver P., and Draggan, Sidney (Eds.) Monitoring Science and Technology Symposium: Unifying Knowledge for Sustainability in the Western Hemisphere. 2004 September 20-24, Denver, CO. Proceedings RMRS-P-42CD, Fort Collins, CO, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 990 p.

IV. Book Reviews:

1. Twilley, R.R. **1993**. Latin American coasts. Review of the book, Coastal Plant Communities of Latin America by U. Seeliger (ed.), 1992. Academic Press. *Ecology*, 74(7): 2174-2176.
2. Twilley, R.R. **1997**. Wetlands in dry regions. Review of the book, Wetlands of South Africa, by G.I. Gowan (ed.), 1995, Department of Environmental Affairs and Tourism Pretoria. *Wetlands* 17:336-337.
3. Twilley, R.R. **1999**. From marsh to market. Review of the book, A Wetland Biography: Seasons on Louisiana's Chenier Plain, by Gay M. Gomez. University of Texas Press, Austin, 1998. Annals of Geography XX:000-000. \

V. Open File Reports

1. Rivera-Monroy, V. H., B. F. Jonsson, R.R. Twilley, O. Casas-Monroy, E. Castañeda, R. Montiel, E. Mancera, W. Troncoso, F. Daza-Monroy. 2002. Cienaga Grande de Santa Marta: a tropical coastal lagoon in a deltaic geomorphic setting. In: LOICZ/UNEP Estuarine systems of the Latin American region (Regional Workshop V) and estuarine systems of the Arctic Region: carbon, nitrogen and phosphorus fluxes. LOICZ Reports & Studies No. 23. Camacho-Ibar, V., V. Dupra, F. Wulff, S.V. Smith, J.I. Marshall Crossland, and C.J. Crossland (eds). Pages: 22-27, LOICZ IPO, Texel, The Netherlands. http://data.ecology.su.se/MNODE/South%20America/cienegagrande/cienegagrandebud.html

2. Rivera-Monroy, V. H., B. F. Jonsson, R.R. Twilley. 2002. Guayas River Estuary, Gulf of Guayaquil. In: LOICZ/UNEP Estuarine systems of the Latin American region (Regional Workshop V) and estuarine systems of the Arctic Region: carbon, nitrogen and phosphorus fluxes. LOICZ Reports & Studies No. 23. Camacho-Ibar, V., V. Dupra, F. Wulff, S.V. Smith, J.I. Marshall Crossland, and C.J. Crossland (eds). Pages: 28-33, LOICZ IPO, Texel, The Netherlands. http://data.ecology.su.se/MNODE/South%20America/guayaquil/GuayasR/GuayasRbud.htm
3. Rivera-Monroy, V.H Mancera Pineda, Twilley, R. R., and others E. 2001. "Estructura y Funcion de un Ecosistema de Manglar a lo Largo de una Trayectoria de Restauración". Final Report. Ministry of the Environment and Instituto de Investigaciones Marinas-INVEMAR,Colombia Government. Colombia.
4. Rivera-Monroy, V.H., Twilley, R.R., Castaneda, E., 2003, Hurricane Mitch: integrative management and rehabilitation of mangrove resources to develop sustainable shrimp mariculture in the Gulf of Fonseca, Honduras: USGS Open File Report 03-177, 120 p.
5. Twilley, R. R. 2003. (ed.), Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Volume I: Tasks 1-8. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2511-02-24. 319 pp.
6. Twilley, R. R. 2004. (ed.), Coastal Louisiana Ecosystem Assessment and Restoration (CLEAR) Model of Louisiana Coastal Area (LCA) Comprehensive Ecosystem Restoration Plan. Volume II: Tasks 9-15. Final Report to Department of Natural Resources, Coastal Restoration Division, Baton Rouge, LA. Contract No. 2511-02-24. 355 pp.

Research Support and Proposals:

Current and Pending

National Science Foundation/LTER Program. FCE/LTER - Florida Coastal Everglades. Subcontract with FIU. March 2000 to February 2006. $299,366

US Department of Agriculture/Environmental Protection Agency, NUMAN – Utilizing Mississippi River Diversions for Nutrient Management in a Louisiana Coastal Watershed. August 2002 through July 2005. Funded. $190,500.

Environmental Protection Agency, Use of Science in Gulf of Mexico Decision Making Involving Climate Change. October 2002 through September 2005. Funded. $375,424.

EPSCOR/EPA, Modeling Impacts of Climate Change on Wetland Ecosystems. June 2002 through June 2004. Funded. $42,186.

LA Department of Natural Resources, Conceptual Ecological Models for Planning and Evaluating the Louisiana Coastal Area Restoration Plan. R.R. Twilley, PI. June 2002 to March 2005. Funded. $1,273,469.

National Park Service. Conceptual Model Development for the National Park Service Units of the Gulf Coast Network. January 2004 to September 2004. Funded. $79,341.

NASA Earth Science Enterprise. "Large scale assessment of landscape changes and recovery in forest structure of mangrove wetlands subject to human (shrimp mariculture, silviculture, agricultural chemicals), freshwater diversion, and natural disturbances (hurricanes, other severe storms, climate and sea level change) using enhanced Shuttle Radar Topography Mission data" Victor Rivera-Monroy, PI, R.R. Twilley, Co-PI. March 2004 to March 2006. Funded. $83,474

National Park Service. "Nutrient Biogeochemistry of the Mangrove Transition Zone: I. Role of Denitrification and Tidal Exchange in Mangrove Sediments as Nutrient Sinks in Taylor and Shark River Sloughs.' V. Rivera-Monroy and R.R. Twilley. CESI Everglades Research Program, NPS. $242,813, 2004-2006, Pending

Evaluating the effect of hydroperiod and soil fertility on the productivity and structure of mangrove forests in South Florida: A Mesocosm Experiment. V. Rivera-Monroy and R.R. Twilley. South Florida Water Management District. $70,000. 2004-2005. Pending.

Funded During Last Five Years

National Science Foundation/Environmental Protection Agency, "Pulses - The Importance of Pulsed Physical Events for Watershed Sustainability in coastal Louisiana", Subcontract with LSU. February 2000 to January 2003, $124,486

Department of Natural Resources. Integrative Approach to Understanding the Causes of Salt Marsh Dieback:Coupled Hydrologic/Ecological Models of Marsh Dieback Processes (II.6). UL Component: $ 102,500. Funded

Department of Natural Resources. Integrative Approach to Understanding the Causes of Salt Marsh Dieback: Experimental Manipulations of Hydrology and Soil Biogeochemistry (Task II.2). $ 134,524. Funded

Department of Natural Resources. Synthesis and Data Management of Salt Marsh Dieback Project:Conceptualization Meeting and Literature Review (Task III.2). $ 19,997. Funded

NBS/USGS, Everglades Restoration Program, "Interfacing the MANGAL Model with the Mangrove Research and Landscape Modelling Efforts of the Everglades Watershed". Funded. Jan 2001 to December 2003. $175,000.

US Department of Energy, " Restoration and rehabilitation of wetland ecosystems to sustain energy technologies in coastal environments" June 1999 to June 2002. Funded. $999,815.

USDA Forest Service, Pacific Southwest Research Station, "Predicting the impacts of sea level rise on Micronesian mangrove forests", June 1997 to June 2002. Funded $42,500.

USGS/NWRC, "Integrative Management and Rehabilitation of Mangrove Resources to Develop Sustainable Shrimp Mariculture in the Gulf of Fonseca, Honduras", January 2000 to December 2001, PI/PD: Robert Twilley; Co-PI's: Victor Rivera-Monroy. $72,406.

COLCIENCIAS, Colombia, "Structure and Function of a Mangrove Ecosystem Along a Trajectory following landscape-Level Disturbance. March 1998 to April 2001. Funded. $135,000.

Abstracts and Presentations (last 2 years)

Krauss, K.W., T.W. Doyle, R.R. Twilley, V.H. Rivera-Monroy & J.K. Sullivan. 2005. Subsidy-stress in estuarine floodplains: evaluating hydroperiod as a growth constraint in mangroves. Estuarine Interactions, 18th Biennial Conference of the Estuarine Research Federation, October 16-21, Norfolk, VA.

Krauss, K.W., P.J. Young, J.L. Chambers, R.R. Twilley & T.W. Doyle. 2004. Whole-tree water use by mangrove forest communities in flooded and drained soils. Page 166 *in Conference Abstracts,* 7th INTECOL International Wetlands Conference, July 25-30, Utrecht, The Netherlands.

Rivera-Monroy, V.H., R.R. Twilley, E. Meselhe, E. Castañeda, K.W. Krauss, C. Coronado-Molina, D. Childers, D. Rondeau & G.D. Losada. 2004. Hydrological characteristics of mangrove forests in Shark River and Taylor Slough. FCE-LTER All-Scientists Meeting, Fairchild Tropical Gardens, March 25-26, Miami, FL.

Krauss, K.W., J.L. Chambers, P.J. Young, R.R. Twilley & T.W. Doyle. 2004. Stand-level physiological response to flooded versus drained soils in basin mangrove forests of southwest Florida. FCE-LTER All-Scientists Meeting, Fairchild Tropical Gardens, March 25-26, Miami, FL.

Rick, H.-J., **Rick, S.,** Twilley, R.R.: Pelagic and Benthic Nutrient Conversions in a Coastal Watershed Influenced by River Diversions (Caernarvon, Louisiana). Vortrag auf 6th International Biogeochemistry Symposium, Louisiana State University, Baton Rouge, LA, USA, Mai 2005.

Rick, J.J., **Rick, S**., Twilley, R.R. 2005: Nutrient dynamics related to river diversions: pelagic and benthic fluxes and phytoplankton community response. Geladener Vortrag auf Symposium Coastal Restoration and Enhancement through Science and Technology (CREST) Symposium: Progress in understanding coastal land loss and restoration in Louisiana: The W. Alton Johnes Foundation Report revisited, River Oaks, Lafayette, LA, April 2005.

Rick, J.J., **Rick, S.,** Twilley, R. 2005 : Linking pelagic and benthic nutrient conversions in a coastal watershed influenced by river diversions (Caernarvon, LA). Poster auf Symposium Coastal Restoration and Enhancement through Science and Technology (CREST): Progress in understanding coastal land loss and restoration in Louisiana: The W. Alton Johnes Foundation Report revisited, River Oaks, Lafayette, LA, April 2005.

International Collaboration/Experience:

International Conference on Environments for the Future (ICEF), Sweedish Academy of Sciences, Zurich, Sweeden, March 2003

Organizing Committee - IV International Wetlands Conference, INTECOL, September 1992.

Collaboration with Corporacion Centro De Investigacion de la Acuicultura de Colombia (CENIACUA) on environmental quality of shrimp ponds and estuaries; and the development of a mangrove biofilter for shrimp effluent. August 1997 to present.

Collaboration with Dr. Ernesto Medina on investigations of mangroves in the Orinoco Delta. Joint project with Centro de Ecologia y Ciencias Ambientales at the Instituto Venezolano de Investigaciones Cientificas (IVIC), Venezuela. To present.

Collaboration with Dr. Leonor Botero, Director of INVEMAR, and Inter-american Development Bank, concerning the rehabilitation of mangroves and estuarine resources in the Magdelena River delta/lagoon ecosystem, Santa Marta, Colombia.

Collaboration with Dr. Alejandro Yáñez-Arancibia, Director of EPOMEX program (Program in Oceanography and Fisheries of Gulf of Mexico) at the University of Campeche, Mexico, to study nitrogen cycling in mangroves and participate with EPOMEX in estuarine ecology course.

Collaboration with Dr. Lucia Solorzano of INP and Dr. Mariano Montano of ESPOL in Guayaquil, Ecuador, during 1990 and 1991 to study ecology of mangroves associated with AID funded grant.

Advisor to the Minister of Environment, INDIA, on the development of mangrove research program as part of the FREE program. May 1998.

Advisor to the Minister of Environment, Sr. Jose Mogollon, on development of mangrove research and management program for country of Colombia. March 1997 to present.

Advisor to the mangrove and coastal ecology program at the University of Sao Paulo and CETSB, Sao Paulo, from 1992 to present.

Study of benthic fluxes in San Juan Harbor and adjacent estuaries, Puerto Rico, as part of EPA water quality model.

Field trips to Belize, CA, in June 1988, 1991,1992, 1993, 1995 and 1997 as part of mangrove research funded by the Smithsonian Institution, Caribbean Coral Reef Ecosystem Program.

Invited Participant to an international workshop sponsored by the European Community, Environmental Protection Agency (EPA) and American Forestry Union on Biospheric Global Carbon Sinks, Germany, March 1993

Invited Participant to an international workshop sponsored by the Department of Energy, Environmental Protection Agency (EPA) and American Forestry Union on Biospheric Global Carbon Sinks, Puerto Rico, March 1992

Attended IUCN conference entitled "Taller internacional de Trabajo para la Elaboracion de un Manual de Evaluacion Economica de los Bienes y Servicios de los Humedales Tropicales", CATIE, Turrialba, Costa Rica. May 1991.

National Research Council/World Bank Panel on Tropical Coastal Ecology, Washington, D.C., October 1990

Organized workshop on the Ecology and Management of Mangroves in Ecuador, Sponsored by USAID and University of Rhode Island ; held at the Institute of Tropical Forestry in Rio Piedras, Puerto Rico in August 1988.

Invited to present an ecological analysis of shrimp farming in Ecuador to workshop organized by World Bank, USAID, and IDB in Guayaquil, Ecuador, August 1986.

Advisor to the Agency for International Development concerning the impacts of dam construction on the ecology of mangroves along the Gambia River, West Africa.

Academic Program

Theses: Directed

1. Gregory Steyer, M.S. **1988**. "Litter dynamics and nitrogen retranslocation in three types of mangrove forests in Rookery Bay, Florida."
2. James C. Lynch, M.S. **1989**. "Recent sedimentation and nutrient accumulation in mangroves in the Gulf of Mexico."
3. Victor Rivera-Monroy, M.S. **1988**. "Uptake and regeneration of nitrogen in Fourleague Bay, Louisiana." (LSU)
4. Heather Warner, M.S. **1990**. "Successional patterns in a mangrove forest in southwestern Florida, USA.
5. Ronald Boustany, M.S. **1991**. "Denitrification in forested wetlands in southern Louisiana".
6. Christine Miller-Way, Ph.D., **1994**. "Nitrogen cycling associated with different functional groups of benthos in Fourleague Bay". (LSU)

7. Thomas Hargis, M.S. **1994**, "Influence of hydrology on site characterization of marshes in coastal Louisiana".
8. John Bourgeois, M.S., **1994**, "Patterns of benthic nutrient fluxes on the Louisiana continental shelf".
9. Victor Rivera-Monroy, Ph.D., **1995**, "Nitrogen fluxes in mangrove sediments and their coupling with aquatic primary productivity in Terminos Lagoon, Campeche, Mexico". (LSU).
10. Washington Cardenas, M.S., **1995**, "Patterns of phytoplankton distribution related to physical and chemical characteristics of the Guayas River estuary, Ecuador".
11. Lamperelli, Claudia C., Ph.D. **1995**. "Dinamica da serapilheira em manguezais de Bertioga, regiao sudeste do Brasil". (University of Sao Paulo, Brazil)
12. Ronghua Chen, Ph.D. **1996**. "Ecological analysis and simulation models of landscape patterns in mangrove forest development and soil characteristics along the Shark River estuary, Florida".
13. John Foret, M.S. **1997**. "Accretion, sedimentation, and nutrient accumulation rates as influenced by manipulations in marsh hydrology in the Chenier Plain, Louisiana".
14. Laura Lawton, M.S., **1997**. "Canopy retranslocation and litter immobilization of nitrogen and phosphorus in three mangrove species along the Shark River estuary, Florida".
15. John Foret, Ph.D., **2001**. "Nutrient limitation of tidal marshes on the Chenier Plain, Louisiana."
16. Ernesto Mancera, Ph.D., **2003**. The contribution of mangrove outwelling to coastal food webs as a function of environmental settings.
17. Nicole Cormier, M.S., **2003**. Belowground productivity in mangrove forests of Pohnpei and Kosrae, Federated States of Micronesia
18. Edward Castaneda, M.S. **2003**. Spatial Patterns of Mangrove Forest Structure in an Arid Environmental Setting, the Gulf of Fonseca, Honduras
19. Pablo Cardona, Ph.D**. 2004**. Competitive performance of neotropical mangroves under the effects of environmental regulators.
20. Ken Krauss, Ph.D., **2004.** Growth, Physiology, and Water Economy of South Florida Mangrove Vegetation in Relation to Hydroperiod.
21. Justin Baker, M.S., **2005.** A Flume Technique to Measure Marsh Nutrient Flux in Coastal Wetlands Associated with a Mississippi River Diversion
22. Paige McMurry, M.S **2006.** Organic Matter Dynamics in Brackish Marshes of the Chenier Plain, Louisiana, USA
21. Daniel Bond, M.S., **2006.** A Modified Batch Core Technique to Measure Potential Marsh Nutrient Flux in Coastal Wetlands Associated with a Mississippi River Diversion
22. Nicole Poret, M.S., **2006.** Belowground Decomposition of Mangrove Roots in the Florida Coastal Everglades.
23. Edward Castenada, Ph.D., in progress
24. Peter Lenaker, M.S. in progress

Thesis: Committees

Matt Draud (USL), Eva Horne (USL), Teresa Biegger (USL), Vania de Silva Nunes (USL), Janet Thomas (USL), Thomas Buchanan (USL), Dan Holland (USL), Christopher Beachy (USL), Paul Baker (USL), Edward Mouton (USL), Patricia Thibodeaux (USL), Todd Zimmerman (USL), John Hook (USL), Roger Griffis (USL), Christine Richards (USL), Deborah Badgwell (USL), Sandra Lentz (USL), Sandra Pius (USL), Gabe Adams (USL), Robin Torres (USL), Troy Mallach (USL), Sergio Nates (USL), Cassie Moreau (USL), Donna Devlin (USL), Tom McGinnis (USL), Bassim Khaled (USL), Troy Barrilleaux (USL), Sharon King (USL), Robert Bourgeois (USL), Bridgette Decoteau, Joy Hunter, Julie Waits, Mark Tolbert, Leigh Anne Phillips, Donna Devlin, Billy Leonard, Clay Green, Danna Huval, Angela Burcham, Francesca Ferrara, Alaina Owens, Rebecca ChaissonMarguerite Koch (LSU), Chris Madden (LSU), Dan Childers (LSU), Karen McKee (LSU), Philippe Hensel (LSU), Martha Sutula (LSU), Pete Swarzinski (LSU), Marguerite Koch (RSMAS), Mike Maher (UT), .Carlos Molina (LSU)

Teaching:

University of Louisiana at Lafayette:

Estuarine Ecology, LSU, 2005, 2006,
Community and Ecosystem Ecology, USL, 1987-2002

Ecological Processes in Estuaries, LUMCON, 1989
Marine Ecology, USL, 1988, 1990, 1996, 1997
Principles of Ecology, USL, 1986, 1988, 1990, 1992, 1996, 1999, 2001, 2003
Wetland and Aquatic Plants, USL, 1987-2002
Statistical Ecology, USL, 1987
Coastal Vegetation, LUMCON, 1987
Limnology and Oceanography, USL, 1986.
Water Quality Methods, LUMCON, 1987
Freshman Biology, USL, 1990, 1995, 1996, 1997, 1998, 1999
Coastal Biogeochemistry, LUMCON, 1996

International Experience:

Ecology and Management of Tropical Estuaries, Institute of Ecology, Xalapa, Mexico, June 2000, July 2001
Mangrove Ecology, Institute of Oceanography, University of Sao Paulo, Brazil, 1990
Advances in Estuarine Ecology, University of Campeche, Mexico, August 1992, February 1994
Integrated Coastal Zone Management, EPOMEX and University of Campeche, Mexico, August 1996
Ecology and Management of Mangroves, University of Simon Bolivar, Caracas, Venezuela, October 1996
Tropical Coastal Ecology, CINVESTAT, Merida, MEXICO, June 1998.
OTS, Vera Cruz, Mexico, Tropical Coastal Ecology, 2003, 2004, 2007

Fotis Sotiropoulos
Professor, Department of Civil Engineering
University of Minnesota

Biographic Sketch

Fotis Sotiropoulos is professor of Civil Engineering and director of the St. Anthony Falls Laboratory at the University of Minnesota (http://www.safl.umn.edu/) since January 2006. He received his diploma in Mechanical Engineering from the National Technical University of Athens in 1986, a MS in Aerospace Engineering from The Penn State University in 1989, and a PhD in Aerospace Engineering from the University of Cincinnati in 1991. In 1991 he joined the Iowa Institute of Hydraulic Research at the University of Iowa as a post-doctoral researcher. In 1995 he joined the faculty of the Georgia Institute of Technology (School of Civil and Environmental Engineering) where he became Professor in 2005. Since 2002, he held a joint faculty appointment with the G. W. Woodruff School of Mechanical Engineering and served as an associate member of the Georgia Tech Center for Non-Linear Sciences.

Professor Sotiropoulos' research is aimed at developing computational and experimental techniques for studying problems that reside at the intersections of fluid mechanics with various disciplines in engineering, bioengineering, and biology. His ongoing work focuses on: the simulation of real-life engineering flows with coherent-structure resolving turbulence models; environmental hydraulics and stream restoration; the fluid mechanics of plankton and aquatic swimming; transport and mixing in chaotically advected flows; renewable energy generation systems; buoyancy dominated flows; mechanical and bio-prosthetic heart valve hemodynamics; and the hemodynamics of Fontan surgeries.

He is a recipient of a NSF Career award (1999) and has also been selected twice by the National Academy of Engineers to participate in Frontiers of Engineering symposia (2002 and 2005). He is serving as an associate editor for the ASCE Journal of Hydraulic Engineering and is on the editorial board of the International Journal of Heat and Fluid Flow.

FOTIS SOTIROPOULOS

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I. EARNED DEGREES

Ph.D. 1991	University of Cincinnati	Aerospace Engineering
MS 1989	The Penn State University	Aerospace Engineering
BS 1986	National Tech. Univ. of Athens, Greece	Mechanical Engineering

II. EMPLOYMENT

2006 – present	Graduate faculty appointment	ME, University of Minnesota
2006 – present	Director	Saint Anthony Falls Laboratory, University of Minnesota
2006 – present	Professor	CE, University of Minnesota
2005	Professor	CEE/ME, Georgia Inst. Technology
2002-2005	Associate Professor (joint appointment)	ME, Georgia Inst. Technology
2000-2005	Associate Professor (with tenure)	CEE, Georgia Inst. Technology
1995-2000	Assistant Professor	CEE, Georgia Inst. Technology
1994-1995	Assistant Research Scientist	Iowa Institute of Hydraulic Research The University of Iowa
1991-1994	Postdoctoral Associate	Iowa Institute of Hydraulic Research The University of Iowa

III. ADVISING AND TEACHING

A. INDIVIDUAL STUDENT GUIDANCE

Post Doctoral Fellows

Current

Liang Ge
Starting Semester: Winter 2005
Research: Numerical Simulation of Complex Unsteady Flows in Hydraulics and Cardiovascular Fluid Mechanics

Joongcheol Paik
Starting Semester: Spring 2001
Research: Hybrid URANS/LES Modeling of Complex Turbulent Shear Flows

Past

Chang Wang (Co-supervisor with Ajit Yoganathan).
Starting Semester: Winter 2004
Completion: Fall 2005
Research: Computational Modeling of Cardiovascular Flows; Modeling Transition to Turbulence in Pulsatile Flows.

Anvar Gilmanov
Starting Semester: Winter 2002
Completion: Summer 2005
Research: Numerical Simulation of Fluid/Structure Interaction in Biofluids Applications
Current position: Senior Research Associate, Center for Computation & Technology, Louisiana State University.

S. Casey Jones
Starting Semester: Spring 2000
Completion: Summer 2003
Research: Computational Modeling of Environmental Flows; LES of free shear flows; Parallel Computing.
Current position: Independent consultant.

Yiannis Ventikos
Starting Semester: Spring 1996
Completion: Winter 1999
Research: Computational studies of swirling flows; Chaotic advection; RANS modeling of hydropower flows
Current position: Lecturer, Department of Engineering Science, Oxford University.

Ph.D. Students

Graduated (at Georgia Tech)

Tahirih C. Lackey
Starting Semester: Fall 1999
*Completio*n: Fall 2004
Thesis title: Numerical Investigation of Chaotic Advection in Three-Dimensional Experimentally Realizable Rotating Flows
Current position: Research Engineer, Waterways Experiment Station, USACOE, Vicksburg, MS.

Liang Ge
Starting Semester: Fall 2000
*Completi*on: Fall 2004
Thesis title: Numerical Simulation of 3D, Complex, Turbulent Flows with Unsteady Coherent Structures: From Hydraulics to Cardiovascular Fluid Mechanics[1]
Current position: Post-doctoral Associate, SAFL, University of Minnesota.

Hansong Tang
Starting Semester: Spring 1998
Completion: Fall 2001
Thesis: Numerical Simulation of 3D Unsteady Incompressible Flows in Complex Geometries
Current position: Senior Research Engineer, Battelle Seattle Research Center, Seattle, WA.

S. Casey Jones (Co-advisor with A. Amirtharajah)
Starting Semester: Fall 1995
Completion: Fall 1999
Thesis: Static Mixers in Water Treatment: A Computational Fluid Dynamics Model[2]
Current position: Independent Consultant, Atlanta, GA.

Graduated (at the Iowa Institute of Hydraulic Research, Univ. of Iowa)

V. Neary (Co-advisor with A. J. Odgaard)
Starting Semester: Fall 1992
Completion: Fall 1995
Research: Numerical Modeling of Diversion Flows
Current Position: Associate Professor with Tenure, Tennessee Institute of Technology

S. K. Sinha (Co-advisor with A. J. Odgaard)
Starting Semester: Fall 1992
Completion: Spring 1995
Research: 3-D Numerical Model for Turbulent Flows through Natural River Reaches
Current Position: Senior Consulting Engineer, Environmental Consulting & Technology, Inc. Detroit, MI.

[1] Thesis awarded the 2005 Sigma-Xi Best PhD Thesis Award, Georgia Institute of Technology.
[2] Thesis awarded the 2001 American Water Works Association Academic Achievement Award.

F. B. Lin (Co-advisor with A. J. Odgaard and V. C. Patel)
Starting semester: Fall 1992
Completion: Spring 1996
Research: Development of a Numerical Method for 3-D Incompressible Flow with Multigrid Acceleration and Near-Wall Turbulence Closures
Current Position: Senior Hydraulic Engineer, Alden Research Laboratory, Holden, MA.

In Progress

Trung Le
Starting semester: Fall 2006
Research: Numerical simulation of plankton flows
Department of Civil Engineering, University of Minnesota

Iman Boranzani
Starting semester: Fall 2003
Research: Numerical Simulation of Fluid Structure Interaction Problems in Biological Flows.
Passed Ph.D. qualifying exam
Department of Mechanical Engineering, University of Minnesota

Cristian Escauriaza
Starting semester: Fall 2002
Research: Numerical Modeling of Sediment Transport and Scour Processes in Bridge Foundations
Passed Ph.D. qualifying exam
Department of Civil Engineering, University of Minnesota

Helen Simon (Co-advisor with A. Yoganathan)
Starting semester: Spring 2004
Research: Computational and Experimental Modeling of Hemodynamics in the Hinge Region of Mechanical Prosthetic Heart Valves.
Passed Ph.D. qualifying exam
School of Chemical Engineering, Georgia Tech

MS Students

Kevin Stewart
Starting Semester: Spring 2001; Completion: Summer 2002
Research: Numerical Simulation of Selective Withdrawal in Stably Stratified Flows
Current Position: Research Engineer, Tennessee Valley Authority, Norris, TN.

Undergraduate Research Students

Nicolas Posada	The fluid mechanics of fish swimming, Fall 2002 to Fall 2003
Todd Taylor	Experiments in confined swirling flows, Fall 1998
Joe Reynolds,	3-D Particle Tracking Algorithms, Fall 1996

B. CLASSROOM INSTRUCTION

A. Classroom Instruction (1995 – present)

Undergraduate Teaching

Quarter/Semester	Course number	Course Title	Class Size	Number of respondents	Teaching effectiveness (Max = 5.0)
Fall 1996	CE3053	Fluid Mechanics I	60	36	4.3
Winter 1997	CE3053	Fluid Mechanics I	64	38	4.4
Fall 1997	CE3053	Fluid Mechanics I	50	40	4.0
Winter 1998	CE3063	Fluid Mechanics II	53	37	4.0
Spring 1998	CE3063	Fluid Mechanics II	47	34	4.0
Fall 1998	CE3063	Fluid Mechanics II	57	46	4.0
Winter 1999	CE3053	Fluid Mechanics I	76	48	4.3
Spring 1999	CE3053	Fluid Mechanics I	47	20	4.0
Fall 1999 (Sem.)	CE3040	Fluid Mechanics	48	25	4.0
Spring 2000	CE3040	Fluid Mechanics	47	18	4.1
Fall 2001	CE3040	Fluid Mechanics	51	26	3.8
Spring 2002	CE3040	Fluid Mechanics	39	11	4.0
Spring 2003	CE3040	Fluid Mechanics	42	17	4.3
Fall 2003	CE3040	Fluid Mechanics	57	17	3.6
Spring 2004	CE3040	Fluid Mechanics	52	27	4.0

Graduate Teaching

Quarter/Semester	Course number	Course Title	Class Size	Number of respondents	Teaching effectiveness (Max = 5.0)
Winter 1996	CE8113A	Comp. Fluid Dyn. I	10	5	4.3
Spring 1996	CE8113B	Comp. Fluid Dyn. II	4	-	-
Winter 1997	CE8113A	Comp. Fluid Dyn. I	7	7	5.0
Spring 1997	CE8113B	Comp. Fluid Dyn. II	5	-	-
Winter 1998	CE8113A	Comp. Fluid Dyn. I	6	-	-
Spring 1998	CE8113B	Comp. Fluid Dyn. II	7	7	5.0
Winter 1999	CE8113A	Comp. Fluid Dyn. I	6	-	-
Spring 1999	CE8113B	Comp. Fluid Dyn. II	5	-	-
Fall 2000 (Sem.)	CE6251	Interm. Fluid Mech.	6	5	2.5
Spring 2000	CE/ME 8802	Comp. Fluid Dyn.	7	5	4.0
Spring 2002	CE 8802C	Turb. Mod. For CFD	7	5	4.0
Fall 2002	CE6251	Interm. Fluid Mech.	8	6	4.7
Spring 2003	CE/ME 7751	Comp. Fluid Dyn.	10	5	5.0
Spring 2004	CE/ME 7751	Comp. Fluid Dyn.	10	5	4.7
Fall 2004	CE6251	Interm. Fluid Mech.	7	6	4.9

<u>Continuing Education Courses</u>

"*CFD Modeling of Complex Turbulent Flows*," Georgia Tech Continuing Education, Atlanta, GA, May 7 – 9, 2001.

"*Fundamentals of Turbulence Modeling for Engineering Flows*," US Army Corps of Engineers, Waterways Experimental Station, Vicksburg, Mississippi, Nov. 12-13, 1998.

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IV. SCHOLARLY ACCOMPLISHMENTS

A. BOOKS CHAPTERS

1. Sotiropoulos, F., "Experimental Visualization of Lagrangian Coherent structures Using Lagrangian Averaging," in proceedings of the International Center for Mechanical Science (CISM) short course on "*Analysis and Control of Mixing with Application to Micro and Macro Flow Processes*" held in Udine (Italy), June 27-July 1, 2005. To be published by Springer Verlag (2007).

2. Sotiropoulos, F., "Turbulence Modeling for Environmental Flows," in *Computational Fluid Mechanics: Applications in Environmental Hydraulics*, John Willey, 2005.

3. Sotiropoulos, F., "Progress in Modeling 3-D Shear Flows Using RANS Equations and Advanced Turbulence Closures," Chapter 6 in *Calculation of Complex Turbulent Flows*, *Advances in Fluid Mechanics Series*, WIT Press, Southampton, UK (2000), pp. 209-248.

B. REFEREED PUBLICATIONS

Articles in refereed archival journals

Submitted

1. Eghbalzadeh A., Paik, J., Javan, M., Sotiropoulos, F., Namin M., S. Ali Akbar Salehi N, "URANS Simulation of 2D Continuous and Discontinuous Gravity Currents," submitted to the *ASCE J. Hydr. Eng.* (2007).

Accepted (in press)

2. Ge, L., and Sotiropoulos, F., "A Numerical method for Solving the 3D Unsteady Incompressible Navier-Stokes Equations in Curvilinear Domains with Complex Immersed Boundaries," in press, *J. Comp. Physics* 2007.

3. Paik, J., Escauriaza C., and Sotiropoulos, F. "On the bi-modal dynamics of the turbulent horseshoe vortex system in a wing-body junction," in press, *Physics of Fluids* (2007).

4. Dasi, L. P., Simon, H. A., Sotiropoulos, F., and Yoganathan, A. P. "Vorticity Dynamics of a Bileaflet Mechanical Heart Valve," in press, *Physics of Fluids (*2007).

5. Tang, H., and Sotiropoulos, F. "Fractional Step Artificial Compressibility Method for the Incompressible Navier-Stokes Equations," in press, *Computers and Fluids (*2007).

Published

6. Lackey, T., and Sotiropoulos, F., "The Relationship between Stirring Rate and Reynolds Number in the Chaotically Advected Steady Flow in a Container with Exactly Counter-Rotating Lids," *Physics of*

Fluids, 18 (5): Art. No. 053601 MAY 2006

7. Paik, J., Sotiropoulos, F., "Coherent structure dynamics upstream of a long rectangular block at the side of a large aspect ratio channel," *Physics of Fluids*, 17 (11), 2005.

8. Yoganathan, A. P., Chandran, K. B., and Sotiropoulos, F., "Flow in Prosthetic Heart Valves: State-of-the-Art and Future Directions," *Annals of Biomedical Engineering* 33 (12): 1689-1694, 2005.

9. Ge, L., Huang, L., Sotiropoulos, F., and Yoganathan, A., "Flow in a mechanical bileaflet heart valve at laminar and near-peak systole flow rates: CFD simulations and experiments," *ASME Journal of Biomechanical Engineering*, 127 (5): 782-797, 2005.

10. Ge, L., and Sotiropoulos, F., "3D Unsteady RANS Modeling of Complex Hydraulic Engineering Flows. Part I: Numerical Model," *ASCE Journal of Hydraulic Engineering* 131 (9): 800-808, 2005.

11. Ge, L., Lee, S, Sotiropoulos, F., and Sturm, T. W., "3D Unsteady RANS Modeling of Complex Hydraulic Engineering Flows. Part II: Model Validation and Flow Physics," *ASCE Journal of Hydraulic Engineering* 131 (9): 809-820, 2005.

12. Gilmanov, A., and Sotiropoulos, F. "A Hybrid Cartesian/Immersed Boundary Method for Simulating Flows with 3D Geometrically Complex Moving Bodies," *Journal of Computational Physics* 207 (2): 457-492, 2005.

13. Pekkan, K., de Zelicourt, Ge, L., Sotiropoulos, Frakes, D., F., Fogel, M., Yoganathan, A. P., "Physics-Driven CFD Modeling of Complex Anatomical Flows: A TCPC Case Study," *Annals of Biomedical Engineering* 33 (3): 284-300, 2005.

14. Paik, J., Sotiropoulos, F., and Sale, M. J., "Numerical Simulation of Swirling Flow in a Complex Hydro-Turbine Draft Tube Using Unsteady Statistical Turbulence Models," *ASCE Journal of Hydraulic Engineering* 131 (6): 441-456 2005.

15. Lackey, T. C., and Sotiropoulos, F. "Role of artificial dissipation scaling and multigrid acceleration in numerical solutions of the depth-averaged free-surface flow equations," *ASCE Journal of Hydraulic Engineering* 131 (6): 476-487, 2005.

16. Paik, J., Ge, L., and Sotiropoulos, F. "Recent Progress in Simulating Complex 3D Shear Flows Using Unsteady Statistical Turbulence Models," invited paper, *Int. Journal of Heat and Fluid Flow*, 25 (3): 513-527 2004.

17. Ge, L., Jones, S. C., Sotiropoulos, F., Healy, T., and Yoganathan, A. "Numerical Simulation of Flow in Mechanical Heart Valves: Grid Resolution and Flow Symmetry," *ASME Journal of Biomechanical Engineering*, 125 (5): 709-718, 2003.

18. Gilmanov, A., Sotiropoulos, F., and Balaras, E. "A General Reconstruction Algorithm for Simulating Flows with Complex 3D Immersed Boundaries on Cartesian Grids," *Journal of Computational Physics*, 191(2), 660-669, 2003.

19. Tang, H., Jones, S. C., and Sotiropoulos, F., "An Overset Grid Method for 3D, Unsteady, Incompressible Flows," *Journal of Computational Physics*, 191(2), 567-600 2003.

20. Meselhe, E., Sotiropoulos, F., "Three-dimensional numerical model for open-channels with free-surface variations*," IAHR Journal of Hydraulic Research*, 41 (1): 110-111 2003.

21. Chrisohoides, A., and Sotiropoulos, F. "Experimental Visualization of Lagrangian Coherent Structures in Aperiodic Flows, *Physics of Fluids* 15(3), 25-28, 2003.

22. Chrisohoides, A., Sotiropoulos, F., and Sturm, T. W. "Coherent Structures in Flat-Bed Bridge Abutment Flows: Experiments and CFD simulations," *ASCE Journal of Hydraulic Engineering* Vol. 129(3), pp. 171-249, 2003.

23. Sotiropoulos, F., Webster, D. R., and Lackey, T. C. "Experiments on Lagrangian Transport in Steady Vortex Breakdown Bubbles in a Confined Swirling Flow," *Journal of Fluid Mechanics,* 466 , 215 – 248, 2002.

24. Mezić, I., and Sotiropoulos, F., "Ergodic Theory and Experimental Visualization of Invariant Sets in Chaotically Advected Flows," *Physics of Fluids* 14(7), 2235-2243, 2002.

25. Jones, C. S., Sotiropoulos, F., and Amirtharajah, A., "Numerical Modeling of Helical static Mixers in Water Treatment," *ASCE Journal of Environmental Engineering*, Vol. 128(5), 431-440, 2002.

26. Sotiropoulos, F., Ventikos, Y., and Lackey, T. C. "Chaotic Advection is Stationary Vortex Breakdown Bubbles: Silnikov's Chaos and the Devil's Staircase," *Journal of Fluid Mechanics,* 444, 257-297, 2001.

27. Sotiropoulos, F., and Ventikos, Y., The Three-Dimensional Structure of Confined Swirling Flows with Vortex Breakdown, *Journal of Fluid Mechanics* , 426, 155 - 175 2001.

28. Sotiropoulos, F., and Wei, C. Y., "New Task Committee on Advanced Environmental-Hydraulics Modeling**,"** *ASCE Journal of Hydraulic Engineering***,** 127(1), pp. 3-4, 2001.

29. Meselhe, E., and Sotiropoulos, F., Three-Dimensional Numerical Model With Deformable Free-Surface For Open-Channels, *IAHR Journal of Hydraulic Research* 38 (2), 2000.

30. Tang, H. S., and Sotiropoulos, F., "A Second-Order Godunov Method for Wave Problems in Coupled Solid-Water-Gas Systems," *Journal of Computational Physics* 151, pp. 1-26, 1999.

31. Fisher, R. K., Franke, G. F., March, P. A., Mathur, D., and Sotiropoulos, F., "Increasing Fish Survival Prospects at Hydro Plants," *The Intern. J. of Hydropower & Dams* 5, 77-82 (1999).

32. Neary, V. S., Sotiropoulos, F., and Odgaard, A. J., "Three-Dimensional Numerical Model of lateral-Intake Flows," *ASCE Journal of Hydraulic Engineering* 125(2), pp. 126-140, 1999.

33. Sotiropoulos, F., and Ventikos, Y., "Transition from Bubble Vortex Breakdown to a Columnar Vortex in a Closed Cylinder with a Rotating Lid," invited paper, *International Journal of Heat and Fluid Flow* 19, pp. 446-458 (1998).

34. Sotiropoulos, F., Ventikos Y., "Prediction of Flow through a 90 Deg Bend Using Linear and Non-Linear Two-Equation Models," *AIAA Journal* 36(7), pp. 1256-1262, 1998.

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35. Sinha, S. K., Sotiropoulos, F., and Odgaard, A. J., "Three-Dimensional Numerical Model For Flow Through Natural Rivers," *ASCE Journal of Hydraulic Engineering*, 124, No. 1, 13-24, 1998.

36. Meselhe, E., Sotiropoulos, F., and Holly, F. M., "Numerical Simulation of One-Dimensional, Transcritical Open-Channel Flow " *ASCE Journal of Hydraulic Engineering*, 774-783, Sept. 1997.

37. Sotiropoulos, F., Constantinescu, G. "Pressure-Based Residual Smoothing Operators for Multistage Pseudo Compressibility Algorithms," *J. Comput. Physics* 133, 129-145, 1997.

38. Lin, F., Sotiropoulos, F., "Strongly-Coupled Multigrid method for 3-D Incompressible Flows Using Near-Wall Turbulence Closures," *ASME J. Fluids Eng.* 119, 331-340, 1997.

39. Lin, F., Sotiropoulos, F., "Assessment of Artificial Dissipation Models for Three-Dimensional, Incompressible Flow Solutions," *ASME J. Fluids Eng.* 119, 314-324, 1997.

40. Patel, V. C., Sotiropoulos, F., "Longitudinal Curvature Effects in Turbulent Boundary Layers," *Progress in Aerospace Science* 33, 1-70, 1997.

41. Sotiropoulos, F., Patel, V. C., "On the Role of Turbulence Anisotropy and Near-Wall Modeling in Predicting Complex, 3D, Shear Flows," *AIAA Journal*, 33, No. 3, pp.504-514, 1995.

42. Neary, V. S., Sotiropoulos, F., "Numerical Investigation of Laminar Flow through 90-Degree Diversions of Rectangular Cross-Section," *Computers and Fluids* 25 (2), pp. 95-118, 1995.

43. Sotiropoulos, F., Patel, V. C., "Application of Reynolds-Stress Transport Models to Stern and Wake Flows," *Journal of Ship Research*, Vol. 39, No. 4, pp. 263-283, 1995.

44. Sotiropoulos, F., Patel, V. C., "Prediction Of Turbulent Flow Through A Transition Duct Using a Second-Moment Closure," *AIAA Journal*, 32, No. 11, pp. 2194-2204, 1994.

45. Sotiropoulos, F., Kim, W. J. and Patel, V. C., "A Computational Comparison of Two Incompressible Navier-Stokes Solvers In Three-Dimensional Laminar Flows," *Computers and Fluids*, 23, No. 4, pp. 627-646, 1994.

46. Sotiropoulos, F., and Abdallah, S., "A Primitive Variable Method For The Solution Of External, 3-D, Incompressible, Viscous Flows," *Journal of Computational Physics*, 103, 336-349, 1992.

47. Sotiropoulos, F., and Abdallah, S., "The Discrete Continuity Equation In Primitive Variable Solutions Of Incompressible Flow," *Journal of Computational Physics*, 95, 212-227, 1991.

48. Sotiropoulos, F., and Abdallah, S., "Coupled Fully Implicit Solution Procedure for the Steady Incompressible Navier-Stokes Equations," *Journal of Computational Physics*, 87 (2), 328-348, 1990.

Book Reviews in Archival Journals

1. Sotiropoulos, F., Review for **Statistical Theory and Modeling for Turbulent Flows**, by P. Durbin and B. A. Pettersson (Wiley), *AIAA Journal* 39(9), pp. 1829-1830, 2001.

2. Sotiropoulos, F., Review for **Turbulence Modeling for CFD***,* 2nd edition, by D. C. Wilcox (DCW industries), *AIAA Journal* 37(9), p. 1140, 1999.

3. Sotiropoulos, F., Review for **Fundamentals of Turbulence Modeling**, by C. J. Chen, and S. Y. Jaw (Taylor & Francis), *AIAA Journal* 37 (1), 1999.

C. OTHER PUBLICATIONS

<u>**Conference Proceedings**</u>

1. Paik, J., Sotiropoulos, F., Smith, R. T., and Sale, M. J., "Recent Advancements in Unsteady Computational Modeling of Hydro Turbine Flows," proceedings of HYDRO 2006, Porto Carras, Greece, 25-27 September, 2006.

2. Paik, J., Escauriaza, C. and Sotiropoulos, F. "Simulation of complex hydraulic engineering flows with coherent structure resolving turbulence models." Proceedings of 7th International Conference on Hydroscience and Engineering, Philadelphia, USA September 10-13, 2006.

3. Paik, J., Escauriaza, C. and Sotiropoulos, F. "Simulation of junction flows with coherent structure resolving turbulence models." Proceedings of 2nd International Conference 'From Scientific Computing To Computational Engineering, Athens, Greece, July 5-8, 2006.

4. Paik, J. and Sotiropoulos, F., "Detached-eddy simulation of the horseshoe vortex system." Wither Turbulence Prediction and Control. Seoul, Korea, March 26-29, 2006.

5. Paik, J., and Sotiropoulos, F., "Coherent vortex shedding in turbulent flow past a long surface-piercing block at the side of a shallow open channel," *4th Conference on Bluff Body Wakes and Vortex-Induced Vibrations*, Santorini island, Greece, June 2005.

6. Gilmanov, A., and Sotiropoulos, F., "Sharp-Interface Cartesian Method for Simulating Flow Past 3D Flexible Bodies," IASME/WSEAS International Conference on FLUID MECHANICS, Corfu Island, Greece, August 17-19, 2004.

7. L. Ge, H. L. Leo, J. Carberrie, F. Sotiropoulos, & A. Yoganathan, "Computational and Experimental Investigation of Flow in a Bileaflet Heart Valve with Leaflets in the Open Position," IASME/WSEAS International Conference on FLUID MECHANICS, Corfu Island, Greece, August 17-19, 2004.

8. Yang, J., Khangaonkar, T., Paik, J., Sotiropoulos, F., and Marshall, K., "Simulation of Hydrodynamics at stratified reservoirs using a staged modeling approach." WSEAS/IASNE International Conference on Fluid Mechanics. Corfu, Greece, August 17-19, 2004.

9. Paik, J., Sotiropoulos, F., and Sale, M. J., "Numerical Simulation of Flow in a Hydroturbine Draft Tube Using Unsteady Statistical Turbulence Models," *22nd IAHR Symposium on Hydraulic Machinery and Systems,* June 29 – July 2, 2004 Stockholm, Sweden.

10. Paik, J., Ge, L., and Sotiropoulos, F., "Recent Advances In The Numerical Simulation Of Hydraulic Engineering Flows With Unsteady Statistical Turbulence Models," *6th Int. Conf. on Hydroscience and Engineering (ICHE-2004),* May 30-June 3, 2004, Brisbane, Australia.

11. Paik, J., Jones, S. C., and Sotiropoulos, F., "DES and URANS of a Turbulent Boundary Layer on a Concave Wall," *3rd International Symposium on Turbulent and Shear Flow Phenomena*, Sendai, Japan, June 2003 Vol. 1, pp. 443-448.

12. Ge, L., Paik, J., Jones, S. C., and Sotiropoulos, F., "Unsteady RANS of Complex 3D Flows Using Overset Grids," *3rd International Symposium on Turbulent and Shear Flow Phenomena*, Sendai, Japan, June 2003, Vol. 1, pp. 63-68.

13. Gilmanov, A., and Sotiropoulos, F., "Numerical Simulation of Aquatic Locomotion on Cartesian Grids," *2nd MIT Conference of Computational Fluid and Solid Mechanics*, June 2003, Vol. 2, pp. 1694-1697.

14. Ge, L., Jones, S. C., Sotiropoulos, F., Healy, T., and Yoganathan, A. P., "Three-Dimensional Numerical Simulation of Flow in a Bileaflet Mechanical Heart Valve Using Overset Grids," *2nd MIT Conference of Computational Fluid and Solid Mechanics*, June 2003, Vol. 2, pp. 1690-1693.

15. Jones, S. C., Gilmanov, A., Paik, J., and Sotiropoulos, F., "Modeling Fish Passage Through Hydropower Facilities," to appear in the proceedings of *Bioengineering IV*, American Fisheries Society Annual Meeting, Baltimore, Maryland, August 2002 (the final proceedings are still in press).

16. Sotiropoulos, F., Lackey, T. C., and Jones, S. C., "Experimental and Computational Studies of Chaotic Stirring in Complex 3D Flows," 2002 ASME Fluids Engineering Summer Conference, Montreal, Quebec, July 2002. FED v. 257, n 1 B, 2002, pp. 1493-1500.

17. Sotiropoulos, F., Mezić, I., and Webster, D. R., "A Non-Intrusive Experimental Technique for Constructing Poincaré Maps in 3D Chaotically Advected Flows,“ 2001 ASME Congress, November 11-16, 2001, New York, NY. FED, v 256, 2001, pp. 61-68.

18. Sotiropoulos, F., Lackey, T. C., "The Lagrangian Dynamics of Steady Vortex Breakdown Bubbles, " 2001 ASME Congress, November 11-16, 2001, New York, NY., FED v256, 2001, pp. 9-16.

19. Chrisohoides, A. and Sotiropoulos, F., "Experimental Visualization of Lagrangian Coherent Structures in Aperiodic Free-Surface Flows ",2001 ASME Congress, November 11-16, 2001, New York, NY. FED, v256, 2001, pp. 69-77.

20. Jones, S. C., Amirtharajah, A., Sotiropoulos, F., and Skeins, B. M. "Using Static Mixers to Mix Coagulants: CFD Modeling and Pilot-Plant Enhancement," proc. of the 9th International Gothenburg Symposium on Chemical Treatment, Istanbul, Turkey, October 2000, CD-ROM proceedings.

21. Jones, S. C., Sotiropoulos, F., and Amirtharajah, A. "Numerical Modeling of Static Mixer Flows for Environmental Applications," proc. of the Protection and Restoration of the Environment V International Conference, Thassos, Greece, July 2000, vol. 1, pp. 339-346.

22. Sotiropoulos, F., and Ventikos, Y. "Three-Dimensional Steady Vortex Breakdown in Laboratory Models of Confined Swirling Flows," FEDSM2000-11203, 2000 ASME Fluids Engineering Summer Conference, Boston, Massachusetts, June 2000 (CD-ROM proceedings).

23. Sotiropoulos, F., and Ventikos, Y. "Coherent Structures in the Near-Field of Rectangular Jets," FEDSM2000-11205, 2000 ASME Fluids Engineering Summer Conference, Boston, Massachusetts, June 2000 (CD-ROM proceedings).

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24. Sotiropoulos, F., Ventikos, Y., and Webster. D. "Stewartson Layer Instabilities in a Cylindrical Container with a Rotating Lid: Numerical Simulations and Experiments," proc. of the *1st Turbulent and Shear Flow Phenomena* meeting, Santa Barbara, CA, September 1999, pp. 601-606.

25. Sotiropoulos, F., "On the Role of Turbulence Modeling in Predictions of Complex Hydraulic Engineering Flows," proc. of the *1999 ASCE Int. Water Resources Engineering Conf.*, Seattle, WA, August 1999 (CD-ROM proceedings).

26. Sotiropoulos, F., Chrisohoides, A., and Sturm, T. "Prediction of Bridge-Abutment Flows Using Advanced Turbulence Models," proc. of the *1999 ASCE Int. Water Resources Engineering Conf.*, Seattle, WA, August 1999 (CD-ROM proceedings).

27. Ventikos, Y., Sotiropoulos, F., Fisher, R. K., March, P., and Hopping, P. "A CFD-Based Framework for Environmentally Friendly Hydroturbines," proc. of *Waterpower 99*, Las Vegas, NV, July 1999. ASCE v101, pp. 45-54.

28. Fisher, R. K., March, P., Mathur, D., Sotiropoulos, F., and Franke, G. "Innovative Technologies Brighten Hydro's Future," proc. of the *XIX IAHR Symposium on Hydraulic Machinery and Cavitation*, Singapore, Sept. 1998, World Scientific, pp. 2 -18.

29. Ventikos, Y., Sotiropoulos, F., March, P., and Hopping, P. "A Lagrangian-Eulerian Method for Estimating Dissolved Oxygen Transfer in Autoventing Hydro Turbine Draft Tubes," proc. of the *4th ECCOMAS Computational Fluid Dynamics Conference*, Athens, Greece, Sept. 1998, Vol. 1, pp. 431-436.

30. Sotiropoulos, F., and Ventikos, Y., "Transition to 3-D Vortex Breakdown in a Closed Cylinder with a Rotating Lid," Proc. of *11th. Int. Conf. on Turbulent Shear Flows*, Vol. 3, Grenoble, France, Sept. 1997, Vol. 3, session 34, pp. 24-29.

31. Sotiropoulos, F., and Ventikos, Y., "A 3-D Numerical Method for Simulating Unsteady Vortex Breakdown in Confined Flows," *1997 ASME Fluids Engineering Division Summer Meeting,* Paper FEDSM97-3671, Vancouver, Canada, 1997, vol. 7, Unsteady Flows, pp. 7-12.

32. Sotiropoulos, F., Constantinescu, G. "Pressure-Based Preconditioner for Multistage Artificial Compressibility Methods," proc. of *1996 ASME FED Summer Meeting*, FED-Vol. 238, pp. 173- 180, San Diego, California, June 1997.

33. Ventikos, Y., Sotiropoulos, F., and Fisher, R.K. Jr. "Predicting Fish Passage Through Hydropower Installations," *Water-Power 97*, Atlanta, Georgia, Vol. 3, pp. 1729-1736, 1997.

34. Ventikos, I., Sotiropoulos, F., and Patel, V. C. "Prediction of Turbulent Flow through a Hydroturbine Draft-Tubes Using a Near-Wall Turbulence Closure," Proc. of *XVII IIAHR Symp. on Hydraulic Machinery and Cavitation* (Cabrera, Espert, Martinez, Eds.), vol. I, pp. 140-149, 1996.

35. Sotiropoulos, F., and Ventikos, Y., "Assessment Of Some Non-Linear Two-Equation Turbulence Models For Flows Through Curved Ducts And Pipes," Flow Modeling and Turbulence Measurements VI, pp. 331-338, Balkema, Rotterdam (proc. Of *6th Int. Symp. on Flow Modelling and Turbulence Measurements*, Tallahassee, Florida, C. J. Chen et al. (Eds.), 1996, pp. 331-338.

36. Sinha, S. K., Sotiropoulos, F., and Odgaard, A. J., “Three-Dimensional Numerical Model Of Turbulent Flow Through Natural Rivers Of Complex Bathymetry,” Flow Modeling and Turbulence Measurements VI, pp. 573-579, Balkema, Rotterdam (proc. of *6th Int. Symp. on Flow Modelling and Turbulence Measurements*, Tallahassee, Florida, C. J. Chen et al.(Eds.), 1996, pp. 573-580.

37. Sinha, S. K., Sotiropoulos, F., and Odgaard, A. J., "A Multiblock Numerical Model for Natural Rivers," *Water-Power 95*, ASCE Int. Conf. and Exposition on Hydropower, San Francisco, California. Vol. 2, pp. 2325-2334, 1995.

38. Meselhe, E., Sotiropoulos, F. and Patel, V. C., "Three-Dimensional Numerical Model for Open Channels," *Water-Power 95*, ASCE Int. Conf. & Exposition on Hydropower, San Francisco, California, Vol. 2, pp. 2315-2324, 1995.

39. Neary, V. S., Sotiropoulos, F., and Odgaard, A. J., "Predicting 3-D Flows at Lateral Water Intakes," *Water-Power 95*, ASCE Int. Conf. And Exposition on Hydropower, San Francisco, California, Vol. 2, pp. 2305-2314, 1995.

40. Meselhe, E., Sotiropoulos, F., and Holly, F. M., "Numerical Simulation of One-Dimensional, Transcritical Open-Channel Flow," proceedings of the *1994 ASCE Hydraulic Conference*, Buffalo, New York, 1994, pp. 512-516.

41. Sotiropoulos, F., and Patel, V. C. "Evaluation of some Near-Wall Models for the Reynolds Transport Equations in a Complex 3-D Shear Flow," *Near-Wall Turbulent Flows*, Elsevier (R. M. C. So, C. G. Speziale, B. E. Launder, Eds), 1993, pp. 987-997.

42. Sotiropoulos, F., and Patel, V. C. "Numerical Calculation Of Turbulent Flow Through A Circular-To Rectangular Transition Duct Using Advanced Turbulence Closures," *AIAA 24th Fluids Dynamics Conference*, Orlando, Florida (AIAA 93-3090), July 6-9, 1993.

<u>National and International Workshop Proceedings</u>

1. Ge, L. Pekkan, P., Leo, H. L., de Zelicourt, D., Sotiropoulos, F., & Yoganathan, A., “Computational Fluid Dynamics Modeling Of Complex Cardiovascular Flows: Integrating High Resolution CFD & Experimental Techniques,” *NSF/NIH Workshop on Transport Processes in Biomedical Systems*, Bethesda, MA, May 6-7, 2004.

2. Ge, L. Pekkan, P., Leo, H. L., de Zelicourt, D., Sotiropoulos, F., & Yoganathan, A., “Toward Quantitatively Accurate Modeling Of Cardiovascular Flows: Integrating High Resolution CFD & Experimental Techniques,” *International Bio-Fluid Mechanics Workshop and Symposium,* Caltech, Pasadena, Dec. 13-15, 2003.

3. Healy, T. M., Sotiropoulos, F., and Yoganathan, A. P., “Computational Simulation of Blood Flow through Bileaflet Mechanical Aortic Valve Prostheses,” 6th Annual Hilton Head Workshop on Prosthetic Heart Valves, Hilton Head Island, SC, March 6-10, 2002.

4. Sotiropoulos, F., and Ventikos, Y. "Prediction Of Flow Through A 90 Deg Curved Duct Using Two-Equation Non-Isotropic Turbulence Models," *5th ERCOFTAC Workshop on Refined Flow Modeling*, Chatou (Paris), April 25-26, 1996.

5. Sotiropoulos, F., and Patel, V. C., "Prediction Of The Thick Boundary Layer On The Stern Of A Ship With A Two-Equation And A Reynolds-Stress Model," proceedings of the *EUROVISC Workshop on Turbulent Boundary Layers in Three Dimensions*, Zurich, Switzerland, 28-29 October 1994.

6. Sotiropoulos, F., and Patel, V. C., "Numerical Study Of Ship Stern And Wake Flows Using A Near-Wall Reynolds-Stress Transport Closure," proceedings of the *1994 CFD Workshop*, March 22-24, Ship Research Institute, Tokyo, Japan.

7. Sotiropoulos, F., and Patel, V. C. "Numerical Assessment Of Advanced Turbulence Models In 3-D Shear Flows," presented at the *Office of Naval Research (ONR) State-of-the-Art Workshop on Non-Equilibrium Turbulence*, March 10-12, 1993, Tempe, Arizona.

8. Sotiropoulos, F., and Abdallah, S., " A Primitive Variable Method for the Computation of Ship Stern & Wake Flows," *Ship Viscous Flow, Proceedings of 1990 SSPA-CTH-IIHR Workshop*, Flowtech International Research Report, No 2, Gothenburg, Sweden, 1991 (L. Larsson, V. C. Patel, G. Dyne, Eds.)

D. PRESENTATIONS (without proceedings)

Conference Presentations

1. Ge., L., Boranzani, I., Dasi, L., Sotiropoulos, F., Yoganathan, A., “Fluid structure interaction (FSI) simulation of a bileaflet mechanical heart valve (MHV),” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

2. Dasi, L., Murphy, D. W., Simon, H., Ge L., Sotiropoulos, F., Yoganathan, A., “Vorticity dynamics of Bi- and Trileaflet Prosthetic Heart Valves,” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

3. Zelicourt, D., Wang, C., Kitajima, H., Pekkan, K., Sotiropoulos, F., and Yoganathan, A., “Unstructured Cartesian/Immersed Boundary Method for Flow Simulations in Complex 3D Geometries,” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

4. Escauriaza, C., and Sotiropoulos, F., “Stirring inertial particles in three-dimensional flows in a cylindrical container with exactly counter-rotating lids,” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

5. Sotiropoulos, F., Paik, J., and Escauriaza, C. “Reynolds number effects on the coherent dynamics of the turbulent horseshoe vortex.” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

6. Paik, J., Escauriaza, C. and Sotiropoulos, F. “On the physics of the bimodal coherent dynamics of the turbulent horseshoe vortex at $Re=1.16\times10^{5}$” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

7. Eghbalzadeh, A. Paik, J. and Sotiropoulos, F. “High-resolution 2D and 3D numerical simulations of gravity currents.” *59th Annual Meeting of the APS Division of Fluid Dynamics*, APS, Tampa, FL, Nov. 19-21, 2006.

8. Ge, L., Boranzani, I., Gilmanov, A., Sotiropoulos, F., "Progress in Computational Bio-Fluid Dynamics: From Aquatic Locomotion to Cardiovascular Hemodynamics," mini-symposium on *Biomimetics and Fluid Mechanics*, 2006 ECCOMAS Conference on Computational Fluid Dynamics, Egmond aan Ze, The Netherlands, Sept. 5-8, 2006.

9. Diane de Zelicourt, Chang Wang, Fotis Sotiropoulos, and Ajit Yoganathan, "Unstructured Cartesian Sharp-Interface Computational Method for Flow Simulations in Realistic Cardiovascular Anatomies," 5th World Congress of Biomechanics, Munich, July 29 – Aug. 4, 2006.

10. Lakshmi P. Dasi, Helene Simon, Liang Ge, Fotis Sotiropoulos, and Ajit Yoganathan, "In-vitro Characterization of Flow through Mechanical Heart Valves," 5th World Congress of Biomechanics, Munich, July 29 – Aug. 4, 2006.

11. Liang Ge, Lakshmi P. Dasi, Helene Simon, Fotis Sotiropoulos, and Ajit Yoganathan, "Simulating Prosthetic Heart Valve Hemodynamics in Realistic Aorta Anatomies**,"** 5th World Congress of Biomechanics, Munich, July 29 – Aug. 4, 2006.

12. Liang Ge, Fotis Sotiropoulos, and Ajit Yoganathan, "Simulating Prosthetic Heart Valve Hemodynamics: Numerical Model Development," APS-DFD 2005 meeting, Chicago, Illinois, Nov. 2005.

13. Chang Wang, Anvar Gilmanov, Fotis Sotiropoulos, and Ajit Yoganathan, "The Hemodynamics of Total Cavo-Pulmonary Connection Anatomies," APS-DFD 2005 meeting, Chicago, Illinois, Nov. 2005.

14. Cristian Escauriaza, Joongcheol Paik, and Fotis Sotiropoulos, "Coherent Structure Dynamics of the Horse Vortex System Induced by a Circular Cylindrical Pier Mounted on a Flat Plate at Re=40,000." APS-DFD 2005 meeting, Chicago, Illinois, Nov. 2005.

15. Joongcheol Paik, and Fotis Sotiropoulos, "DES of Turbulent Flow Past a Wall-Mounted Wing," APS-DFD 2005 meeting, Chicago, Illinois, Nov. 2005.

16. Kerem Pekkan, Prasad Dasi, Chang Wang, Diane deZelicourt, Fotis Sotiropoulos, Ajit Yoganathan, "Fluid flow and dissipation in intersecting counter-flow pipes," APS-DFD 2005 meeting, Chicago, Illinois, Nov. 2005.

17. Sotiropoulos, F., Paik, J., and Sale, M. J. "Unsteady CFD modeling of hydraulic turbine flows: Toward environmentally friendly and energy efficient hydropower installations." *World Water & Environmental Resources Congress*, Salt Lake City, Utah, USA, June 27 – July 1, 2004.

18. Gilmanov, A., Ge, L., Sotiropoulos, F., and Yoganathan, A., "Numerical Simulation of Flow in Anatomically Realistic Total Cavo-Pulmonary Connections," APS-DFD 2004 meeting, Seattle, Washington, Nov. 2004.

19. Ge, L., Leo, H, Sotiropoulos, F., and Yoganathan, A., "Flow Physics in a Bileaflet Heart Valveat Near Peak-Systole Reynolds Number," APS-DFD 2004 meeting, Seattle, Washington, Nov. 2004..

20. Ge, L., Gilmanov, A., Leo, H., Carberie, J., Sotiropoulos, F., and Yoganathan, A. "Toward a Predictive CFD Framework for Multi-Scale Cardiovascular Flows," BMES 2004 Annual Meeting, Philadelphia.

21. Ge, L., Pekkan, K., Leo, H., de Zelicourt, D., Sotiropoulos, F., and Yoganathan, A., "Numerical Modeling of Cardiovascular Flows: CFD & Experiments," *XXI ICTAM*, 15-21 August 2004, Warsaw, Poland.

22. Sotiropoulos, F., Gilmanov, A., and Yen, J. "Hydrodynamics of Planktonic Microcrustacean Locomotion: CFD Simulations and Experiments," ASLO-TOS 2004 Ocean Research Conference, Honolulu, Hawaii, Feb. 17 – 19, 2004.

23. Gilmanov, A., Posada, N., and Sotiropoulos, F., "Hydrodynamics of Fishlike Swimming: Effects of swimming kinematics and Reynolds number," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003

24. Yen, J., Gilmanov, A., and Sotiropoulos, F., "Hydrodynamics of Planktonic Microcrustacean Locomotion: Turning Wake Vortices into Communication Signals," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003.

25. Ge, L., Sotiropoulos, F., and Yoganathan, A. "DNS and URANS of Flow in a Bileaflet Mechanical Prosthetic Heart Valve," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003.

26. Paik, J., and Sotiropoulos, "DES and URANS of a Complex Separated 3D Flow," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003.

27. Sotiropoulos, F., and Paik, J. "Numerical Simulation of Concave Wall Turbulence Using Unsteady Statistical Turbulence Models," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003.

28. Lackey, T., and Sotiropoulos, F. "Chaotic Advection in a Closed Cylinder with Exactly Counter-Rotating Endwalls," 56th Annual Meeting of the Division of Fluid Dynamics, APS, Newark, NJ, Nov. 2003.

29. Balaras, E., Gilmanov, A., and Sotiropoulos, F., "A non-boundary conforming method for unsteady incompressible flows with moving boundaries," 55th Annual Meeting of the Division of Fluid Dynamics, APS, Houston, TX, Nov. 2002

30. Gilmanov, A., and Sotiropoulos, F., "Numerical Simulation of Fish-Like Swimming at Low Reynolds Numbers," 55th Annual Meeting of the Division of Fluid Dynamics, APS, Houston, TX, Nov. 2002.

31. Ge, L., and Sotiropoulos, F., "Unsteady RANS of Complex 3D Turbulent Flows Using Overset Grids," 55th Annual Meeting of the Division of Fluid Dynamics, APS, Houston, TX, Nov. 2002.

32. Sotiropoulos, F., Tang, H., and Jones, C., "The dynamics of massively separated laminar flows past wall-mounted obstacles in a channel," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

33. Jones, S., and Sotiropoulos, F., "Fluid motion and mixing in helical static mixers," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

34. Tang, H., Sotiropoulos, F., " An overset-grid, domain decomposition method for simulating 3D, unsteady, incompressible flows," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

35. Sotiropoulos, F., Tang, H., and Jones, C., "The dynamics of massively separated laminar flows past wall-mounted obstacles in a channel," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

36. Jones, S., and Sotiropoulos, F., "Fluid motion and mixing in helical static mixers," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

37. Lackey, T. C. and Sotiropoulos, F., "Particle path dynamics in a steady confined swirling flow," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

38. Chrisohoides, A., and Sotiropoulos, F., "An experimental technique for visualizing Lagrangian coherent structures in aperiodic free-surface flows," ," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

39. Healy, T., Sotiropoulos, F., and Yoganathan, A., "Computational Simulation of Blood Flow through Bileaflet Heart Valve Prosthesis," 54th Annual Meeting of the Division of Fluid Dynamics, APS, San Diego, CA, Nov. 19-21, 2001.

40. Sotiropoulos, F., Lackey, T. and Webster, D. R. "Chaotic and Quasi-Periodic Dynamics in 3D Steady Vortex Breakdown Bubbles," ICTAM-2000, Chicago, Aug. 27 – Sept. 2 2000.

41. Sotiropoulos, F. and Mezić, I., "Ergodic theory and experimental visualization of chaos in 3D flows," 53rd Annual Meeting of the Division of Fluid Dynamics, APS, Washington, D.C., Nov. 19-21, 2000.

42. Lackey, T., Sotiropoulos, F., and Webster, D. R., "The Dynamics Of Multiple Vortex Breakdown Bubbles In Confined Swirling Flows: Quasi-Periodic Order In The Wake Of Chaos," 53rd Annual Meeting of the Division of Fluid Dynamics, APS, Washington, D.C., Nov. 19-21, 2000.

43. Jones, C., and Sotiropoulos, F., "Vorticity dynamics in the near-field of non-axisymmetric jets," 53rd Annual Meeting of the Division of Fluid Dynamics, APS, Washington, D.C., Nov. 19-21, 2000.

44. Tang, H., and Sotiropoulos, F., "Numerical simulations of low Reynolds number flow past wall-mounted obstacles in a channel," 53rd Annual Meeting of the Division of Fluid Dynamics, APS, Washington, D.C., Nov. 19-21, 2000.

45. Sotiropoulos, F., and Ventikos, Y., "Three-Dimensional Vortex Breakdown In A Cylindrical Container: Artifact Of Flow Visualization Or Cross-Sections Through Chaos?" 1999 APS Division of Fluid Dynamics Meeting, New Orleans, LA.

46. Ventikos, Y., Sotiropoulos, F., and Webster, D., "Chaotic Advection in Stationary Vortex Breakdown Bubbles: Computations and Experiments," 1999 APS Division of Fluid Dynamics Meeting, New Orleans, LA.

47. Sotiropoulos, F., and Ventikos, Y., "Structure of Steady Vortex Breakdown in a Cylindrical Container with a Rotating Lid," 1998 APS Division of Fluid Dynamics Meeting, Philadelphia, PA.

48. Ventikos, Y., and Sotiropoulos, F., "Sidewall Instabilities in a Cylindrical Container with a Rotating Lid," 1998 APS Division of Fluid Dynamics Meeting, Philadelphia, PA.

Invited Seminar Presentations

1. "*Numerical Simulation of Fluid-Structure Interaction Problems in Biological Fluid Mechanics*," Center for Environmental and Applied Fluid Mechanics, Johns Hopkins University, March 2, 2007.

2. "*Probing the Physics of Real-Life Environmental Flows via Computational Fluid Dynamics: Some Recent Insights and Future Challenges*," Environmental Fluid Mechanics Laboratory, Dept. of Civil Engineering, Stanford University, February 13, 2007.

3. "Computational Bio-Fluid Dynamics: From Aquatic Locomotion to Cardiovascular Hemodynamics," ETH Zurich Computational Laboratory, Zurich, Switzerland, April 19, 2006.

4. "*Recent Progress in Computational Biofluids Research: From Cardiovascular Hemodynamics to Eco-Hydraulics*," Saint Anthony Falls Laboratory, University of Minnesota, Minneapolis, MN, Nov. 9, 2005.

5. "*Modeling 3D Flows in Complex Domains with Flexible Immersed Boundaries: From Hydrodynamics to Biofluids*,"
   - Laboratory for Hydraulic Machines, Ecole Polytechnic Federal de Lausanne (EPFL), Lausanne, Switzerland, May 3 2005.
   - Department of Building, Civil & Environmental Engineering, Concordia University, Montreal, Canada, May 20, 2005.

6. "*Toward the Simulation of Complex 3D Incompressible Shear Flows with Unsteady Statistical Turbulence Models*," Boeing Corporation, Renton, WA, September 23, 2003.

7. "*Simulating 3D Unsteady Flows in Arbitrarily Complex Geometries: From River Hydraulics to Biological Fluid Mechanics*," Battelle Seattle Research Center, Seattle, WA, September 22, 2003.

8. "*Modeling 3D Unsteady Flows and Fish Motion in Hydraulic Power Plants,"* Water Resources Group Environmental Sciences Division," Oak Ridge National Laboratory, April 23, 2003.

9. "*Modeling 3D Unsteady Flows in Arbitrarily Complex Domains with Flexible Immersed Boundaries: From River Hydraulics to Biofluids*," Department of Mathematics and Computer Science, Emory University, Atlanta, Georgia, October 11, 2002.

10. "*CFD framework for Assessing Fish Friendliness in Hydropower Installations*," US Army Corps of Engineers, Portland, Oregon, July 2002.

11. "*Experimental and Computational Studies of Lagrangian Coherent Structures: Exploring Complexity in Fluid Trajectories*," Department of Civil and Environmental Engineering, The University of Iowa, Iowa City, IA, April 12, 2002.

12. "*Recent Progress in Domain Decomposition Methods for Simulating 3D Unsteady Incompressible Flows*," Department of Mechanical Engineering, University of Ottawa, Canada, February 15, 2002.

13. "*Computational Fluid Dynamics for Hydraulic and Environmental Engineering Applications*," MW HARZA, Chicago, Illinois, December 18, 2001.

14. "*On The Lagrangian Properties Of Steady Flows With Vortex Breakdown Bubbles*," *Applied Mechanics Colloquium*, Division of Engineering and Applied Science, Harvard University, February 28, 2001.

15. "*Instabilities of Sidewall Boundary Layers and Chaotic Advection in Rotating Flows*," Department of Mechanical and Aerospace Engineering, Arizona State University, Tempe, AZ, February 15, 2000.

16. "*Chaotic Advection in Stationary Vortex Breakdown Bubbles*," Laboratory of Geophysical and Industrial Flows, Grenoble National Polytechnic Institute, Grenoble, France, October 27, 1999.

17. "*Progress in Modeling 3-D Shear Flows Using RANS Equations and Advanced Turbulence Closures*," Department of Civil and Environmental Engineering, Virginia Tech, October 20, 1999.

18. "*Prediction of Hydroturbine Flows Using Advanced Turbulence Models*," US Army Corps of Engineers, Portland, Oregon, July 1997.

19. "*Recent Advancements in Numerical Simulation of Complex Turbulent Shear Flows*," US Army Corps of Engineers, Waterways Experimental Station, Vicksburg, Mississippi, April 1997.

20. "*Advanced CFD Modeling for Fish-Friendly Hydropower Installations*," Centre for Research on Computation and its Application (CERCA), University of Montreal, Montreal, March 27, 1997.

21. "*Recent Developments in Numerical Simulation of Three-Dimensional Shear Flows*," Department of Mechanical Engineering, Florida State University, March 26, 1996.

22. "*Numerical Modeling Of Complex 3-D Shear Flows: The present and future of Reynolds-Averaged Methods*," Ecole Central de Nantes, Fluid Mechanics Laboratory, Division of Numerical Modeling, Nantes, France, April 29-30, 1996.

23. "*Numerical Simulation of Hydropower Flows: From the forebay to the tailrace*," Department of Mechanical Engineering, University of Manchester, Manchester, UK, June 10, 1996.

24. "*Advanced Numerical Modeling for Advanced Hydroturbines*," Hydrosystems Group," Oak Ridge National Laboratory, November 13, 1995.

25. "*Computational Study of Longitudinal Vorticity and Reynolds-Stresses in Three-Dimensional Turbulent Flows*," Dept. of Mech. and Aerospace Eng., Arizona State University, October 5, 1994.

V. SERVICE

A. PROFESSIONAL CONTRIBUTIONS

Journal Editorial Board

International Journal of Heat and Fluid Flow:	Editorial board	January 2006 – present.
ASCE Journal of Hydraulic Engineering:	Associate editor	February 2002 – present.

Organization and Chairmanship of Conferences, Technical Sessions, and Workshops

1. Advisory committee member, 5th *International Symposium on Turbulence and Shear Flow Phenomena* (TSFP-5), 2007.

2. Advisory committee member, 4rd *International Symposium on Turbulence and Shear Flow Phenomena* (TSFP-4), Williamsburg, Virginia, June 2005.

3. Session co-chair, Multi-scale Modeling in the Cardiovascular Systems, BMES 2004, Cardiovascular Engineering Track, Philadelphia, Pennsylvania, October 2004.

4. Session chair, IAHR Symposium on Hydraulic Machinery and Systems, Stockholm, Sweden, June 2004.

5. Session co-chairman, *3rd International Symposium on Turbulence and Shear Flow Phenomena* (TSFP-3), Session: Turbulence Control I, Sendai, Japan, June 2003.

6. Session chairman, *55th Annual Meeting of the APS Division of Fluid Dynamics*, Session Title: Biofluids II, Dallas, TX, November 2002.

7. Session chairman and co-organizer, *4th Bio-Engineering Symposium*, American Fisheries Society, Session Title: CFD Modeling for Fish Friendly Hydraulic Structures, Baltimore, August 2002.

8. Session co-chairman, *6th Annual Hilton Head Workshop on Prosthetic Heart Valves*, Session title: *Computational Modeling I*, Hilton Head Island, SC, March 6-10, 2002.

9. Advisory committee member, 3rd *International Symposium on Turbulence and Shear Flow Phenomena* (TSFP-3), Sendai, Japan, June 2003.

10. Advisory committee member, *2nd International Symposium on Turbulence and Shear Flow Phenomena* (TSFP-2), Stockholm, Sweden, June 2001.

11. Organizing committee co-chairman, *20th IAHR Symposium on Hydraulic Machinery and Systems*, Charlotte, North Carolina, August 2000.

12. Session chairman, *ASCE Waterpower 97*, Session: CFD for Turbine Rehabilitation and Design, Atlanta, Georgia, August 1997.

13. Session chairman, *1996 ASME Fluids Engineering Division Summer Meeting*, Session: Numerical Developments in CFD III, San Diego, CA 1996.

Technical Committee Activities

- Founder and Chair of a new ASCE-EWRI task committee on *Advanced Environmental Hydraulics Modeling* – 2000-2005.

- Member of the ASCE-EWRI technical committee on *Eco-hydraulics (*2003 – present).

External Examiner/Reader for Ph.D. Thesis Exams

- Examiner in Dr. A. Perrig's defense, Laboratory for Hydraulic Machinery, École Polytechnique Fédéral de Lausanne, Lausanne, Switzerland, Dec. 12, 2006.

- Examiner in Dr. J. Qu's defense, Dept. of Building, Civil & Environmental Engineering, Concordia University, Monteral, Canada, May 20, 2005.

- Reader of the thesis of Dr. I. Avrahami, Dept. of Biomedical Engineering, Tel Aviv University, Tel Aviv, Israel, 2004.

Technical Journal Referee

Paleobiology (since 2003)
ASME Journal of Biomechanical Engineering (since 2003)
Physics of Fluids (since 2002)
Journal of Fluid Mechanics (since 1998)
Journal of Computational Physics (since 1999)
American Institute of Aeronautics and Astronautics (AIAA) Journal (since 1992)
ASME Journal of Fluids Engineering (since 1993)
ASCE Journal of Hydraulic Engineering (since 1995)
ASCE Journal of Engineering Mechanics (since 2002)
International Journal of Heat and Fluid Flow (since 1997)
International Journal of Numerical Methods in Fluids (since 1992)
Computers and Fluids (since 1991)

Proposal Reviewer

National Science Foundation
National Institutes of Health

B. CAMPUS CONTRIBUTIONS

University of Minnesota

- Chair of the search committee for the Civil Engineering department head (2007).
- Provost's advisory committee for the planning of the *Institute for the Advancement of Science and Technology* (2006 – present)
- Elected member of the Dept. of Civil Engineering Planning Council (2006 – present)

Georgia Institute of Technology

- College of Engineering Assistant-to-Associate Reappointment, Promotion and Tenure Committee (2004 – 2005).
- Elected member of CEE Statutory Advisory Committee (2004 – 2005)
- Chair of CEE *Information Systems* Committee (Sept. 2001 – Dec. 2003)
- Member of *ad-hoc CEE Faculty Search Committee* for the EFMWR group (Feb. 2003 – April

2003)

- Member of *ad-hoc CEE Faculty Search Committee* (Jan. 2002 – March 2002)
- Member of *ad-hoc CEE Faculty Search Committee* for the Geosystems group search (Jan. 2001 – April 2001)
- Member of the CEE *Computer Committee* (Sept. 97 – Aug. 2001)
- Member of the ad-hoc CEE Committee for the "Computational Modeling in CEE" course (Jan. 97– Sept. 99)
- Member of the CEE *Awards Committee* (Jan. 97 – May 97)
- Member of various campus-wide committees for evaluating five "*Best Intellectual Products*" of faculty from Aerospace, Chemical, and Civil and Environmental Engineering applying for promotion and tenure (Fall 1997 – present).

VI. HONORS AND AWARDS

A. NATIONAL ACADEMY OF ENGINEERING DISTINSCTIONS

1. *National Academy of Engineering 2005 German-American Frontiers of Engineering Symposium* Invited Participant, Potsdam, Germany, May 4-7, 2005.

2. *National Academy of Engineering 8th Annual Symposium on Frontiers of Engineering* Invited Participant, Irvine, CA, Sept. 19-21, 2002.

B. NATIONAL SCIENCE FOUNDATION DISTINSCTIONS

3. Recipient of the NSF Faculty Early Career Development (**CAREER**) award, Division of Civil and Mechanical Systems (1999 to 2003).

4. Invited speaker, *NSF/NIH Workshop on Transport Processes in Biomedical Systems*, Bethesda, MA, May 6-7, 2004.

C. INVITED REVIEW PANELS

5. Biofluids panel, CTS, National Science Foundation, Washington, DC, January 20 – 22 2006.

6. Modeling and Analysis of Biological Systems (MABS) Study Section, National Institutes of Health, Bethesda, Maryland, Oct. 31 – Nov. 1 2005.

7. Review panel for NSF's *Information Technology Research* program, Feb. 24 2003.

D. KEYNOTE AND PLENARY ADDRESSES

8. "Visualizing Coherent Vortices in Simulated Engineering and Biological Flows: From Rings and Hairpins to Horseshoes and Worms," keynote lecture, 9th Asian Symposium on Visualization (9ASV), Hong Kong, China, June 4-8, 2007.

9. "Modeling 3D Flows in Arbitrarily Complex Domains with Deformable Immersed Boundaries: From Hydrodynamics to Biofluids**,"** Plenary address, IASME/WSEAS International Conference on FLUID MECHANICS, Corfu Island, Greece, August 17-19, 2004.

10. "Toward Quantitatively Accurate CFD Predictions of Hydroturbine Flows," Keynote address, 20th IAHR Symposium on Hydraulic Machinery and Systems, Charlotte, North Carolina, August 2000.

E. INVITED SYMPOSIA, WORKSHOP, PANEL, CONFERENCE TALKS

11. Mini-Symposium on *Biomimetics and Fluid Mechanics* at the 2006 ECCOMAS Conference on Computational Fluid Dynamics, Egmond aan Ze, The Netherlands, Sept. 5-8, 2006.

12. Mini-symposium on *Advances in Turbulence Modeling* at 2006 International Conference on Hydroscience and Engineering (ICHE 2006), Philadelphia, Fall 2006.

13. Advanced course and workshop on "*Analysis and Control of Mixing with Application to Micro and Macro Flow Processes*" at the International Center for Mechanical Science (CISM) in Udine (Italy), June 27-July 1, 2005

14. Panelist for session "Symposium III: Eco-Power: Using Modeling Tools for Environmental Gains," Waterpower XIV Conference in Austin, Texas, July 18-22, 2005.

15. Symposium on "Advances in Modeling of the Cardiovascular System" at the 12th International Conference on Biomedical Engineering, Singapore Dec 7-10, 2005.

16. Mini-symposium on *Advances in Turbulence Modeling at 2004 International Conference on Hydroscience and Engineering* (ICHE 2004), Brisbane, Australia, May 30 – June 3, 2004.

17. *International Bio-Fluid Mechanics Workshop and Symposium,* Caltech, Pasadena, Dec. 13-15, 2003.

18. Mini-Symposium on *Dynamical Systems and Control of Mixing*, *International Conference on Industrial and Applied Mathematics*, Sydney, Australia, July 2003.

19. Mini-Symposium on *Three-Dimensional Mixing*, *2003 SIAM Conference on Applications of Dynamical Systems*, Snowbird, Utah, May 2003.

20. Forum on the *Fluid Mechanics of Mixing Phenomena II: Fundamentals and Industrial Applications*, 2002 ASME Fluids Engineering Division Summer Meeting, Montreal, Canada, July 14-18, 2002.

F. INVITED JOURNAL PAPERS

21. Paper presented at the 3rd Turbulence and Shear Flow Phenomena Meeting (Sendai, Japan, June 2003) was selected by the Editors-in-Chief of the *International Journal of Heat and Fluid Flow* to be included in a special issue of the Journal containing the best papers from the meeting.

22. Paper presented at the 11th Turbulent Shear Flows Meeting (Grenoble, Sept. 1997) was selected by the Editors-in-Chief (B. E. Launder, N. Kasagi, and F. W. Schmidt) of the *International Journal of Heat and Fluid Flow* to be included in a special issue of the Journal containing the best papers from the meeting (*IJHFF* 19(5), 1998).

G. DISTINCTIONS OF PhD THESES SUPERVISED

23. The thesis of S. C. Jones (*Static Mixers in Water Treatment: A Computational Fluid Dynamics Model*) was awarded the **2001 AMERICAN WATER WORKS ASSOCIATION *Academic Achievement Award***.

24. The thesis of Liang Ge (*Numerical Simulation of 3D, Complex, Turbulent Flows with Unsteady Coherent Structures: From Hydraulics to Cardiovascular Fluid Mechanics*) was awarded the **2005 Georgia Tech Sigma-Xi best Thesis Award**.

H. JOURNAL COVER PAGE

25. *ASCE Journal of Hydraulic Engineering* new cover page will feature results from our recent CFD work on 3D, unsteady modeling of turbulent flows past complex bridge piers (starting with the January 2004 issue).

I. OTHER HONORS AND DISTINCTIONS

26. Appointed to the board of directors of the *Hydropower Research Foundation*, 2007 – present.

27. Invited Visitor, *Institute for Computational Sciences, ETH*, Zurich, April 10 – 26, 2006.

28. Fellow of the Minnesota supercomputing Institute (2006 – present).

29. Listed in Marquis *Who's Who in Science and Engineering* (2004 – present).

30. Recipient of the 2003 *Sustained Research Development Award*, School of Civil and Environmental Engineering, Georgia Tech.

31. Offered the *Chair in Computational Fluid Dynamics*, Department of Mechanical Engineering, *University of Manchester Institute of Technology* (Manchester, UK)—May 1999.

32. *R. T. DAVIS* award for *demonstrated aptitude and scholarship in the field of Computational Mechanics* from the Department of Aerospace Engineering & Engineering Mechanics, University of Cincinnati (1991).

33. Graduate studies scholarship from the Bodosakis Foundation, Athens, Greece (1987-90)

34. Scholarship from The Greek Chamber of Engineers (1986)

35. Scholarship from the National Scholarship Foundation of Greece (1985 & 1986).

VII. GRANTS AND CONTRACTS

Active grants

1. Collaborative Research—Biologically-Generated Flow by Plankton: Numerical Simulations & Experiments. National Science Foundation (2006-2009)
   Role: Principal Investigator $150,000

2. Bioengineering Research Partnership: The Hemodynamics of Fontan Surgeries
National Institutes of Health (2004-2007)
Sub-contract. PI: A. P. Yoganathan (Biomedical Eng., Georgia Tech)
$60,000

3. Computational Modeling of Flows in Mechanical Heart Valves
National Institutes of Health (2003-2007)
Co-PI with A. P. Yoganathan (Biomedical Eng., Georgia Tech)
Total budget: $1,400,000 $660,000

Completed grants

4. *Unsteady Numerical Modeling of Draft-Tube and Tailrace Flows in Hydropower Plants*
U.S. Department of Energy and Oak Ridge National Laboratory (2001-2005)
Principal Investigator $800,000

5. *Laboratory and 3D Numerical Modeling with Field Monitoring of Regional Bridge Scour in Georgia*
Georgia Department of Transportation (2000-2005)
Co-PI with T. W. Sturm (Civil & Environ. Eng., Georgia Tech) & M. Landers (USGS)
Total budget: $673,912 $200,000

6. *Physical and Numerical Modeling of Mixing in Water Storage Tanks*
American Water Works Association Research Foundation (2002-2005)
Co-PI with P. Roberts, Civil & Environ. Eng., Georgia Tech
Total budget: $150,000 $55,000

7. *Advanced Numerical Modeling of Bridge Foundation Scour*
National Science Foundation **CAREER** award (1999-2004)
Role: Principal Investigator $310,000

8. *LES of circular jet flows*
U.S. Department of Energy and Oak Ridge National Laboratory (1999-2001)
Role: Principal Investigator $124,000

9. *Two-Dimensional Hydrodynamic Model for the ACT and ACF River Basins*
Georgia Water Resources Institute (2000-2001)
Role: Principal Investigator $17,000

9. *Coupled Two-Phase Flow Numerical Model for Autoventing Hydroturbines*
Voith Hydro Inc. (1998-1999)
Role: Principal Investigator $30,000

10. *A Numerical Model for Estimating Fish Passage through Hydraulic Powerplants*
Voith Hydro Inc. (1997-1999)
Role: Principal Investigator $220,000

11. *Conceptual Designs for Advanced Hydroturbines*

U.S. Department of Energy and Voith Hydro Inc. (1995-1998)
Role: Principal Investigator
$128,500

12. *A Lagrangian/Eulerian Method for Predicting DO Transfer in Autoventing Hydroturbines*
Tennessee Valley Authority (1997)
Role: Principal Investigator $30,000

Proposals in review

Collaborative Research—Physics Based Modeling of Bridge foundation Scour: Numerical Simulations and Experiments. Collaborators: P. Diplas and C. Dancey (Civil Engineering, Virginia Tech). Submitted to NSF June 1, 2006. Requested amount: $620,000. Total funding for the Sotiropoulos group: $300,000

NIH Bioengineering Research Program (BRP): Biophysical Multi-Scale Modeling of Aortic Valve Stenosis. F. Sotiropoulos is co-PI in this grant and the leader of the CFD team of the BRP. The PI is A. P. Yoganathan (Georgia Tech). Other co-PIs are: C. Aidun, R. Haj-Ali (Georgia Tech), H. Jo (Emory University), Greg Simons (Univ. of Toronto) and P. F. Davies (Univ. of Pennsylvania). Submitted to the NIH National Heart Lung & Blood Institute in May 20, 2006. Requested amount: $9,400,000 for 5 years. Total funding for the Sotiropoulos group: $950,000.

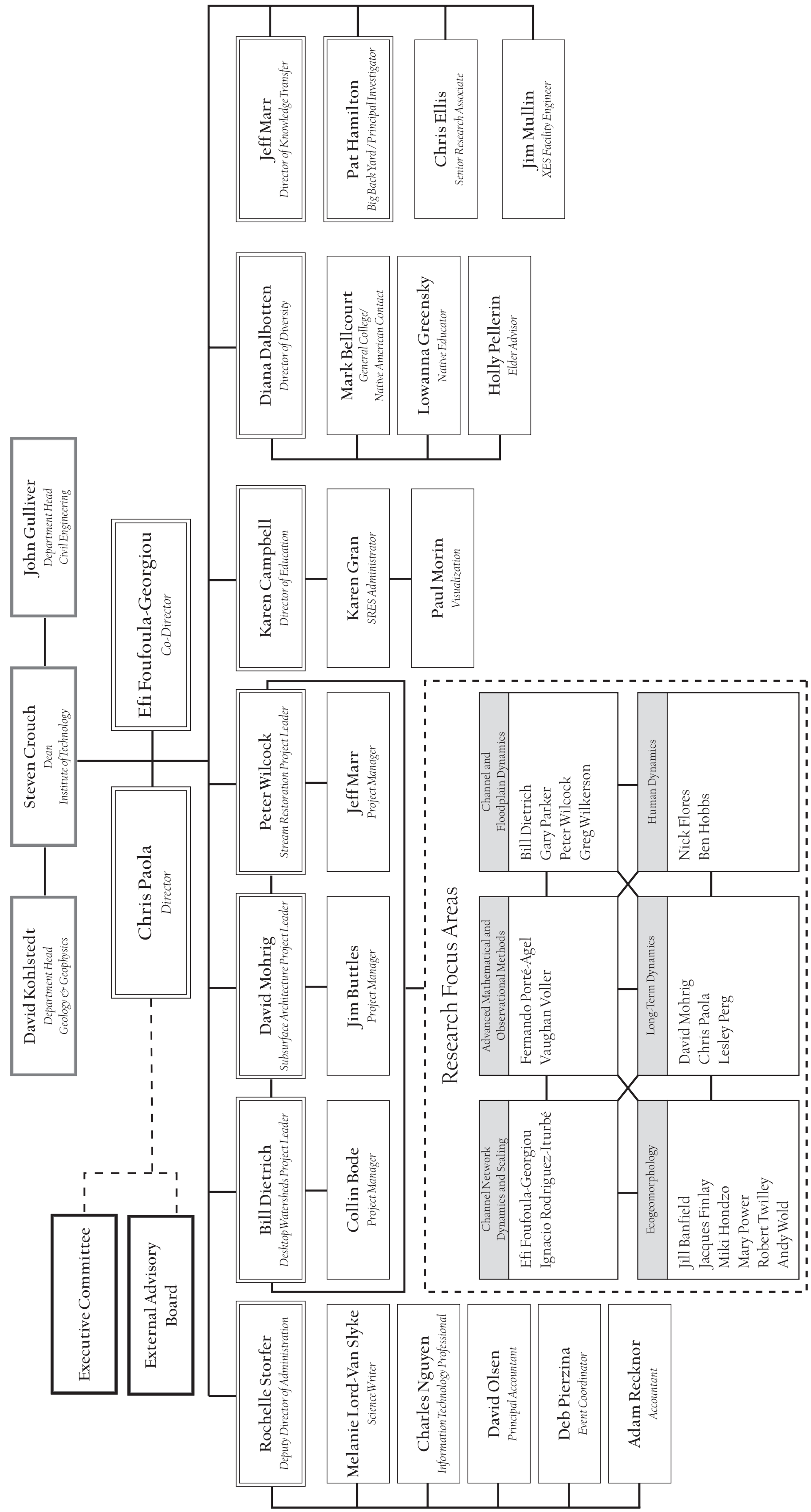
VIII. CONSULTING

1. 1D and 2D hydrodynamic modeling of the Lake Victoria basin, WREM International, 2003 – present.

2. Numerical Modeling of Selective Withdrawal in the lake Billy Chinook Reservoir, *Battelle Seattle Research Center*, 2003 - 2006.

3. Numerical modeling of selective withdrawal in the intakes of the Jardine water treatment plant, *MW Harza*, Chicago, IL (2000 – 2004).

Organizational Chart



Appendix C: External Advisory Board

Active Members

Richard P. Hooper, President, CUAHSI

Matthew Larsen, Chief Scientist for Hydrology, Water Resources Division

Jean Moon, Director, Board on Science Education, The National Research Council

Margaret A. Palmer, Director and Professor, Chesapeake Biological Laboratory, University of Maryland

William Schulze, Professor, Applied Economics and Management, Cornell University

Rudy Slingerland, Professor, Department of Geosciences, Pennsylvania State University

Russell Stands-Over-Bull, Senior Geologic Advisor, Anadarko Petroleum Company

David V. Taylor, Provost and Senior Vice President for Academic Affairs, Morehouse College

Emeritus

Anthony Paul Murphy, Assistant Professor, Department of Education, College of St. Catherine

Report of the External Advisory Board

January 2007

This report of the NCED External Advisory Board follows the Review Meeting of 31 October – 01 November, St. Anthony Falls Laboratory, Minneapolis. Board members present included: Dhamo Dhamotharan, David Furbish, Richard Hooper, Matthew Larsen, Jean Moon, Anthony Murphy, William Schulze and David Taylor. The report is organized as follows.

Preamble

NCED is making significant advances, both in terms of honing its identity as a national center, and in terms of fulfilling its science-and-education-driven vision and mission. These advances include key steps in the structural evolution of NCED, a focusing and integration of science themes, and important progress focused on education and transfer of knowledge to students and the wider community, with innovative attention to diversity issues. Based on Review Meeting presentations and supporting documents, as well as presentations of PIs and students at the recent 2006 NSF Site Visit, there is ample evidence that NCED is greater than the sum of its parts, with a thriving spirit of cross-discipline exchange of ideas and inspired research.

This report has little to say about the science of NCED — which is first-rate. The report focuses mostly on key issues concerning the future — of which NCED's legacy looms large — as represented in five questions posed to the Advisory Board prior to the Review Meeting. For reference below, these five questions are:

1. How can we most effectively integrate social sciences with natural sciences? Is there anything we can do better than what we're doing now?
2. How can we get the broader community more involved and engaged? Current/recent activities include short courses, visitors program, working groups/workshops, postdocs, and

major research meetings (e.g. RCEM). Is this package the most effective way we could use our resources?

3. What should be the main elements of NCED's legacy and how can we best transition to permanent center status without NSF-OIA funding?
4. How can we maintain and improve momentum on recruiting talented minority students into NCED's graduate programs? What can we do to use our new Stream Restoration certificate program effectively for minority recruiting?
5. We are now increasingly involved in work on restoring the Mississippi Delta. What is the EAB's advice on negotiating the complex politics of setting up such a large (billions of dollars) restoration project? What is the best role for NCED in what will inevitably be a project much larger in scope than even an STC? Note in this regard: the newest STC class includes a center for coastal research headquartered at Oregon Health & Science University, with which we have initiated contact with regard to the Delta project.

Comments and recommendations of the Board regarding these questions, perhaps mostly pertaining to Questions 1 and 3, are dispersed among the sections below. Board members did not feel that they had sufficient background and information to thoughtfully address Question 5. Because Question 3 carries a sense of urgency in planning now for the future, Section 6 highlights this question.

1 NCED Structural Progress

Several structural items emerged as representing particularly important steps achieved during the initial five-year period of NCED. These are briefly highlighted here as a reminder of good things deserving continued nurturing or, perhaps, fine tuning.

* Foremost, the focusing of NCED's science research efforts into the three theme areas of Desktop Watersheds (DW), Subsurface Architecture (SA) and Stream Restoration (SR) — specifically designed as Integrated Projects (IP) — is a key advance. This importantly includes the growing of a social science component that is folded initially into the SR IP, and which may in the future inform that part of the SA IP related to engaging stakeholder ownership in the management and remediation of Gulf Coast lands/environments.

* The IP structure is sound, notably as its design is aimed at encouraging, if not expecting, cross-discipline efforts and intellectual exchanges among PIs, students and post-docs (including transdisciplinary advising of students.) The Review Meeting presentations, as well as those of PIs and students at the recent 2006 NSF Site Visit, together with supporting documents (including NCED publications) offer clear evidence of success in this aim.

* The idea of providing a formal structure of autonomy (including a budget) for participating graduate students is outstanding. This novel structural ingredient will almost certainly contribute positively to the long-term intellectual legacy of NCED, a point that is elaborated below.

* Despite continuing questions from NSF regarding administrative and (internal) funding structure, the "minimalist" management/oversight structure currently in place (following

initial adjustments) is entirely reasonable. The practice of funding PIs versus projects, with the aim/expectation of engaging PIs in multiple projects, fundamentally fits the IP structure. Nonetheless, this management structure deserves candid review and readjustment as necessary. As discussed at the Review Meeting, for example, there may be merit in adjusting the process of proposal review (possibly involving EAB members), with attention given to protocol, PI and reviewer guidelines, and timing of the review process.

* Although a point of continuing concern, NCED has made key steps in growing its national visibility and involvement in the science, education and policy communities. This starts with NCED's growing web presence (its web pages and associated resources, including toolboxes and educational resources) together with its newsletters and short courses. This progress is punctuated by a number of high-quality high-visibility publications, in addition to high-quality publications in high-impact specialty journals, addressing NCED themes.

2 Research Integrated Projects

Below are brief, general comments regarding the three IPs. And, because of the importance of Question 3 (and for reference below), certain items regarding intellectual legacy are summarized. This section then mostly elaborates on the addition of a social science component to the SR IP (Question 1).

2.1 Natural Science Components

Some Board members felt that linkages between the SA IP and the SR and DW IPs were not entirely clear from the presentations. Although connections were explained, and the "Jurassic Tank" (and similar experimental facilities) are important innovations that should yield insights into basin sedimentation processes and architecture, the SA work seemed to be relatively apart from the SR and DW work. Linkages could be strengthened, or at least made clearer, if SA is truly an equal component of NCED with SR and DW. (Indeed, Board members attending Chris Paola's subsequent presentation at the 2006 Gilbert Club in Berkeley noted that it very nicely clarified connections between SA, and directly related work, with other NCED efforts. This point is therefore aimed mostly at the need to clarify these connections in communications to the larger science community as part of NCED's outreach strategy.) NCED's effort with SA could serve as a mechanism to better connect the scientific communities that currently work in these three areas. At present, in the larger scientific community, these areas are not well connected; and here NCED has an important role.

It was noted that success in the Missisippi delta restoration project could well hinge on effective interfacing with the petroleum industry in dealing with remediation of land loss, etc., and that stakeholder ownership in such efforts is needed for navigation of the political landscape. Herein may be an opportunity to gain insight from the SR social science effort (see next section) regarding engagement of stakeholders.

If sustained, NCED leadership in stream restoration should be a major contribution to the field, which currently lacks scientific rigor and follow-up evaluation in many applications. It was not altogether clear whether NCED has specific guidance or recommendations with respect to medium to long-term monitoring and follow-up evaluation of SR projects.

Concerning the presentation of SR to the larger community, there may be merit in spinning the presentation to make the message less NCED-centric. Even though NCED can play a significant role in the SR area, it should be tactful about presenting and carrying out this role, so that it can be as inclusive as possible in the larger academic and engineering communities involved with SR.

The basic concepts and approach for the DW IP are excellent. The impact the DW will have on the community will be enhanced, however, if it is developed with an eye to the various community modeling frameworks that are out there (as opposed to developing its own standards or protocols). CUAHSI Hydrologic Information Systems in the current phase of the work is beginning to address these frameworks and would be happy to assist the DW developers in evaluating the options (see Supplementary Items 1 below).

Several items resonated as being key contributions to the intellectual legacy of NCED. As with items under structural progress (Section 1), these legacy items — as articulated by the PIs in their presentations and in the October 2006 document of "transformative" themes — are briefly highlighted here as a reminder of good things deserving continued investment and refinement.

Desktop Watersheds: A key point of this IP is to develop and champion an approach, a style of thinking — whose legacy will be a deeper understanding of basic processes that shape landscapes, and a viable path for integrating Earth-surface dynamics with ecology at the watershed scale. Placed within the overarching NCED theme of channel-network structure, this work (evidently with strong, growing interest and buy-in from ecologists) has a real chance of changing how environmental assessment and management agencies do work, meshing digital-format approaches (e.g. GIS-based modeling/layering) with hypothesis-driven field work — in addition to contributing to the basic science of Earth-surface dynamics.

Subsurface Architecture: An intellectual gem of this IP is its aim to clarify how process-similarity-scaled laboratory experiments can inform our understanding of the dynamics and architecture of natural erosional-depositional systems at grand scales, and to elucidate commonalities between submarine and terrestrial systems. The legacy of this approach will be its recognized place in the theory/experiment/field-based trinity of research in the larger community, and not viewed as just a novel idea residing with NCED. The applications involving Gulf Coast/Mississippi delta restoration are challenging undertakings, with considerable added value if they involve buy-in from stakeholders.

Stream Restoration: The legacy of this IP is unambiguous — the application of superior (natural) science in SR projects, incorporating principles of ecologically motivated objectives and desirables to inform physical restoration, in combination with application of strategies for success (informed by social science) that necessarily engage all stakeholders in this process.

2.2 Social Science Component

The two key highlights of this research component (and pilot project) are: 1) that it is aimed at the decision-making processes in river restoration, incorporating considerations of choices and tradeoffs (e.g. economics, benefits, costs) and values; and (2) that it is aimed at a broader context for restoration (which normally is treated as an "in-channel" issue). This latter point nicely meshes with the vision of the DW IP. The PIs are understandably fretting about issues of long-term assessment and monitoring, and mechanisms for how such work will inform the political process.

More generally, with regard to the role of the social sciences in NCED and how the social sciences might be better integrated into NCED, there are two answers. First, there is a basic science question that could be undertaken which would necessarily consume a large amount of limited resources. Just as NCED has undertaken to attempt to explain the natural causes that underlie earth-surface dynamics, one could ask the social sciences to address the economic and social causes that underlie human changes to the earth's surface, which may be of equal or greater magnitude (as suggest by R. Hooke). Clearly earth-surface dynamics are in actuality explained by both natural and human causes as well as by the interaction between them. For example, deforestation accelerates natural erosion, changing landforms, and consequent sediment loading of rivers and deposition downstream. Social science modeling of deforestation is, thus, essential to understanding earth surface dynamics. Urban patterns of housing, roads, filling of wetlands, etc. all serve to vastly alter the landscape both directly and by altering natural processes.

The state-of-the-art in land use modeling has been characterized as follows: "However, urban modelers have for a long time ignored ecological aspects of the processes simulated in their models. Existing land-use transport (LT) models are being augmented by environmental submodels to become land-use transport environment (LTE) models. Yet worldwide today there exist no full-scale urban LTE models. The first efforts to extend LT models to LTE models have concentrated on environmental impacts of land use and transport and ignored the opposite direction, the impact of environmental variables on location decisions of investors, firms and households." (http://www.wspgroup.fi/lt/propolis/index.htm)

However, as noted above, it is unclear whether NCED has the resources to pursue this issue (or whether it should make this investment), and no comprehensive social science study or modeling has been done to attempt to explain human modifications to the earth's surface in conjunction with the necessary integrated natural and biological models.

The second role for the social sciences is to demonstrate the usefulness of the tools and models developed by NCED in solving policy problems. The current applications of valuation and multi-attribute decision-making to restoration of the Minnesota River is an excellent demonstration project where the social sciences are a necessary intermediate step to bring the tools, modeling and knowledge gained from the river restoration project to policymakers. It is too early in the social science research, which was a late addition, to provide an evaluation of accomplishments. However, the planned research uses a state of the art approach and is highly likely to succeed. The one recommendation is that the odds of success of this demonstration project will be enhanced if decision makers can be brought into the early stages of the design process so that they have a voice and consequently buy into the research.

Regarding this last point, there may be valuable lessons for both the SR and SA IPs contained in the vision and ongoing efforts of CRESP (Consortium for Risk Evaluation with Stakeholder Participation; see http://www.cresp.org/). The Amchitka Project, in particular, stands as a recent model of the demonstrated merits in early engagement of stakeholders within efforts of this sort.

3 Education

The implementation of cross-disciplinary training at the graduate level (with transdisciplinary advising of students), and a structure of autonomy that involves students retreats and travel, are outstanding. And, it is noted and acknowledged that achieving the lofty goals of excellence in the NCED educational vision is not limited by funding, but rather, by people's time.

Results to date have been very good, but the efforts can come off as being opportunistic more than planned (although opportunism is not undesirable). Part of the issue is making sure the efforts are packaged to give a sense of strategy — this is mostly cosmetic. More substantively, these efforts appear less than ideally integrated with the research — parts of the Education effort seem to be a separate activity. This impression may have derived from the way the material was presented, but it was not clear that all (or nearly all) PIs have an integral role in the education efforts. This is always a challenge, but is something the Directors need to consider as they evaluate proposals and make resource allocation decisions — ensuring that each effort has an education component that can be coordinated, inasmuch as is desirable and possible, through Karen Campbell and Diana Dalbotten for the Center.

There seems to be ample potential to integrate education into more "core"/interdisciplinary aspects of the NCED. Most of the comments below have to with "legacy" issues for the Center.

The Board recommends investigating the pros and cons of enlarging the certificate program in stream restoration to develop a certificate program for high school teachers. This would provide a pathway to integrate more of the research/content/research practices as well as the interdisciplinarity of NCED to high school science where the need is great.

What is imagined is a certificate program (recognized by the state department of education) that would provide an opportunity for teachers to grow expertise in stream restoration as a multi-disciplinary context in which to create science curriculum and laboratories experiences in high school science. One of the major challenges in high school science is the lack of any movement toward interdisciplinarity and improved laboratory experiences. The promise of the stream restoration certificate program is that it will address both of these shortcomings. There may also be merit in building research experiences for high school teachers as part of a summer program at NCED.

Both of the above suggestions have to do with integrating the work of NCED as a context for learning science. Whereas the outreach activities address issues of NCED visibility and public understanding of science in surface dynamics (in a general way), more can be done in positioning the work of NCED as a direct classroom resource at the high school level. This suggestion also builds on the increasing interest in pre-college engineering as situating and contextualizing engineering principles and professional activities in science contexts. The work of NCED is very well situated to move this agenda forward.

There may be corporate dollars to support this direction, especially among petro-chemical companies such as Shell and ExxonMobil, who have a history of supporting science education.

It may be that the Science Museum has some interest in partnering in some of these suggestions given the desire of museums to build bridges with schools.

A more general comment is the lack of transparency as to the overall science education goals defining/shaping the education component of NCED. The goal of the program aimed at public understanding is very clear and has been quite well done. What is less visible are linkages back to the "interdisciplinarity" that is a hallmark of NCED. More could be done on this.

4 Diversity

The high goals of this NCED effort are particularly laudable, and the accomplishments thus far through the gidakiimanaaniwigamig and ando-giikendaasowin programs in partnership with the Fond du Lac Tribal Community College, the Science Museum, and the University of Minnesota, are inspiring. A particularly notable item (also articulated in the NSF Site Visit) is the care given to developing strategies for learning that are informed by the culture, extending to the family level, of the participating native American community. The ongoing need to involve additional NCED faculty in this effort is noted.

As NCED looks to other opportunities for increasing diversity through student recruiting, there may be merit, as discussed during the Review Meeting, in aiming at liberal arts colleges, notably in NCED's effort to recruit women. In addition, NCED has 20 PIs. Many could probably work with the R. McNair Program to mentor, or to find mentors, for minority students. This is an effective program that helps foster first-generation minority college students through their undergraduate program into graduate school (http://www.ed.gov/programs/triomcnair/index.html). Suggested contacts for invitation to participate in NCED programs to enhance diversity are listed in Supplementary Items 2.

One additional possibility for diversity outreach in the stream restoration topical area involves the Anacostia River in Washington, DC. This is the focus of various community environmental projects, including some with local residents who are predominantly African Americans. A sustained NCED project or similar effort here could have high visibility and impact.

5 Knowledge Transfer

As mentioned in Section 6 below, the "knowledge transfer" part of NCED holds a key role in its legacy, inasmuch as this legacy resides in the extent to which NCED achieves community engagement, and is perceived as a community leader. Focusing here specifically on the visiting scientist program, the shift to limit this program to critical research areas and project goals — aimed at enhancing buy-in from NCED scientists and developing partnerships — is smart, notably as this meshes well with the vision of "integrated projects" and lends priority to resource allocation. Engagement of early-career scientists is key.

Turning to a larger scale, the United States reentered UNESCO two years ago, and this year reconstituted a U.S. National Committee for UNESCO International Hydrology Programme (see http://water.usgs.gov/nrp/IHP). NCED could collaborate with UNESCO IHP to advance goals that both entities have in common: training, research, and capacity building. (M. Larsen is currently the Chair of the National Committee). This could potentially enhance several NCED goals: diversity, knowledge transfer, and outreach. The Committee meets twice per year in Washington, DC; NCED is welcome to have an observer participate, in person or via phone bridge. (NCED's sister center, SAHRA, has a member on the Committee — Jim Shuttleworth).

NCED could develop relationship with the National Research Council (NRC) Post-doctoral Fellow program to help place NCED graduates. For example, this year the USGS funded six NRC post-docs, including one from NCED (Ben O'Connor).

When NCED PIs have talks, poster sessions, short courses, etc. at AGU, GSA or similar meetings, it could be worthwhile to notify EAB members. Many of us participate in these meetings and we would be able to get a better feel for NCED activities and meet NCED supported researchers and students.

6 NCED Legacy

Two notions were offered regarding the legacy of NCED, that of its continuing in some form as a center of research and education, and that of sustaining the technology and knowledge transfer resulting from its NSF-funded life. Several potential areas/opportunities were presented. Advisory Board members had limited time to ponder and collectively discuss the issue of legacy. So at the risk of offering the obvious, below are several general points to ponder in further deliberations on this issue.

Regarding the second notion above, for many good reasons the knowledge and technology resulting from NCED activities will, in part, naturally be sustained collectively by the larger science, education and policy communities, regardless of NCED's eventual status. A particularly important part of this will be the intellectual legacy represented in the education and research-training of students who become members of these larger communities. Restating the issue, then: Should NCED evolve to a form that possesses (and sustains) a similar science-and-education-driven vision, mission and set of activities, compatible with PI interests and the availability of non-NSF funding, thereby building its intellectual legacy? Or should NCED evolve to a form that is centered on fueling the longevity of its 10-year knowledge and technology legacy through applications in science, education and policy, again in a way that is compatible with PI interests and availability of non-NSF funding? Or some combination of these? It is noted that, in any case, important infrastructure elements — notably, for example, the experimental facilities at SAFL and the field-based facilities at Angelo Reserve — can continue to have important roles.

The power of NCED resides in its collective intellect, and the enthusiasm of its members to collectively engage in challenging problems and issues. This leads to an important point. The current PI makeup consists of folks aimed at pressing the very edge of science. Notwithstanding the excitement that goes with seeing, if not participating in, the transfer of one's creativity into things of immediate social utility, it deserves pause whether NCED's members are likely to enthusiastically take on a collective role that does not have doing on-the-edge science as a centerpiece.

Momentarily considering one possible "applications version" of NCED, Stream Restoration notably emerged from the presentations and discussion as a natural opportunity for developing an NCED legacy identity. We offer here comments on the merits, and counter points, to this idea (as one possible example), with the disclosure that Board members hold mixed views regarding the extent to which NCED should aim at SR as a possible centerpiece of its legacy.

SR is strongly informed by DW, and thus has a close connection to this IP. Indeed, this is a clear example of "the-whole-is-greater-than-the-parts" idea, involving cross-project PIs, students and post-docs. Together these IPs offer opportunity for intellectual contributions that go far beyond current thinking aimed at "in stream" restoration, instead aiming at understanding the larger context (the watershed) as a key part of sustainable restoration. In turn, there are obvious, strong connections to social issues, and opportunities for folding in the social sciences, as has been started. This topic inherently has growing national visibility, with ample opportunity to secure buy-in and participation, if not financial partnering, from national groups and agencies in both public and private sectors. Thus, clear and exciting opportunities for making a significant, lasting national impact (and clear legacy identity) exist in an SR focus.

On the other hand, whereas SR per se is an important application of the science that is being advanced by NCED, the real strength and legacy opportunities of NCED are intellectual, and transcend SR. Whereas SR and similar applied topics certainly motivate important basic-research questions and intellectual challenges, SR represents a relatively narrow focus. And it is not clear that the current NCED team of folks would be the ideal group to collectively engage with equal enthusiasm in this narrow focus in the long haul. NCED has the opportunity to build on what it is creating intellectually, and aim at a larger, richer legacy centered on intellectual advances — meanwhile maintaining and building on the strong merits of the SR IP summarized above.

NSF has made it clear that it is looking for "transformative research" from NCED. One can argue that this translates to "research with a strong intellectual legacy." History suggests that many, if not all, great legacies of science — the works of Galileo, Newton, Darwin and Einstein, to name a few "classics" — transcended the technical advances they represented, and more importantly involved fundamental transformations in styles of thinking. In pondering various models (and missions) for (re)structuring NCED beyond its NSF-funded life, perhaps there is merit in focusing on key elements of NCED activities, research and otherwise, which possess, or rally around, a strong promise of transforming community thinking. Items in the October 2006 document outlining "transformative" themes and activities provide a great starting point, importantly including those parts given to Education, Diversity and Knowledge Transfer. Whatever model, or blending of models, that emerges — a think tank, a national broker for science informed remediation/restoration, an experimental-facilities driven center, a center of excellence in education, etc. — should then retain ingredients that are key to NCED's strength and success, namely, its hallmark of cross-discipline engagement of participating PIs and students, and a structure to fully support these interactions.

More pragmatically, it will become increasing important for NCED to align its mission and activities with those of the participating home institutions as part of a strategy for maintaining internal support, financial and programmatic. In addition, a particularly key part of NCED's legacy will reside in the extent to which it achieves community engagement, and is perceived as a community leader. In addition to building on current efforts aimed at increasing NCED's visibility and community involvement (Section 1), there may well be merit in a focused effort to advertise the availability of NCED's spectacular data sets, possibly highlighting those data sets that complement existing and planned toolboxes as part of self-training on these toolboxes by community users. This could help raise the profile of NCED in the community as these benchmark data sets become known (currently, it seems, community knowledge of these data sets is limited to those visiting the NCED website), and would be an important complement to the existing engagement strategy of visitors, etc. And, on this point, we recommend that NCED make a special effort through its various programs (e.g. visitors program, working groups) to engage early-career folks to enhance "early" buy-in and sustained participation.

Finally, we recommend that NCED leadership aggressively lean on outsiders to provide fresh perspectives, ideas and insight as NCED moves forward in pondering the legacy question.

Supplementary Items

1. Possible contact regarding modeling standards and protocols (Richard Hooper can provide additional information):

Jon Goodall, Duke University (jon.goodall@duke.edu), is the main point of contact. He has evaluated the OpenMI standards mentioned during the NCED EAB meeting discussion.

2. Possible contacts regarding enhancing diversity (Matthew Larsen can provide additional information):

Professor Ingrid Padilla, Department of Civil Engineering and Surveying, University of Puerto Rico, Mayaguez, PR. padillai@uprm.edu, phone: 787-832-4040, ext 3417.

Professor José Molinelli, Department of Environmental Science, University of Puerto Rico, Río Piedras, PR. jmoline@upracd.upr.clu.edu, phone: 787-764-0000, ext. 2550.

Professor Kimberly L. Jones, Department of Civil Engineering, Howard University, Washington, DC (Kim is currently on the National Academy of Science Water Science & Technology Board). kljones@howard.edu, phone: 202-806-4807.

Dr. Thomas Byl, USGS Water Science Center, Nashville, Tennessee. Tom is a geomorphologist and has a faculty position at Tennessee Tech University, a minority university. He regularly mentors Tennessee Tech students. tdbyl@usgs.gov, phone: 615-837-4750

Directors' Response to the Report of the External Advisory Board

Preamble

We thank the EAB members for their sincere interest in NCED progress and continued success as a Center of excellence in Earth-surface science, education, and outreach. Their advice and feedback on the questions we posed are much appreciated. Below we provide a brief reply to the main issues of the report.

NCED Structural Progress

We are pleased to see that both the site visit panel, the reviewers of the renewal proposal, and the EAB members continue to view our three Integrated Projects (IPs) as a successful way of structuring our science to maximize cross-disciplinary efforts.

We continue to encourage leadership and autonomy among our students and post-docs, who seem to thrive in such an environment.

We have transitioned to allocation of funds based upon IPs. To achieve this, this year we introduced a proposal-based system of resource allocation, accountability, and overseeing of cross-IP integration activities. The proposals were reviewed by the Executive Committee (EC) and extensively discussed in three 2-hour teleconferences of the EC. Review comments are being provided to each PI addressing quality, relevance of research to NCED's mission, integration with research of other PIs, as well as contributions to Education, Knowledge Transfer, and Diversity.

We continue our efforts to include a broader spectrum of the community in NCED activities and provide visibility and service via short-courses, special sessions in major conferences, and presentations. Also, several of our PIs are involved in major national efforts such as CUAHSI, CSDMS, NCALM, NCAR, Hydrology synthesis activities, a broader Mississippi Delta Initiative, and national education and knowledge transfer activities.

Research Integrated Projects

Research IPs

Subsurface Architecture (SA)

We have expended considerable effort over the past two years to ensure that all IPs (SA, DW, and SR) are well integrated and complementary to each other. We are striving to make sure that this comes across well in our presentations, especially on how SA relates to DW and SR. In fact, over the past year, further focusing of the SA IP has taken place as reflected in the revised SIP. The main idea, as elegantly expressed in the EAB report too, is to create a new way of thinking in understanding the dynamics of erosional-depositional systems via (a) exploration of the subsurface and development of the surface-subsurface connection, and (b) a trinity of theory/experiment/field-based research.

Stream Restoration (SR)

We appreciate the comment to present our SR efforts in a less NCED-centric way. There are many parallel SR efforts in the larger community and over the next years (in view of developing a plan for NCED legacy and sustainability) the unique leadership that NCED can provide in this arena will be further sharpened and clarified.

Desktop Watersheds (DW)

We appreciate the positive comments of the scope and accomplishments in the IP. This year, as more DW tools become available, we will develop the links to other modeling efforts (CUAHSI-HIS and CSDMS) to ensure compatability of standards and protocols.

Social Science Component

The EAB's assessment of the role of social sciences in the Earth-surface dynamics is very insightful. Our social sciences component has focused more on demonstrating the usefulness of the models and tools developed by NCED in solving environmental decision and policy making problems, rather than incorporating predictive social and economic components into landscape modeling. However, an exploration of the possible use of a market model to predict land use dynamics in the context of the Mississippi Delta restoration efforts will be undertaken.

Education

We are pleased that the EAB recognizes the value in providing NCED graduate students a unique experience; one they could not have outside a Center, by providing them opportunities such as retreats, international research travel and cross-disciplinary advising. We believe this will make our graduates especially effective leaders in their research generation; in many ways, they are NCED's education legacy.

Several comments from the EAB fall into the general category of a seeming lack of strategy to NCED's Education efforts and a lack of integration of these efforts with NCED's unique interdisciplinary research and/or with individual PIs. We believe this is largely a matter of perception, so here we re-iterate language from NCED's Strategic Plan. We believe this constitutes a very clear and thoughtful strategy and apologize that the brief duration of the EAB retreat did not allow sufficient time to communicate this well.

> *"Motivation: The familiarity and natural appeal of landscapes, and the methods of NCED's integrative research approach, provide rich opportunities to excite students about science and encourage them to pursue careers in many areas of science and policy.*
>
> *Goal: Bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED's key mission areas of land, resource, and ecosystem management.*
>
> *Approach: NCED uses the familiarity and natural appeal of landscapes to promote active learning about critical concepts: (1) that the Earth's surface is "the environment" in which human, ecologic and physical dynamics are intimately interwoven; (2) that the Earth's surface is naturally dynamic; and (3) that the landforms we see around us – whether from the ground, from the air, or via maps and 3D imagery – tell us about what the Earth's surface is doing and how it has evolved.*
>
> *At the graduate level, NCED engages students, across NCED institutions, in integrative research and unique center-based activities, such as video-conferenced seminars, joint advising, integrative seminars and short courses, center retreats, museum assistantships and internships with Partners. At the undergraduate level, NCED engages students within and outside NCED institutions in research experiences and infuses the methods, perspectives and results of NCED research into undergraduate coursework. At the K-12 level, NCED engages pre- and in- service teachers in research experiences and field-based institutes, develops teaching materials to supplement K-12 curriculum, brings experimental research to classrooms, and conducts environmental camps at middle- and high-school levels. NCED engages the public in NCED research through innovative museum experiences, such as outdoor parks and traveling exhibits, and media, such as films and television programs."*

In summary, both in partnership with the Science Museum of Minnesota (SMM) and otherwise, NCED conducts learning experiences for learners at a variety of levels, infusing into each of these programs the appropriate (or realistic given staffing levels) degree of direct participation in NCED research and/or direct use of the same tools and methods used in NCED research, such as physical experiments, collection of field data, and use of cutting edge visualization techniques.

The suggestion that all NCED PIs should be a part of NCED's education initiatives is a good one. To the degree that they advise our graduate students and summer interns, they all are involved in NCED Education. In addition, several NCED PIs have been involved in developing and delivering very successful graduate level short courses, held in conjuction with annual professional meetings. Attempts to involve all PIs or their individual research across all of NCED Education is somewhat impractical, given the fact that NCED spans the entire US geographically. It simply is not possible to regularly directly involve such far flung PIs in the programs that are administered from NCED's headquarters.

The EAB recommends extending the Stream Restoration Certificate program to high school teachers. To some degree, our current Earthscapes Teacher Institute, which has been conducted through SMM for 3 years, does mirror the SRC. Beyond that effort, however, we do not see a logical motivation for high school teachers to seek stream restoration certification. There is some earth science at the high school level in the Minnesota Science Standards, but most of it is at the middle-school level. In addition, rivers are not directly addressed anywhere in the standards. We believe our current program of a river-based summer institute for middle- to- high-school teachers, the River Restoration Residency program, which is available for in-class use at the same levels, and our ESTREAM internship program for pre-service or in-service teachers constitute a set of experiences similar in spirit to the Board's suggestion, but more in keeping with the realities of teaching in Minnesota. We also note that the Board recommends in-school work with SMM and development of an internship program for teachers. As detailed above, we do already do both of those things and apologize if that was not made clear during the meeting.

There is a theme in the EAB recommendations that suggests more work with high school students and teachers. While we appreciate the spirit of this suggestion, this advice differs fairly substantially from that we have received from NSF and from Site Visit Committees. NSF has specifically asked STC's to limit direct programming at the K-12 level, in favor of focused efforts to improve science instruction and diversity involvement at the undergraduate level and beyond. We have specifically been encouraged by Site Visit committees to work harder on improving undergraduate instruction, hence our work in the past year on the "delta box". NCED is committed to the full educational pipeline and so has chosen not to fully embrace the NSF suggestions, but we do not feel we have the staff, resources or funding mandate to expand, at the K-12 level, beyond our current activities.

NCED's Education program has evolved on the same time scale as NCED's research. This means the excellent Board suggestions to make greater Educational use of NCED data and its research core has been a bit of a "moving target". As we move into the renewal and legacy periods, we will make a concerted effort to make NCED data and its research core a more integral and visible aspect of NCED's Education programs.

Diversity

NCED's faculty have responded enthusiastically to the EAB's suggestions and taken a particularly active role this past year in NCED's recruiting efforts, bringing in new graduate students, post-docs, and staff scientists from underrepresented backgrounds, bringing the percent of our research personnel from these backgrounds to 19% of our total research group. In addition, our Native American youth science enrichment programs have been successful in broadly recruiting scientists from centers and research laboratories at the University of Minnesota and around the country. In addition, NCED faculty, post-docs, and graduate students will host our *gidakiimanaaniwigamig* students and other scientists from the University of Minnesota this summer for a Science Fair Day, where students will have will have a chance to brainstorm science fair projects for next year and be paired with mentors who can act as advisors for their projects.

Knowledge Transfer

We agree that KT is a key component of NCED's legacy, and community engagement and leadership are necessary ingredients on which we continuously invest considerable effort. The idea of EAB approaching the UNESCO IHP, is great and we plan to follow up on this. We note that we are pursuing similar involvement with CUAHSI at the national level. We plan to pursue more vigorously NRC post-doc fellowship opportunities although most of our NCED graduates are successful in securing good positions as faculty or in targeted research groups of their choice. The advice to notify EAB members of NCED presentations at national conferences so they can have the chance to link with PIs and students is a good one and we plan to implement starting with the AGU Spring meeting.

NCED Legacy

The overaching philosophy of NCED's legacy is to sustain our position as a center of research, as well as to sustain the technology and knowledge transfer resulting from this research. To realize these objectives, the Executive Committee will appoint a transition team to develop a master plan that prioritizes between alternative possibilities and create an investment strategy for the next five years of Center operation. In order to start diversifying the Center's sources of support, the transition team will also work with staff at the University of Minnesota and our partner institutions to define networking, visibility, and fundraising objectives.

A formal document stating the guiding principles and goals, as well as the composition of the transition team, will be available prior to the annual site visit and will be distributed to the EAB at that time.

Supplementary Items

We thank the EAB members for the excellent references for diversity members to add to EAB. We will evaluate these suggestions in light of the evolving makeup of the EAB and NCED's needs and goals.

Appendix D: Media Publicity Materials

1. Minnesota Public Radio "The mountains beneath us" interview with Chris Paola (August 2006)
2. Minneapolis Star-Tribune "A river runs through it" (November 2006)
3. Minnegram "StreamLab research bridges disciplines" (December 2006)
4. National Geographic Channel "Naked Science: Dino Meteor" (April 19, 2007)
5. Scientific American "Down go the dams" (March 2007)

Minnesota Public Radio "The mountains beneath us" interview with Chris Paola (August 2006)

MINNESOTA PUBLIC RADIO®

The mountains beneath us

Broadcast: Midmorning, 08/08/2006, 10:06 a.m.

After Hurricane Katrina ravaged New Orleans, our focus on the geology of the area sharpened. Midmorning takes a closer look at areas where the Earth's crust is sinking, and how they are connected to human settlement and the kind of flooding we saw along the Gulf Coast.

GUESTS

Chris Paola: Professor of geology and geophysics at the University of Minnesota, and director of the National Center for Earth-surface Dynamics.

Minneapolis Star-Tribune "A river runs through it"
(November 2006)

StarTribune.com | MINNEAPOLIS - ST. PAUL, MINNESOTA

Last update: November 28, 2006 – 10:32 PM

A river runs through it

When some testing equipment from a U lab set off a bomb scare, lab officials decided to use the publicity to show off their facility.

Tom Meersman, Star Tribune

It's unlikely that scientific tools from the St. Anthony Falls Laboratory on the Mississippi River will cause another bomb scare at the Minneapolis-St. Paul International Airport or anywhere else.

That's because researchers at the lab ordinarily don't need to travel very far to conduct their experiments. The five-story structure on the edge of Hennepin Island in downtown Minneapolis uses a natural waterfall as its prime source of water for experiments in how rivers work.

"We have an indoor river right in this building," said Karen Campbell, the lab's education director.

Over the weekend, an Oregon researcher left behind a water temperature monitor she had been using at the lab in a rental car at the airport. When a rental car employee discovered the pipe-like device, a bomb squad was called in and the device was destroyed before the equipment was deemed harmless.

The incident thrust the St. Anthony Falls Laboratory, already well-known in the scientific community, into the public spotlight. On Tuesday, researchers at the lab were both amused and a bit taken aback at all the attention.

At the same time, they also appreciated a chance to make people more aware of what they do and its importance. Campbell said that the lab is unique because gravity from the 50-foot drop in river level allows scientists to route water into the lab and through numerous flumes, channels, basins and tanks that are used for experiments. The indoor river is nearly 300 feet long, 9 feet wide and 6 feet deep, and has been used to study the dynamics of flowing water over different river bottoms.

The lab has developed an international reputation during the past 70 years, said Campbell. The attention spiked in 2002 when it was named as one of the National Science Foundation's science and technology centers. It received a five-year, $19.5 million grant from the foundation and became the headquarters for the National Center for Earth-surface Dynamics. The lab has about 100 employees, she said, including faculty members, research fellows from other countries, post-doctoral scientists, graduate students and technical staff.

Campbell said the lab focuses on three areas: field work, experiments and building computer models. The common purpose, she said, is to better understand how the earth, and particularly its river channels, respond to forces ranging from floods and tsunamis to erosion and sedimentation. "By combining engineers with field-based geologists and ecologists, we get an interdisciplinary approach that builds bridges from the theoretical to real-world applications," she said.

Omid Mohseni, the lab's associate director of applied research, said that ecology is playing a larger role in the lab's experiments. As natural resource managers and others consider removing dams along rivers, or restoring the natural meanders of rivers that were straightened and channelized, Mohseni said there's more need to understand how rivers operate.

Some of the works in progress are visible on a quick tour of the lab. One scientist is "growing" a river delta by releasing sediment slowly into a tank, while another studies the rate of algae growth on progressively rougher surfaces at the bottom of an artificial stream. Another mimics nature by introducing different sediments into moving water and studying how they settle and stratify over a period of weeks or longer.

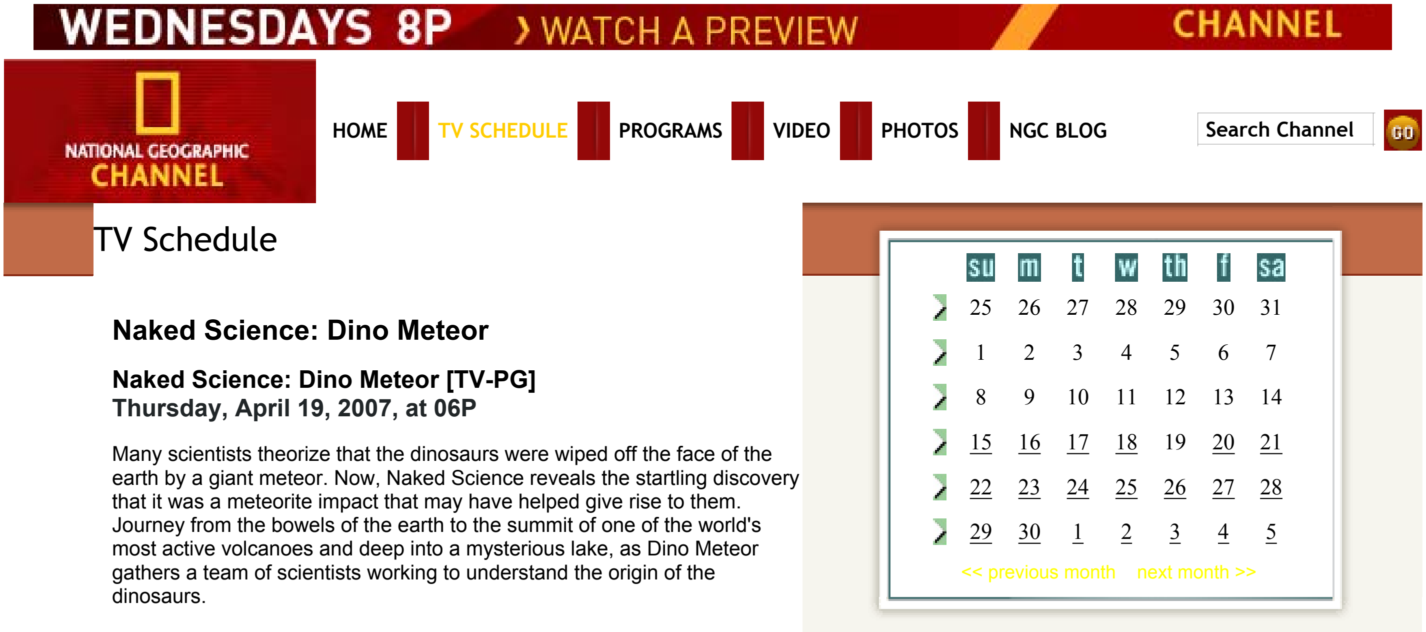
Some of the lab's experiments test industrial equipment, and whether computer models are accurate, but Mohseni said that the lab is also helping Minnesota officials develop better ways to treat storm water, to deal with road salt runoff, and to protect trout streams from large-scale developments.

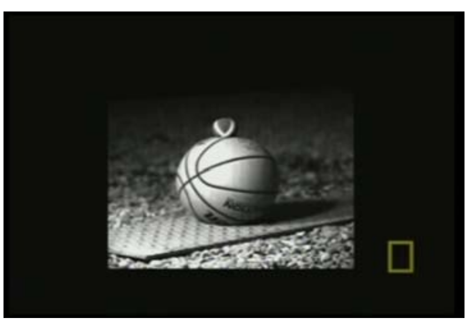
Campbell said the lab may not be famous locally, but that it has created visuals for television programs such as Nova and National Geographic, and that it has allowed news programs to put reporters into its wind tunnel -- which can produce winds of up to 110 miles per hour -- to demonstrate the velocity of tropical storms and hurricanes.

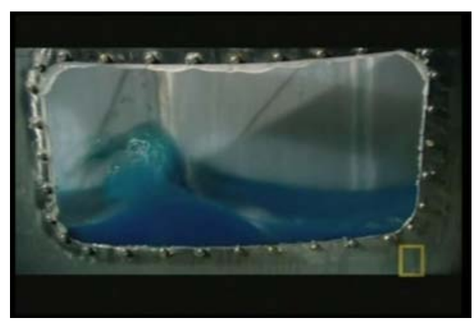
The lab's relative obscurity seems to be changing. Earlier this year it adorned its white industrial exterior with colorful signs, Campbell said, so that Guthrie Theater patrons and others spending time along the river could identify it. And the scheduled opening of a new private park on Hennepin Island next spring, owned by Xcel Energy, will also bring the public closer to where the lab sits near the river's edge.

Tom Meersman • 612 673-7388 • meersman@startribune.com

National Geographic Channel "Naked Science: Dino Meteor" (April 19, 2007)







In November 2006, a film crew for the National Geographic Channel came to the St. Anthony Falls Laboratory to film a series of demonstrations showing the formation and unique features of meteor impact craters and antipodal force effects. These demonstrations appeared as part of National Geographic Channel's "Naked Science" series in the episode "Dino Meteor." This episode first aired on the National Geographic Channel on April 19, 2007. NCED Director Chris Paola, NCED Postdoctoral Associate Doug Jerolmack, and Junior Scientist Craig Hill all appeared in the documentary.

Minnegram "StreamLab research bridges disciplines" (December 2006)

StreamLab research bridges disciplines

by Cailin Huyck Orr, Postdoctoral Associate with the National Center for Earth-Surface Dynamics

As social demand for stream restoration increases, restoration practitioners are challenged by our limited understanding of stream disturbance and restoration dynamics in river and floodplain ecosystems. The scientific basis for stream restoration is insufficient, and the outcome of existing projects is often undetermined. This scarcity of information exists, in part, because the answers to restoration questions require interdisciplinary answers. Now the challenge of integrating research across disciplines is being met by a new approach at the National Center for Earth-Surface Dynamics (NCED) called "StreamLab" that combines physical, biological, and social sciences in an integrated approach to stream restoration.

StreamLab is a multi-phase research endeavor being conducted in the Main Channel flume at the St. Anthony Falls Laboratory of the University of Minnesota. This program brings together a spectrum of research expertise and includes investigators from several fields including Jacques Finlay (University of Minnesota, Ecology, Evolution and Behavior), Miki Hondzo (UMN, SAFL, eco-fluid dynamics), and Peter Wilcock (Johns Hopkins University, geomorphology).

Photo by Brad Stauffer

NCED post-doc Nancy Brown works in the Main Channel facility to deterime effects of algal growth on sediment transport during flood periods.

River restorations can have multiple goals. These depend on the setting and the ecosystem functions that need to be rehabilitated. The motivation behind StreamLab is to determine how the stream parameters commonly manipulated during restoration impact basic ecosystem functions such as nutrient uptake and retention, periphyton biomass accumulation, gross primary productivity, and community respiration. Understanding these interactions will allow practitioners to design restoration projects that promote favorable and sustainable ecosystem function.

While it is possible to study some aspects of sediment transport and hydraulics in the laboratory using small-scale models, many key features of stream ecosystems cannot be scaled down. Thus consideration of ecological and biological aspects of stream restoration demands a physically realistic field-scale facility. The Main Channel facility, and a larger outdoor facility to be completed in 2007, will be ideal for such studies because each retains some aspects of a controlled laboratory environment, while operating at a scale similar to a real stream.

The flume test reach in the Main Channel facility is 50 meters long and draws water directly from the Mississippi River. This has the benefit of providing ambient levels of nutrients and microorganisms, but also provides the challenges of the natural, seasonal variability in the river. While water is taken continuously from the river, the flume has a sediment recirculation system that allows experimenters to introduce different sizes of sediment.

Recent data collection carried out by the StreamLab team included examining nutrient uptake by algae and bacteria, autotrophic and heterotrophic biomass measurements and the impact of these on surface water chemistry done by NCED post-doc Cailin Huyck Orr and EEB graduate student Becky Stark. Jeff Clark, a visiting professor from Lawrence University, conducted measurements of water exchange with the hyporheic zone under different bed conditions. NCED post-doc Nancy Brown and UC Berkeley graduate student Mike Limm are currently measuring how strongly algae growth can limit sediment transport during flooding. Plans for next year include employing findings from StreamLab06 to NCED fieldsites at the Angelo Coastal Reserve in Northern California and in the new outdoor flume facility being built at SAFL.

More information about Streamlab can be found on the NCED Web site: http://www.nced.umn.edu/Streamlab/.

Cailin Huyck Orr, an NCED post-doc, retrieves a water sample from the Main Channel facility at St. Anthony Falls Laboratory.

Scientific American "Down go the dams"
(March 2007)

DOWN GO THE

Many dams are being torn down these days, allowing rivers and the ecosystems they support to rebound. But ecological risks abound as well. Can they be averted?

BY JANE C. MARKS

DAMS

KEITH PLUMMER *Courtesy of NOAA Restoration Center*

At the start of the 20th century, Fossil Creek was a spring-fed waterway sustaining an oasis in the middle of the Arizona desert. The wild river and lush riparian ecosystem attracted fish and a host of animals and plants that could not survive in other environments. The river and its surrounds also attracted prospectors and settlers to the Southwest. By 1916 engineers had dammed Fossil Creek, redirecting water through flumes that wound along steep hillsides to two hydroelectric plants. Those plants powered the mining operations that fueled Arizona's economic growth and helped support the rapid expansion of the city of Phoenix. By 2001, however, the Fossil Creek generating stations were providing less than 0.1 percent of the state's power supply.

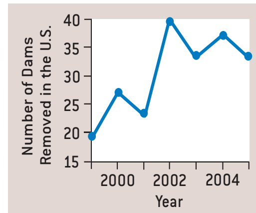
Nearly two years ago the plants were shut down, and an experiment began to unfold. In the summer of 2005 utility workers retired the dam and the flumes and in so doing restored most of the flow to the 22.5 kilometers of Fossil Creek riverbed that had not seen much water in nearly a century. Trickles became waterfalls, and stagnant shallows became deep turquoise pools. Scientists are now monitoring the ecosystem to see whether it can recover after being partially sere for so long, to see whether native fish and plants can again take hold. They are also on the lookout for unintended ecological consequences of the project.

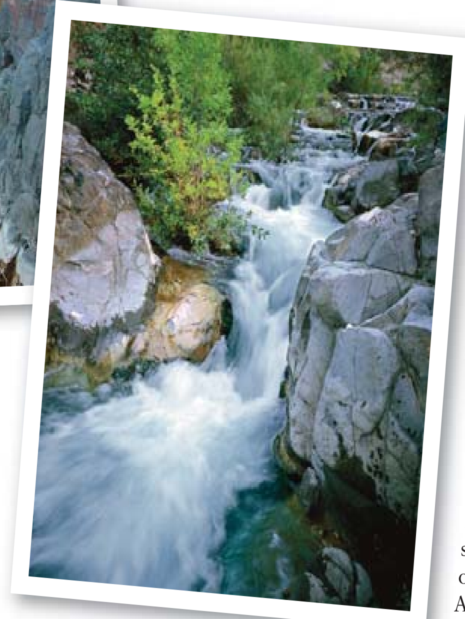
Decommissioning dams (particularly small ones, as is the case in Fossil Creek) is becoming a regular occurrence as structures age, provide an inconsequential share of a region's power, become unsafe or too costly to repair, or as communities decide they want their rivers wild and full of fish again. But simply removing a dam does not automatically mean a long-altered ecosystem will flourish once more. As with all things natural, reality often proves far more complex and intricate than people anticipate. Those of us who have witnessed many of the unexpected consequences of dam removals are now using that knowledge to try to minimize negative results in the future.

A Global Trend

TODAY ABOUT 800,000 dams operate worldwide, 45,000 of which are large—that is, greater than 15 meters tall. Most were built in the past century, primarily after World War II. Their benefits are clear. Hydroelectric power makes up 20 percent of the globe's electric supply, and the energy is largely clean and renewable, especially when contrasted with other sources. Dams control flooding, and their reservoirs provide a reliable supply of water for irrigation, drinking and recreation. Some serve to help navigation, by stabilizing flow.

SANDY RIVER DAM removal is part of the long-term restoration of Maine's Kennebec River. In 1999 the Edwards Dam on the Kennebec was taken down; soon after, many of the river's native fish returned and their populations grew dramatically. Unconstrained flow of the Sandy River, a tributary of the Kennebec, was restored last summer to ensure that no barriers prevent migratory fish from moving freely.





FOSSIL CREEK, which is fed by seven underground springs, went from merely a trickle (*above*) to a bubbling flow of 314 gallons a second after engineers redirected the water around an old hydropower dam (*right*). Scientists are now studying the creek to see how the food chain changes and to determine whether native species flourish. The dam was one of more than 30 removed in the U.S. in 2005 (*graph*).

NICK BEREZENKO *Arizona Public Service (Fossil Creek photographs)*; SOURCE: AMERICAN RIVERS *(graph)*

Their costs are obvious as well. Dams displace people and as a result have become increasingly controversial in the developing world [see "The Himba and the Dam," by Carol Ezzell; SCIENTIFIC AMERICAN, June 2001]. The structures ruin vistas, trap sediments (needed for deltas, riverbanks and beaches), stymie migratory fish and destroy ecosystems in and around waterways. Conservationists have a long history of opposing dams: John Muir tried to block the dam in Yosemite's Hetch Hetchy Valley; Edward Abbey's novel *The Monkey Wrench Gang* targeted Arizona's Glen Canyon Dam for guerrilla demolition. In recent years, as the downsides of dams have become more widely recognized, groups made up of several interested parties—utility officials, regulators, policymakers, conservationists, native peoples, researchers and the public—have fought to decommission aging dams.

In the U.S., where hydropower dams must be relicensed every 30 to 50 years, the rate of dam removal has exceeded the rate of construction for the past decade or so. In the previous two years alone, about 80 dams have fallen, and researchers following the trend expect that dams will continue to come down, especially small ones. Although the U.S. is currently leading the effort, it is not alone. France has dismantled dams in the Loire Valley; Australia, Canada and Japan have also removed, or are planning to remove, dams.

Clear successes have driven much of this activity. In 1999 engineers took apart the Edwards Dam on Maine's Kennebec River after a long battle waged by environmentalists culminated in the Federal Energy Regulatory Commission's denial of a renewal permit. Within years, biologists observed with some surprise the return of scores of striped bass, alewives, American shad, Atlantic salmon, sturgeon, ospreys, kingfishers, cormorants and bald eagles. They also found that the water became well aerated and that populations of important food-chain insects such as mayflies, stoneflies and caddisflies grew.

In the Loire Valley, the story is similar. Salmon were abundant in the 19th century—about 100,000 would migrate each year—but by 1997, only 389 were counted making the trip. Despite the incorporation of fish ladders and elevators, the eight dams along the Loire and its major tributaries—as well as their turbines and pumps—had decimated the salmon population. Nongovernmental organizations, including the European Rivers Network, led a campaign to bring the salmon back. In response, the French government decommissioned four of the dams—two in 1998, one in 2003 and one in 2005. Within a few months of each dam removal, five species of fish, Atlantic salmon and shad

Overview/Restoring River Flows

- Some 800,000 dams exist around the world, but small ones—and even some large ones—are increasingly being removed so rivers and streams can recover.
- Ecologists are learning, however, that removing or lowering dams takes a great deal of careful planning and active intervention because sometimes the dams confer environmental benefits, such as holding back toxic sediments or blocking the progress of invasive species.
- Before decommissioning a dam on Fossil Creek in Arizona, managers poisoned exotic fish and airlifted native species to safety. Such strategies could prove key to the success of future dam removal projects.

among them, began to reestablish their historic migratory pathways.

In most places where dams have been eliminated, the stories of the Kennebec and the Loire have been repeated. Water clarity and oxygen levels increase as flow comes back, and aquatic insects thrive again. Warm stagnant water runs from behind the dam along with the fish, such as nonnative carp, that love it. As the water moves freely, its temperature falls and cold-loving fish species, such as trout, proliferate or return. The carp population, which tends to squeeze out others, dwindles, sometimes disappearing completely. People, in addition to flora and fauna, return to enjoy the rivers. Biologists have observed these benefits from Wisconsin—one of the U.S. leaders in small dam removal—to New South Wales in Australia. Even restoring some water to rivers without removing a dam has had positive effects [see "Experimental Flooding in Grand Canyon," by Michael P. Collier, Robert H. Webb and Edmund D. Andrews; Scientific American, January 1997].

The Downsides

Biologists have also recorded unexpected problems. The release of sediments trapped behind a dam's walls can choke waterways, muddying the environment and wiping out insects and algae, which are important food for fish. This wave of turbidity can also eliminate habitat for sessile filter feeders, such as freshwater mussels. Sometimes the mud that had been held back by the structures is rife with contaminants. When engineers removed the Fort Edward Dam on the Hudson River in 1973, concentrations of PCBs rose in downstream fish and remained high for many years; even today the striped bass fishery remains closed because of high levels of PCBs.

Sediments that are not washed downstream can become problematic as well. As they dry out, they may provide fertile ground for potentially noxious exotic plants whose seeds they harbored. Eurasian reed canary grass—which homogenizes wetlands by outcompeting native plant species—grew explosively after Wisconsin's Oak Street Dam fell, even though restoration scientists had seeded the area with native prairie plant species.

In some cases, dams have blocked invasive species from moving upriver and into zones above the dam. The dam at Fossil Creek, for example, halted the advance of exotic fish such as bass and sunfish, creating a sanctuary above the structure for imperiled southwestern fish, including headwater chub and speckled dace. The reservoir also provided habitat for a locally threatened species, the lowland leopard frog.

And dam removal can pose dangers for people living nearby. In places where flood control is crucial, government organizations have had to devise safety strategies before dams could come down. In the case of the Loire basin, the government computerized data on weather patterns, rainfall and river levels so flood warnings could be released at least four hours before danger arrived. Engineers also redesigned riverbeds to be wider and deeper, so the waters of the Loire Valley could move more freely without overflowing the banks.

Often a big issue facing managers is what to do with ACCUMULATIONS OF DIRT AND DEBRIS.

Delicate Decommissioning

The Fossil Creek restoration project offers a prime example of the kind of planning that could help minimize the damaging effects of dam removal. Researchers carefully planned to control possible disadvantages of the operation. Their principal concerns were what to do with the accumulated sediments, whether to manage the fishery as a native one (which would mean removing exotic species) and how to protect the reservoir-resident frogs. Ultimately engineers decided to reroute water around the dam, keeping it as a barrier to exotics and permitting the frogs to survive in the backwater.

In addition, biologists decided to actively manage the native fish. They caught as many as they could from the creek itself and airlifted them to a holding tank. They then doused the creek with fish poison to kill exotic species and returned the natives to the water once the poison had dissipated. The U.S. Bureau of Reclamation built a fish barrier 12 kilometers below the existing dam to further impede exotics. Now managers are waiting to see how the Fossil Creek species do. The dam's fate will be decided in 2010: if the leopard frog becomes established downstream and exotic fish have not reinvaded the creek, the dam will come out. If not, it will be lowered but not eliminated.

Interestingly, restoring Fossil Creek involves the creation of many more dams—but these will be made of travertine, formed naturally as the calcium carbonate–rich water of the springs interacts with algae to form layers of limestone. These barriers create small, deep pools, the perfect habitat for a variety of fish and insects. They also trap leaf litter, a crucial food source for the river's denizens—one that the presence of manmade dams often eliminates by trapping it permanently behind the barrier.

Wrangling Sediment

Sediments stuck behind dams are proving crucial variables when dams are

THE AUTHOR

JANE C. MARKS owes her career as an ecologist to algae. After completing her undergraduate degree in English at the University of Michigan at Ann Arbor, Marks became fascinated with aquatic plants and earned an M.S. in biology from Bowling Green State University and then a doctorate from the University of California, Berkeley. In 1995 she began working for the U.S. Agency for International Development, advising the organization about conservation and resource management issues all over the world. In 1999 she joined the faculty at Northern Arizona University. Her work on Fossil Creek is being featured in a new documentary, *A River Reborn: The Restoration of Fossil Creek* (see www.riverreborn.org).

taken down. Often the biggest issue facing managers is how to contend with what can be a massive accumulation of dirt and debris. Because of the legacy of releasing PCBs downstream in the Hudson River, scientists now routinely test these materials for toxicity. If the sediments contain high levels of pollutants, the cost of removing them—especially from remote locations—has to be weighed against the ability of the waterway to wash them away. If the sediment load is very high and the river's flushing capacity low, engineers might opt to remove the dam in stages, allowing small amounts of sediment to be released at a time. Sometimes engineers build channels through reservoirs, planting vegetation to stabilize sediments or placing physical barriers such as rocks or temporary fencing to hold the dirt in place.

In Fossil Creek, where roughly 25,000 cubic yards of sediment are trapped behind the dam, geologists and others predicted that the river would naturally flush the sediments downstream within a decade, without any adverse effects. So the project did not have to weigh the cost and negative environmental impacts of transporting heavy machinery into a wilderness area.

Sediments pose a much bigger problem in many other places, however. Six million cubic yards of dirt lie behind the Matilija Dam on the Matilija Creek in southern California. (So much sediment, in fact, that the dam no longer serves to store water for irrigation or drinking.) At the same time, the downstream beaches are starved of sediment: they badly need dirt and sand to stave off ongoing erosion from wind and rain.

Matilija Dam is scheduled to be decommissioned in 2009, and managers have devised an elaborate sediment plan. They intend to transport fine sediments from behind the dam through a slurry pipe to sites five to 11 kilometers downstream. From there, the river will do the work by redistributing these materials during flood events to form beaches and sandbars. The larger, or coarse-grained, sediments that have accrued upstream of the dam will be left in place, but engineers will regrade the river channel there into a more naturally sinuous one, which will better protect against flooding by allowing sediments to settle and rebuild the banks.

Going Forward

AT FOSSIL CREEK and elsewhere, managers and scientists are using all available information about dam removal and restoration ecology, as well as what they know of the entire watershed, to make decisions. But many gaps in our knowledge about ecosystems remain, and those working on decommissioning dams recognize they are conducting long-term experiments that may have unanticipated results. Fossil Creek, for example, was the first such project in which exotic fish were removed. If successful, this strategy could become routine, especially in smaller streams where chemical treatment is feasible.

At Fossil Creek our research team will now document how the river recovers. Among many unanswered questions we hope to focus on in the next five to 10 years are: Will native fish prosper without intervention? Will exotic fish come back? One interesting but problematic twist in the Fossil Creek story is that the chemical used to eliminate the exotic fish does not harm exotic crayfish, which are notorious for wreaking havoc on the food chain. The exotic fish had consumed crayfish, thereby keeping the crustacean's population down. Perhaps we will have exchanged one adverse situation for

NATIVE FISH return to Fossil Creek in buckets (*above*), after having been airlifted out and placed in holding tanks. Biologists treated the river with fish poison to get rid of the exotic species before returning the natives. Nonnative species were also a problem after engineers removed the Oak Street Dam on the Baraboo River in Wisconsin. Eurasian reed canary grass dominated the riverbanks, even though managers had planted native species (*right*).

CARRI J. LEROY (*left*); FROM "TRADING OFF: THE ECOLOGICAL EFFECTS OF DAM REMOVAL," BY E. H. AND M. W. DOYLE, IN *FRONTIERS IN ECOLOGY AND THE ENVIRONMENT*, VOL. 1, PAGES 15–22; 2003; COURTESY OF CAILIN HUYCK ORR (*right*) another. In addition, as Fossil Creek rebounds, so do the numbers of visitors to it. With more hiking trails in place along the river, managers now need to devise rules that can allow people access but also protect the fragile ecosystem.

To supplement the in situ experiments such as the one at Fossil Creek, researchers are using computer simulations and are conducting indoor studies. The National Center for Earth-surface Dynamics in Minnesota has created a model ecosystem of miniature streams, dams and reservoirs. Investigators there use time-lapse photography to determine how sediments move downstream as dams are removed in different ways and to different extents.

Many engineers who were once dedicated to building dams now find themselves instead working on decommissioning them. U.S. government agencies such as the Bureau of Reclamation and the Army Corps of Engineers, as well as their European counterparts, are studying not only how to remove dams but also how to provide the benefits of the structures without their injurious effects—for instance, how to extract water from rivers without building blockades. In response to a 2000 report by the World Commission on Dams, engineers are also trying to incorporate decommissioning into the original designs of future dams.

Societies will continue to balance the pros and cons of dams, weighing their utility and benefits against their destructive costs. And scientists must continue to learn about how best to remove dams so natural ecosystems and human communities both can thrive. In the next few years the decommissioning of several large dams will provide further important knowledge. In 2009 two dams will be removed from Washington State's Olympic National Park: the 210-foot-high Glines Canyon Dam and the 108-foot-high Elwha Dam. Scientists in both locations are now collecting baseline data about salmon and steelhead, as well as oxygen levels, insect populations and sediment loads. Japan's Arase Dam will come down in 2010 in response to a long campaign by citizen activists concerned about poor water quality and a decline in fisheries. Australia will transform the 19,500-acre Lake Mokoan into a wetlands again when its dam is removed, while France contemplates the fall of a fifth Loire Valley dam.

In most cases, controversy about decommissioning arises—and sometimes the debate is unexpected. In the Loire Valley, a father and son ended up on different sides of the divide. The father remembered the wild rivers and the salmon runs; the son had grown up swimming and boating in the reservoir. In the case of Fossil Creek, the local community wanted to preserve components of the generating station, the Childs-Irving facility. Built by one of the few female engineers of that era, Iva Tutt, and maintained by generations of engineers who lived at the site with their families, the plant was culturally significant, and, accordingly, its preservation became part of the restoration plan.

The same proved true of the Wellington Dam in New South Wales, Australia. In 2002 the State Water Corporation ensured that a one-meter-high footprint of the structure remained (minus one gap for flow) across Bushrangers Creek so the public could still appreciate the dam that was built in 1898. With compromises such as these, along with further ecological insights and more flexible engineering, it seems possible to think of the world's waterways as ultimately fulfilling their promise for all parties—from plants to people. SA

RIVER MODEL at the National Center for Earth-surface Dynamics in Minnesota provides scientists with a way to study how sediments move. This research can help experts plan what to do with the dirt and other material that accumulates behind dams.

CHRIS BROMLEY AND NATIONAL CENTER FOR EARTH-SURFACE DYNAMICS

MORE TO EXPLORE

Undamming Rivers: A Review of the Ecological Impacts of Dam Removal. A. T. Bednarek in *Environmental Management*, Vol. 27, No. 6, pages 803–814; June 2001.

Dam Removal: Challenges and Opportunities for Ecological Research and River Restoration. D. D. Hart et al. in *BioScience*, Vol. 52, No. 8, pages 669–681; August 1, 2002.

Dam Removal Research: Status and Prospects. Heinz Center, 2003. Available at **www.heinzcenter.org/NEW_WEB/PDF/Dam_Research_Full Report.pdf**

Trading Off: The Ecological Effects of Dam Removal. Emily H. Stanley and Martin W. Doyle in *Frontiers in Ecology and the Environment*, Vol. 1, No. 1, pages 15–22; 2003.

Interactions between Geomorphology and Ecosystem Processes in Travertine Streams: Implications for Decommissioning a Dam on Fossil Creek, Arizona. Jane C. Marks et al. in *Geomorphology*, Vol. 77, Nos. 3–4, pages 299–307; July 2006.

American Rivers: **www.americanrivers.org**

Flyer for Congressional Visits Day sponsored by the American Geophysical Institute (April 2007)

Restoring the Rivers of a Great Nation

The National Science Foundation: Breaking down barriers and building a new environmental science.

From the grand Mississippi River to the smallest cold-water trout creek, our rivers and streams are woven into the history of this great country.

Our rivers:

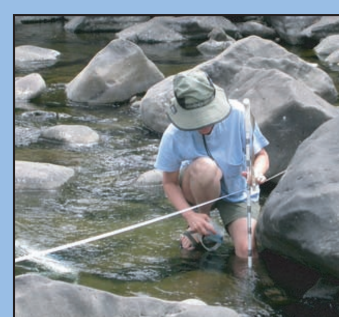
- **serve as a vital network for transportation and commerce;**
- **provide drinking water for our people;**
- **support our diverse agricultural system through irrigation and drainage;**
- **sustain our indigenous communities by providing water, fish and crops;**
- **provide an important source of electricity through hydropower dams.**

It is also true, however, that the heavy reliance on our rivers has resulted in impairment, pollution, and degradation of our most valued rivers and streams.

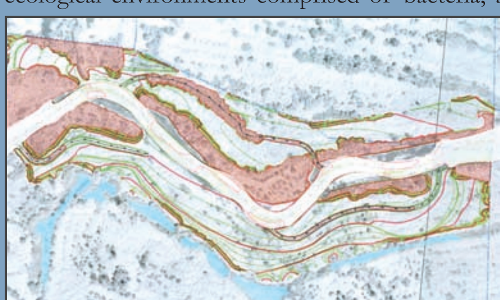
A national love affair

We are a nation that treasures its rivers and streams - a fact that is made clearer every year by a nation-wide call for restoration of one of our greatest national treasures - our river networks. Over $1 billion is spent annually on the restoration of our nation's rivers - largely from public funds. Stream Restoration is an industry that includes state and federal agencies, consulting engineers, research scientists, contractors, educators, and community groups, all focused on giving new life to impaired river systems. The most common objectives of river restoration projects are to protect property by protecting streambanks from erosion, improve water quality by reducing turbidity and pollutant levels, and revitalize the ecological health of rivers so that they remain viable habitats for important species, such as trout and salmon.

A river's secrets revealed through interdisciplinary research



To this day, we are challenged in our understanding of how rivers operate. Even a problem as simple as predicting the depth, width, and path of a river puzzles river scientists and provides challenges to engineers who attempt to predict river behavior. River Restoration brings a new comprehension of these systems to the table; an understanding of rivers as far more than just flowing water in a channel. River are complex systems balancing the flow of water and dissolved nutrients, the movement of gravel and sand, the growth of vegetation on banks and bars, and rich ecological environments comprised of bacteria, algae, insects, fish, and mammals. River Restoration demands an approach that embraces these complexities. The research questions in River Restoration are fundamentally multi-disciplinary. In other words, they require not just engineers or hydraulics specialists, but also geologists, ecologists, and chemists. Through its Science and Technology Program (STC) and establishment of the National Center for Earth-surface Dynamics (NCED), the National Science Foundation (NSF) is leading a national effort for river restoration research that is built upon true collaboration and discovery amongst our nation's most talented research scientists, engineers and educators on the issues most fundamental to river restoration. The National Science Foundation (NSF) is setting the direction for major research initiatives focused on generating the fundamental knowledge and creative solutions needed by our most impaired rivers and streams.



National Science Foundation - Office of Integrated Activities - Science and Technology Centers (STC) Program

Conducting world-class research in partnerships among academic institutions, national laboratories, industrial organizations, and other public/private entities to create new and meaningful knowledge of significant benefit to society.

The National Center for Earth-surface Dynamics

Interdisciplinary River Restoration Research

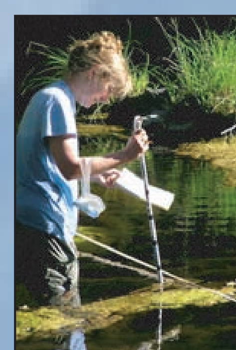
Rivers take myriad beautiful and fascinating forms. These forms and patterns develop spontaneously, out of the interplay of earth, water, and living organisms. We term this process of spontaneous development of patterns through natural interactions "self-organization". Stream restoration scientists and engineers seek ways to work with these natural patterns, processes, and tendencies to restore the natural function of streams. Doing this requires combining new methods of "green engineering" with a better understanding of rivers as complex, living systems.

The National Center for Earth-surface Dynamics promotes an approach to River Restoration that not only considers the physical river channel but also biogeochemical and ecological aspects of the system.

Physical River

Width, depth, slope, pattern, and rates of change define the physical river. The physical river is the easiest for humans to alter but do we know what we are doing? Many stream restoration projects fail because of an incomplete understanding of what determines a river's physical characteristics and form. Research at NCED is focused on improving our understanding of river geometry, hydraulics and sediment transport.

River Chemistry



The waters flowing in our rivers carry with them a wide range of nutrients, chemicals, and particles. Some of these are natural and some are introduced by human activity. The chemistry of rivers is a vital part of the connection between the physical river and river ecology. NCED is studying how flowing water and sediment are linked to the chemical reactions that occur in riverine environments. With better understanding of these linkages, it is likely that stream restoration projects can be designed to maximize water quality benefits.

River Ecology

Many stream restoration projects seek to improve the ecological health of a river by focusing on improving habitat for a target species, such salmon or trout. We are just beginning to recognize the complexity involved in designing stream restoration projects to improve habitat since this requires an understanding of not only the physical river and river chemistry but also interactions within the ecological food web. NCED is leading a multi-disciplinary research effort to discover the linkages between the physical, chemical and ecological aspects of river systems. Our research utilizes field work, laboratory experiments, and theoretical analysis. The products of our research will improve our ability to design stream restoration projects for maximum ecological benefit.

The National Center for Earth-surface Dynamics - 2 Third Avenue SE, Minneapolis, MN 55414
http://www.nced.umn.edu

Appendix E: Knowledge Transfer Publications

THE
STREAM RESTORATION NETWORKER
Published by the National Center for Earth-surface Dynamics
Fall 2006

Project Profile:

Provo River Restoration Project

By Michael Kelberer

The Provo River Restoration Project (PRRP) is charged with effecting a full ecosystem restoration along the Middle Provo, that section of the Provo River flowing from the Jordanelle Reservoir to the Deer Creek Reservoir in central Utah. Like the Trinity River Restoration Project featured in our last issue, the PRRP's guiding principle is that if they restore the natural, fluvial processes to the Middle Provo, the ecosystem will follow.

Aerial photographs of Reach 7 of the Middle Provo. Left: photo taken before construction (1999) and shows how channelized the river had become. Right: Photo taken after reconstruction (2004) of meanders and side channels, and shows the wide corridor now available to the river. Photos courtesy of PRRP.

Project background

The first of the two reservoirs (Deer Creek) was built to store water from the Provo as well as water being imported from two adjacent drainage basins. Subsequent substantial flooding in the Heber Valley just upstream of the dam, however, resulted in a major project to channelize and dike the river above the dam from the mid 1950's to 1965. In addition, this stretch of the river was dry-dammed at many locations to provide water for local irrigation. Finally, a separate reclamation project (the Central Utah Project - CUP) made plans to construct the Jordanelle Dam about 10 miles up the Provo from the Deer Creek Dam.

To this point, efforts to mitigate the environmental effects of these projects were limited to ensuring that anglers had sufficient access to the Middle Provo, and that a certain minimum flow was maintained to sustain fish habitat. The final authorization for the Jordanelle, however, provided for additional habitat restoration, and allowed for further restoration work on the Provo as mitigation for the Provo River Project and the CUP. This further mitigation work was included, resulting in a project to restore full ecological function to the Middle Provo.

The project

The PRRP's ability to restore full ecological function is greatly improved by two project assets: a natural hydrograph, and space for the river to use it.

Re-establishing a natural hydrograph for the Middle Provo was greatly facilitated by having a dam on each end. "Having two dams actually gives us some flexibility," says Tyler Allred, who was the restoration designer for the project. "The primary concern of the dam operators is that they have X number of acre-feet of water that they have to move from the upper dam to the lower dam over a period of time – but within limits, they don't particularly care what the shape of that release is."

Once you have the hydrograph, its important that the river have room to adjust naturally to its ups and downs – in fact, these "adjustments" create a lot of the habitat restorers are looking for. To this end, the legislation creating the PRRP also provided for the acquisition of a corridor along the Middle Provo within which fluvial processes would be allowed to operate reasonably naturally.

Within that corridor, the PRRP has designed and implemented a series of construction projects to try and restore the physical condition of the Middle Provo to one favorable to those fluvial processes. First, they used models (primarily HEC-RAS) to come up with channel designs that would handle the planed flows, and that would allow transport of the valley's cobble-sized alluvium during large flow events.

They also relocated the flood-control dikes back to the edge of the protected corridor, and will remove all drop structures added to the river so that the river's slope is continuous again. The PRRP has also given the corridor's vegetation a jump-start through large-scale plantings, and learned something valuable in the process. "We've put about 500,000 plantings into the ground

Continued on page 2

Provo River Restoration Project (continued)

over the past six or seven years," says Mark Holden, Project Manager at the PRRP. "But that number literally pales in comparison to what has come in naturally where we've gotten the conditions right (which, fortunately, is most of the area). There are reaches right now where the planted willows and cottonwoods just disappear into the landscape because of the natural vegetation's tremendous response."

Going forward, the PRRP will maintain a multi-faceted monitoring system to see if they are reaching their objectives, objectives that are stated in terms of restoring processes, not achieving a particular form. They understand that there is a fair amount of complexity, and therefore project uncertainty, involved in ecogeomorphic systems, especially when the system is being given a relatively free hand in determining the end product.

One thing their monitoring has already shown is that, like most reaches below a dam, the Middle Provo has a sediment deficit. But adding sediment to a river is still as much a political and social problem as a technical one, says Holden. "Many people don't understand how rivers work, and view a lot of natural and necessary river functions as 'bad.' The classic example is flooding; but many also view a cloudy river as unattractive at best and polluted at worst."

Full circle: mitigation plans for the Provo started with angler access, and now in 2006... Photo courtesy of PRRP.

Current status

The PRRP is nearly finished with the construction phase, and there already are signs that the project "has focused on the right things and that the processes are coming back," says Mark Holden, "although it will of course be decades before any real conclusions can be drawn. There is a lot of variability in the real world."

> ***"The biggest failure to me would be to come back in 10 years and find the river looking exactly the same as it does today." – Tyler Allred***

The thing they are trying to avoid, continues Holden, is seeing five or ten feet of bank erosion and rushing out there with riprap and logs to stop the process. "We have to remember that the river is doing exactly what we want it to do."

Visit our **PRRP Project Profile** for more on the project, and a look at some important lessons learned by doing it.

NCED Stream Restoration Updates

StreamLab: NCED's Indoor River Observatory

StreamLab is a multi-phase research endeavor involving academic researchers, federal agencies and stream restoration practitioners. This ongoing project is being conducted in the Main Channel of the St. Anthony Falls Laboratory in Minneapolis, Minnesota. The StreamLab program brings together a spectrum of research expertise (stream ecology and biology, engineering, hydrology, hydraulics and geomorphology) to conduct focused, field-scale studies in a laboratory environment.

The fifth phase of this year's suite of experiments (StreamLab06) is now complete. Researchers examined the effects of increasing sand content in the bed from 5% to 25% on an array of stream variables. The sixth and final phase of StreamLab06 began on Aug. 30th and is focused on 1) establishing the conditions for periphyton growth in the channel and 2) studying the effects of periphyton growth on sediment transport, nutrient uptake, hyporheic exchange and other stream variables. Please visit the **StreamLab06 update** web page for more information.

SR Partners Group Meeting and Physical Modeling Symposium

The NCED Stream Restoration Partners Group met in July as part of a three-day workshop co-hosted by SRPG member Stillwater Sciences at the Richmond Field Station in California. The workshop involved in-depth discussions of new research results on gravel augmentation, dam removal, sediment pulse propagation in rivers, and channel reconstruction; new tools available to aid stream restoration projects; a discussion and analysis (including field trips) of several active urban and rural stream restoration projects; and the need for training and educational opportunities in process-based approaches to stream restoration design.

**The
Stream Restoration Networker**

Published quarterly by the National Center for Earth-surface Dynamics and distributed free of charge to members of the stream restoration community.

More information and a subscription form can be found on NCED's Stream Restoration web site:

www.streamrestoration.net

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The Stream Restoration Networker **Fall 2006**

Research Profile:

Applications of stratigraphy to stream restoration

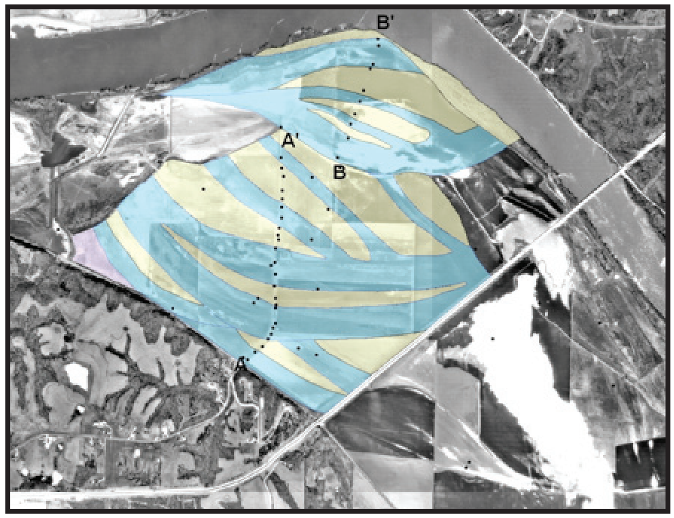
by Michael Kelberer

You don't often hear "stratigraphy" and "stream restoration" mentioned in the same sentence, but Professor John Holbrook thinks that should change. Holbrook, professor of geology at the University of Texas, Arlington and specializing in fluvial sedimentology, sees two practical applications of stratigraphy to stream restoration:

1. A stratigraphic *map* of the valley alluvium can provide critical insights into where to best place channel and floodplain elements; and
2. A stratigraphic *history* of the valley can provide information on the channel's behavior under a much more diverse set of discharge scenarios than can a couple of centuries of historical records.

The reason for paying attention to the surficial alluvium, says Holbrook, is that it forms the foundation for the biological and physical processes in the channel-floodplain system by determining local moisture retention, infiltration and flow patterns. So the first step is to map out the fundamental stratigraphic units of the valley alluvium: channel loops, point bars, flood deposits, mud caps on the point bars, splays. Now, says Holbrook, you know "which places are likely to hold water after floods, and what areas are places where water is going to infiltrate down into the floodplain aquifer and work its way back to the river. You'll know what areas are going to tend to be the spots that drain well, and what types of vegetation are going to grow better on the floodplain and around the banks."

Holbrook and his students are using this concept to assist in restoration work at the Overton Bottoms North Unit of the Big Muddy National Fish and Wildlife Refuge on the Missouri River, and have published a USGS SIR describing their findings to date. For more, please go to our web site and click on **Research Profiles/Holbrook**.



Allostratigraphic map of Overton Bottoms North prepared by Holbrook shows the locations of differing "allounits": channel fills (blue) and bars (tan). Graphic courtesy of John Holbrook.

Research Profile:

NCED's Ecological Fluid Dynamics Research Group

by Michael Kelberer

NCED's Ecological Fluid Dynamics research group is lead by University of Minnesota Associate Professor Miki Hondzo, and is based at the university's St. Anthony Falls Laboratory. The group studies the interactions among fundamental fluid mechanics, microbiological processes, and chemical reactions that are mediated by biological organisms. Results of their research are being used by two of NCED's Integrated Projects: Desktop Watersheds and Stream Restoration. Applications of this research to Stream Restoration are numerous, and fall into two general categories: understanding the base interactions of the food web, and quantifying how biological processes can affect a stream's water quality.

Miki Hondzo. Photo courtesy of NCED.

One area of the team's research involves studying the variability of microbial concentration and activity along a stream's length. "It turns out that microbes are everywhere," says Hondzo. "However, certain combinations of physical and chemical processes can amplify or de-amplify their activity levels." Research is underway to model how these activities (rates, periphyton growth rates) are affected by the differing geomorphic, chemical and physical conditions along the length of a stream.

Water quality, a second research focus, is being studied in a number of ways, including macrophyte nutrient uptake, which includes heavy metals, and Biochemical Oxygen Demand measurement, an important component of effluent standards that needs to be modified to account for the dynamic/turbulent conditions found in the field.

Finally, the group is very involved in the use of wireless technologies to provide real-time data on stream eco-functionality in support of real-time stream management decisions. See the group's **research profile** on the web for more on their work.

The Stream Restoration Networker **Fall 2006**

Newsletter goes all electronic!

Starting with this issue, the Stream Restoration Networker will be distributed in electronic format only. Quarterly issues will be emailed to subscribers and will continue to highlight news, research and projects of interest to the Stream Restoration community, with links to feature articles on our website: www.streamrestoration.net.

If you have been receiving our newsletter in hardcopy form only, please send us your email address so you can continue to receive it. If you have questions or comments about this change, please email us!

Stream Restoration Calendar:

Here's a sample from our online Calendar:

December 9, 2006: The 4th Annual Berkeley River Restoration Symposium (UC Berkeley) Berkeley, CA

December 9-13, 2006: The 3rd National Conference on Coastal and Estuarine Habitat Restoration. (Restore America's Estuaries) New Orleans, LA

January 28 - February 1, 2007: USDA-CSREES National Water Conference. (NC State) Savannah, GA

February 6-8, 2007: 2007 Northwest River Restoration Design Symposium. (UC Berkeley) Skamania Lodge, Stevenson, WA

April 22-27, 2007: 2nd National Conference on Ecosystem Restoration. (USACE et al.) Kansas City, MO

Fall 2006 Issue

Stream Restoration Networker
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THE STREAM RESTORATION NETWORKER
Published by the National Center for Earth-surface Dynamics
Spring 2007

Project profile:

Physical Modeling Experiments to Guide River Restoration

by Michael Kelberer

Key elements

Stream restoration physical models, dam removal, gravel augmentation, channel-floodplain dynamics

Overview

Stillwater Sciences is performing the Physical Modeling Experiments to Guide River Restoration (PMEGRR) project with participation and funding from the California Bay-Delta Authority, the University of California at Berkeley (UCB), San Francisco State University, and NCED. PMEGRR's goal: Use physical experiments and numerical modeling to perform basic research into three problems facing the stream restoration community and to translate that research into usable tools.

Location

Experiments are being performed in specially designed flumes at UCB's Richmond Field Station.

New flume at Richmond Field Station.

Experimental context

The California Bay-Delta Authority is supporting a wide range of stream restoration projects in California's Bay-Delta watershed. Unfortunately, it has found itself hampered by the lack of a strong scientific basis for the use of three widely-used stream restoration methods: gravel augmentation, dam removal, and channel-floodplain reconstruction. Specifically, the Authority found large knowledge gaps in understanding the fluvial processes underlying episodic sediment delivery (dam removal and gravel augmentation) and the response of channel-floodplain geometry to changes in discharge and sediment supply. PMEGRR is addressing these specific issues through:

1. A series of flume experiments that seek to establish the basic geomorphic relationships involved; and
2. The creation of new, or modification of existing, numerical models that translate the basic science into usable form.

Project description

Leonard Sklar, a Principal Investigator and PMEGRR co-Manager, summarized the three concurrent (and interacting) physical modeling threads:

1. Gravel augmentation. Streambeds downstream of a cutoff, or significant reduction of discharge, become armored with the coarsest fraction of the previous bedload. This type of streambed is usually unsuitable habitat, and restoration efforts often address this problem by adding large amounts of finer, more desirable gravel sizes. The approach of this modeling thread is to use gravel augmentation primarily to re-mobilize the armor layer and make the finer gravels trapped below it available again. Experiments to date indicate that this is not only possible but can be accomplished with much smaller quantities of gravel.
2. Dam removal. This modeling thread is closely related to the first modeling thread since it also studies the effects of episodic sediment delivery on the bed, although the size of the pulses is much greater. Research to date has been on studying the infiltration of fines into the bed under various scenarios—a major concern for restoration practitioners since fines fill the interstitial pores in

Physical Modeling (cont'd)

the hyporheic zone, effectively degrading this crucial habitat zone. Experiment results to date indicate that the current assumption (damage to the hyporheic zone increases with pulse size) may not be correct. In fact, the larger pulses of fines may quickly seal the bed preventing further infiltration while still allowing the habitat to function.

3. Channel-floodplain reconstruction. This modeling thread's first task was to determine how to create a self-formed, meandering channel in a flume in order to study channel-floodplain reconstruction under laboratory conditions. PMEGRR started with a strategy developed by NCED (using alfalfa sprouts in the bank-stabilizing role of riparian vegetation) and created channels that exhibit the right real-world behaviors (lateral migration, alternate bar topology, meander loop cut-offs). PMEGRR hopes to eventually study the effects of different hydrographs on these processes, and the resulting channel geometries, to produce a detailed model of bar growth.

A self-formed, meandering channel created in a flume using alfalfa sprouts to provide strength to banks and bars.

Food for thought

Leonard Sklar shares his thoughts on stream restoration on NCED's website.

Project website

More information can be found at http://flume.stillwatersci.com.

Gravel augmentation: photos of the bed surface before (left) and after (right) gravel augmentation. Approximately 11% of the (armored) surface was mobilized.

All photos courtesy of PMEGRR.

Resources on the web: www.streamrestoration.net

Calendar: Upcoming events, workshops, and training related to stream restoration.

Toolbox: NCED is developing a stream restoration toolbox—the latest research in usable form!

Training: A catalog of available certificate programs, short courses, and manuals.

Stream Restoration in Action: Profiles of restoration projects on the Trinity River, Provo River, and others.

Research: Stream restoration research at NCED and within the stream restoration community.

The Stream Restoration Networker Spring 2007

Project profile:

Little Topashaw Creek Stream Corridor Rehabilitation Project

by Michael Kelberer

Key elements

Bank stabilization, biomechanical erosion control, large woody debris structures

Location

This project focused on a reach of Little Topashaw Creek, located in Chickasaw County, North Central Mississippi. It is a tributary within the Yalobusha River watershed, which itself flows into a large US Army Corps of Engineers flood control reservoir, Grenada Lake, and then into the Yazoo River, a tributary to the Mississippi River.

Historical context

The creek is located in hilly terrain just east of the Mississippi River alluvial floodplain and has been subjected to a great deal of watershed disturbance, starting about the time of European settlement in the 1830s and '40s. The channels in the watershed were prone to blockage from extreme amounts of eroded sediment from cultivated lands and were repeatedly channelized by local drainage districts. In the late 1960s and early '70s, the federal government sponsored a comprehensive channelization project that triggered several waves of head cutting and channel incision in the system. As a result, the study reach, which has a contributing drainage area of about 15 square miles, has a channel width of about 33 meters and an average channel depth of more than three meters. Bank heights on the outside of bends are enlarged to six meters. The bed material is medium sand, with outcrops of consolidated, cohesive material.

Project description

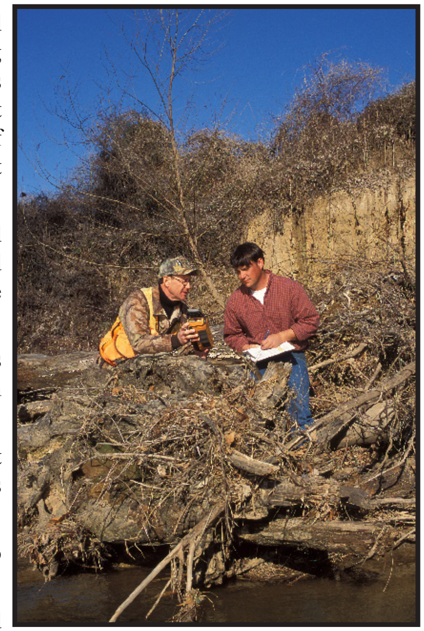
The Little Topashaw Creek project, implemented as part of the Demonstration Erosion Control Project (DEC), was a collaborative effort between DEC members, the US Army Corps of Engineers, the USDA's National Resources Conservation Service, and the USDA's National Sedimentation Laboratory. One of its major objectives was to demonstrate the efficacy of using large woody debris (LWD) and other biomechanical techniques as an inexpensive alternative method of controlling bank erosion. In particular, the project hoped to show that LWD structures could stabilize banks for less than $25 per foot of bank, compared to various stone and concrete methods that can cost twice as much. This article focuses on the LWD portion of the project.

Large woody debris structure in the making.

Doug Shields, Little Topashaw Creek Project Director and lead scientist on the LWD portion, notes that in addition to the specific erosion control objective, "we were very interested in in-stream habitat rehabilitation. Two aspects of this were primary: creating a stable pool habitat and

Little Topashaw Creek (cont'd)

increasing LWD density in the channel." Both of these, according to Shields, were seriously deficient compared to lightly disturbed reaches in the same watershed: channel incision had eroded the riparian vegetation, reducing wood loading in the channel, and channel widening meant that channels didn't retain very well what woody debris remained. Widening channels have also caused baseflows to become shallower, thereby reducing pool habitat. The project team's hypothesis was that by encouraging sedimentation in the reach, through the use of LWD and willow posts, they would end up with a narrower and deeper baseflow channel that had vegetation on the berms.



Doug Shields and John Massey atop one of the structures.

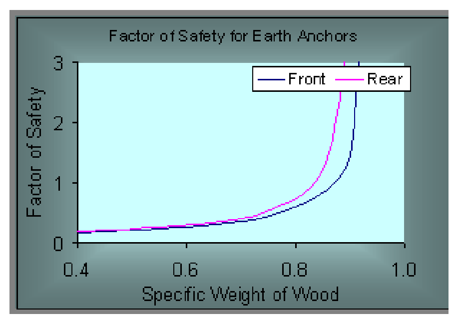
The Little Topashaw Creek project built and installed 72 structures using materials found either in the channel or on the floodplain away from the channel. Each structure was designed to protect about 25 meters of channel. About 65% of the key members of the structures were buried in the bank and 80% of them had earth anchors as well.

The project team did pre-project monitoring in 1999 and 2000, installed the LWD structures in late 2000, and planted willow posts in 2001. Post-project monitoring continued through 2004.

The monitoring revealed that, although positive outcomes (structure retention, habitat restoration, and fish populations) were seen over the first two years, many of these effects disappeared by 2004 as 35% of the installed structures failed.

There were several factors that played into the failure of these structures, according to Shields:

1. Based on field inspections of the reach, the team expected that the reach had finished the widening phase (Stage 4 in the Channel Evolution Model) and was beginning to aggrade (Stage 5). This turned out to be too simplistic an hypothesis as the geomorphic behavior of the reach varied over both space and time. "Geomorphically," said Shields, "we misread the signs. We thought we weren't going to get any more bed degradation, but we did."
2. In hindsight, not enough of a safety factor was applied when sizing the anchors. Duckbill-type earth anchors cabled together were installed (and load-tested) at a depth of 1.2 meters, yet most of them pulled out. There may have been two factors at play here. First, the woody material dried out quite rapidly, leading to a significant increase in the buoyant forces at work on the structure (see graph). Second, the woody material started to decay, and the first things to go were the smaller twigs and branches. As the woody decay progressed, the structure matrix simplified, flow velocities increased, and sediment that had been trapped in the matrix began to erode. All of these factors not only reduced the bank's hold on the structure but removed the substrate for vegetation growth. "We expected that woody vegetation would colonize the sediment deposits that were triggered beside and within the large woody structures," said Shields, "and that did not happen, at least not on a large enough scale."



Data showing that the safety factor diminishes rapidly as the wood dries out. Graph courtesy of the USDA.

All photos courtesy of the Little Topashaw Creek project.

The short-term, positive results from the LWD experiment demonstrate that the technique has merit and warrants further study, says Shields, and the information learned from the structure failures, like all research "failures," will hopefully help the next group of researchers succeed.

Food for thought

Doug Shields shares his thoughts on the field of stream restoration on NCED's website.

Project website

More information can be found at http://ars.usda.gov/Research/docs.htm?docid=5526.

The Stream Restoration Networker Spring 2007

Research profile:

Incorporating stream restoration's social context

by Michael Kelberer

NCED's commitment to bringing its basic research on stream restoration into the field is exemplified by the creation of the Social Context Research Group. The group's two PIs, Ben Hobbs of the Department of Geography and Environmental Engineering at Johns Hopkins University and Nick Flores of the Department of Economics at the University of Colorado, are developing normative decision-making models to integrate sociology, politics, and economics with geomorphology, engineering, and ecology. "We're trying to quantify what people want, and the trade-offs they're willing to accept among different objectives or risks, and to establish a method that comes up with a project recommendation that is consistent with those values," says Hobbs.

Engaging the public

The first area of Nick Flores' research is to bring public preferences into the decision-making process. "Most stream restoration work is funded with public money," says Flores, "and it makes sense to give the public a voice in how that money is spent."

So far, Flores has researched the literature and has concluded that solution trade-offs and public preferences are rarely incorporated into stream restoration projects. His group has also published work regarding the use of economic valuations in stream restoration projects. Recently, NCED became involved in stream restoration (mainly involving sediment management) in the Minnesota River Valley. This work will allow Flores to test his methods. He plans to survey the various stakeholder groups. One of the goals of the surveys will be to get stakeholder inputs into choices concerning trade-offs among restoration objectives. For example, not all reaches of the river can be restored. So, what criteria does the project use to prioritize them? A part of this goal is to arrive at methods of quantifying costs and benefits.

A second goal of the surveys is to get input on the various restoration options being considered. The project could focus on getting farmers to adopt "best practices" to manage sediment from tilled acreage, or lawn water runoff, or the creation of wetlands and riparian buffers. For each option, stakeholders directly affected by the strategy will have different preferences from those who aren't. In addition, preferences are affected by the scope of the option's outcomes. A best practices strategy, for example, has only one outcome—sediment reduction. Establishing wetlands, on the other hand, not only ameliorates the sediment problem but also creates wildlife habitat and a potential recreation site.

The best practices strategy vs. wetlands trade-off highlights the second major area of Flores' research: dealing with uncertainty. "The element of uncertainty is present in almost all stream restoration science," says Flores, "yet it is rarely explicitly included in the decision-making process." In this example, the best practices option may have a narrower benefit potential, but the benefits are more certain. On the other hand, establishing a wetlands has a potentially greater benefit, but the benefits are less certain and harder to measure. Flores aims to quantify the underlying uncertainties so that the communities involved can make a more scientifically informed choice.

Choosing among alternatives

The focus of Ben Hobbs' research is the use of Multi-Criteria Decision Analysis (MCDA) to assist stream restoration decision makers in recognizing and evaluating the trade-offs among objectives and methods—trade-offs that involve assessing risk and uncertainty. Unlike Flores' work, which considers the community as a whole, MCDA is intended to improve decision-making within a single group, says Hobbs, "and is as much psychology as it is economics." People are often not sure of what they want or how much they want it. And, real-world choices among objectives and means are often tempered by the risks and uncertainties inherent in each choice. "For instance, if you use boulders to solve a bank-erosion problem," Hobbs continues, "you might be more certain about what you are going to get than if you institute a program to educate area farmers about no-till agriculture that might reduce sediment influxes into the stream."

MCDA differs from standard economic valuation methods in that it doesn't reduce everything to dollars and cents. Instead, MCDA values criteria in its own terms (eg, tons of sediment). The idea is to integrate values and priorities with technical information in order to arrive at a clear set of whole-system options.

Stream restoration's social context (cont'd)

The first step in using MCDA is to set quantifiable performance criteria (eg, nutrient influx reduction). Next, the performance of possible decision variables upon each criterion is quantified: an outreach program to farmers, the restoration of a certain reach of the stream, etc. Further, each of these goal/variable sets can be multidimensional (eg, separate goals for reducing different nutrients). Finally, the risks and uncertainties (quantified as a probability that the goal will be achieved) associated with each decision variable are incorporated into the model. "The upshot," says Hobbs, "is an analysis that can show you what combinations of objectives are attainable, and to what degree, with a given budget."

In addition, using MCDA helps keep the project's real objectives front-and-center. "Too often," says Hobbs, "the original justification for a project gets lost in the shuffle, and you see a project's success criteria stated in terms of methods (geomorphic engineering) instead of...objectives (fish populations). Going through the MCDA process helps keep the focus on the fish."

Another benefit of this type of analysis is that it can shed light on how better information —reduced uncertainty or additional forecasts—can improve decisions. This provides feedback to scientists as to the value of improvements in their models and data.

Hobbs' students—Jen Bassman and Sarah Jacobi—are presently working with NCED scientists and others on applying this type of analysis to sediment management in the Minnesota River Basin, with a focus on stream restoration's possible contributions.

Is Multi-Criteria Decision Analysis right for your project?

A project that has three or more of the following characteristics is a good candidate for using Multi-Criteria Decision Analysis or MCDA:

- Three or more distinct objectives
- Restoration objectives not explicitly defined in terms of specific ecological or social outcomes
- Multiple (two or more) non-governmental stakeholders
- Large in terms of geographic scope
- Large in terms of economic scope
- Uncertainties acknowledged but not evaluated

The Stream Restoration Networker welcomes your ideas and suggestions. In particular, please let us know about stream restoration projects or cutting edge research that you are involved in so we can share this information with the stream restoration community. How? Email the Editor.

The Stream Restoration Networker

Published quarterly by the National Center for Earth-surface Dynamics and distributed free of charge to members of the stream restoration community.

More information and a subscription form can be found on NCED's Stream Restoration website:

www.streamrestoration.net

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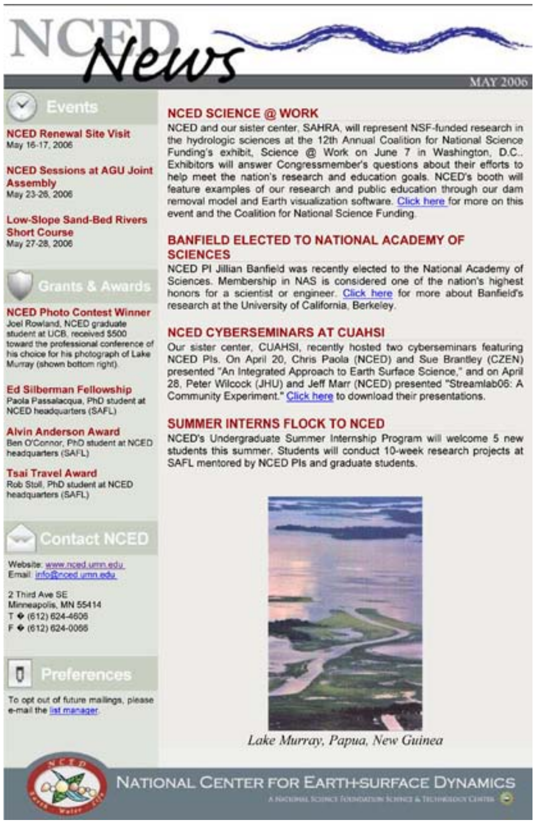

NCED News

MAY 2006

Events

NCED Renewal Site Visit
May 16-17, 2006

NCED Sessions at AGU Joint Assembly
May 23-26, 2006

Low-Slope Sand-Bed Rivers Short Course
May 27-28, 2006

Grants & Awards

NCED Photo Contest Winner
Joel Rowland, NCED graduate student at UCB, received $500 toward the professional conference of his choice for his photograph of Lake Murray (shown bottom right).

Ed Silberman Fellowship
Paola Passalacqua, PhD student at NCED headquarters (SAFL)

Alvin Anderson Award
Ben O'Connor, PhD student at NCED headquarters (SAFL)

Tsai Travel Award
Rob Stoll, PhD student at NCED headquarters (SAFL)

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NCED SCIENCE @ WORK

NCED and our sister center, SAHRA, will represent NSF-funded research in the hydrologic sciences at the 12th Annual Coalition for National Science Funding's exhibit, Science @ Work on June 7 in Washington, D.C.. Exhibitors will answer Congressmember's questions about their efforts to help meet the nation's research and education goals. NCED's booth will feature examples of our research and public education through our dam removal model and Earth visualization software. Click here for more on this event and the Coalition for National Science Funding.

BANFIELD ELECTED TO NATIONAL ACADEMY OF SCIENCES

NCED PI Jillian Banfield was recently elected to the National Academy of Sciences. Membership in NAS is considered one of the nation's highest honors for a scientist or engineer. Click here for more about Banfield's research at the University of California, Berkeley.

NCED CYBERSEMINARS AT CUAHSI

Our sister center, CUAHSI, recently hosted two cyberseminars featuring NCED PIs. On April 20, Chris Paola (NCED) and Sue Brantley (CZEN) presented "An Integrated Approach to Earth Surface Science," and on April 28, Peter Wilcock (JHU) and Jeff Marr (NCED) presented "Streamlab06: A Community Experiment." Click here to download their presentations.

SUMMER INTERNS FLOCK TO NCED

NCED's Undergraduate Summer Internship Program will welcome 5 new students this summer. Students will conduct 10-week research projects at SAFL mentored by NCED PIs and graduate students.

Lake Murray, Papua, New Guinea

NATIONAL CENTER FOR EARTH-SURFACE DYNAMICS
A NATIONAL SCIENCE FOUNDATION SCIENCE & TECHNOLOGY CENTER

May 2006 eNews

NCED News

Vol. IV (June 2006)

Events

Earthscapes Teacher Institute
June 19-23, 2006

International Conference on Rivers & Civilization
June 25-28, 2006

Teaching Sedimentary Geology in the 21st Century
July 14-19, 2006

Grants & Awards

The Aditya Birla Chair was awarded to NCED PI Vaughan Voller this year. Voller will spend 6 weeks at the Indian Institute of Science in Bangalore this summer, teaching and researching models of crystal growth processes.

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NCED ENDORSED BY SITE VISIT TEAM

NCED's 4th Annual Site Visit, in which the renewal proposal was defended, proved a great success. The final report given by the Site Visit Team concluded with "The panel enthusiastically recommends continuation of NSF support for another five years."

NCED PRESENTS AT NSF

NCED PIs and colleagues presented on "Unified Earth-surface Science" at the National Science Foundation this month. One presentation addressed rebuilding the Mississippi Delta, and the other presentation focused on environmental observatories.

NCED WELCOMES NEW PI

Robert Twilley, professor at Louisiana State University, is the newest PI to join NCED. Twilley's research focuses on systems ecology and biogeochemistry of coastal wetlands both in the Gulf of Mexico and throughout Latin America.

Karen Campbell, Director of Education, demonstrates Glines Canyon Dam removal at CNSF reception on Capitol Hill.

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June 2006 eNews

NCED News

Vol. V (July 2006)

Events

Teaching Sedimentary Geology in the 21st Century
July 14-19, 2006

Publications

Paper in Sedimentary Record
PhD student **Nikki Strong** and NCED director **Chris Paola** co-authored "Fluvial Landscapes and Stratigraphy in a Flume" featured on the cover of The Sedimentary Record this month.

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CASE MADE FOR DELTA RESTORATION

How do you restore deltas that have been ravaged by hurricanes? The National Science Foundation wants to find out. This summer, NSF invited a group of five scientists to present a restoration plan for the Mississippi Delta. Included in the group were three NCED PIs: Chris Paola, David Mohrig, and (newest PI) Robert Twilley. NSF's objective in inviting this presentation was to learn more about scientific research that supports delta restoration, research that may someday help rebuild the Mississippi Delta. To read the full story about their restoration plan, click here.

EXPLORING THE ST. CROIX RIVER

NCED Imaging Specialist Paul Morin created an interactive 3-D map of the St. Croix River to aid the Minnesota Department of Natural Resources in environmental education.

EARTHSCAPES TEACHER INSTITUTE A SUCCESS

Early July wrapped up another successful Earthscapes Teacher Institute. This annual, week-long experience immerses K-12 teachers in studying the science of rivers, watersheds, and surface processes in the same interdisciplinary ways NCED researchers do. Teachers conducted a field study between two rivers, visited the Science Center at the Maltby Preserve, and explored the Big Back Yard exhibit at the Science Museum of Minnesota. Participants also received materials to use in their own classrooms and shared Action Plans that will bring their institute experience to their classrooms.

Earthscapes teacher Tom Yellowman, a teacher at Ojibwe School, measures the chemical composition of Otter Creek.

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July 2006 eNews

NCED News

Vol. VI (August 2006)

Events

Experimental Stratigraphy Short Course
Fukuoka, Japan
August 30, 2006

AGU Fall Education Session Abstracts due Sept. 7
San Francisco, CA
December 11-15, 2006

STC Directors' Meeting
September 18-19, 2006

AIPG Sustainability Meeting
NCED to share booth with AWG
September 23-28, 2006

National Monitoring Workshop
NCED provides Stream Restoration day for National Workshop
September 24-28, 2006

Grants & Awards

CoreWall grant received
NCED Imaging Specialist Paul Morin is a key collaborator on the UMN's CoreWall project. The recent $280k grant from NSF was given for "Collaborative Research: CoreWall-Integrated Environment for Interpretation of Geoscientific Data from Sediment and Crystalline Cores."

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NCED ON THE CUTTING EDGE

An NSF-sponsored "On the Cutting Edge" workshop, was held July 14-19 in Salt Lake City, Utah. This exciting collaborative effort focused on enhancing the teaching of sedimentary geology at the undergraduate level, and brought together college and university faculty who teach sedimentary geology to explore a wide variety of topics related to teaching effectively in the classroom, lab, and field. NCED participants included Director Chris Paola, and Director of Education Karen Campbell.

NCED SUMMER CAMPS GO SWIMMINGLY

At NCED's recent gidakiimanaaniwigamig Native American Youth Math and Science Camps, NCED ESTREAM teacher Amy Chen led campers in a hands-on science lesson using dam removal models. These models, based on research done at NCED, were created by the Science Museum of Minnesota for school outreach in conjunction with the Big Back Yard. (See photo below.)

August 2006 eNews

NCED News — Vol. VII (September 2006)

Events

Delta Restoration Meeting
Tulane University
September 27-October 1, 2006

EAB Semi-annual Meeting
Minneapolis, MN
November 1, 2006

Grants & Awards

Efi Foufoula-Georgiou to be honored on Scholars Walk
September 29, 2006 (12-2pm)
University of Minnesota

Publications

Grad students present at ESA
NCED graduate students Wendy Palen and Kerwyn Suttle (both at Berkeley) each presented a research paper at the Ecological Society of America's annual meeting.

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DIRECTOR SPEAKS ON "THE MOUNTAINS BENEATH US"
NCED Director Chris Paola was a guest on a recent MPR's Midmorning show, where he spoke on "inverse mountains" and the geology of New Orleans. Click here to listen to the broadcast.

NCED ADDS NEW PARTNER INSTITUTION
With the move of PI David Mohrig to the Jackson School of Geosciences at the University of Texas at Austin, NCED is pleased to include UT Austin on our list of Partner Institutions.

AN EVENING AT THE BIG BACK YARD
At a recent celebration at the Big Back Yard, NCED Graduate Museum Assistant Emily Horth and the SMM Park Crew guided NCED visitors and guests through the interpretive activities they devised this summer to expand the engagement of Museum visitors in NCED science. Attendees enjoyed a round of golf and the fruits of a successful collaboration with the Science Museum of Minnesota. (See photo below.)

NCED PI Jacques Finlay enjoys NCED Day in the Big Back Yard

National Center for Earth-surface Dynamics
A National Science Foundation Science & Technology Center

September 2006 eNews

NCED News — Vol. VIII (October 2006)

Events

EAB Semi-annual Meeting
Minneapolis, MN
November 1, 2006

Grants & Awards

Scholars Walk honorees
Efi Foufoula-Georgiou and Chris Paola

UCAR Board of Trustees
Efi Foufoula-Georgiou was recently elected to the University Corporation for Atmospheric Research (UCAR) Board of Trustees

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CONTROVERSIAL SCIENCE ARTICLE HEATS UP NCED
A recent article in Science magazine claims evidence that storms, not rivers, are the largest contributor of sediment to the delta- a theory with which NCED researchers involved in Mississippi delta restoration strongly disagree. To read about the article, please click here. A response by NCED researchers and collaborators will be available soon.

STREAM RESTORATION NETWORKER GOES DIGITAL
The quarterly publication of NCED's Stream Restoration group, "Stream Restoration Networker," makes the move into an electronic-only format this month. Click here to view the recently released Fall issue.

GLINES CANYON DAM MODEL TRAVELS WEST
A working model of the Glines Canyon Dam developed by NCED and the Science Museum of Minnesota (based on the research of Visiting Researcher Chris Bromley) has made its way to the West Coast. As described in the Sept. 10 Peninsula Daily News, instructors from the Olympic Park Institute used the model to educate the public about sediment transport at a local StreamFest celebration in Port Angeles, WA.

High school students from the Lower Elwha Klallam Tribe observe how the model works.

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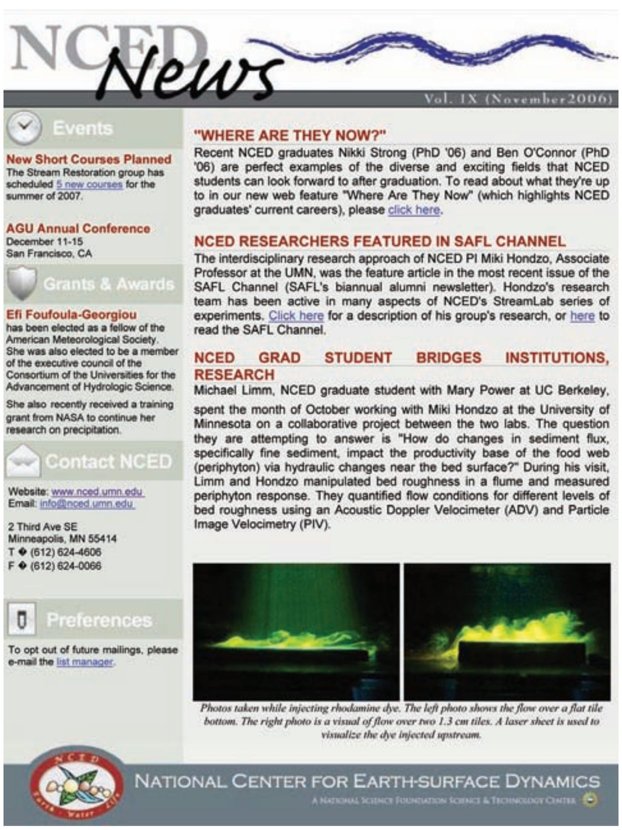
October 2006 eNews



NCED News — Vol. IX (November2006)

Events

New Short Courses Planned
The Stream Restoration group has scheduled 5 new courses for the summer of 2007.

AGU Annual Conference
December 11-15
San Francisco, CA

Grants & Awards

Efi Foufoula-Georgiou
has been elected as a fellow of the American Meteorological Society. She was also elected to be a member of the executive council of the Consortium of the Universities for the Advancement of Hydrologic Science.

She also recently received a training grant from NASA to continue her research on precipitation.

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"WHERE ARE THEY NOW?"
Recent NCED graduates Nikki Strong (PhD '06) and Ben O'Connor (PhD '06) are perfect examples of the diverse and exciting fields that NCED students can look forward to after graduation. To read about what they're up to in our new web feature "Where Are They Now" (which highlights NCED graduates' current careers), please click here.

NCED RESEARCHERS FEATURED IN SAFL CHANNEL
The interdisciplinary research approach of NCED PI Miki Hondzo, Associate Professor at the UMN, was the feature article in the most recent issue of the SAFL Channel (SAFL's biannual alumni newsletter). Hondzo's research team has been active in many aspects of NCED's StreamLab series of experiments. Click here for a description of his group's research, or here to read the SAFL Channel.

NCED GRAD STUDENT BRIDGES INSTITUTIONS, RESEARCH
Michael Limm, NCED graduate student with Mary Power at UC Berkeley, spent the month of October working with Miki Hondzo at the University of Minnesota on a collaborative project between the two labs. The question they are attempting to answer is "How do changes in sediment flux, specifically fine sediment, impact the productivity base of the food web (periphyton) via hydraulic changes near the bed surface?" During his visit, Limm and Hondzo manipulated bed roughness in a flume and measured periphyton response. They quantified flow conditions for different levels of bed roughness using an Acoustic Doppler Velocimeter (ADV) and Particle Image Velocimetry (PIV).

Photos taken while injecting rhodamine dye. The left photo shows the flow over a flat tile bottom. The right photo is a visual of flow over two 1.3 cm tiles. A laser sheet is used to visualize the dye injected upstream.

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November 2006 eNews

NCED News — Vol. X (December 2006)

Events

PI Retreat
February 1-3, 2007
Location to be determined

BRIC Workshop
April 11-14, 2007
St. Anthony Falls Laboratory
Minneapolis, MN

Grants & Awards

Paul Morin
received 2.8 million dollars from NSF Ecosystems for a collaborative research project. The goal of this project, entitled "An Interdisciplinary Investigation of Groundwater-Carbon Coupling in Large Peat Basins and its Relation to Climate Change," will be to develop a transient 3D numerical model to study the linkages between climate, groundwater, landscape, and peatland carbon fluxes.

Aurelia Eugenia-Glory DeNasha
was recognized at the American Indian Science and Engineering Society (AISES) annual national conference, held October 2006, for her outstanding performances at the 2005 and 2006 Intel International Science Fairs. Aurelia, a participant in NCED's American Indian Youth Science Immersion Program, has been researching muskrats and their effects on wild rice with NCED advisor Andrew Wold.

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NCED POST-DOCTORAL ASSOCIATE INVESTIGATING CLIMATE AND LAND USE CHANGE IN ETHIOPIA
NCED Post-Doctoral Associate Nikki Strong recently returned from Ethiopia where she is investigating the history of climate and land use in the Northern Highlands of Ethiopia together with undergraduate students, graduate students, and researchers (biogeochemists, foresters, archeologists, geographers, hydrologists, and geologists) from the U.S. and Ethiopia. This international research team is using numerous climate and land use proxies and tools, including stable isotope and compound specific carbon and nitrogen analysis, paleomagnetic intensity measurements, paleohydraulic reconstructions based on exposed modern and ancient fluvial systems, and carbon 14 dating, to reconstruct the last 7,000 years of climate and land use change in Ethiopia.

Soil erosion in the Northern Highlands (left photo) has been a major source of Nile Delta sediment for thousands of years, as well as a major factor contributing to recent famine. Ethiopian and NCED researchers collecting paleosol samples (right photo) for carbon and nitrogen isotope analysis.

3D WORLD FLOOR MAP AT SCIENCE MUSEUM OF MINNESOTA
Using NCED mapping tools and techniques, a new 3D floor map of the world was recently installed in the lobby of the Science Museum of Minnesota. This map is 4.4 meters high by 8.8 meters wide and contains satellite data with a resolution of 500 meters. Visitors entering the museum, according to Paul Morin, NCED Visualization, can truly see the "biology of the world on the [map's] surface." To view pictures of the world floor map, click here.

NCED AT AGU CONFERENCE
Last week NCED participated in the American Geophysical Union (AGU) conference in San Francisco, California. Jane Staiger and Doug Jerolmack, NCED Post-Doctoral Associates, were among the participants. Jane gave a presentation about a new methodology that would constrain the erosional effect of human land use by using beryllium 10, a terrestrial in situ cosmogenic isotope. By measuring the beryllium-10 concentration in sediment, you can determine the amount of erosion above that due to natural processes and the depth from which that sediment came. Doug hosted a session that involved several NCED researchers. This session, "Autogenic Dynamics in Landscape Evolution and the Geologic Record," provided background on the theory that large changes in landscape can be brought about by river processes and sediment transport alone - not necessarily major climate changes. In addition, Doug and other NCED researchers are working on numerical models for predicting these types of statistically rare events. For a complete list of NCED sessions and talks at AGU, click here.

December 2006 eNews

NCED News

Vol. XI (January 2007)

Events

PI Retreat
February 1-3, 2007
Louisiana Universities Marine Consortium (LUMCON)
Chauvin, LA

Short Courses
The Stream Restoration group has scheduled 5 courses for the summer of 2007.

Grants & Awards

NASA GPM Study
Efi Foufoula-Georgiou, co-Director of NCED, along with Bill Dietrich, PI at the University of Berkeley, were awarded funding this past fall from NASA. They will be studying how Global Precipitation Measurement (GPM) observations over steep mountainous terrains can be coupled with earth-surface models to predict rainfall-induced landslide hazards. GPM is a multi-satellite mission, through an international partnership of space agencies led by NASA and the Japan Aerospace Exploration Agency, aimed at monitoring global precipitation from space at the unprecedented resolution of 4 kilometers and 3 hours.

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ANGELO RESERVE WIRELESS NETWORK ONLINE

Located at the Angelo Coast Range Reserve, the Angelo Wireless Network Infrastructure (ANWI) is a high-speed broadband wireless network that functions as an environmental sensor observatory. ANWI, designed and implemented by NCED for field research and communication, is available for use by researchers with two operational microwave relays and two more relays to be operational this summer. This network includes not only high-speed microwave relays but also point-to-point river uplink sites. These uplink sites allow researchers to download their data, obtained from any set of sensor devices that use a data logger, to a central server via the network. In addition, researchers can be up to 0.4 kilometers from an uplink site and still access the network. Another benefit of the uplink sites will be the Voice Over Internet Protocol (VOIP) phones at these locations, which increases researcher safety: Angelo is too remote and rugged for cell phone reception. For further information on NCED and the Angelo Coast Range Reserve, please click here.

Left photo: Collin Bode, Desktop Watersheds Project Manager, performing extreme computing at 37 meters up a redwood. Right photo: Robotic security camera with wireless connection taking daily photographs of stream conditions on the South Fork Eel River.

BILL DIETRICH ON THE MOVE

Bill Dietrich, NCED PI, with the help of several able graduate students, organized and hosted the Luna Leopold memorial dinner as well as the 22nd Annual Gilbert Club meeting. The memorial, held December 14th at the Berkeley Faculty Club, was in honor of Leopold and his significant contributions to the theory and practice of modern river science. Leopold was 90 years old when he died on February 23, 2006. Colleagues (including Dave Rosgen, Wildland Hydrology, and M. Gordon "Reds" Wolman, B. Howard Griswold Professor, The John Hopkins University), former students, and family attended the memorial. Subsequently, the Gilbert Club meeting on December 16th at the Lawrence Hall of Science brought together students, postdoctoral associates, NCED PIs, and visitors for an opportunity to share current and upcoming developments in geomorphology. Chris Paola, Director of NCED, gave a presentation. The National Science Foundation sponsored the meeting.

NEW PROJECT MANAGER FOR SUBSURFACE ARCHITECTURE INTEGRATED PROJECT

NCED welcomes James Buttles as the new Project Manager for the Subsurface Architecture Integrated Project. Buttles, formerly with MIT as a Research Scientist, will be working at the Department of Geological Sciences, Jackson School of Geosciences, at The University of Texas at Austin. Buttles will be working with Subsurface Architecture Project Leader David Mohrig.

National Center for Earth-surface Dynamics
A National Science Foundation Science & Technology Center

January 2007 eNews

NCED News

Vol. XII (February 2007)

Events

International Bedload Surrogate Monitoring (BRIC) Workshop
April 11-14, 2007
St. Anthony Falls Laboratory
Minneapolis, MN

NCED Undergraduate Summer Intern Program
Application deadline extended to **February 28**

Grants & Awards

NCED Director receives honors
Chris Paola named a Founding Fellow of the Institute on the Environment and a Fellow of the American Geophysical Union (AGU).

NCED Notes

Thanks to Aggregate Industries
Aggregate Industries donated a special mix of gravel (182 tons) to NCED for StreamLab06 experiments.

Contact NCED

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NCED PI LEADS DELTA FIELD TRIP

Dr. Robert Twilley, though having long collaborated with several NCED PIs, met the entire group of NCED PIs and staff for the first time at a PI retreat in Cocodrie, Louisiana. While in Cocodrie, Twilley hosted a Mississippi Delta field trip where the group had a chance to learn first hand the unique challenges facing the Delta ecosystem. Twilley, a wetlands ecologist, brings to NCED not only his considerable research experience but the resources and perspectives of CLEAR: Coastal Louisiana Ecosystem Assessment and Restoration. This collaborative effort among university, state, and federal agency scientists and engineers shares NCED's goal of developing tools for landscape and ecosystem forecasting.

Mississippi Delta field trip with Dr. Robert Twilley and NCED PIs/Staff.

STUDENTS REPORT ON INTERNATIONAL RESEARCH EXPERIENCE PROGRAM

Leslie Hsu, University of California-Berkeley (UCB), Robert Haydel, University of Illinois at Urbana-Champaign (UIUC), and Michal Tal, University of Minnesota (UMN), participated in the International Research Experience Program (IREP) last year. This program, open to graduate students affiliated with National Science Foundation Science and Technology Centers, allows students the opportunity to conduct international research and learn about different cultures. Hsu, Haydel, and Tal presented their research at NCED videoconferences:

- Hsu - Channel erosion in the Illgraben torrent [PowerPoint]
- Haydel - Morphology and flow structure downstream: Two bar-confluences in a large river [Abstract]
- Tal - Untangling the management practices of New Zealand's Canterbury rivers [Abstract]

Graduate students Peter Nelson (UCB), Sara Johnson (UMN), and Amy Hansen (UMN) will participate in the IREP, and present their research to the NCED community, later this year.

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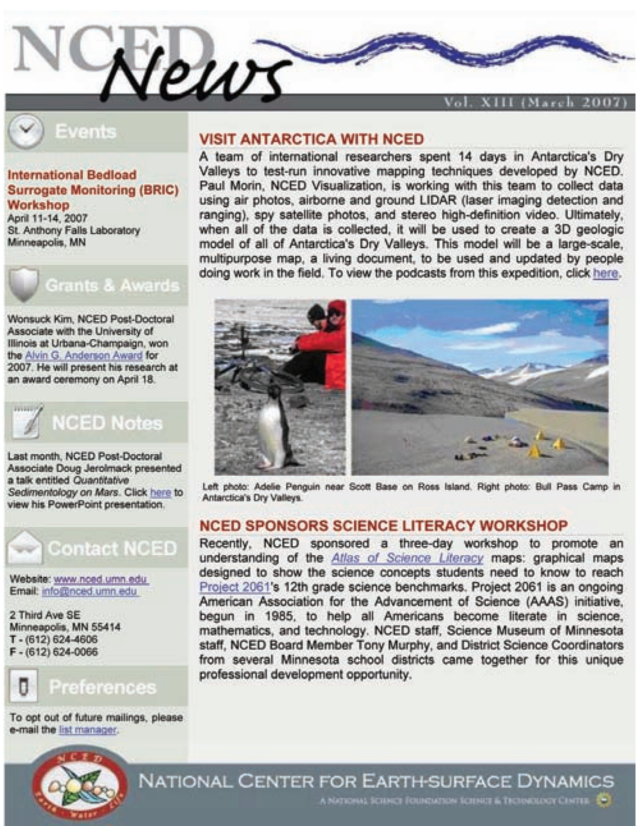
February 2007 eNews



NCED News

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International Bedload Surrogate Monitoring (BRIC) Workshop
April 11-14, 2007
St. Anthony Falls Laboratory
Minneapolis, MN

Grants & Awards

Wonsuck Kim, NCED Post-Doctoral Associate with the University of Illinois at Urbana-Champaign, won the Alvin G. Anderson Award for 2007. He will present his research at an award ceremony on April 18.

NCED Notes

Last month, NCED Post-Doctoral Associate Doug Jerolmack presented a talk entitled *Quantitative Sedimentology on Mars*. Click here to view his PowerPoint presentation.

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VISIT ANTARCTICA WITH NCED

A team of international researchers spent 14 days in Antarctica's Dry Valleys to test-run innovative mapping techniques developed by NCED. Paul Morin, NCED Visualization, is working with this team to collect data using air photos, airborne and ground LIDAR (laser imaging detection and ranging), spy satellite photos, and stereo high-definition video. Ultimately, when all of the data is collected, it will be used to create a 3D geologic model of all of Antarctica's Dry Valleys. This model will be a large-scale, multipurpose map, a living document, to be used and updated by people doing work in the field. To view the podcasts from this expedition, click here.

Left photo: Adelie Penguin near Scott Base on Ross Island. Right photo: Bull Pass Camp in Antarctica's Dry Valleys.

NCED SPONSORS SCIENCE LITERACY WORKSHOP

Recently, NCED sponsored a three-day workshop to promote an understanding of the *Atlas of Science Literacy* maps: graphical maps designed to show the science concepts students need to know to reach Project 2061's 12th grade science benchmarks. Project 2061 is an ongoing American Association for the Advancement of Science (AAAS) initiative, begun in 1985, to help all Americans become literate in science, mathematics, and technology. NCED staff, Science Museum of Minnesota staff, NCED Board Member Tony Murphy, and District Science Coordinators from several Minnesota school districts came together for this unique professional development opportunity.

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March 2007 eNews

Stream Restoration eNETWORKER

Spring 2007

Events

International Bedload Surrogate Monitoring Workshop
April 11-14, 2007
St. Anthony Falls Laboratory
Minneapolis, MN
Workshop Directors: John Gray, Jonathan Laronne, Jeff Marr

Participate in IBSMW Live!
Click here for more information.

Stream Restoration Principles (Part 1 of Stream Restoration Principles)
July 16-20, 2007
Utah State University
Logan, UT
Course Coordinator: Lael Gilbert

Introduction to Field Methods
August 9-11, 2007
Sagehen Creek Field Station
Truckee, CA
Course Coordinator: Matt Kondolf

Geomorphology and Sediment Transport in Channel Design (Part 2 of Stream Restoration Principles)
August 20-24, 2007
Utah State University
Logan, UT
Course Coordinator: Lael Gilbert

Net Notes

Updated Stream Restoration website
View the recently reorganized Stream Restoration website, the updated Stream Restoration events calendar, and the new Stream Restoration in Action webpage.

Contact Us

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ANNOUNCING NEW ONLINE NEWSLETTER

We are excited to introduce a new online newsletter: the *Stream Restoration eNetworker*. This online newsletter includes an overview of what you will find in the *Stream Restoration Networker*, which is available on our website in html and as a printable pdf. The *Stream Restoration Networker* is a quarterly newsletter that provides useful and timely information to the stream restoration community. We hope you enjoy this new format. Please let us know if you have any comments by contacting the editor at editor@streamrestoration.net.

PHYSICAL MODELING EXPERIMENTS TO GUIDE RIVER RESTORATION

The California Bay-Delta Authority is supporting a wide range of stream restoration projects in California's Bay-Delta watershed. However, their work has been hampered by a lack of scientific understanding in three areas of stream restoration: gravel augmentation, dam removal, and channel-floodplain reconstruction. Physical Modeling Experiments to Guide River Restoration (PMEGRR) is addressing these three areas of stream restoration through a series of flume experiments (to establish the basic geomorphic relationships involved). PMEGRR will also create new, or modify existing, numerical models to create usable tools for the Stream Restoration Community. Read more about this story on NCED's website.

INCORPORATING STREAM RESTORATION'S SOCIAL CONTEXT

Led by NCED PIs Ben Hobbs and Nick Flores, the Social Context Research Group is developing stream restoration decision-making models that will integrate sociology, politics, and economics with geomorphology, engineering, and ecology. "We're trying to quantify what people want, and the tradeoffs they're willing to accept among different objectives or risks, and to establish a method that comes up with a project recommendation that is consistent with those values," says Hobbs. Read more about this story on NCED's website.

LITTLE TOPASHAW CREEK STREAM CORRIDOR REHABILITATION PROJECT

The Little Topashaw Creek project hoped to show that large woody debris (LWD) could stabilize the bank of Little Topashaw Creek (Chickasaw County, Mississippi) for far less money than stone and concrete. Doug Shields, Little Topashaw Creek Project Director, also hoped to create a stable pool habitat as well as increase LWD density in the channel, both of which would help rehabilitate in-stream habitat. The project obtained positive outcomes (e.g., restored habitat and increased fish populations) during its first two years that then diminished in subsequent years. Read more about this story on NCED's website.

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Spring 2007 Stream Restoration eNetworker

Appendix F: Partner Meetings

Stillwater Sciences - Physical Modeling Experiments to Guide River Restoration Projects: A Joint Meeting with the NCED Stream Restoration Community Partners Group and Stillwater Sciences
July 6 – 8, 2006 — Richmond Field Station, Richmond, CA

Motivation

Many of NCED's stream restoration community partners seek innovative approaches to incorporate into their river restoration projects, and they look to the research community for answers. This workshop was motivated by the wealth of ongoing research using physical model and laboratory experiments in stream restoration. NCED and Stream Restoration Community Partner, Stillwater Sciences, jointly organized this workshop. The goals of the workshop were to 1) engage the NCED Stream Restoration Community Partners Group in the ongoing physical experiments at NCED, 2) receive feedback from the community partners group on NCED's social science initiative in stream restoration and NCED's recent work on stream restoration training, 3) provide early discussion of results from the physical model experiments completed by Stillwater Sciences and collaborators on the California Bay-Delta Authority's project — "Physical Modeling Experiments to Guide River Restoration" and 4) examine, via a day-long field trip, several stream restoration projects underway in northern California, with emphasis on identifying broader project motivations, design needs, post-project assessment, and funding issues.

Workshop Summary

A small, but dedicated, group of NCED stream restoration community partners and a larger number of Stillwater Science project stakeholders attended the workshop. The first day of the workshop focused on the physical model experiments results and included the following sessions:

- Physical experiments in river restoration I & II.
- Field experiments in river restoration I & II.

On the second day of the workshop, attendees spent time exploring and discussing several urban and rural stream restoration projects in California's Central Valley. The primary urban site involved a guided hike through the Tassajara Creek restoration site by lead investigator Dr. Matt Kondolf. In the afternoon, workshop attendees visited two major rural restoration sites: the Merced River and the Tuolumne River. The project managers of each of these projects, Pete Downs (Stillwater Sciences) and Scott McBain (McBain and Thrush) respectively, led discussions that included project motivation, project goals, design process, funding, and post-project assessment. The formal NCED Stream Restoration Community Partners Group meeting took place on the final day of the workshop. The group discussed, during each session, the following topics:

- Restoration for fish recovery
- Learning from doing: monitoring and post-project assessment
- Public preference in the selection and location of projects for water quality improvement
- Stream restoration tools: routing mixed-sized sediment
- Changing practice by changing stream restoration education and training

All session topics involved adequate time for group discussion.

Workshop Outcomes

1. Stream restoration community partners and stakeholders received good exposure regarding the many projects currently underway with NCED and NCED's collaborators. These collaborations will benefit stream restoration. In addition, several new collaborations, which were initiated at the workshop, have led to direct work between NCED researchers and community partners.
2. This workshop represents a joint effort between NCED and a stream restoration community partner that provided for a new standard of partner/center interaction. This interaction served to strengthen the exchange of knowledge between environmental research and industry.

3. NCED received good feedback on the University of Minnesota Certificate Program for Stream Restoration Science and Engineering. This certificate program has helped strengthen our commitment to education and training.
4. NCED received positive feedback on the Stream Restoration Toolbox, which led to a direct collaboration between NCED and the US Bureau of Reclamation's Trinity River Restoration Program (TRRP), specifically on the issue of applying the Spawning Gravel Refresher tool in the TRRP system.

Agenda

Thursday 7/6	**Presentations & Discussion**	***Presenters***
8:00-9:00	Gathering, Breakfast Transportation provided from Golden Bear Inn 0800	
9:00-9:30	Opening/Introductions	Leonard Sklar, Peter Downs
9:30-10:30	Tour of Flume	
10:30-12:00	Physical Experiments in River Restoration I • Fine Sediment Infiltration into Gravel Beds • 1-d and 2-d Gravel Augmentation • 2-d Sediment Pulse Dynamics	Yantao Cui, Jeremy Venditti, John Wooster
12:00-1:00	Lunch	
1:00-1:30	Physical Experiments in River Restoration II Channel-floodplain interactions	Glen Leverich
1:30-2:00	StreamLab	Jeff Marr, Peter Wilcock
2:00-3:00	Field Experiments in River Restoration I • Introduction • Coarse sediment augmentation - Umpqua River • Simulating sediment passage around structures	Leonard Sklar, Christian Braudrick, Kris Vyverberg
3:00-3:30	Break	
3:30-5:00	Field Experiments in River Restoration II • Combining numerical models, laboratory and field experiments • Re-scaling following gold dredging: Merced River • Re-scaling following aggregate mining - Tuolumne River (Final two presentations double as preview of field trip)	Yantao Cui, Peter Downs, Scott McBain
5:30-7:00	Cookout @ RFS	
Friday 7/7	**Field trip**	***Presenters***
8:00	Bus departs from Richmond Field Station Transportation provided from Golden Bear Inn 0730	
8:00-9:00	Travel to Tassajara Creek	
9:00-10:00	Suburban Restoration: Tassajara Creek compound channel and floodway	Matt Kondolf, Mark Tompkins
10:00-12:00	Travel to Merced River	
12:00-1:00	Lunch – Henderson Park, Snelling	
1:00-3:00	Restoring Salmon Habitat in the Central Valley I: gravel augmentation and restoration plans for the Merced River Dredger Tailings Reach	Peter Downs, Kevin Faulkenberry
3:00-3:45	Travel to Tuolumne River	
3:45-5:45	Restoring Salmon Habitat in the Central Valley II: restoration after aggregate mining – Tuolumne River "7/11" site	Scott McBain
5:45-6:00	Travel to dinner location	

6:00-7:30	Dinner – Tuolumne River Regional Park – site of riparian restoration	AJ Keith
7:30-9:30	Return travel to Berkeley/Richmond	
Saturday 7/8	**Presentations & Discussion**	***Presenters***
8:00 – 8:30	Gathering, Breakfast Transportation provided from Golden Bear Inn 0800	
8:30 – 9:00	Introduction, agenda	Peter Wilcock
9:00 – 10:00	Restoration for fish recovery • Monitoring the restoration of a constrained channel; high flow design elements • Discussion: ecohydraulic design and prediction	Ed Herricks
10:00 – 10:30	Break	
10:30 – 12:00	Learning from doing: Monitoring and post-project assessment • USGS Reconfigured Channel Monitoring and Assessment Program (RCMAP) • Discussion: prospects for coordinated regional and national post-project assessment	John Elliott, Jack Schmidt
Noon – 1:00	Lunch	
1:00 – 2:00	Public preference in the selection & location of projects for water quality improvement • Discussion: willingness to pay & uncertainty in stream restoration	Nick Flores
2:00 – 3:00	Stream restoration tools: routing mixed-size sediment • NCED Tools • Case studies; need for improved tools	Gary Parker, Peter Wilcock, Blair Greiman
3:00 – 3:15	Break	
3:15 – 4:30	Changing practice by changing stream restoration education and training • University programs including the new UMN/NCED graduate program • Discussion: consistent training curricula and proposal for exam-based certification in stream restoration	Karen Gran, Peter Wilcock

Participants

Attendee Name, Affiliation	
1.	Jeff Marr National Center for Earth-surface Dynamics, Stream Restoration Project Manager
2.	Karen Gran University of Minnesota, Duluth, Research Associate
3.	Gary Parker University of Illinois, Urbana-Champaign, NCED Principal Investigator
4.	Peter Wilcock The Johns Hopkins University, NCED Principal Investigator
5.	Greg Wilkerson University of Illinois, Urbana-Champaign, NCED Principal Investigator
6.	Peter Downs Stillwater Sciences
7.	Yantao Cui Stillwater Sciences
8.	John Wooster Stillwater Sciences
9.	Jeremy Venditti University California, Berkeley, NCED Postdoctoral Associate

Attendee Name, Affiliation	
10.	Christian Braudrick University California, Berkeley, Graduate Student
11.	Bill Dietrich University of California, Berkeley, NCED Principal Investigator
12.	Edward Herricks University of Illinois, Urbana-Champaign
13.	John Elliott US Geological Survey
14.	Jack Schmidt Utah State University
15.	Nick Flores University of Colorado, Boulder, NCED Prinicpal Investigator
16.	Tim Randle US Bureau of Reclamation
17.	Blair Greimann US Bureau of Reclamation
18.	Drew Baird US Bureau of Reclamation
19.	Leonard Sklar San Fransisco State University, NCED Collaborative Investigator
20.	Glen Leverich San Fransisco State University, Graduate Student
21.	Kris Vyverberg Department of Fish and Game, California
22.	Scott McBain McBain and Thrush
23.	Matt Kondolf University of California, Berkeley, NCED Collaborative Investigator
24.	Mark Thompkins University of California, Berkeley, Graduate Student

International Bedload Surrogates Monitoring Workshop
April 11 – 14, 2007 — St. Anthony Falls Laboratory, Minneapolis, MN

Motivation

A variety of difficulties are encountered in measuring and monitoring bedload discharge (transport) and particularly in gravel and mixed gravel-sand bedded rivers. Direct bedload measurements, which normally require medium and high-flow measurements to be useful, tend to be time-consuming, expensive, and potentially unsafe. Indirect, or surrogate, technologies developed largely over the last decade show considerable promise toward providing relatively dense, robust, and quantifiably reliable bedload datasets. The motive behind this workshop was to gather the scientists who developed and (or) are using these surrogate methods so that they could present and discuss these new ideas, approaches, and technologies. Workshop objectives were 1) to further the development and verification of novel bedload surrogate methodologies toward their acceptance in large-scale operational programs, and 2) to consider the needs related to international standardization of bedload data-collection, storage, and dissemination protocols.

Workshop Summary

Jeff Marr, NCED Stream Restoration Project Manager, John Gray, United States Geological Survey (USGS) Office of Surface Water, and Jonathan Laronne, Ben Gurion University of the Negev, co-organized the workshop. This three-and-a-half day workshop was structured into sessions. Each session contained up to three talks with an approximately 30 minute moderated discussion period after each session. All presenters were invited to participate in the workshop based on the organizers knowledge of their research on bedload technologies. On the final day of the workshop, attendees participated in a moderated discussion with the goal of generating recommendations for workshop sponsors and setting the direction for ongoing collaborations.

In addition, NCED provided a free, live webcast of the workshop over the world wide web. This unique experience came courtesy of the Adobe Breeze 5.1 platform. Though the success of the webcast has not been fully evaluated, approximately 50 people, representing 12 countries (including Brazil and New Zealand), participated in the workshop. An archive of the workshop webcast is available through the NCED website (www.nced.umn.edu/bric_2007).

Workshop Outcomes

1. The workshop resulted in developing new international collaborations.
2. A workshop paper proceeding (USGS Circular), containing 24 technical papers on surrogate technologies, will be published electronically in fall 2007.
3. Workshop attendees provided recommendations for establishing a small number of continuously monitored bedload transport sites that would allow 1) field-ground truthing of bedload technologies and 2) generation of long-term datasets of bedload transport and hydraulics.
4. The webcast of this workshop, which was broadcast and archived for under $2,000, was NCED's first exposure to the Breeze technology. It is likely that we will use this technology to webcast future meeting, seminars, and workshops.

Agenda

Tuesday 4/10	**Introduction**	***Presenters***
18:00 - 21:00	Informal social for workshop attendees at the TownePlace Suites.	
Wednesday 4/11	**Presentations & Discussion (includes webcast)**	***Presenters***
07:30	Load and depart TownePlace Suites for SAFL.	
07:45 – 08:15	Registration and continental breakfast at SAFL.	
8:30 – 09:30	Opening welcome (~20 min). – Welcome SAFL (~10 min). – Welcome NCED (~10 min). – Workshop Logistics (~15 min).	John R. Gray, Fotis Sotiropoulos, Chris Paola, Jeff Marr
	Introduction to Bedload Surrogate Monitoring Workshop	
09:30 – 10:30	Part A: Bedload Research International Cooperative (BRIC). Part B: Review: Why surrogate monitoring? Part C: Workshop session themes.	Jonathan Laronne, John R. Gray & Jeff Marr
10:30 – 10:45	Session break	
	Technical Presentations	
10:45 – 10:50	Introduction to Technical Presentations	John R. Gray, Session Leader
	Bedload flux: modeling and monitoring	*Bob Holmes, Moderator*
10:50 – 11:15	Some personal observations of bedload behavior in rivers and their implications for indirect methods of measurements.	Bill Emmett
11:15 – 11:40	Building robust models on uncertain data.	Peter Wilcock
11:40 – 12:05	Some random thoughts on bedload sampling.	Panos Diplas
12:05 – 12:30	Discussion	
12:30 – 13:20	Catered lunch at SAFL.	
	Passive acoustics I: lab calibration	*Colin Rennie, Moderator*
13:20 – 13:55	Bed load measurement in rivers using passive acoustic sensors.	Knut Møen, Jim Bogen*, John F. Zuta, Premus Ade & Kim Esbensen
13:55 – 14:20	Laboratory tests of a Japanese pipe hydrophone for continuous acoustic monitoring of coarse bedload.	Takahisa Mizuyama, Akira Oda, Jonathan Laronne, Michinobu Nonaka & Miwa Matsuoka
14:20 – 14:40	StreamLab06: Large-flume testing and analysis of conventional and surrogate bedload monitoring technologies.	Jeff Marr, John R. Gray, Broderick Davis, Chris Ellis, Sara Johnson, Dave Dean & Ben Erickson
14:40 – 15:00	Discussion.	
15:00 – 15:15	Session break (at Main Channel) and preparation for SAFL Seminar.	
	Tour of the St. Anthony Falls Laboratory	*Jeff Marr*
15:15 - 17:30	SAFL tour including Main Channel Facility (2 groups).	

17:30	Adjourn for day, transportation from SAFL for social and dinner at the Sawadtee Thai Restaurant, Minneapolis.	
20:00	Transportation back to the TownePlace Suites.	
Thursday 4/12	**Presentations & Discussion (includes webcast)**	***Presenters***
07:00	Load vans and depart for SAFL.	
07:15 – 07:45	Continental breakfast	
08:00 – 08:15	Overview of Thursday sessions:	Jeff Marr, Session Leader
	Passive acoustics II: field calibration:	*Ian Reid, Moderator*
08:15 – 08:40	Integrated automatic bedload transport monitoring.	Helmut Habersack, Hugo Seitz & Marcel Liedermann
08:40 – 09:05	Calibration of a passive acoustic bedload monitoring system in Japanese mountain rivers.	Takahisa Mizuyama, Jonathan Laronne*, Michinobu Nonaka, Toyoaki Sawada,Yoshifumi Satofuka, Miwa Matsuoka, Shintaro Yamashita, Yoichi Sako, Shohei Tamaki, Masaaki Watari, Shinji Yamaguchi & Kenji Tsuruta
09:05 – 09:30	Monitoring coarse bedload transport with passive acoustic instrumentation: A field study.	Jonathan S. Barton, Rudy L. Slingerland, Smokey Pittman, & Thomas B. Gabrielson
09:30 – 10:00	Discussion.	
10:00 – 10:20	Session break.	
	Active acoustics:	*Jim Bogen, Moderator*
10:20 – 11:45	Laboratory measurement of bedload with an ADCP.	Rauf Ramooz & Colin D. Rennie*
11:45 – 12:10	Measuring bedload/suspended load using multi-frequency-acoustic backscatter.	Stuart McLelland
12:10 – 12:35	Relative contributions of sand and gravel bedload transport to acoustic Doppler bed-velocity magnitudes in the Trinity River, California.	Dave Gaeuman & Smokey Pittman
12:35 – 13:00	Discussion	
13:00 – 13:45	Catered lunch at SAFL.	
	Prototype bedload monitoring:	*Wojciech Froehlich, Moderator*

13:45 – 14:10	Incipient bed-material motion in gravel-bed rivers: Field observations and measurements.	Ramon Batalla, Damia Vericat, Chris Gibbins & Celso Garcia
14:10 – 14:35	Bedload dynamics in steep mountain rivers: insights from the Rio Cordon experimental station (Italian Alps).	Luca Mao, Francesco Comiti* & Mario Lenzi
14:35 – 15:00	Ancillary data requirements for the validation of surrogate measurements of bedload flux: non-invasive bed material grain-size and definitive measurements of flux.	Ian Reid, David Graham, Jonathan Laronne & Stephen Rice
15:00 – 15:30	Discussion.	
15:30 – 15:45	Session break.	
	Bedload monitoring in sand bedded rivers:	*Kristin Bunte, Moderator*
15:45 – 16:15	Measurement of bedload transport in sand-bed rivers: status and future direction.	Robert Holmes
	Principles of acoustics and signal processing:	*Kristin Bunte, Moderator*
16:15 – 16:40	Acoustic principles	Jim Chambers
16:40 – 17:05	Scaling in bedload sediment transport: Characterization and implications.	Efi Foufoula-Georgiou, Arvind Singh, Kurt Fienberg, Doug Jerolmack & Jeff Marr
17:05 – 17:30	Discussion.	
	IBSMW Poster Session	
17:30 – 18:15	Poster session (not web cast)	
	River bedload monitoring using radar system.	S. M. Shrestha**, K. Shibata, K. Hirano, T. Takahara & K. Matsumura
	Investigating the dynamics of the bed load transport with a hydro-acoustic measuring system.	Andreas Krein, Jonathan Laronne, L. Hoffmann, L. Pfister, W. Symader, H. Klinck & M. Eiden
	Bedload Research International Cooperative (BRIC).	Jonathan Laronne & John R. Gray
	Video tracking of bed load with a light table.	Andre Zimmermann, Marwan Hassan, & Michael Church
18:15 – 18:30	Adjourn, transportation to the TownePlace Suites	
18:30 – 20:00	Open evening to explore Minneapolis - Optional pizza dinner at Hotel at 18:30 (sign-up required).	
Friday 4/13	**Presentations & Discussion (includes webcast)**	***Presenters***
07:00	Load vans and depart for SAFL.	
07:15 – 07:45	Continental breakfast.	

08:00 – 08:15	Overview of Friday sessions:	Jonathan Laronne, Session Leader.
	Piezoelectric and magnetic methods:	*Dave Gaeuman, Moderator*
08:15 – 08:40	Bedload-transport measurements using piezoelectric impact sensors and geophones.	Dieter Rickenmann & Bruno Fritschi
08:40 – 09:05	Calibration/development of a magnetic bedload tracking system.	Marwan Hassan
09:05 – 09:30	Measurements of gravel transport using the magnetic tracer technique: temporal variability over a highflow season and field-calibration.	Kristin Bunte
09:30 – 10:00	Discussion.	
10:00 – 10:20	Session break.	
	Passive acoustics II and in-situ samplers I: field monitoring	*Dieter Rickenmann, Moderator*
10:20 – 10:45	Effect of streamflow fluctuations on sediment-transport rates inferred from hydrophones.	Wes Smith
11:45 – 11:10	Bedload trap samples for field calibration of signals from surrogate techniques in gravel-bed streams: possibilities and difficulties.	Kristin Bunte, Kurt Swingle & Steve Abt
11:10 – 11:30	Discussion.	
11:30 – 12:30	Catered lunch at SAFL.	
	Impact methods & passive acoustics III: field monitoring	*Takahisa Mizuyama, Moderator*
12:30 – 12:55	Monitoring of bed load transport within a small drainage basin in the Polish Flysch Carpathians	Wojciech Froehlich
12:55 – 13:20	A particle tracking technique for bedload motion.	Thanos Papanicolau & Doug Knapp
13:20 – 13:40	Discussion.	
	Special topics in bedload monitoring	*Broderick Davis*
13:40 – 13:55	The Glines Canyon Dam removal, Washington, USA: An unprecedented opportunity for bedload monitoring.	Tim Randle
13:55 – 14:10	Field application of RFID tagged rocks for particle tracking.	Mary Nichols
14:10 – 14:30	Discussion.	
14:30 – 14:50	Session break.	
	Open forum discussion period	*John Gray, Moderator*
14:50 – 17:30	Open forum, future of bedload surrogate monitoring:	John R. Gray
17:30	Depart in vans for group dinner at The Times, Minneapolis.	
21:00	Return to TownePlace Suites.	
Saturday 4/14	**Conclusion (not webcast)**	***Presenters***
08:00	Transportation to SAFL.	
08:15 – 08:45	Continental breakfast.	
09:00 – 09:15	Overview of Saturday session:	John R. Gray
09:15 – 10:15	Steps to develop operational-scale bedload surrogate monitoring techniques (incl. the prior calibration of multi-surrogate techniques).	John R. Gray, Jonathan Laronne & Jeff Marr
10:15 – 10:30	Session break.	

10:30 – 11:15	Enumeration of major workshop findings, and recommendations to be presented to the Subcommittee on Sedimentation and other workshop sponsors:	John R. Gray, Jonathan Laronne & Jeff Marr.
11:15 – 11:30	Closing remarks, adjourn.	
	* Indicates speaker if other than first author. ** Poster and submitted manuscript.	

Participants

Attendee Name, Affiliation	
1.	Kurt Swingle Colorado State University
2.	Broderick Davis Federal Interagency Sedimentation Project
3.	Efi Foufoula-Georgiou St. Anthony Falls Laboratory
4.	Jonathan Barton Penn State University
5.	Debra Pierzina NCED
6.	Wes Smith Graham Mathews and Associates
7.	Arvind Singh NCED
8.	Kurt Fienberg NCED
9.	Dave Gaeuman Trinity River Restoration Program
10.	Alan Gellis USGS
11.	Thanos Papanicolaou University of Iowa
12.	Josef Schuler USGS
13.	Hugo Seitz OKU - U. of Nat. Res. And Ap. Life Sci.
14.	Andre Zimmermann University British Columbia
15.	Ramon. J Batalla University of Lleida
16.	Jim Bogen Norwegian Water Resources Institute
17.	Kristin Bunte Colorado State University
18.	Jim Chambers National Center for Physical Acoustics
19.	Francesco Comiti Dept. Land and Agroforest Environments
20.	Panos Diplas Virginia Tech

Attendee Name, Affiliation	
21.	Faith Fitzpatrick U.S. Geological Survey
22.	Wojciech Froehlich Institute of Geography and Spatial Organization, Polish Academy of Sciences
23.	John, R. Gray U.S. Geological Survey
24.	Helmut Habersack BOKU - U. of Nat. Res. And Ap. Life Sci.
25.	Marwan Hassan U. of British Columbia
26.	Rob Hilldale USBR, Sed. And Riv. Hyd. Group
27.	Robert Holmes U.S. Geological Survey
28.	Jonathan Laronne Ben Gurion U. of the Negev
29.	Jeff Marr NCED
30.	Stuart McLelland University of Hull
31.	Knut Møen Norwegian Water Resources Institute
32.	Taka Mizuyama Kyoto University
33.	Michinobu Nonaka Hydrotech Co., Ltd.
34.	Rolf Tore Ottesen Geological Survey of Norway
35.	Akira Oda Civil Engineering Research Laboratory
36.	Tim Randle USBR, Sed. And Riv. Hyd. Group
37.	Ian Reid Loughborough University
38.	Colin Rennie U. of Ottawa, CE
39.	Dieter Rickenmann Swiss Federal Research Institute WSL
40.	Rebecca Soileau U.S. Army Corps of Engineers
41.	Damian Vericát Institute of Geography and Earth Sciences
42.	Peter Wilcock Johns Hopkins University
43.	William Emmett USGS, Retired

Appendix G: StreamLab Laboratory Experiments

Over the last two decades, the desire to rehabilitate impaired rivers has developed into a booming industry. Fostered by public interest demanding designs that promote natural processes, stream restoration implementation happens in a variety of local and federal agencies, consultants, contractors, short-course trainers, and nonprofit environmental interest groups. There is a recognized need for improving the scientific basis of stream restoration practice (e.g., see Whol et al., 2005). NCED and SAFL are joining this national movement to improve stream restoration practice through the development of large-scale indoor and outdoor facilities dedicated to research, technology development, and training in stream restoration. Here we present the motivation driving the development of SAFL's StreamLab facilities, an overview of those facilities, and the results from the first year's experiments (StreamLab06).

Motivation

Stream restoration activities span the globe and include rivers of all shapes and sizes. Recent survey results published by the NRRSS estimate that over $1 billion dollars are spent annually on river restoration projects in the US (Bernhardt et al, 2005). The funding for these projects is largely from public sources, derived directly or indirectly from taxes and levies. The NRRSS survey indicates that the primary goals for river restoration projects are associated with improving the ecological health of the stream, e.g., enhancing water quality, managing riparian zones, providing in-stream fish habitat, and improving fish passage (Bernhardt et al, 2005). The success rate of projects in achieving their design goals is unclear since little evaluation is performed and less than 10% of the 37,000 records in the NRRSS database show that any results were quantified, making it impossible to learn from these projects.

Stream restoration, as a practice, is in its infancy and thus lacks typical professional standards for training, design methodology, project assessment, and accountability—surprisingly so for a field largely funded with public resources. There is also a lack of acknowledgement by both the public and stream restoration practitioners of the knowledge gaps and resulting design uncertainties that exist in stream restoration. Stream restoration design processes differ from more traditional engineering design in that the quantitative design methodologies are currently not available. In some respects, the goals of improving the ecological functions of streams through restoration are more challenging than strict physical designs. Stream restoration must incorporate the living components of streams as well as channel geomorphology and hydrology.

Figure 1. SAFL Main Channel looking upstream with gravel alternate bar morphology.

StreamLab Overview

NCED is focused on improving stream restoration practice through joint research, training, and tool development. Based on guidance from NCED's Stream Restoration Community Partner Group to focus research effort on linking geomorphic stream restoration design, open channel hydraulics, and ecological outcomes, we have developed the StreamLab concept. StreamLab is a multi-investigator research concept that uses field-scale experiments and advanced technology to link physical, biological, and chemical processes in streams. NCED and SAFL are developing three StreamLab facilities that will be used in multi-investigator research. The first of these facilities, SAFL's Main Channel, was upgraded to a StreamLab facility in the fall of 2005 and was the site for the first test of the concept: StreamLab06. Two additional outdoor channels will be completed by the end of 2009.

StreamLab06 Results

StreamLab06 was conducted from March through October of 2006 in the SAFL Main Channel (Figure 1). A 40-member research team composed of university faculty, graduate students, visiting researchers, environmental consultants, undergraduate researchers, and research staff provided necessary research expertise in hydraulic engineering, sediment transport, geomorphology, and ecology. The goals for the project were: (1) to demonstrate the capability of transforming a large experimental channel into a dynamic, living gravel-bed stream system with measurable physical, biological, and chemical processes; (2) explore the impact of hydrology and grain size distribution of the river bed morphology and sediment flux characteristics; (3) to conduct experiments on the impact of periphyton growth on various stream-system processes; and (4) to derive from the research, knowledge and insight that will benefit stream restoration practice.

Figure 2. Three-axis automated data collection carriage.

The Main Channel is 2.4 m wide, 1.75 m deep, and 80 m total length with a 55 m test section. Water for the experiments comes directly from the Mississippi River at rates up to 8.5 m3/s. The Main Channel is equipped with advanced technologies for thorough and precise data collection that is only possible in a laboratory setting. Essential features of the Main Channel include 1) a sediment flux monitoring and recirculation system capable of moving and measuring particles up to 75 mm (3 in), 2) a high-speed data carriage that can traverse the entire 55 m test section at speeds up to 2 m/s and has the capability of three-axis positioning of sensors (Figure 2) and carries digital still cameras, high resolution topography laser and sonar scanners, and an ADV, and 3) a backbone data acquisition computer programmed to continuously monitor essential environmental conditions such as water temperature, water discharge and sediment flux during the experiments. The net result of these upgrades has transformed the SAFL Main Channel into a well instrumented, large-scale, mobile bed research facility that can be used as an indoor "field site" for interdisciplinary stream system research for years to come.

Phase	Morphology	Bed grain size	Details
Phase 1a	Plane bed	Clean gravel	Base flow and floods
Phase 1b	Alternate bar	Clean gravel	Base flow and floods
Phase 2	Alternate bar	Clean gravel	Gravel augmentation Patch Dynamics
Phase 3	Alternate bar	Clean gravel	Sand infiltration
Phase 4a	Plane bed	Sandy gravel	Base flow and floods
Phase 4b	Alternate bar	Sandy gravel	Base flow and floods
Phase 5	Alternate bar	Sandy gravel	Periphyton growth (base flow and floods)

Table 1. *Five phases of StreamLab06.*

StreamLab06, conducted over five phases (Table 1), addresses issues important to stream restoration that will ultimately help stream restoration practitioners design projects resulting in improved and sustainable ecosystem functioning.

Ecogeomorphology in gravel bed rivers (Phases 1, 4, and 5)

Restoration efforts commonly focus on altering the physical structure of streams (channel geometry, hydrology, sediment composition), and we need to determine how these alterations impact ecological processes that form the basis of aquatic food webs.

The research conducted in Phases 1, 4, and 5 determined how channel morphology and grain-size composition influence hydraulic, biological, and chemical processes. We were specifically interested in how heterogeneity generated by sediment transport and small-scale fluid dynamics influenced surface and subsurface water, autotrophic and heterotrophic biomass accumulation, metabolic rates, and the uptake and retention of ecologically important nutrients.

Bed grain size and channel morphology constitute the primary independent boundary conditions in our indoor gravel channel. We measured a suite of biophysical variables (Table 2) and their interactions. Phase 1 was done with a "clean gravel" bed material (D50 = 11.6 mm, D84 = 22.8 mm, and D16= 5.4 mm) and minimal sand. Phases 4 and 5 used the same gravel mix with the addition of roughly 20% volume of sand. In Phases 1 and 4, we examined the system under plane bed and alternate bar configurations and also measured the impact of flooding. In Phase 5, high intensity grow lights were added over the alternate bar configuration to allow periphyton growth during 2 two-week periods separated by a bed scouring flood (Figure 3). Initial results showed biomass accumulation had a greater impact on nutrient retention, water storage, and flow paths than differences between geomorphic configurations.

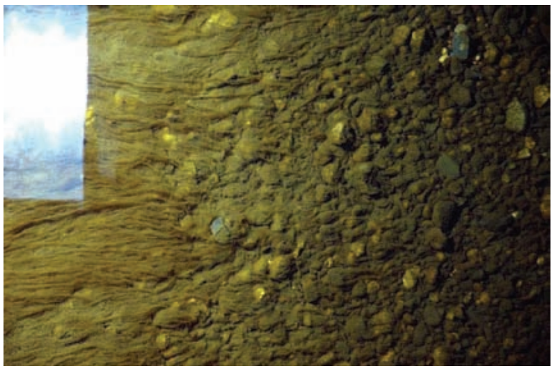

Figure 3. *Image of streambed showing the growth of periphyton and biofilms on the gravel surface. Reflection in the upper left corner is from growth light on the water surface. Periphyton abundance diminishes with distance from the light. The width of the image is approximately 1 m and stream flow is from left to right.*

Physical	Biologic and chemical
Sediment flux rates (local and bulk)	Periphyton location and abundance
Bedform migration rates	Subsurface hetrotrophic biomass and respiration
Bed permeability	Nutrient uptake and retention
Surface-patch formation and movement	Dissolved oxygen and community metabolism
Stream temperature	Carbon retention and availability
Ground water temperature	Invertebrate colonization
Transient storage and exchange	
Water surface and channel slopes	
Flow field characterization	

Table 2. *Stream variables monitored over the course of the StreamLab06.*

<u>Sediment augmentation and patch dynamics (Phase 2)</u>

Gravel augmentation is a common technique used in alluvial river systems to try and restore natural geomorphic processes and habitat. A typical application example is downstream of dams where natural sediment supplies have been reduced causing the formation of a static armor layer on the river bed. This situation can have negative ecological consequences such as a reduction in available habitat for fish spawning and rearing. Augmentation is designed to replenish desirable rock sizes and transport dynamics back to the river. We investigated the use of a fine-grained augmentation, as opposed to commonly used coarse gravel, to return a river to a mobile bed regime. We were interested in determining if a fine-grained augmentation could successfully break up the static armor layer thereby providing access to the full range of grain sizes in the bed and reducing the amount of coarse gravel augmentation needed to restore sediment transport rates to predam levels.

In conjunction with the gravel augmentation experiments, we investigated the development of bed surface grain size patches, focusing on forced patches: persistent, stationary sorting features associated with bed topography. The large size of the Main Channel enabled us to develop self-formed bed topography together with large sediment sizes and flow depths so that detailed hydraulic measurements were possible. Our primary goal was to examine where patches formed relative to bar position and divergent boundary shear stress resulting from the bars. We also monitored the movement of patches in the flume. The data collected here will be used to further test hypotheses and numerical models of the effect of shear stress divergence on surface sorting.

Phase 2 experiments were an extension of ongoing experiments with the California Bay-Delta Authority's Physical Experiments to Guide River Restoration project (REFERNCE TO DWIP), and they highlight the collaborative nature of the StreamLab concept. The data and results from these experiments will be used to improve the utilization of gravel augmentation in stream restoration.

Fine sand infiltration (Phase 3)

The input, movement, and infiltration of fine-grained sediment in gravel bed rivers is another important issue for stream restoration in cases where an elevated quantity of fine material enters rivers such as in regions of recent logging, forest fires, or landslides. Phase 3 experiments examined the infiltration of fine sand into a gravel bed to determine how bed topography affects the spatial patterns of depth, grain size distribution, and quantity of infiltrated fine sediments. Phase 3 experiments also examined whether infiltration relationships determined in 1D (plane-bed) flume experiments remain true when bed surface topography exists. Experiments involved detailed, pre-infiltration measurements of sand concentration followed by infiltration of fine sand and then post-infiltration measurements. Initial results from the work support past findings on infiltration. Infiltration of fine sand resulted in a sand seal: a high concentration layer of sand that forms at depth and serves as a barrier for further penetration of sand. Sand seals formed at about 8 cm below the bed surface, which is at the deep end of expected values (14 mm, based on 3(D90)2, where D50¬ = 0.33 mm, D90 = 2.1 mm). There was moderate spatial variability of infiltration that appeared to be correlated to topography and flow patterns. The data collected in this phase will be used to further develop theories and numerical models of sand infiltration in heterogeneous flows.

Conclusions

The experiments of StreamLab06 are the first of their kind in which a multi-disciplinary team of engineers, geologists, and ecologists examined the physical, chemical, and biological linkages in an indoor gravel-bed river. StreamLab06 highlights the diverse range of experiments that can be conducted in this facility, and also demonstrates that the facility can be used as a surrogate for a dynamic, living gravel-bed stream system. In aggregate, the five phases of StreamLab06 constitute a major effort in using state of the art physical experiments, instrumentation, and a multi-expertise research team to explore fundamental science questions of stream system interactions. This work will further both the fundamental understanding of stream systems and the application of stream restoration practice.

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Appendix H: Program Evaluations

Summative Evaluation of the River Restoration Residency Program: Executive Summary

Prepared by Amy Grack Nelson, Science Museum of Minnesota

Overview

A summative evaluation of the River Restoration Residency (RRR) program was carried out in spring and fall of 2006. Student pre- and post-surveys and teacher surveys were used to gather summative data.

1. A pre-post survey design was used to collect evaluative data from students. SMM staff administered the pre-surveys as the first activity of the residency and post-surveys as the final activity. Pre-surveys were used to gauge students' prior knowledge about river systems. Post-surveys asked students about their experience with the program and what they learned about river systems. A total of 284 students in eighth and eleventh grade completed the surveys.

2. An online survey was sent to educators who participated in the River Restoration Residency (RRR) Program from 2004 – 2006. The purpose of the survey was to obtain feedback about educators' experience with RRR Program and feedback on the program's educational content. A total of 30 teachers received the survey, with 27 teachers completing the survey for a 90% response rate. Responding educators ranged from fifth grade teachers to eleventh grade teachers. Note: The survey sent to 2004 to Spring 2006 teachers had more questions than the survey sent to Fall 2006 teachers.

Major Findings

Student Pre- & Post-Surveys

Students were asked to rate their overall experience with the RRR Program. Almost all of the students had a positive experience with the program. On a four-point scale (from strongly disagree to strongly agree), most students agreed or strongly agreed that the river model was a fun way to learn about science (97%), they were interested in using the river model again in class (93%), and they enjoyed the RRR program (93%).

The program was also successful in increasing some of the students' interest in rivers. Students were asked to rate their level of interest in learning about rivers on a scale of 1 to 10, where 1 was "I have absolutely no interest" and 10 was "I am extremely interested". On the pre-survey, a fifth of students (18%) rated their interest an eight or above, while on the post-survey a third of students (32%) chose an eight or above rating.

RRR staff used the river models to help students understand that scientists use models to test what would happen to a river in real life. To find out if students learned this concept, they were asked on the pre- and post-surveys, "Why do scientists use scientific models of rivers?" On the pre-survey, only a quarter (23%) of students' responses were related to scientists using models to test what would happen in real life, while on the post-survey over half (59%) gave this response. Students also stated a variety of other valid reasons scientists use models: models help scientists understand how rivers work, it is easier to study rivers by using a model than going to a real river, and using a model prevents disturbing a real river system.

One of the survey questions asked students to state their agreement with the nature of science statement, "Different groups of scientists may get different solutions to the same problem". Using a four-point scale (from strongly disagree to strongly agree), most students on both the pre-and post-surveys (94%) gave a correct response by either agreeing or strongly agreeing with the statement. To see the effect the program had on increasing students' confidence in understanding this nature of science knowledge, the percent of students strongly agreeing with the statement from pre to post was compared. On the pre-survey a fifth of students (21%) strongly agreed with the statement, while on the post-survey a third of students (34%) strongly agreed. The RRR program was able to increase some students' confidence; however there were still two-thirds of students who were not completely confident in their understanding of this nature of science knowledge.

The bulk of the RRR Program used the Elwha river models to carry out both qualitative and quantitative studies of what happens to a river system when a dam is built and removed. The activities also teach about the movement of sediment, specifically collection, transportation, and deposition of sediment. Students were asked on both the pre- and post-surveys to describe what happens to a river system when a dam is built. On the pre-survey, only one student (<1%) mentioned anything about sediment being deposited. On the post-survey, half of the students (48%) mentioned sediment deposition. Students were also asked to describe what happens to a river system when a dam is removed. On the pre-survey, only 3% of the students mentioned anything about the effect of dam removal on sediment movement. On the post-survey, two-thirds of students (68%) mentioned something about sediment being transported, collected, and/or deposited. Sediment transport was mentioned by a little over half of the students (53%), while sediment collection and transport were mentioned by a little less than a fifth of the students (16% collected, 11% deposited). Looking at both questions about dam construction and dam removal, the program was most successful in teaching students about sediment deposition (when a dam is built) and sediment transport (when a dam is removed).

Educator Survey

Teachers were asked to rate their experience with the RRR Program by indicating the extent to which they agreed or disagreed with a variety of statements. A six-point scale was used (from strongly disagree to strongly agree). Almost all of the educators had a positive experience with the program. Most teachers agreed or strongly agreed that they enjoyed the RRR program (96%), they would like to use the river models again in their classroom (96%), they would recommend the RRR program to other teachers (96%), and their students enjoyed the RRR program (96%). Only one educator disagreed or strongly disagreed with the statements.

Teachers were asked to rate how engaging they felt the program was for their students who are usually less engaged or involved in class. On a six-point scale, most teachers felt the program was engaging for these students (89% agreed or strongly agreed). "Some of the students who are not very engaged usually, were very engaged and did a nice job with this lab. Students who are always engaged, were still engaged." None of the teachers disagreed or strongly disagreed with the statement.

Teachers were also asked what they felt was the most engaging aspect of the program for their students (thinking about all of their students). A majority of teachers felt the hands-on activities (63%) and the process of carrying out an experiment (63%) were the most engaging aspects of the program for their students. "Hands-on subject matter that was different from your traditional science lesson." "They enjoyed observing, manipulating and observing again. The prediction and comparison aspects of dam removal captivated them as well."

The RRR Program was developed to address various science skills and concepts as well as make connections to the Minnesota Academic Standards for Science and other disciplines of study. Educators were asked to rate the effectiveness of the RRR program in accomplishing these goals. As shown in Table 1, educators felt the program was effective at addressing the various science skills and concepts listed, with the program most effective at providing opportunities for students to make qualitative observations. Educators felt the program was least effective at connecting science to other disciplines of study.

The RRR Program covered a variety of river-related topics. The survey sent to 2004 to Spring 2006 teachers asked them to rate how effective they felt the river model and related activities were in addressing these topics for the students. As illustrated in Table 2, teachers felt the program was most effective in addressing the processes that occur in a river system and the impact humans have on a river system. The topics with the lowest ratings were related to how rivers change the Earth's surface over time and how river systems change to remain in equilibrium. None of the educators felt the program was ineffective at addressing any of the topics.

The RRR Program was not structured to provide educators with pre- and post-visit activities or ideas on how to integrate the program into their regular classroom curriculum. For this reason, teachers were asked to share how they incorporated the RRR Program's content into their regular curriculum/course of study. All educators found a way to connect the RRR Program content into their curriculum/course of study, with some mentioning more than one way the program connected. The most common connections were made curriculum topics related to river systems (58%) and sediment movement (54%).

Educators were asked if they would be interested in using the river models in the future if they were available to check out. All teachers expressed some interest in the models with three-quarters of teachers (77%) interested and a quarter (23%) "maybe" interested. The main reason educators were interested in using the models was that the models were a unique resource. Teachers were also interested in the models because of the connections the models made to their curriculum and the hands-on experiences they provided for their students. Teachers who were "maybe" interested provided a variety of reasons for their uncertainty, with concerns about transporting the models mentioned most frequently.

Table 1. *Effectiveness of RRR Program in Accomplishing Goals*

	Very Ineffective	Ineffective	Somewhat Ineffective	Somewhat Effective	Effective	Very Effective
Providing opportunities for students to make qualitative observations. (n=27)	0%	0%	0%	0%	44%	56%
Illustrating how scientists use models to predict natural phenomena. (n=27)	0%	0%	0%	7%	44%	48%
Demonstrating real-world applications of science research. (n=27)	0%	0%	0%	11%	30%	59%
Providing opportunities for students to make quantitative measurements. (n=24)*	0%	0%	0%	17%	58%	33%
Providing opportunities for students to analyze data to predict an outcome. (n=27)	0%	0%	0%	4%	67%	30%
Showing how to design and conduct an experiment based on natural systems. (n=27)	0%	0%	0%	11%	59%	30%
Connecting to the Minnesota Academic Standards for Science. (n=27)	0%	0%	0%	19%	52%	30%
Connecting science to other disciplines of study. (n=27)	0%	0%	4%	26%	56%	15%

*The quantitative section of the class was not taught to fifth graders, which explains the smaller “n” size.

Table 2. *Effectiveness of RRR Program in Addressing Various River-Related Topics (n=20)*

	Very Ineffective	Ineffective	Somewhat Ineffective	Somewhat Effective	Effective	Very Effective
The processes that occur in a river system (e.g. collection, transportation, deposition)	0%	0%	0%	0%	40%	60%
The impact humans have on a river system.	0%	0%	0%	0%	45%	55%
Rivers as a system.	0%	0%	0%	10%	60%	30%
How rivers change the Earth’s surface over time.	0%	0%	0%	20%	50%	30%
How river systems change to remain in equilibrium.	0%	0%	0%	15%	60%	25%

Big Back Yard Studies: Summer 2006: Executive Summary

Prepared by Amy Grack Nelson, Beth Janetski, and Levi Weinhagen; Science Museum of Minnesta
March 29, 2007

Overview

Three Big Back Yard (BBY) evaluations were carried out during the summer of 2006.

Major Findings

Timing and Tracking Study

Big Back Yard visitors were categorized by their golfing behavior. There were similar numbers of golfers (44%) and non-golfers (46%). There were also a small percentage of visitors who were with a golfing group but chose not to golf (8%) or walked into the BBY but did not interact with any components (3%). Golfers spent the longest median time in the BBY (36 minutes, 15 seconds), while non-golfers', not with a golfing group had a significantly shorter median time (12 minutes, 32 seconds).

Golfing was the most popular activity in the BBY, with 52% of visitors golfing or with a golfing group. The next most popular activity was the Prairie Maze (47%). Science House (23%) and the Native American gardens (11%) were least popular.

Timing data was collected for the Prairie Maze, Science House, and Native American gardens. Visitors spent similar median times in the three exhibits (Science House 4 minutes, 56 seconds; Prairie Maze 4 minutes, 30 seconds; Native American Gardens 4 minutes) with slightly more time in the Science House.

Exit Interviews

Visitors were provided with a list of potential reasons for visiting the BBY and asked if any of them were reasons they visited. Many visitors had more than one reason for their visit. The most common reasons were to be outside (83%) and the appeal of the BBY to the children in the group (60%). Some visitors said the attractions drew them to the BBY, specifically the Prairie Maze (42%) and miniature golf (40%). Few visitors went to the BBY specifically to see the Science House (14%) or Native American gardens (10%).

Most visitors (75%) decided to visit the BBY when they got to the museum. There were a variety of ways visitors found out about the BBY at the museum. Visitors most commonly saw the BBY from a museum window or terrace (38%) or noticed a sign in museum (33%). The fact that visitors are noticing the BBY from windows or terraces points to an opportunity to provide interpretation in some of these areas so visitors know what they are viewing down below.

Visitors who had visited the BBY for the first time were asked about their awareness of certain components before visiting the BBY. Most visitors knew the BBY included mini golf (73%). Less than half the visitors were aware of the Prairie Maze (45%) and Panning for Gems (33%). Few visitors knew about the Native American gardens (13%) and the Science House (12%). This lack of awareness of the gardens and Science House could help to explain why these attractions were least visited in the timing and tracking study.

Visitors who golfed were asked if they read any of the signs located on the ground at the beginning of each hole. Most golfers (77%) read at least one of the signs. Of these visitors, 70% said the questions on the signs improved their experience. Most visitors said the signs improved their experience by providing more explanation of what they saw at the hole, "They gave an instant idea of the hole's theme."

Golfers were also asked to describe what they thought was the golf course's main message. Visitors' responses were coded into themes and responses were spread across the themes. The most common themes were water systems such as rivers and oceans (28%) and the flow and movement of water (20%).

Besides golf holes, the golf course contained numerous exhibits and provided access to the Native American gardens and Science House. Visitors who didn't golf were asked if they still walked through the golf course. Almost two-thirds (63%) of non-golfers walked through the course. The most common reasons visitors gave for not walking through the golf course were they thought the course was for golfers and they were not interested in golf.

Lobby Interview

Only 14% of visitors went to the BBY during their visit to the museum and an additional 10% had visited it in the past. A majority of museum visitors (63%) are unaware that the BBY exists.

Visitors who had heard of the BBY but did not visit it were provided with a list of potential reasons for not visiting the BBY and asked if any of them were reasons they did not visit. Many visitors had more than one reason for not visiting the BBY. The most common reason was that visitors only came to the museum to see Body Worlds (70%). Only 22% cited the extra cost of golf as a reason for not visiting the BBY.

The visitors who had never visited the BBY, but knew it existed, were asked about their awareness of various exhibit components. Most (70%) knew that the BBY included mini golf. Less than half (40%) were aware of Prairie Maze. A small percentage of visitors (15%) knew about Panning for Gems, the Native American gardens, and Science House.

The visitors who had never been to the BBY (both those who had heard of it and those that had not) were asked to read a description of the BBY taken from the museum website. After reading the description, 70% of visitors were interested in visiting the BBY, with another 13% maybe interested in visiting. Visitors named a variety of BBY components they were interested in, with visitors most frequently mentioning miniature golf (38%), Native American gardens (30%), and Prairie Maze (29%). The overwhelming percentage of museum visitors not visiting the BBY and their high level of interest in visiting the BBY after they learn more about it suggests an opportunity to strengthen marketing efforts to increase awareness within the museum not only of the BBY, but of the variety of features visitors can find there.

Appendix I: Review Site Visit Report

Fourth Annual and Renewal Site Visit Report
National Center for Earth-Surface Dynamics (NCED)
University of Minnesota
Minneapolis, Minnesota
May 16-17, 2006

Introduction

The National Center for Earth Surface Dynamics (NCED) is a coordinated activity consisting of nine institutions engaged in integrative predictive science of the processes shaping the surface of the Earth. This report documents the findings of the fourth annual NCED site visit with particular emphasis on the Center's proposal for a second five year's of existence.

The NSF site visit team was composed of eight external members including Ana P. Barros (Chair, Duke University), Patricia L. Wiberg (University of Virgina), Alan Covich (University of Georgia), Thomas Henyey (University of Southern California), Karen Havholm (University of Wisconsin-Eau Claire), Kirk Johnson (Denver Museum of Nature and Science), Bradford Prather (Shell International Exploration and Production), and Colin Stark (Lamont-Doherty Earth Observatory). NSF was represented by Dragana Brzakovic, H. Richard Lane, John Cozzens, William Smith, Michael Ellis, Shana Pimley, and Thomas Baerwale.

The panel views NCED as a valuable national asset and finds that the Center has made significant progress toward its stated goals over the first four years of operation, and especially in the last two years. A summary of the panel's assessment of ongoing activities over the first four years and their proposed plans for continued NSF support for an additional five-year period are presented next.

Overview of the Center

The panel is encouraged by the fact that the Center has articulated in their most recent Strategic and Implementation plan well thought out and appropriate vision and mission statements. Rather than a shift in basic thinking or research focus from the original proposal, these statements reflect clarity of thought and knowledge as to how to construct such statements. The incorporation of the three Integrated Projects was an important step in assisting with development of the current vision and mission statements.

The panel believes the Center is potentially moving toward its legacy, although this issue has not been incorporated into Center plans by the management at this time. The panel has identified a number of areas that are potentially ripe for the Center's legacy and should be incorporated into the Center's management plans as they move through the next 5 years. They include: 1) The process-oriented integrated predictive models and approach of the research program, 2) the two-way informal education pipeline to the Science Museum, and 3) the cadre of graduate students and post-docs that have moved through the Center during its 10-year lifetime. The Center should consider ways to highlight its legacy such as synthesis documents, web-based modules, and data bases. It is not too early to begin addressing NCED's legacy.

It is important for the Center to begin considering life following its sunset in 2012. In this regard, Center management must begin a dialogue with the University of Minnesota administration as to the continuity of the Center's basic research, rehabilitation and maintenance of infrastructure, the sustainability of its education and diversity efforts, and the potential for interdisciplinary activities across departmental and school boundaries. The Center may be in a better position to negotiate commitments from the university while well-funded than near the end of the project.

Proposed Research Plan and Accomplishments

The research plan for the Center seems appropriate with respect to scope and direction for a national research center. The panel is particularly intrigued with the Mississippi Delta restoration project and agrees with the NCED leadership that their next five-year plan should accommodate this project. We see this research as a possible flagship project to demonstrate integration of technology and knowledge across the NCED IPs. NCED leadership clearly understands the value-added nature of their work through integration of several of their research activities. The PIs are beginning to visualize what integrated products coming from the Center should be and can articulate the value of their transfer to the science and society in general. The leadership, however, needs to articulate clearly how integration takes place within and across the IPs. The panel agrees with the NCED leadership that moving the science toward more processed-based hypothesis testing as opposed to conventional analog-based paradigms is potentially transformational. It seems, however, that the leadership team has yet to consider fully how to sustain the legacy of NCED as a center of research or sustain the technology and knowledge resulting from their research (see above for further elaboration).

The research goals for the future in each of the IPs (see Appendix) are highly appropriate and better aligned with the objectives of the Center than in the preceding four years. The budgeting process used by the NCED leadership is not based on project prioritization but rather on a consensus process designed to assure that all IPs receive a "fair share" of the total budget. Although this process may assure that IPs will achieve their objectives more or less at the same time, this budgeting practice could put timely completion of the legacy-setting projects at risk in the future.

The panel is encouraged with the continued progress in integration in the form of convergence of ideas and research activities within the three IPs. The metrics used to measure this progress seem appropriate, but it still may be too early to measure progress toward achieving goals as re-established by the SIP v. 2.2. More thought is needed to establish additional metrics that cover the broad range of outcomes in knowledge transfer and educational effectiveness.

Education Plan and Accomplishments

NCED's education efforts are laudable. In addition to results noted below, an important attribute is that the educational component of the Center is integral to Center activities, and in no way feels like an after-thought add-on. There is regular cross-pollination among the scientists (including graduate students) and the educators (formal and informal). Budget allocation (15 to 33% in each of years 2 through 5) is consistent with the importance accorded to education. This elevates the status and visibility of science education within the science community, which is critical for improving science education broadly, and could be an important legacy of this center.

NCED should be commended for attempting to serve nearly all levels of the educational spectrum in some capacity. Surprisingly, even though so many educational levels are being addressed, the effort does not seem diffuse. The model of selecting key science themes, first developing small, local working versions, and then expanding in scale and in space to new locations as opportunities arise appears to be effective. Educational effectiveness is greatly enhanced by true partnerships with educational professionals like the Science Museum of Minnesota and the Fond du Lac tribal summer camp program.

The graduate student and post-doc group is a large, vibrant, enthusiastic community that has become "self-governing" and highly interactive. The legacy of this will be a cadre of scientists from a variety of disciplines that are trained in cross-disciplinary and quantitative research approaches with collegial relationships that extend broadly. The panel encourages NCED to go forward with plans to implement and integrate the certification program and to offer short courses that expand the reach of these efforts.

The informal education program, a close, interactive collaboration with the Science Museum of Minnesota, serves as a model for leveraging expertise in service of getting cutting-edge science to the general public. The Big Back Yard and Science on a Sphere stand out in this regard. Data collected to evaluate the success of this program indicates that museum visitors are highly engaged in the NCED-inspired exhibits. The youth interpreter program appears to be a particularly effective way to engage teens in science, and has the potential for involving underrepresented populations in science in a positive way, as well as providing more opportunity for science-based interpretation for museum visitors. The panel supports expansion of the Graduate Museum Assistantships program and plans to create new indoor exhibits, traveling exhibits and Science Buzz modules based on research on cognition. Collaboration in informal education efforts provides a model for other scientists and museums. The panel commends efforts to collect data on visitor engagement and learning gains, and recommends probing impacts on visitor attitude towards the value of science as well.

NCED's initiatives to engage pre-service and in-service teachers through ESTREAM internships, the Earthscapes Teacher Institute, and development of materials that can travel to classrooms (such as flumes for the River Restoration Residency) are all effective modes of outreach to 4-12 educators. The panel endorses establishing linkages with science educators already experienced in providing in-service teacher professional development (PD) opportunities to bring the NCED science to a larger number of teachers, including teachers in the areas of collaborating institutions. NCED staff have already noted that short-term PD experiences are much less effective than sustained ones (this is supported by the research literature), but with the right collaborator(s) state education funding can be leveraged to build year-long or ongoing PD opportunities for teachers. If an evaluation plan based in part on student learning outcomes is not already in place, it should be instituted so that science education may benefit from any best practices developed in these programs.

NCED's efforts in undergraduate education are in a nascent stage. However, initial steps (new course at UM, use of lab facilities and UMM in undergraduate courses, development of GeoWall facilities) are promising and there is potential for significant impact, particularly because the vehicles for dissemination of such educational materials are robust. Focus on development of materials supported with appropriate pedagogical methodologies. Continue to disseminate through existing, widely recognized methods such as Cutting Edge Workshops, the Science Education Research Center website, NAGT Distinguished Speaker program, and workshops at regional and national meetings. Conduct research into the pedagogical value of the NCED materials and methods, publish these in the Journal of Geoscience Education and other appropriate peer-reviewed journals.

Knowledge Transfer Plan and Accomplishments

The Center has examples of effective KT including presentations at national meetings, science working groups, extra-mural workshops and, especially via its Science Museum partnership. NCED has succeeded in establishing science partner groups for each IP. For example, building of flumes by several industry groups (e.g. ExxonMobil, ConocoPhillips) based on knowledge acquired through involvement with NCED is testament to the effectiveness of some of the Center's KT efforts.

The framework being developed for solving problems using the Desktop Watershed approach is promising, and has the potential to impact all IPs. It is expected that the release of the first version of the static model in Year 5 will make a significant contribution, especially in land-management. Successive revisions at regular intervals can be useful for synthesizing research and documenting progress.

Efforts to jump-start KT in the Stream Restoration IP via development of interdisciplinary science-based short-courses are commendable. The panel encourages planning for and developing additional tools and methodologies for stream restoration practitioners.

Design of the external networking needs more strategic planning. For example, the NCED web site is likely to be one of the main access points for researchers, educators and the public who hear about NCED and has the potential to draw them into the vision, research, results and accomplishments of the program. At present, this potential is not fully realized. Moreover, it is not clear how the Center is effectively taking its basic science "breakthroughs" to the media. The PIs recognize the importance of transferring their research into applications for science education and for policy but more accounting of their successes will enhance their regional and national visibility.

Transfers of unique "added values" will be evident from applications of the basic sciences that increase the probability of successful: 1) restorations of streams and rivers that have multiple society values and provide a highly visible and persistent ecosystem services; 2) drilling for water and hydrocarbons with better understanding of the locations of reservoirs and transport of fluids; 3) restoration of wetlands and deltaic sediments to buffer storm effects and provide appropriate rates of sediment accrual to reestablish the natural regime. Linking these successes through discussions of fundamental processes will be important to highlight in national meetings and major journals. This process has begun and needs to continue across the various components of the Center's research.

Diversity

NCED has a well-defined goal of achieving center diversity that reflects the U.S. census and they have approached that goal with several well-conceived strategies. These include focused attention to the demographics of the research and project staff, a novel Faculty-to-Faculty program that builds research relations with minority-serving institutions, an undergraduate summer internship that targets underrepresented groups, a formal relationship with Minnesota-based Native American groups that starts with K-12 camps and migrates to a primarily Native American community college, and a cooperation with the Science Museum of Minnesota that targets inner city kids as interpreters for the museum's Earthscape programming. This plan is solid and effective as reflected by positive movement in the diversity metrics defined by the program.

The Project Director clearly supports the Diversity Initiative and sees it as a major strength of the center. This is demonstrated by the steady allocation of approximately 5% of the overall budget and the thoughtful selection of partners. Key diversity partners include the Science Museum of Minnesota, the Fond du Lac Tribal and Community College, Florida A&M, Texas A&M-Kingsville, and Jackson State University. In addition, the NCED External Advisory board includes the Provost of Morehouse College and the President of Turtle Island Communications, a Native American telecommunications company.

The strength of the partnerships varies, but the panel was particularly impressed by the depth of the relationship with the Minnesota-based Native America groups. Active participation by the Native American Director of the Science Museum of Minnesota and leadership by Holly Pellerin, a respected elder from the Fond du Lac Reservation has produced tremendous community buy-in, ownership, and participation. The Earth Surface orientation of NCED and the Earth respect of the Native American participants is a natural one that has potential to grow. The integration of Pellerin has greatly enhanced the effectiveness of both the NCED diversity and education initiatives. This elder is nationally active and there is the potential for her to help export this effort to other Native America groups located in proximity to other NCED collaborating institutions.

The Faculty-to-Faculty program has potential to build functional relationships to connect underrepresented groups with research opportunities through internships and visits and by connecting faculty at low-resource institutions with the NCED research network. The Mississippi Delta project, in addition to being a high profile research opportunity for NCED, also has the potential to engage the region's diverse population in science.

Participation of underrepresented groups in the geosciences is lower than other sciences and NCED is making measurable progress to rectify this situation. The panel urges of all PIs and institutions in these efforts.

Center Organization and Management

The management structure of the center at the top level is constituted by the directorate (the PIs Paola and Foufoula-Georgiou), the executive committee (all of whom are NCED PIs) and the external advisory board. NCED has included students and postdocs in the organizational structure through creation of a student council and a synthesis postdoc group. Both are welcome additions – through panel member discussions with the students and postdocs it is clear that this community has a strong feeling of inclusion in NCED activities and direction.

The directorate and executive committee appear to be functioning well and no serious problems were identified by the panel. The panel discussed in some depth the constitution of the external advisory board. There was a concern raised by the peer-reviews that participation by additional top-rank academics would be beneficial. In general, however, the panel felt that the choice of EAB members was appropriate.

NCED has established a range of means of coordinating group efforts, from monthly postdoc video conferences to a small travel-grant program for students. The panel was generally impressed with the mutual awareness shared by NCED participants of the broad range of NCED activities and goals. This level of "common knowledge" is a good indication of the health of the trans-disciplinary effort at the core of NCED.

A significant change has taken place in the thematic organization of NCED during its first few years: the initial theme-based structure was replaced with a project-based architecture formalized as three Integrative Projects. The PIs state in their renewal proposal that the new approach serves a "crucial management need" in tying short term objectives to long-term goals, and the panel would concur with this. The IPs do indeed provide a solid cross-disciplinary underpinning upon which the individual PIs and their groups have identified specific scientific tasks and built specific projects. It is apparent that the IP structure has begun to mature and is functioning well as a tool for coordination of research.

NCED has begun to focus significant effort towards the Mississippi Delta and the urgent problems brought by the Hurricane Katrina floods in 2005. This initiative was welcomed by the panel. Its advent highlights an issue in the current management structure, which is the lack of any clear mechanism within NCED for shifting resources (particularly budgetary) towards new projects and away from others. Decisions regarding NCED budget allocation and reallocation have so far been made within the consensual management framework, and there was a concern among the panel that in the future NCED may need a clear management protocol for resource re-allocation. The renewal proposal states that funding allocation is by PI and not by project, and the panel is concerned that while this approach has worked well until now, this choice may in the future hamper prioritization.

Involvement of partner institutions is vital in the shaping of NCED's vision and direction. In the areas of education and knowledge transfer, engagement with the SMM appears crucial. Participants from the SMM are closely involved IP activities, and the panel was particularly impressed by this.

NCED has stated that the highest priority of management is to plan for sustainability of the center beyond the term of NSF funding, and that NCED is in the process of creating a committee to address this issue. Since the challenge of sustainability was a recurrent theme during the site visit, the panel welcomes this effort.

Shared Experimental Facilities

NCED's shared experimental facilities, especially the Experimental Earthscapes (XES), StreamLab and new Outdoor Laboratory for Ecogeomorphology and River Restoration (OLERR) at SAFL and the Angelo Coast Range Reserve (ACRR) in northern California, provide a natural template for integration of research efforts within SAFL. In fact, these facilities are central to the transformative role envisioned by NCED in moving the earth surface dynamics community toward transdisciplinary, integrated, predictive research by providing models of the power and excitement of this approach to research. These facilities are used by most of the NCED PI research groups and many student research projects are directly tied to these experimental facilities. They are used additionally as research sites for summer interns and undergraduates and provide outreach opportunities for K12 students. One of the valuable knowledge transfers has been the adaptation of some of the experimental facilities at SAFL to dynamic museum displays, traveling exhibits (e.g., USFS/NCED exhibit at the Smithsonian Folklife Festival) and undergraduate curriculum materials (e.g., Tabletop dam removal).

The shared facilities exist as entities independent of but strongly supported by NCED. As such, they each have administrative/management structures in place and a base of support significantly greater than that provided by NCED. Allocations for these facilities, other than modest equipment and supply requests, do not appear to be included as specific items in the NCED budgets. Specific performance indicators for shared facilities are not explicitly provided in the NCED documents, but utilization, theses and dissertations, publications, and research and partner funding are obvious metrics for these shared experimental facilities.

The ACRR has attracted researchers and partners. All elements of the Desktop Watershed utilize the ACRR facilities. Notably, ACRR has attracted $1.6M of funding from the W. M. Keck Foundation for research in ACRR. Similarly XES has attracted industry interest and support and results, which are publicly accessible, are changing the way sedimentologists think about depositional systems. The development of the new Outdoor Laboratory for Ecogeomorphology and River Restoration (OLERR) promises to serve a central role in research in river restoration within NCED and in the broader community.

Overall Assessment

Major Strengths and Accomplishments

- NCED is composed of an outstanding group of engineers and scientists from major institutions who are engaged in tackling fundamental challenges in Earth Sciences that cut across traditional disciplines and have far-reaching societal implications.
- NCED is pioneering the transformation from a descriptive to an integrated and predictive approach to Earth Surface Dynamics.
- NCED is making a major contribution in creating a new generation of truly trans-disciplinary scientists.
- NCED has a fully integrated, wide-ranging and innovative educational program that is unique in the panel's experience.
- NCED has made meaningful advances in the integration of under-represented groups, in particular Native-Americans, in science.

Recommendations

The panel enthusiastically recommends continuation of NSF support for another five years. However, the strategic and implementation plan for the next five years needs further clarification of deliverables, including milestones, assessment metrics, time-lines and contingency plans.

Appendix

At the end of the first day of the site visit, the panel requested that the NCED leadership provide written answers to two questions on strategic planning for years 5-10 in the context of the renewal proposal submitted to NSF in November 2005. This appendix contains both the questions posed by the panel and the replies obtained from NCED.

1 - Provide a representation of expected results or outcomes (deliverables and milestones with a timeline) for all project components for years 5-10. These should be focused, but not at the level of detail of the tables in the current SIP.

NOTE: Because Knowledge Transfer is integrated into the Integrated Projects, milestones for research and KT are presented together by IP.

Desktop Watershed Milestones

NCED Year	Deliverables/Milestones
5 2007	Complete and make available to the community a *static* version of the Desktop Watershed model that predicts the spatial distribution of salmon populations along with required physical variables (grain size, channel geometry) throughout a watershed. This model will consist of modules for predicting (from digital topographic data) channel attributes that influence habitat carrying capacity.
6 2008	• Map-based predictions of key environmental conditions and regimes (solar radiation, substrate texture, and bed mobility) down drainage networks calibrated using sensor networks and field measurements; document the effects of these factors on species performances and interactions (fish growth, algal accrual, denitrification, insect emergence). • New experimentally based rate law for bedrock wear by debris flows. • Determine the extent to which soil microbial species richness varies with rainfall regime.
7 2009	• First 3-dimensional slope stability model for shallow landsliding. • Hydrologic models for predicting runoff hydrographs throughout Elder Creek channel network will be applied and tested, to determine the optimal choice to drive the dynamic DW model.
8 2010	• Complete development and testing of a model for predicting bed patchiness in gravel bedded rivers. • Develop a mechanistic understanding to predict thresholds in ecological regimes at particular locations in watersheds and how these thresholds would change under scenarios of altered climate, land use, or biota. • Determine conditions (e.g. high flow, low flow, nutrient augmentation, high litter inputs) under which organisms, nutrients, and organic matter accrue or transform locally, are transported down the channel network, or are exported to the watershed. • Determine how rainfall regimes alter *rates* of microbial transformation of key ecosystem resources (C, N, P).
9 2011	• First coupled debris flow, bedload transport river incision model • First test of ACRR-based ecological predictions in other watersheds.
10 2012	• Complete dynamic version of the Desktop Applications model including storm runoff, sediment routing and ecological consequences (for land management purposes). • Models to scale watershed wide fluxes of carbon, nutrients, and river organisms. • Biogeochemical models to predict a subset of solute *fluxes* (especially nitrogen, phosphorus) from the soil to river channels.

Subsurface Architecture Milestones

NCED Year	• Deliverables/Milestones
5 2007	• Predictor for subsurface fluvial channel density tested with experimental data • Develop first complete long-profile model for source to sink sediment partitioning including valley evolution based on dam-removal studies
6 2008	• New methods for prediction of statistics of 3D subsurface structure based on depositional system channel dynamics verified with laboratory data • Complete morphodynamic model of large-scale delta evolution verified with data from Wax Lake. • Develop and rollout short course notes on predictive subsurface architecture based on NCED generated laboratory experiments.
7 2009	• First test using field-based geometric and seismic attribute information to predict the subsurface architecture (3D sand vs mud, channel connectivity) of a natural system (expected target: Mississippi Delta Holocene/Pleistocene). • Functioning multi-scale process based geostatistical model for 3D subsurface channel density verified with experimental data
8 2010	Integrate salient results from analysis of subsurface Mississippi Delta architecture into morphodynamic model of delta evolution.
9 2011	Initial coupling of geostatistical model with geometric and seismic-based models for subsurface prediction; testing with field and laboratory measurements
10 2012	• Complete multi-scale models incorporating interactions between allogenic forcing and autogenic dynamics to predict 3D structure (statistical + deterministic) of subsurface properties (e.g. grain size, channel density and connectivity), applicable to fluvial and submarine channel systems. • Complete integration of subsurface architecture into morphodynamic model of delta growth; application of model to restoration schemes for the Mississippi Delta. • Widespread adoption of NCED predictive results in industry

Stream Restoration Milestones

NCED Year	• Deliverables/Milestones
5 2007	• Calibrated model for the hydraulic geometry of both sand and gravel-bed channels • Demonstrate full case studies of tradeoff evaluation and public value estimation • Hand-off restoration certification to professional organization • Determine physical controls on nutrient uptake and periphyton abundance (StreamLab)
6 2008	• Completed channel stability and nutrient cycling experiments in OLERR • Channel geometry model extended to include vegetation and tie channels.
7 2009	• Predictive model for reach-scale sediment routing, including sediment storage and spatial sorting • Predictive model for the transport and fate of nitrogen at the reach scale.
8 2010	• Field-tested generalization of physical controls on nutrient uptake and periphyton abundance • Demonstrate Bayesian approach for implementing adaptive environmental management: the quantitative evaluation of the worth of improved information in restoration decision making
9 2011	• Formal, externally funded collaboration with environmental management agencies • Field-tested generalization of nutrient models to design for water quality standards
10 2012	• Channel geometry model extended to include watershed context, migration and planform change; integrated with nutrient models (e.g. N) and upscaled model connecting local habitat to fish population dynamics and used to inform decision and valuation models • Adoption of decision analysis methods and economic valuation techniques across broad range of restoration agencies

Education Milestones

NCED Year	Program	Deliverable/milestone
5 2007	Grad	Graduate first class of post-baccalaureate certificates in stream restoration.
	Undergrad	• McGraw-Hill textbook, Visualizing Geology, published. • Develop significant undergraduate teaching material based on NCED research. (e.g., web-based modules utilizing data and visualizations from XES or delta basin facilities).
	Teachers	• New Teacher Resource Center in Science House (in the Big Back Yard) opens.
	Public	Follow-up content evaluation of BBY
6 2008	Grad	Establish common curriculum for graduate classes in stream restoration.
	Undergrad	SMM evaluates use of museum space for undergraduate instruction using Science on a Sphere
	Public	Water Planet opens at the Science Museum of Minnesota (SMM) in fall 2008. NCED content will be present as visualizations of channel processes and related human activities. It will be seen by 700,000 people during its stay at SMM.
7 2009	Public	• EarthScapes 3D opens at the Science Museum of Minnesota (SMM) in summer 2009 and begins its national distribution in fall 2009. It will be seen by 140,000 people during its two-year run at SMM. • WaterPlanet begins touring.
8 2010	Grad	Teach components of the stream restoration certificate at other NCED institutions
	Public	New layer of interpretation or significant new exhibit component developed for Earthscapes in BBY
10 2012	Grad	• At least 10 NCED-recruited graduate students have completed Graduate Museum Assistantships • Reach a sustainable level (a steady state of 5-10 students a year) for the stream restoration certificate
	Undergrad	Modules or courses developed and in use nationally for undergraduate instruction (e.g., 15 modules or 3 courses)
	Teachers	Earthscapes Teacher Institute II has been conducted 5 times
	Public	• WaterPlanet travels nationally and visited by 1.8 million people. • EarthScapes 3D visited by up to 840,000 people in at least eight museums.

Diversity Milestones

NCED Year	Program	Deliverable/Milestone
5 2007	USIP	Pilot NIBI program (bridging FDLTCC 2-yr students to grad school) with first USIP student recruited from FDLTCC
	F2F	Complete survey of all MSI's to identify maximum number of potential collaborators for F2F program
6 2008	USIP	Formalize NIBI program with FDLTCC
	F2F	Complete 4th F2F Faculty Visit
7 2009	USIP	First USIP interns receive graduate degrees
	Gidak	First class of gidakiimanaaniwigamig students enter college or university
	Gidak	gidakiimanaaniwigamig students' Math and Science GPA proficiency levels > 95% proficient (2004 benchmark year: Math GPA: 85% proficient; Science GPA 88% proficient)
	Diversity	% of NCED researchers from underrepresented groups reaches 20% (baseline 7% in 2002)

NCED Year	Program	Deliverable/Milestone
8 2010	F2F	Faculty-to-Faculty program reaches steady state with 2-3 faculty visits per year
9 2011	USIP	Independent funding sources established for USIP program
	Gidak	Independing funding sources established for gidak program
10 2012	F2F	Well-established institutional links with 5-10 MIS's generated from F2F contacts
	USIP	Steady state established of 2-3 USIP alumni entering graduate school each year
	Diversity	% of NCED researchers from underrepresented groups surpasses 25%

2. What is the major expected legacy in science knowledge (either overall or by IP)? What is it about center status that allows you to achieve this?

We would like to note that the center's legacy is discussed in the renewal proposal and the Overview presentation and three IP presentations from the site visit. Rather than repeat this material, here we present the center's scientific legacy in a different, summary, format: the state of basic science (and application where appropriate) before NCED began (*then*), *now*, and the *future* at the end of ten years of NCED operation. Note that while we emphasize NCED contributions, the advances we envision will involve NCED and the broader research community.

Stream Restoration

Then: Current stream restoration practice is non-predictive, based on analogy and anchored to an equilibrium condition not likely to exist. Project objectives are typically ill-defined. We lack scientific understanding needed to predict channel geometry and ecological effects of physical stream interventions.
Now: NCED has established a national presence by promoting a rigorous and predictive restoration practice anchored in predictive modeling of the interwoven physical, biological and chemical processes. NCED has developed an initial set of tools for mechanistically-based, predictive restoration design, and is beginning work on incorporating public preference and scientific uncertainty in evaluating tradeoffs among restoration objectives.
Future: Professional stream restoration practice is defined by quantitative objectives and predictive methods incorporating uncertainty, informed by public preference and effective tradeoffs, and supported by rigorous training and routine research/practice collaboration. This will provide more efficient and economical restoration actions and reduce the frequency of failure of projects that often cost more than $1 Million/mile.

NCED's science enables the prediction of the physical, biological, and chemical response of river channels and floodplains to interventions, as a function of watershed position and local channel conditions.

Desktop Watershed

Then: Large gaps in process understanding, poor knowledge of linkages among physical, biological and chemical processes, and limited tools to guide and interpret field studies prevent quantifying connections between landuse and ecosystem conditions.
Now: NCED is defining and quantifying the interplay between physical, biological, and chemical processes that shape watershed systems to provide the basis for models that can be used for landscape and ecosystem management. It is advancing tools to exploit high resolution topographic data to model landscape processes.
Future: High resolution digital environmental data (topography, vegetation, precipitation, runoff, etc.) are widely available to researchers and practitioners, and are used in models to guide field work, generate hypotheses, evaluate landuse management decisions, and provide critical input for stream restoration. NCED observations form the foundation for this approach, and our models enable it to take place.

Subsurface Architecture

Then: Stratigraphy remains a largely descriptive science, and prediction of conditions for subsurface resources like hydrocarbons and water is typically based on analogy rather than process-based predictive models.

Now: NCED has fostered adaptation of advanced methods (scaling, spatial statistics, interface models, moving-boundary methods) from hydrology and engineering to provide a suite of tools for analyzing and predicting autogenic and allogenic dynamics in depositional systems, and a first set of predictors of fluvial architecture (channel stacking density) in terms of channel geometry, kinematics, and net deposition. Initial model testing has focused on experiments using unique NCED facilities.

Future: By adapting methods and understanding from engineering, hydrology, applied mathematics, and biology, NCED has enabled stratigraphy to move beyond the qualitative understanding embodied in sequence stratigraphic models to predictive, process-based, multi-scale models for subsurface architecture. This work is widely applied in industry, optimizing the siting of wells costing millions of dollars or more apiece.

We "learn from the past to predict the future" by applying practical tools that use the sedimentary archive of depositional system behavior to provide baseline data and uncertainty estimates in stream restoration and environmental management.

NCED has integrated an understanding of subsurface architecture with land-building models for the evolution of controlled avulsions into a predictive model for the rehabilitation of the Mississippi Delta. This integration will serve as a template for the use of controlled avulsions to rehabilitate deltas on a worldwide basis.

Why is center status needed?

Even if they were being pursued independently of one another, the three Integrated Projects around which NCED's research is built could not be accomplished through standard research funding. They are too ambitious, too complex, and too multidisciplinary to achieve their goals through uncoordinated single-discipline grants with a few PIs and time scales of a few years. Each IP requires the full force of a sustained, coordinated effort by a flexible, committed research team spanning disciplines (and NSF divisions) from engineering through earth science and ecology to human behavior. In addition, the three IPs are *not* being pursued independently; rather they are linked by a web of shared ideas, data, theory, and results that allow each to take immediate advantage of discoveries in the others and advance even more rapidly.

The center mode also provides some less immediate, but equally crucial, features to make the legacy we envision possible: the visibility and presence necessary to disseminate a new approach; the necessary incubation period for the dismantling of walls between disparate fields leading to the creation of new avenues of communication and research; an honest broker in sometimes-contentious areas of applied practice; and a community center that can provide research tools and examples, and help organize the broader research community toward the overall vision of an integrated, predictive science of "the environment" – the surface of the Earth.

Appendix J: Provisional SIP

Introductions

Global Climate Models predict a change in precipitation in a watershed in California.

How will this affect key watershed properties like sediment yield and fish populations?

A stream restoration project team decides to create a series of natural-looking meander bends in an engineered stream.

Will the bends be stable over time?

Land loss in the Mississippi Delta threatens increasing exposure of population centers like New Orleans to hurricanes..

Can the Delta be rebuilt?

What these questions have in common, apart from being highly relevant to society, is that addressing them requires a sophisticated, cross-disciplinary understanding of the dynamics of the Earth's surface (the "critical zone"), and in particular, of the channel systems that serve as its arterial network.

The National Center for Earth-surface Dynamics was created to provide this understanding.

NCED's Purpose

NCED's purpose is to catalyze development of an integrated, predictive science of the processes shaping the surface of the Earth, in order to transform management of ecosystems, resources, and land use.

NCED's Mission

NCED is a partnership of research and educational institutions, government agencies, and industry that pursues its goal of predictive Earth-surface science by integrating physical, biological, and social sciences. Our research mission is to provide the science needed for landscape prediction and restoration. We achieve research synthesis by focusing on a fundamental component of the Earth-surface system – channel networks and their surroundings – that recurs in varying but fundamentally related forms across a wide range of environments and scales. We collaborate in the application of our research with partners to identify knowledge gaps and develop tools to forecast landscape dynamics, guide landscape management, restore river systems, and promote environmental awareness. NCED shares the excitement of landscape science with a diverse community, exchanging perspectives through partnering, nurturing, and interacting in formal and informal education settings.

NCED's Primary Initiatives

NCED activities are organized around six primary initiatives: three research initiatives (Integrated Projects or IPs), and three non-research initiatives.

Desktop Watersheds Integrated Project (DW)

Motivation: Digital topographic data offer the possibility of building watershed-scale numerical models of real landscapes to explore problems ranging from the long time-scale controls on landscape evolution to short time-scale response of aquatic ecosystems to land-use change. Such modeling efforts are inhibited, however, by a lack of knowledge and quantitative expressions for many of the fundamental geomorphic and biotic processes. Closure of this knowledge gap and introduction of new theories and approaches by NCED and collaborators will lead to discoveries about landscape evolution, and to the construction of practical numerical models that will revolutionize land-use management and environmental forecasting. NCED's unique breadth of researchers, experimental facilities, and field programs enables it to assume this leadership role.

Goal: To discover and advance the fundamental relations needed to predict landscape evolution and to model the coupling of ecosystem, landscape, and land-use dynamics.

Approach: High-resolution digital topography provides the template for Desktop Watersheds modeling. To unlock the potential of digital topography, we introduce new theories, propose new analytical approaches, conduct innovative experimental studies, and perform intensive field studies to discover, parameterize, and evaluate the fundamental driving equations. Our findings are made available to others to improve watershed-scale numerical modeling being developed across the community. We use our current digital-terrain based models (prototype Desktop Watersheds), to guide prioritization of research and maintain a tight coupling between modeling and observation. In their simplest form, in which the topography is used to estimate such features as biological productivity, probable landslide location, channel morphology or bed grain size, Desktop Watersheds models can provide a relatively parameter-free prediction of landscape attributes useful in guiding field work and in applications such as planning timber harvests and stream restoration projects. The advances from the new research will lead to the ability to model cumulative watershed effects, controls on total maximum daily load levels of sediment, and to "game" management scenarios in order to optimize land-use activities for ecosystem protection and restoration.

Science questions: (1) What is the topographic signature of tectonic, climatic, and other external influences on watersheds? (2) Where in the landscape do ecological regimes change, what factors cause these changes, and how would the locations of these ecological boundaries shift under altered climate, land use, or biological states? (3) How does the physical organization of the landscape provide a template for organization of the ecologic and channel-scale processes in the watershed? (4) Do biotic processes influence large-scale topographic form? (5) How predictable is landscape evolution, and what are the principal sources of uncertainty? (6) What are the driving equations of landscape evolution and how can they be scaled-up to large-scale, coarse-grained applications (such as entire mountain ranges)? (7) What are the long-term environmental consequences of various approaches to land use and how will use history influence future landscape evolution?

Subsurface Architecture Integrated Project (SA)

Motivation: As channels evolve under conditions of net deposition, they leave records of the natural variability of the surface and of its response to imposed changes. These records provide insight on how depositional systems organize and maintain themselves in the absence of human interference. "Reverse engineering" the stratigraphic record to extract this information requires that we understand the complex, nonlinear processes by which surface dynamics is encoded into 3D stratal geometry. In the course of this, we also provide insight that can improve prediction of variations in the distribution of porosity and permeability that control the flow and accumulation of water, oil, and gas in the subsurface. These variations in porosity and permeability also set the spatial patterns of mechanical compaction that control land subsidence and influence the ecology of lowland settings.

Goal: To develop methods to extract quantitative information on structure and dynamics of depositional systems from stratigraphic records and apply this information to landscape prediction and restoration.

Approach: The theme of the SA Integrated Project is "surface to subsurface". Extracting information from preserved deposits entails understanding how surface channel properties, spatial patterns, ecology, and temporal evolution interact with net deposition to create the architecture of sedimentary deposits. The main field area for the SA IP is the Mississippi Delta. Natural channel systems evolve slowly, so SA also relies heavily experimental research that in effect speeds up time, and complements field and theoretical studies.

Science questions: (1) What are the biasing and filtering properties of the sedimentary recording process? (2) How can we extract quantitative information on the rates, spatial pattern, and variability of transport and depositional processes from preserved strata? (3) How do low-lying depositional systems respond to external changes such as changes in sediment supply, channelization, differential subsidence, and rising relative sea level? (4) How do depositional channel networks self-organize and what information can be extracted from observed spatial patterns? (5) How does life (microbes, plants, and/or animals) influence depositional processes and depositional environments? (6) How can stratigraphic information on natural variability and channel-system response to change be used to inform environmental management?

Stream Restoration Integrated Project (SR)

Motivation**:** The stream restoration project is motivated by the collision of social demand for stream restoration with a limited understanding of stream disturbance and restoration dynamics. The science basis for stream restoration is weak, the success of existing projects is poorly known, and the connection between research and practice is poorly developed. Progress requires a two-way collaboration between those developing new knowledge and those applying it.

Goal**:** To advance the science and practice of stream restoration by conducting and coordinating research and by working with agency and industry partners to identify information needs, develop improved tools, and transfer this knowledge into practice.

Approach**:** Together with agency and industry partners, we examine stream restoration practice, its scope, details, and missing links, so that we can define the most pressing research priorities and determine the best ways to get new information to those who use it. By combining expertise in biological, physical and social sciences with a research focus spanning the space and time scales needed to characterize stream disturbance, NCED is well placed to develop the integrated knowledge needed to improve the practice of stream restoration. By its position – affiliated with, but separate from both government and industry – NCED can define problems, propose solutions, and provide continuity and coordination without the constraints that can restrict those advocating, regulating and conducting restoration practice.

Science questions: (1) How can we determine resilient, dynamically stable channel bed, cross section, and planform characteristics in terms of water and sediment supply? (2) How do stream morphology and riparian vegetation influence the structure and function of the fluvial ecosystem and how can these be manipulated for ecological benefit? (3) How can we extend grain-scale understanding to the reach and network scale in order to better predict water and sediment supply and place restoration projects within their watershed context? (4) How can we estimate natural stream variability and incorporate variability and uncertainty in restoration design? (5) How can restoration objectives be more effectively identified and combined with physical and biological models in predictive restoration design?

Grand research challenges

Across all three Integrated Projects, NCED's research revolves around three fundamental grand challenge problems:

1) Developing mechanistic understanding of the processes driving erosion and deposition that shape landscapes;

2) Understanding the linkages among physical, chemical, and biological processes;

3) Predicting the linkages among land use, changing climate and other conditions, human decision-making, and ecosystem response to guide management decisions.

Education (ED)

Motivation: The familiarity and natural appeal of landscapes, and the methods of NCED's integrative research approach, provide rich opportunities to excite students about science and encourage them to pursue careers in many areas of science and policy.

Goal: Bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED's key mission areas of land, resource, and ecosystem management.

Approach: NCED uses the familiarity and natural appeal of landscapes to promote active learning about critical concepts:

> (1) that the Earth's surface *is* "the environment" in which human, ecologic and physical dynamics are intimately interwoven; and
>
> (2) that the Earth's surface is naturally dynamic; and (3) that the landforms we see around us – whether from the ground, from the air, or via maps and 3D imagery – tell us about what the Earth's surface is doing and how it has evolved.

At the graduate level, NCED engages students, across NCED institutions, in integrative research and unique center-based activities, such as video-conferenced seminars, joint advising, integrative seminars and short courses, center retreats, museum assistantships and internships with Partners. At the undergraduate level, NCED engages students within and outside NCED institutions in research experiences and infuses the methods, perspectives and results of NCED research into undergraduate coursework. At the K-12 level, NCED engages pre- and in- service teachers in research experiences and field-based institutes, develops teaching materials to supplement K-12 curriculum, brings experimental research to classrooms, and conducts environmental camps at middle- and high-school levels. NCED engages the public in NCED research through innovative museum experiences, such as outdoor parks and traveling exhibits, and media, such as films and television programs.

Knowledge Transfer (KT)

Motivation**:** NCED has a strong commitment to creating new insights and tools relevant to Earth-surface science. We have an equal commitment to communicating and disseminating these insights and tools to the practicing community and the public.

Goal: Create and maintain two-way communication and exchange among our applied science stakeholders, the broader research community, and NCED participants, in order to insure that NCED research is informed by societal needs and to insure that NCED results are disseminated.

Approach: NCED's knowledge transfer activities are integrated into the IPs and stem from our goals of informing NCED research and disseminating research findings and tools. To inform NCED research, we establish Science Partner Groups: appropriately selected practitioners committed to informing research and advancing practice. Through regular interaction with Science Partner Groups we establish avenues for open communication and exchange of research needs and new knowledge. Collaborations are through partner meetings, working groups, shared research (field and laboratory) experiences and workshops. Through our website we establish a repository of information, tools, data, images, and a platform for information exchange for the Earth-surface science community. We also have community impact through education and training programs. This includes workshops and short courses.

Diversity (DV)

Motivation: NCED's research mission is enriched by the inclusion of diverse voices. The environmental sciences have generally underperformed other areas of science and engineering in minority representation. For long-term success, efforts must be made to interest minority students in the sciences at an early age, and to sustain that interest over the course of their educational careers. To achieve this, NCED must itself be a model of a diverse research and learning community.

Goal: Increase participation by underrepresented groups in NCED scientific disciplines until minority representation is continuously reflective of the US national population. This includes an immediate improvement in participation by members of all under-represented groups in NCED itself, and a specific focus on improvement in representation of Native Americans in NCED-related disciplines.

Approach: NCED actively pursues research collaborations with faculty from institutions with high minority enrollments, and particularly with Minority-Serving Institutions, to spread the excitement of NCED research beyond the boundaries of our institutions. NCED provides research experiences for underrepresented undergraduate students so that they can engage in field and laboratory experiments and gain the desire to be research scientists. NCED networks with local communities in order to immerse youths in science so that they can discover and gain necessary skills for pursuing careers in science, technology, engineering, and mathematics.

Research Focus Areas

Research Focus Areas group investigators by common interests and skills. They inform each of our Integrated Projects and provide an important vehicle for the cross-disciplinary collaborations necessary for transformative advances:

1. Channel Network Dynamics and Scaling The spatial structure of landscapes provides an organizing template for many of the hydrologic, geomorphic, and ecologic processes that occur on them. This spatial organization, often

manifested through self-similarity and scaling, provides one of NCED's major unifying themes. This Focus Area seeks to understand the space-time organization of channel networks, including morphology, hydrology, and ecology.

2. Channel and Floodplain Dynamics Channel and floodplain dynamics encompasses the local "unit processes" by which channels and their associated floodplains evolve, and as such forms the natural complement to the Channel Network Dynamics and Scaling group's focus on network-scale behavior and properties. This Focus Area works to understand the flux and morphodynamic laws governing channel and floodplain evolution.

3. Advanced Mathematical and Observational Methods The complexity of the surface environment – space and time scales spanning many orders of magnitude, strong nonlinearity, spontaneous pattern formation, and strong coupling between physical and biological processes – is a major reason why study of it has remained descriptive for so long. Transformation of surface process science requires infusion of advanced techniques in quantitative analysis and observation that can address these complexities. This Focus Area identifies and develops effective mathematical and observational techniques for analysis of channel systems, including localization, scaling, instability, and the coupling of physical and biological dynamics.

4. Ecogeomorphology The physical structure of the landscape provides an organizing template for life, influences habitat quality and diversity, and controls inputs, production, transformations and fluxes of materials, energy, and organisms. In turn, organisms shape the landscape through microbial weathering, mixing, dilation, and diffusion of soil, flow baffling, and the stabilization of bars, banks, and floodplains. This Focus Area investigates interactions of physical, biologic and biogeochemical processes in channels and floodplains.

5. Long-term Dynamics Planetary time and space scales are the arena in which slowly changing variables such as topographic long profile and overall sediment budget are determined; these in turn control channel evolution on shorter time scales. This Focus Area seeks to understand and model the behavior of channels and channel systems on planetary (geologic) time scales.

6. Human Dynamics The "fingerprint" of human influence extends across nearly all aspects of Earth-surface dynamics. Thus it is essential that we understand how humans make decisions that affect landscapes. This Focus Area integrates multicriteria decision analysis methods and economic valuation methods to develop a more comprehensive decision-making framework for landscape management.

Research Organization and Evolution

NCED's Integrated Projects represent priority applications of our core channel-system research that are: (1) scientifically compelling, (2) broad and cross disciplinary, but also (3) focused enough to allow for measurable progress each year and major progress over several years, (4) societally relevant, and (5) integrative in terms of our core scientific expertise. In particular, all three IPs capitalize on NCED's strength in combining field, laboratory, and theoretical approaches.

These Integrated Projects provide a natural means of establishing goal sets and work clusters that are intermediate in scale between the center's overall mission and day-to-day research tasks. Thus they serve to maintain a clear "line of sight" between day-to-day research activities and the center's overall mission. They provide natural pathways for synthesis across the six Research Focus Areas. Each Integrated Project is led by a project leader and steering committee who, together with NCED management, establish priorities and targets for work on the IP.

We expect the Integrated Projects to evolve in time. They will be continuously evaluated in terms of their scientific importance, societal relevance, and appropriateness for NCED. To insure that we remain open to new possibilities for growth, we will also initiate small research programs in areas that are possible targets for future work and/or high-risk but potentially high-return topics consistent with our mission but outside our current IP structure.

IMPLEMENTATION PLAN

NCED's three research Integrated Projects are organized around NCED's goal of providing tools for landscape restoration and prediction, building on our core science: the dynamics of channels and channel networks. This common goal and scientific core across scales and environments is the primary vehicle for integration and synthesis of NCED research. It provides a network of pathways for cross-fertilization and the application of theoretical ideas, observational techniques, and research findings across apparently disparate fields. Thus the primary way we achieve center-scale research synthesis is by applying *common concepts and methods* across Integrated Projects. Our second approach to achieve synthesis is to insure that each IP can *incorporate and build on results* from the other IPs.

Common research concepts and methods that link and energize the IPs include: recurring structures, such as tributary and distributary networks, incisional valleys, cyclic steps, and scour-lobe couplets; common processes such as channel meandering and braiding, bedform dynamics, channel-floodplain interaction, and avulsion; scaling and self-similarity; biological-physical coupling; self-organization and pattern formation; stochastic behavior and uncertainty; mapping for prediction; and humans as geomorphic agents. In many cases, experiments are particularly useful in clarifying the essential dynamics of these common processes. In addition, we seek ways in which IP results build on each other. Examples include: using desktop watersheds models to provide the landscape context for stream restoration; making source-to-sink connections from watersheds and individual stream channels to downstream depositional systems; and using stratigraphic results to understand long-term trends and variability in sediment yield and channel dynamics.

NCED's center structure adds value by promoting synergy and common themes among its education, knowledge transfer, diversity, and research activities. Our strategy for promoting synergy across all Center Initiatives is analogous to that for promoting synergy across our research: we seek common themes that cut across multiple Initiatives; and we seek ways that results from one Initiative can feed and energize other ones.

At the end of Year 10, NCED will have provided a set of scientific tools that can be used to guide land-use decisions, aid in restoration design, and predict landscape response to imminent changes such as rising sea level and changing climate. By demonstrating the predictive power of combining the disciplines that contribute to understanding the Earth's surface – the "critical zone" – NCED will have transformed both Earth-surface science and environmental management.

Desktop Watersheds (DW)

Implementation Approach: We tackle the essential elements, listed below, needed to build Desktop Watersheds through theory building, modeling, experimentation, and fieldwork. Initial focus is on steep, relatively rapidly eroding landscapes, and, fieldwork is concentrated on the Angelo Coast Range Reserve (ACRR), in the Eel River basin, California. We will build from a static form of the Desktop Watersheds, in which fixed topography and steady state fluxes are used to estimate environmental properties, to a dynamic form in which solutes and sediment are routed from hillslopes through channel networks, and ecosystems respond to changing environmental conditions.

Project plan

	Project name	**Explanation**	Milestones	Links
DW01	Numerical techniques for feature extraction	The challenge is to learn to extract useful information—channel dimensions, landslides location, channel slope, fan detection, floodplain detection, terrace detection, etc. from high resolution lidar data. It remains surprising what the eye can do that is difficult to instruct a program to do. BUT this is really important—and needed for the community.	1) Channel bank identification and automated channel dimension mapping 2) automated mapping of fans, floodplains and terraces 3) channel head location detection 5) automated mapping of deep-seated landslide features 6) automated road mapping (location, slope, width, channel crossings) 7) exploit water penetrating lidar for channel topography mapping	

	Project name	**Explanation**	Milestones	Links
DW02	Exploit topographic signatures to estimate properties of and processes in the environment	Use static topographic features and steady state assumptions to estimate things like: gravel size, channel morphologic attributes (size, bed morphology), potential landslide location; potential high sediment load from roads, etc. This is the non-dynamic first approximation approach that relies largely on simple theory and empricism	1) Improved model for grain size prediction (based on DW01) 2) Shallow landslide size and location model 3) Empirical use of mapped roads to estimate average fines yield to channels 4) Estimate spatially explicit soil properties 5) Estimate spatially explicit root strength contribution to soils 6) improved stream temperature model : use canopy cover from lidar	SR09
DW03	Predictive mapping of key biotic populations: relationships to habitats	Link distribution and abundance of organisms to habitat state and availability in a spatially explicit channel network framework. We use the term "steady state" when there is some kind of flux involved but we are not worrying about its temporal variation. "Static" state could also be used.	1) Steady state models estimate of spatially explicit salmon populations 2) Steady state models of frog reproduction patterns 3) Steady state model spatially explicit of seasonal peak algae distribution 4) Steady state model of aquatic insect abundance and emergence rates	SR03, SR09
DW04	Understand linkages among solutes, soil production and biota	For an algae based foodweb we need to "Follow the nitrogen" which is mediated by microbial activity.	1) document how microbial community in soil responds to changes in seasonal water loading	SR06
DW05	Controls on rate of landslide transport to channels	Landslides are commonly the primary deliverers of sediment to channels in hilly and mountainous. We lack theory to predict landslide flux	1) develop a shallow landslide flux "law" 2) develop a deep seated landslide flux "law"	SR06
DW06	Sediment routing; coarse sediment transport in shallow flow; fine sediment interaction with coarse bed	1) how does gravel move over boulders, and under what conditions boulders move, and 2) how fine sediment (sand and smaller) dynamically is deposited and eroded from the bed. And all this through a river network	1) Theory for gravel over boulder transport 2) theory for boulder transport 3) theory for routing of coarse sediment through networks--- the challenge of transient lateral storage 4) theory for fines interaction with the bed	SR07
DW07	Develop predictive models for channel incision	Channel incision drives landscape evolution—so for longer time scale analyses we need this. Upscaling is important for all erosion and transport problems	1) Observation and theory for river incision by fluvial sediment wear 2) Obervation and theory for debris flow incision 3) Observation and theory for debris flow bulking up and runout down valley networks.	
DW08	Upscaling transport laws and biotic processes	To go from local mechanisms to the watershed scale, and to the long time scale, upscaling techniques are needed	Example: 1) Is the intergral effects of repeated landslides across the landscape describable by some general expressions (with appropriate pdf of variance?). 2) How do we translate local knowledge of biotic production and fluxes to watershed scale interactions?	

	Project name	**Explanation**	Milestones	Links
DW09	Link food webs and channel networks, including dynamic response	In contrast to DW03, here we want to predict seasonal and interannual dynamics driven by runoff magnitude and timing, temperature etc. of river ecosystems	1) Dynamic stream temperature model 2) Dynamic sediment routing model that affects habitat dynamics 3) Dynamic algae bloom model 4) Dynamic "bug flux" model 5) Dynamic frog population model 6) Dynamic fish population model	
DW10	DW model code development	Code development to assemble the static model better and to start work on the dynamic model	1) Steady state model for linking topography to populations of critical organisms 2) Dynamic model for linking topography, climate change, and landuse to populations of critical organisms	
DW11	Use of Desktop watershed models in landuse management decisions	Explore the use of gaming models in decision making—in real problems: TMDL analysis, land-conversion problems (e.g. oaks to vineyards), agricultural activity). Focus on how our models can affect decision making process.	To be determined	

In the above table, the two solid lines represent major breaks. The first is between the static and dynamic model. The second is between the dynamic model and the problem of implementation (model development and model use).

Subsurface Architecture (SA)

Implementation Approach:

The Subsurface Architecture project applies NCED's integrated, predictive approach to extracting information from subsurface stratigraphy to infer rates, spatial patterns, and mechanisms of natural (pre-human) delta building processes. The data base for this is primarily seismic imaging, well logs, and cores. This data is extremely costly to obtain and is mostly privately held in the oil industry, so we seek to maintain industrial connections that will give us access to data. In parallel, we perform experiments and field studies in the modern Delta, and develop predictive models of the processes by which deltas build land and maintain themselves and their associated ecosystems against subsidence and sea-level rise. These processes are strongly influenced by biota such that deltaic land-building must be seen as a bio-physical process, and collaboration among ecologists, Earth scientists, and engineers is essential. Our approach involves understanding internally generated (autogenic) deltaic dynamics as well as delta response to external controls like subsidence, climate, and sea level. To provide additional focus and connect the SA IP with Stream Restoration, we are developing a depositional field site, the Wax Lake Delta, in the Mississippi Delta. This will be done in collaboration with the NCED SR group and outside PIs. The end result will be predictive tools for delta restoration. To make the final step to restoring the Delta requires collaboration between natural and social scientists to understand and optimize the interaction of scientific input and human decision making.

Project plan:

	Project name	**Explanation**	**Milestones**	Links
SA01	Current sediment budget and subsidence distribution in Mississippi Delta	(1) Develop quantitative measures of bedload, suspended, and wash load supply near Baton Rouge; (2) Determine net loss to in-channel deposition d/s of Baton Rouge; (3) Determine regional spatial distribution of subsidence from seismic records.	(1) Sediment budget (sand vs mud) for the Mississippi & Atchafalaya rivers; (2) Regional maps of Delta subsidence in the critical coastal zone.	SR5

	Project name	Explanation	Milestones	Links
SA02	Behavior and deposition of cohesive sediment	(1) Determine role of flocs (biotic vs abiotic) in transport and deposition of silt and clay; (2) Determine the right flux law to use in modeling deposition of clay with silt and sand	(1) Preliminary numerical model based on existing understanding by Year 6; (2) Refined numerical model with experimental and field data by Year 9.	DW02, DW06, SR01
SA03	Vegetation-sedimentation interaction in island & marsh development & maintenance	(1) Determine role of growing plants in inducing and stabilizing sedimentation; (2) Determine correlation between bed elevation and plant community and physical plant properties	(1) Synthesize existing field data from Wax Lake Delta by Year 6; (2) Carry out targeted set of field measurements on WLD defining island levee and marsh growth and in-channel sedimentation by Year 8.	DW03, SR02
SA04	Reconstructing delta dynamics from seismic records	(1) Map fault location and offset (2) Map interaction of active faults and channels (3) Measurement of geometry, spatial arrangement, and variability of deltaic depositional units as a function of relative sea level rise and fall	(1) Produce statistics of subsidence & sedimentation patterns associated with growth faulting in Breton Sound by Year 7. Additional milestones are functions of procuring external funding.	
SA05	Reconstructing delta dynamics from cores and other records	(1) core collection and basic data analysis (grain size, C14), initial focus on Barataria Bay & WLD; (2) Use core data to constrain bulk spatial distribution of grain size and sedimentation rate for La Fourche lobe (40-8ka); (3) for WLD, use sediemntary structure and textures to constrain depositional conditions from SA6 numerical model	(1) Use existing core set from WLD to place quantitative constraints on levee & marsh building events during last 35 yrs. Additional milestones depend on additional external funds.	
SA06	Modeling land building; integration with LSU CLEAR	(1) Development of laterally averaged lobe-construction model; (2) use results of network analysis, field data, and experiments to estimate fine-scale properties and variability of evolving delta lobes	(1) Help to produce a new, extensively tested, Land-Building Module for the CLEAR Program using results from SA02 & SA03.	DW06
SA07	Self-organization of distributary systems including elevation statistics	(1)Adapt existing network analysis tools to (static) distributary networks (2) Develop methods for quantifying space-time statistics of active, evolving distributary systems to forecast distribution of elevation, grain size, and rate of deposition.	(1) PDFs of elevation, channel size and distance from channels for one experimental and one natural delta by Year 7; (2) Physically based theory for controls that is fully incorporated into land building model by Year 10.	DW01, DW02
SA08	Upscaling short-term rates and small-scale geometries	(1) Develop methodology for upscaling laboratory delta data to natural scales for use in numerical models; (2) Develop physical theory to explain spatial distribution of deposition rate as function of time scale.	(1) Relation of rates and geometries between experimental deltas and Wax Lake by 2009; (2) Compare data from lab & modern systems to Quaternary stratigraphic records by Year 10.	DW08
SA09	Coastal system response to rising relative sea level	(1) Develop and calibrate suite of numerical models for rivers that forecast lowland sediment accumulation and shoreline advance/ retreat under conditions of relative sea-level rise.	(1) Use existing NCED model to explore behaviors of select GOM rivers by 2008; (2) Add realistic fines deposition component by Year 8.	
SA10	Social tradeoffs in Delta restoration	(1) Conflicts between marsh restoration, business and society; (2) Risk and uncertainty analyses.	To be determined	

3. Stream Restoration (SR)

Implementation Approach:

NCED combines physical, biological, and social sciences in an integrated approach to stream restoration. Better restoration science requires a better understanding of the physical and biological dynamics of stream systems; better identification and implementation of restoration priorities require a better understanding of the social drivers, tradeoffs, and constraints in restoration decision making.

A large part of NCED's work in Stream Restoration involves training; this is discussed later in the Knowledge Transfer section.

Project Plan:

	Project name	Explanation	Milestones	Links
SR01	Channel geometry, including variability in space and time	Channel size and shape are fundamental attributes of any stream restoration design. An ability to predict these features and their variability lies at the heart of improved restoration practice.	Hydraulic Geometry: (a) development of sand-bed and universal hydraulic geometry relations, (b) applications of HG and its variability to stream restoration. Basis for scaling laboratory bank strength and vegetation effects to the field. Generalizable models for the influence of vegetation on channel geometry	
SR02	Dynamics of mixed-size sediment	Streambed materials provide the basic organism-scale template for the stream ecosystem and bed material transport drives channel change. The goal of this project is to develop predictive relations for the sorting and transport of coarse bed material.	Completed models for armor and stochastic Exner. Management guidelines for gravel augmentation and sand infiltration. Validated model for mixed-size morphodynamics for homogeneous beds Strategy for capturing and scaling up local variability	DW06
SR03	Channel-floodplain interaction	Floodplain deposition is a key part of riparian ecosystems and also sets channel bank height. Channel-floodplain sediment exchange and bank erosion are key gaps in developing a predictive understanding of sediment budgets and evaluating the benefits of streambank stabilization project.	To be determined	SA02, SA03
SR04	Design stream restoration projects to optimize net primary productivity	Improving net primary productivity is a common objective in restoration design.	Food web engineering?	DW03, DW04
SR05	Define physical channel attributes and flows that control nutrient processing	Restoration projects frequently cite nutrient removal as an objective. An ability to predict the effect of channel alterations on changes in bed/bank/channel exchange and nutrient processing is needed to support or evaluate this objective.	StreamLab06. Future StreamLabs Model for characterizing hot spots and moments of denitrification in upland and lowland systems (location, controls, rates)	DW03, DW04
SR06	Specify structure, inputs, and disturbance regime for species recovery	Many restoration projects are driven by the recovery of individual species, which depends on the interplay among a wide range of factors. Building adequate structure without necessary inputs and disturbance will not promote species recovery.	Model impact of fine sediments on carrying capacity and productivity of fish habitats. *Fine sediment is a good topic, but do we need to ask first what the most important next steps are?*	DW03, DW04

	Project name	Explanation	Milestones	Links
SR07	Develop improved sediment storage and sediment routing models	The performance of stream restoration projects depends essentially on the supply of both water and sediment. An inability to predict sediment supply is a leading barrier to development of predictive stream restoration design.	Sand routing through steep and low gradient systems. Development of reach-averaged sediment routing models with explicit sediment storage functions for both sand and gravel rivers	
SR08	Sediment sourcing and yield	Restoration projects are often proposed for the purpose of reducing sediment and nutrient loading to receiving waters. There is little basis for connecting local bank stabilization measures with watershed sediment yield.	Establish sediment fingerprinting methods for sediment source and history. Evaluate geochemical fingerprinting and physical sediment budgets for same time scale in same watershed. Incorporate valley bottom sediment storage and streambank erosion in network routing models	DW all
SR09	Stream restoration objectives, tradeoffs, and decision-making under uncertainty	As the ability to predict landscape and restoration dynamics improves, we must also anticipate the challenges to putting these tools to work. How does predictive understanding best inform to management actions? Can management requirements guide more effective model development? How should uncertainty be incorporated in the decision-making process?		SA10, DW11
SR10	Dam removal, dam management	Dam re-operation and dam removal represent major restoration opportunities, but the effect on the downstream channel of dam-released flows and sediment injections requires improved understanding of how large volumes of sediment move through rivers.	Downstream: Trinity River and Clear Ck: routing of gravel augmentation; flushing of sands Sandy River and Marmot Dam removal fate of reservoir sediments Reservoir (*are we still doing this?)* Predictive relations for the style and rate of reservoir erosion.	

Common field areas

Angelo Coast Range Reserve: Early in Year 2, we selected Angelo Coast Range Reserve (ACRR) in the rugged, rapidly uplifting Coast Range of northern California as our primary erosional field site. The ACRR is located in the South Fork of the Eel River, about 3.5 hours by car from the U.C. Berkeley Campus and the San Francisco or Oakland airports. The entire study area is protected from unrestricted public access by a gated road, which provides easy transportation of material and equipment to field sites. Co-PI Mary Power is the Faculty Manager of this University of California Natural Reserve System Preserve. Various buildings and outbuildings on the reserve are available for year-round housing, laboratory use, and equipment storage. A new $1.4 M Environment Science Center includes a two large laboratories (with ovens, muffle furnace, fume hood, and extensive workspace), a computer lab and DSL connectivity to all rooms where sensors can be calibrated etc., a herbarium, and a facility providing access to the canopy of old growth redwood and Douglas fir trees along a river-to-ridgeline gradient. At present, in collaboration with fellow STC the Center for Embedded Network Sensing (CENS), we are constructing a wireless network at ACRR. The network will support automated environmental sensors of light, temperature, and soil moisture, plus imaging for algal blooms and acoustic detection of bats. In the years to come we will add new sensing capability (e.g. nitrate). Recently acquired LIDAR also supports analysis of relations between network structure and habitat, local channel properties, and vegetation as discussed above under the Desktop Watersheds IP.

Mississippi Delta: NCED's transdisciplinary approach, emphasis on prediction, and status as an independent national research center make it ideally suited to provide predictive understanding and tools to support restoration of the Mississippi Delta, an issue long recognized as fundamental to protecting New Orleans and the Gulf Coast from hurricanes. From its inception, NCED's plans have included a center-wide initiative on restoration of the Mississippi Delta. As our research program has evolved, we have continued work on this initiative to develop a second, depositional field site in the Delta region that would be of societal benefit and also link our SR and SA Integrated Projects. The recent disasters related to hurricanes Katrina and Rita have accelerated our efforts. The overall goal is to combine studies of the modern delta with quantitative reconstruction of the behavior of the delta in the past to provide predictive tools that can be used to evaluate the complex scenarios involved in large-scale reconstruction of lost delta surface. Our current plan includes (1) adapting existing understanding of channel and floodplain processes and carrying out new research in the Mississippi and other low-gradient river systems to develop tools for analysis of restoration scenarios for the Delta; (2) an initiative with the broader research community to develop a natural "subsurface laboratory" that would use the Quaternary record of the Mississippi Delta to quantify the rates and spatial distribution of natural depositional mechanisms, strongly influenced by biota, that compensate for subsidence; (3) continued work to adapt methods from drainage networks to understand natural distributary patterns and how they self-organize to nourish the delta surface; and (4) experiments in our subsiding-floor XES experimental facility on depositional channel dynamics and the response of deltaic channels to absolute and differential subsidence, including vegetation effects.

Education (ED)

Implementation Approach:

NCED adopts a broadband approach to education, emphasizing informal as well as formal learners, and strong connections between its research and education programs. Key elements of our Education Initiative include:

1. Work intensively with the Science Museum of Minnesota and other science museums to develop engaging new methods for informal education centered on Earth-surface dynamics and environmental awareness.

2. Enhance the education of NCED student participants by providing unique opportunities and an extended, cross-disciplinary peer and mentor network.

3. Adapt research tools such as 3D visualization, wireless sensors, and laboratory experiments to provide novel K16 educational tools.

4. Develop a new, practice-oriented program in Stream Restoration that will help advance training in restoration as well as attract a broader student population into NCED areas, including students who are not intent on research careers.

5. Design programs to engage science teachers in NCED research in ways that allow them to bring this knowledge to their students in practical ways, and share the products of this work via the NCED website.

Project plan

	Project name	PIs	Milestones	Links
ED01	Bring surface dynamics to informal education with the Science Museum of Minnesota	KC, JM, CP	Big Back Yard (BBY) exhibits fully functioning, at least one new component added, and functioning Youth Science Center –NCED docent program for Big Back Yard; BBY visitor target of 150,000 reached or surpassed; initial NCED components of Water Planet and Science on a Sphere developed; 3D film outline developed with SMM	all
ED02	Provide unique center-based experience for graduate students	all	Strong graduate student participation in cross-disciplinary research & seminars, Grad Student Council, videoconferences, NCED retreats, site visits, partner research, internships; thriving Grad Museum Assistantship program;	all

	Project name	PIs	Milestones	Links
ED03	Stream Restoration certificate program	VV, KC, SR	Functioning certificate program in Stream Restoration	SR, DV
ED04	NCED enhancements to undergraduate education	all	Non-NCED participation in summer research surpasses 20 total (shared with Diversity); at least 3 NCED-inspired undergrad courses developed and taught; NCED research-based course materials available on web with documented use	all
ED05	K-12 teacher development	KC, CP, VV, MH, EF	Functioning ESTREAM and Earthscapes Summer Institute summer teacher programs, with commensurate participation in Earthscapes School Residencies; materials developed through above programs made available for broad use over the web, and promoted at local and national conferences	all
ED06	Visualization tools to enhance Earth-science education	PM, KC, others	Research-grade 3D surface visualization and anaglyph map tools widely and successfully used in K16 education	DW, SA, KT

Knowledge Transfer

Implementation Approach:

Knowledge transfer programs are incorporated into NCED's research Integrated Projects. Each research IP has specific KT activities designed to support the goal of establishing two-way exchange between research and practice. The following elements are common to our approach to knowledge transfer across the IPs:

1. Establish regular communication between NCED and Science Partner Groups for each IP area.
2. Develop website content for each IP including recent research products (articles, data, technologies, software), links, and future directions.
3. Conduct application-oriented short courses and workshops both at NCED facilities and at other meetings.
4. Provide opportunity for collaborative research between NCED and non-NCED researchers within each IP through joint research, the Working Groups program, the Faculty to Faculty program, and the Visitor Program.

The Stream Restoration IP has a particularly wide range of applications. NCED's goal is to explicitly link restoration practice, research, methods, and training. Much of current stream restoration practice is based on research that is 50 years old and does not fully connect cause and effect in stream channel dynamics. NCED works with a variety of partners to improve training and provide broad distribution of methods and models within an organized, open-source framework. To achieve this, the SR Integrated Project has three unique KT implementation components:

5. Develop a Stream Restoration Newsletter that highlights issues important to the stream restoration community.
6. Produce a stream restoration "toolbox" containing helpful numerical models, equations, and information derived directly from NCED research efforts.
7. Support the development of education and training programs in stream restoration.

Project Plans (divided by IP)

	Project name	PIs	Milestones	Links
Desktop watershed				
KT01	Desktop Watershed Partner Group	All DW	Identify and formally adopt partners into the DW Partner Group; hold initial meeting	DW
KT02	Make components of the Desktop Watershed available to practitioners and the public	All DW, KC	Initial results available through website and publication, including DTW web portal on NCED site	DW, ED

	Project name	PIs	Milestones	Links
KT03	Collaborative DW research with non-NCED researchers	All DW	DW working group established, 1-2 Visitors' Program participants complete DW projects	DW
Stream restoration				
KT04	NCED Stream Restoration Partner Group	All SR	Annual SRPG meetings with report; - Subgroup activities, including Training, Evaluation Team, and Field Meetings	SR
KT05	Stream Restoration website	KC, All SR	- Website has comprehensive inventory of training opportunities and compiles training materials following the open courseware model; NCED SR data and results; newsletter & enhancements; at least 10 tested NCED Stream Restoration tools for free download	SR, ED
KT06	Stream Restoration Newsletter	PW, MK, KC, JM	Quarterly Stream Restoration Networker; Circulate to agencies and research institutions involved in stream restoration	SR, ED
KT07	Stream restoration "toolbox" containing useful numerical models, equations, and guidance for practitioners	All SR	At least 10 tested NCED Stream Restoration tools for free download, with guidelines governing access and usage of tools, and supporting documentation available online	SR, ED
KT08	Education and training programs in stream restoration	KC, All SR, non-NCED participants	Establish certificate program in Stream Restoration at the University of Minnesota, with collaboration from PIs at other NCED institutions; develop and present new training courses in stream restoration	SR, ED
Subsurface Architecture				
KT09	Establish regular communication between NCED and Subsurface Architecture Partner Group	All SA	Annual meetings with SA Partner group	SA
KT10	Develop website content for Subsurface Architecture goals, current progress, and future direction	KC, All SA	Experimental stratigraphy results freely available online	SA, ED
KT11	Conduct short courses and workshops	DM, CP, GP, KC	Two industrial short courses per year in quantitative sedimentology and stratigraphy	SA, ED

Diversity

Implementation Approach:

NCED uses the intrinsic appeal of landscapes and surface dynamics to engage diverse communities in the study of Earth-surface science at all levels, and to attract diverse participants into its research programs. Key elements in our approach are:

1. Use a vigorous Undergraduate Summer Internship Program to bring upper-level students from underrepresented groups to NCED facilities for a summer to do research on NCED topics.
2. Develop a *Faculty-to-Faculty* program to build research ties to faculty from schools with large minority enrollments, particularly Minority Serving Institutions. Identify faculty at MSIs who work in NCED research areas and bring faculty with their students to NCED as visiting researchers, to participate in conferences and workshops, and to speak at seminar series.
3. Work with and support efforts by NCED participating institutions, STC partners, and other broader efforts to recruit and fund students from underrepresented groups into NCED-related graduate research.
4. Use the NCED certificate program in Stream Restoration to provide an additional gateway to NCED graduate programs.

5. Increase the number of potential future recruits by collaborating with local communities, including the Fond du Lac Reservation, to provide Native American youth science enrichment and immersion programs including seasonal camps and after-school activities.
6. Use the Youth Science Center at the Science Museum of Minnesota, especially the Big Back Yard Park Crew, to team underrepresented youths with faculty and graduate student mentors from NCED and create NCED-based hands-on activities.

Project plan

	Project name	**PIs**	**Milestones**	Links
DV01	Faculty-to-Faculty: building durable connections to Minority-Serving Institutions	All	3 new faculty introduced to NCED research in Years 3-5 through visits or participation in conference or workshop, including multiple visits to NCED facilities; new collaborations, and recruiting visits by NCED faculty	all
DV02	Direct recruiting of under-represented students to NCED graduate and postdoc program	All	Bring percentage of graduate students from underrepresented groups to approximately 10% of total graduate students and postdocs by end of year 5 including participation in the SR certificate progam	all
DV03	Undergraduate Summer Internship Program	All	Ongoing participation of 5 undergraduate students each summer, with consistent recruitment of USIP students to NCED graduate program and the majority of USIP students going to graduate school.	all
DV04	Gidakiimanaaniwigamig (Our Earth Lodge) and Ando-giikendaasowin (Seek To Know) science camp programs	DD, AW, PH,	90 students per year participate in the two camps and programs in Years 3, 4, 5; documented improvement in grades and test scores for students in both programs; majority of participants attend college, with substantial fraction majoring in science, math, engineering or technology	DW, SR, ED
DV05	Earthscapes in the SMM Youth Science Center (YSS)	DD, PH	Substantial participation by minority students in YSC park crew and other activities	all

Appendix K: Non-referenced Publications

Publications that are related to center activities but do not acknowledge STC award:

In Press:

Lyons, W., et al. (in press), Deepwater lobes of the Zerrissene Turbidites System, Namibia, in American Association of Petroleum Geologists Studies in Geology No. 56, edited.

Parsons, J. D., C. T. Friedrichs, P. Traykovski, D. Mohrig, J. Imran, J. Syvitski, G. Parker, P. Puig, and M. H. Garcia (in press), Chapter 7: The mechanics of marine sediment gravity flows, in Continental Margin Sedimentation: Transport to sequence, special publication, edited by C. Nittrouer.

Post, D., et al. (in press), The problem of boundaries in defining ecosystems: A potential landmine for uniting geomorphology and ecology, Geomorphology.

2007:

Day, J., et al. (2007), Restoration of the Mississippi Delta: Lessons from Hurricanes Katrina and Rita, Science, 315, 1679-1684.

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Brenkert-Smith, H., et al. (2006), Insights into wildfire mitigation decisions among wildland-urban interface residents, Society and Natural Resources, 19, 759-768.

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Weiss, J., et al. (2006), Laboratory study of heavy metal phytoremediation by three wetland macrophytes, International Journal of Phytoremediation, 8, 245-259.

Yoo, K., R. Amundson, A. M. Heimsath, and W. E. Dietrich (2006), Spatial patterns of soil organic carbon on hillslopes: Integrating geomorphic processes and the biological C Cycle, Geoderma, 130, 47-65.

2005:

Aalto, R., and W. E. Dietrich (2005), Sediment accumulation determined with 210Pb geochronology for Strickland River flood plains, Papua New Guinea, paper presented at Sediment Budgets I (Proceedings of symposium S1 held during the Seventh IAHS Scientific Assembly), Foz do Iguaçu, Brazil, April.

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Appendix L: Graduate Student Theses

2007:

Kim, W. (2007), Coupled fluvial and shoreline dynamics: Experiments and theory, PhD thesis, Dept. of Geology and Geophysics, advisors C. Paola and V. Voller, University of Minnesota, Minneapolis.

Wan, F. (2007), Evaluation of dynamic subgrid-scale models in large-eddy simulations of neutral turbulent flow over a two-dimensional rough sinusoidal hill, MS thesis, Dept. of Civil Engineering, advisor F. Porte-Agel, University of Minnesota, Minneapolis.

2006:

Blumentritt, D. J. (2006), Constraining slip rates using cosmogenic isotopes (10Be and 3He) and ASLM data: Calico fault, Mojave desert, California, MS thesis, Dept. of Geology, advisor L. Perg, University of Minnesota, Minneapolis.

Carper, M. (2006), *A priori* studies of subfilter-scale physics in turbulent boundary layers, PhD thesis, Dept. of Civil Engineering, advisor F. Porte-Agel, University of Minnesota, Minneapolis.

Grams, P. (2006), Sand transport over a coarse and immobile bed, PhD thesis, Dept. of Geography and Environmental Engineering, advisor P. Wilcock, Johns Hopkins University, Baltimore.

Jerolmack, D. (2006), Modeling the dynamics and depositional patterns of sandy rivers, PhD thesis, Dept. of Earth, Atmospheric & Planetary Sciences, advisor D. Mohrig, Massachusetts Institute of Technology, Cambridge.

Lauer, W. (2006), Channel-floodplain interaction on meandering rivers, PhD thesis, Dept. of Civil Engineering, advisor G. Parker, University of Minnesota, Minneapolis.

O'Connor, B. (2006), Fluid-flow effects denitrification hot spot activity in streams, PhD thesis, Dept. of Civil Engineering, advisor M. Hondzo, University of Minnesota, Minneapolis.

Sittoni, L. (2006), The development and application of a shallow water model for flow over sediment fans, MS thesis, Dept. of Civil Engineering, advisors V. Voller and C. Paola, University of Minnesota, Minneapolis.

Strong, N. (2006), Mass-balance effects in clastic fluvial stratigraphy, PhD thesis, Dept. of Geology and Geophysics, advisor C. Paola, University of Minnesota, Minneapolis.

Theodoratos, N. (2006), The effect of channel-floodplain interactions on the scaling of floods, MS thesis, Dept. of Civil Engineering, advisor E. Foufoula-Georgiou, University of Minnesota, Minneapolis.

Yager, E. (2006), Prediction of sediment transport in steep, rough streams, PhD thesis, Dept. of Earth and Planetary Science, advisor W. Dietrich, University of California, Berkeley.

2005:

Markfort, C. D. (2005), Dissolved oxygen measurements in aquatic environments: the effects of changing temperature and pressure on three sensor technologies, MS thesis, Dept. of Civil Engineering, advisor M. Hondzo, University of Minnesota, Minneapolis.

Passalacqua, P. (2005), Scale dependence and subgrid-scale closure in numerical simulations of landscape evolution, MS thesis, Dept. of Civil Engineering, advisor F. Porte-Agel and E. Foufoula-Georgiou, University of Minnesota, Minneapolis.

Suttle, K. B. (2005), Spider interactions with arthropod prey and their consequences in temperate and tropical communities, PhD thesis, Dept. of Department of Integrative Biology, advisor M. E. Power, University of California, Berkeley.

Tilman, E. (2005), Scaling relationships for the depth and width of channels in an experimental braided river, MS thesis, Dept. of Civil Engineering, advisor E. Foufoula-Georgiou, University of Minnesota, Minneapolis.

Warnaars, T. A. (2005), The influence of fluid motion on freshwater algae: a biophysical investigation, PhD thesis, Dept. of Civil Engineering, advisor M. Hondzo, University of Minnesota, Minneapolis.

2004:

Basu, S. (2004), Large-eddy simulation of stably stratified atmospheric boundary layer turbulence: a scale-dependent dynamic modeling approach, PhD thesis, Dept. of Civil Engineering, advisor E. Foufoula-Georgiou and F. Porte-Agel, University of Minnesota, Minneapolis.

Gupta, R. (2004), Parametric and non-parametric approaches for validation and blending of multi-sensor precipitation estimates, MS thesis, Dept. of Civil Engineering, advisor E. Foufoula-Georgiou, University of Minnesota, Minneapolis.

Lyons, W. J., III (2004), Quantifying channelized submarine depositional systems from bed to basin scale, PhD thesis, Dept. of Earth, Atmospheric & Planetary Sciences, advisor D. Mohrig, Massachusetts Institute of Technology, Cambridge.

McNeely, F. C. (2004), Herbivore responses to stream size gradients in a Northern California watershed, PhD thesis, Dept. of Integrative Biology, advisor M. E. Power, University of California, Berkeley, CA.

Sheets, B. A. (2004), Assembling the alluvial stratigraphic record: spatial and temporal sedimentation patterns in experimental alluvial systems, PhD thesis, Dept. of Geology and Geophysics, advisor C. Paola, University of Minnesota, Minneapolis.

Weiss, J. D. (2004), Laboratory measurements of stormwater quality improvement in detention ponds, MS thesis, Dept. of Civil Engineering, advisor M. Hondzo, University of Minnesota, Minneapolis.

2003:

Dodov, B. A. (2003), Analysis of the effects of channel morphometry and network topology on the nonlinearity of hydrologic response as a function of scale, PhD thesis, Dept. of Civil Engineering, advisor E. Foufoula-Georgiou, University of Minnesota, Minneapolis.

Hasbargen, L. E. (2003), Erosion in steady state drainage basins, PhD thesis, Dept. of Geology, advisor C. Paola, University of Minnesota, Minneapolis.

Lima Vivancos, V. (2003), Unsaturated flow in layered media, MS thesis, Dept. of Civil Engineering, advisor V. R. Voller, University of Minnesota, Minneapolis.

Sklar, L. S. (2003), The influence of grain size, sediment supply, and rock strength on rates of river incision into bedrock, PhD thesis, Dept. of Earth and Planetary Science, advisor W. E. Dietrich, University of California, Berkeley.

Stock, J. D. (2003), Incision of steepland valleys by debris flows, PhD thesis, Dept. of Earth and Planetary Science, advisor W. E. Dietrich, University of California, Berkeley.

Violet, J. A. (2003), Experiment on turbidity currents and their deposits in a model 3D subsiding minibasin, MS thesis, Dept. of Civil Engineering, advisor G. Parker, University of Minnesota, Minneapolis.

Wright, S. A. (2003), Density stratification, suspended-sediment transport, and downstream fining in large, low-slope, sand-bed rivers, PhD thesis, Dept. of Civil Engineering, advisor G. Parker, University of Minnesota, Minneapolis.

2002:

O'Connor, B. L. (2002), Variability of water quality and sediment provenance in the Minnesota River Basin, MS thesis, Dept. of Civil Engineering, advisor M. Hondzo, University of Minnesota, Minneapolis.

Toniolo, H. A. (2002), Debris flows and turbidity current deposition in the deep sea and reservoirs, PhD thesis, Dept. of Civil Engineering, advisor G. Parker, University of Minnesota, Minneapolis.

Appendix M: Activity Tables

Education Activity Tables

Internal Education Activities

Graduate Education			
Intended Audience	NCED Graduate students		
Date	Location	Led by	Attendees
Ongoing	SAFL	Paola	NCED Stratigraphic Partners
NCED graduate students John Martin and Wonsuck Kim and NCED SRES student Craig Hill organize portions of Short Courses and Annual Meeting, maintain private web site, conduct experiments for NCED Stratigraphic Partners.			
ongoing	St. Paul, MN	Hamilton	Ted Fuller, Emily Horth, Kate Rosok
NCED Graduate student Ted Fuller and ESTREAM teachers Horth and Rosok serve as Graduate Museum Assistants in the BBY, developing fossil program and activities for YSC Park Crew youth docents.			
Ongoing	all sites	Dalbotten	all NCED
NCED graduate students present and participate in weekly videoconferences.			
ongoing	Minneapolis	Hondzo, Neuhauser	Ted Fuller, Amy Hanson
Two cohorts of students continue in IGERT program. Various NCED PIs lecture in intro class. Fuller and Hanson are also NCED graduate students.			
ongoing	SAFL, UCB, UIUC	Campbell, Hondzo, Voller	Michal Tal, Leslie Hsu, Robert Haydel, Amy Hanson, Peter Nelson, Sara Johnson
NCED students Tal, Hsu and Haydel complete IREP international travel/research; report to NCED through video conferences. Hanson, Nelson and Johnson plan trips			
Winter-fall 2006	SAFL	Marr	Postdocs: Brown, Orr, Venditti, Students: Jazdzewski, Limm, Nelson,, O'Connor, Stark
Several NCED Graduate Students and post docs from across NCED participate in StreamLab			
Ongoing	various	Voller, Paola, Gran	SRES students
First cohort of students admitted to Stream Restoration Science and Engineering certificate program; introductory course taught by Paola and Gran, capstone experience planned.			
May 2006	St. Paul, MN	Paola	NCED graduate students
NCED graduate students attend 2006 NCED site visit, prepare and present posters, meet to elect new Graduate Student Council representatives.			
May 2006	Baltimore, MD	Wilcock	Various
NCED students attend Low-slope Sand-bed Rivers short course (along with students from outside NCED).			
Summer 2006	ACRR	Various	
Several NCED graduate students conduct research at ACRR.			
December 2006	San Francisco	Various	AGU attendees
NCED students present posters, staff NCED/SAHRA Exhibit floor booth at fall AGU.			
Spring 2007	Texas, Minnesota	McElroy	NCED students/post docs
McElroy organizes Grad students/postdocs-only retreat at Minnesota, to be held in June 2007.			

NCED Videoconference Series		
Date	Presenter, Organization	Presentation Title
Apr 4, 2006	Nicholas E. Flores, NCED PI and Assoc. Prof. Institute of Behavior Science University of Colorado, Boulder	Ecological Restoration Standards: Social Analysis and Incentives

NCED Videoconference Series		
Date	Presenter, Organization	Presentation Title
Apr 11, 2006	Bruno Lashermes, NCED Post-Doc St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	River Network Topology and Multiscaling in Flow Paths
Apr 18, 2006	Juan Jose Fedele, NCED Post-Doc St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	A Theoretical Approach to Predict the Alluvial Architecture
Apr 25, 2006	Matt Wolinsky, NCED Post-Doc St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Modeling Earth Surface Dynamics from Source to Sink
May 2, 2006	Mark Green, NCED Graduate Student Bioproducts and Biosystems Engineering University of Minnesota, St. Paul	Examining Watershed Mechanism That Cause Regional Variation of Stream Water N:P Ratios
May 9, 2006	Jane Staiger, NCED Post-Doc St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Assessing Long-term Catchment-scale Denudation and Storage Using Cosmogenic Isotopes
May 30, 2006	Chris DiVittorio, Post-Baccalaureate Student Department of Integrative Biology University of California, Berkeley, CA	Feedbacks between riparian trees and channels: The case of White Alder
Sept 25, 2006	Vaughan R. Voller, NCED PI and Professor St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Comminution: Linking the Blast Furnace to the Production of Loess
Oct 2, 2006	Leslie Hsu, NCED Graduate Student Department of Earth and Planetary Science, University of California, Berkeley, CA	Waiting for debris flows: Channel erosion in the Illgraben torrent, Switzerland during summer 2006
Oct 9, 2006	Doug Jerolmack, NCED Post-Doc St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	What are the conditions leading to multiple channels in a river system?
Oct 16, 2006	Michael Limm, NCED Grad Student Department of Integrative Biology University of California, Berkeley, CA	The effect of biofilms on sediment transport: a sticky situation?
Oct 23, 2006	Collin Bode, Desktops Watershed Project Mgr, University of California, Berkeley, CA	Angelo Environmental Sensor Observatory, an Overview and Update
Oct 30, 2006	Assefa M. Melesse, Assistant Professor Department of Environmental Studies Florida International University, Miami, FL	Understanding the Ecohydrological Response of Impacted Watersheds to Restoration: Remote Sensing and GIS Application
Nov 14, 2006	Judy K. Haschenburger, Assistant Professor Department of Earth and Environmental Science University of Texas, San Antonio, TX	Vertical mixing of gravels after a long flood series
Nov 20, 2006	Jeffrey A. Nittrouer, NCED Graduate Student and David Mohrig, NCED PI and Professor Department of Geological Sciences University of Texas, Austin, TX	Lower Mississippi River bed material (sand) transport: recent work and thoughts for future research
Nov 27, 2006	Efi Foufoula, NCED PI and Professor Department of Civil Engineering St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Connecting Process and Form: The power of statistical signatures extracted from high-resolution DEMs
Jan 23, 2007	Robert Haydel, NCED Graduate Student Department of Civil and Envir. Engineering University of Illinois, Urbana-Champaign, IL	Morphology and Flow Structure Downstream: Two Bar-Confluences in a Large River

NCED Videoconference Series		
Date	Presenter, Organization	Presentation Title
Feb 6, 2007	Michal Tal, NCED Graduate Student St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Untangling the Management Practices of New Zealand's Canterbury Rivers
Feb 13, 2007	Chris Paola, Professor, Dept of Geol. and Geo., & Director, NCED, St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Systematic Effects of Sediment Extraction in Net-Depositional River Systems
Feb 20, 2007	Greg Wilkerson, NCED PI Department of Civil and Envir. Engineering University of Illinois, Urbana-Champaign, IL	Robust Bankfull Discharge Prediction
Feb 27, 2007	Fotis Sotiropoulos, Professor, Civil Engineering and Director, St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Computational Fluid Dynamics Modeling for Stream Restoration: Toward the Virtual Stream Lab
Mar 6, 2007	Michael Puma, NCED Post-Doc Department of Civil and Envir. Engineering Princeton University, Princeton, NJ	Linking the Statistical Properties of Surficial Processes and Stratigraphy in River Deltas
Mar 13, 2007	Jeff Marr, Engineer and Stream Restoration Project Manager St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Ground-Truth Testing of Conventional and Surrogate Bedload Monitoring Technologies in SAFL's Main Channel
Mar 20, 2007	Phairot Chatanantavet, NCED Grad Student St. Anthony Falls Laboratory University of Minnesota, Minneapolis, MN	Quantitative Testing of the Saltation-Abrasion Model with Field Data from the Clearwater River, Washington
Mar 27, 2007	Robert Twilley, NCED PI and Director, Wetland Biogeochemistry Institute Department of Oceanogr. and Coastal Science Louisiana State University, Baton Rouge, LA	Coastal Restoration Science and Engineering: A Systems Ecology Perspective

SAFL Seminars		
Date	Presenter	Title
Apr 5, 2006	Jeannette Yen, Dept. of Biology Georgia Institute of Technology	*Small-scale Biological-Physical-Chemical Signals in the Sea*
Apr 7, 2006	First Annual Barr Distinguished Lecture: Mark Solien Vice Pres Techn Organization Exxon Mobile Exploration Company	*Human Technology: Leadership in the application of intellect*
Apr 12, 2006	Ben O'Connor, Graduate Student Dept. of Civil Engineering	*"Happenin' Places" for Denitrification in Streams*
Apr 19, 2006	Sveinn Thorolfsson, Professor Dept. of Hydraulic and Environ. Engrg, Norwegian Univ of Science and Technology	*Stormwater-Meltwater Management Under Cold Climate Conditions: Some examples in Norway*
Apr 26, 2006	Alvin G. Anderson Award Speaker: Dr. Lucinda Johnson, Assoc. Dir Center for Water and The Environment Natural Resources Research Institute University of Minnesota, Duluth	
May 3, 2006	NCED Distinguished Lecture Series: Andrea Rinaldo Professor of Civil Engineering University of Padova, Itala	*Challenges in Watershed Research*
Sept 20, 2006	Liam Reinhardt, Post-doctoral fellow SAFL from the University of Memphis	*The dynamics of high-relief transient landscapes*

SAFL Seminars		
Date	Presenter	Title
Sept 27, 2006	Dr. Sergio Fagherazzi Department of Geological Sciences and School of Computational Science Florida State Univ.	*Critical bifurcation of shallow microtidal landforms in tidal flats and salt marshes*
Oct 4, 2006	William Herb, Research Associate St. Anthony Falls Laboratory	*Hydro-thermal models for stormwater runoff from developed and undeveloped areas*
Oct 9, 2006	Mehran Parshes, Research Engineer Georgia Institute of Technology	*Orientation of stiff fibers suspended in turbulent flow inside a planar contraction: evolution of turbulence and its effect on fiber orientation*
Oct 11, 2006	Anne Lightbody Dept. of Civil and Envir Engineering Massachusetts Institute of Technology	*Short-circuiting channels within constructed treatment wetlands*
Oct 11, 2006	Connie Fortin Fortin Consulting Inc., Minnesota	*Lakescaping for wildlife and water quality*
Oct 18, 2006	SAFL Distinguished Seminar Series Dr. Robert L. Street Environmental Fluid Mechanics Laboratory Civil Engineering, Stanford University	*Large-eddy simulation: Some new schemes, degrees of success, and future ventures*
Oct 25, 2006	Dr. Bruce Wilson Dept of Bioproducts and Biosystems Engrg University of Minnesota	*Ecological Indicators of Stream Health for TMDL Studies*
Oct 26, 2006	Roi Gurka Dept. of Mechanical and Material Engineering University of Western Ontario	*Turbulent characteristics of wake flows of various bridge sections*
Nov 1, 2006	SAFL Distinguished Seminar Series Dr. Robert A. Dalrymple Dept. of Civil Engineering Johns Hopkins University	*Modeling free surface flows with smoothed particle hydrodynamics*
Nov 8, 2006	Dr. Jeffrey J. McDonnell Richardson Chair in Watershed Science Dept. of Forest Engineering Oregon State University	*Runoff generation in gauged and ungauged watersheds: Status and future*
Nov 13, 2006	Paul Gram, Research Associate Department of Aquatic, Watershed, and Earth Resources Utah State University	*Sand entrainment in coarse-bedded rivers*
Nov15, 2006	Dr. Michael J. Sale Oak Ridge National Laboratory (ORNL)	*Technology innovation opporunities in the hydropower industry*
Nov 17, 2006	Professor Douglas Durian Department of Physics and Astronomy University of Pennsylvania	*Granular impact cratering*
Nov 29, 2006	Dr. Fotis Sotiropoulos Director and Professor St. Anthony Falls Laboratory, UMN	*Stirring & settling in chaotically advected flows: When down the devil's staircase is the only way out*
Dec 6, 2006	Dr. Peter B. Reich Professor and Chair in Forest Ecology and Tree Physiology Department of Forest Resources, UMN	*Linking plant traits, community and ecosystem dynamics, and global change: Keys to a predictive ecology?*

SAFL Seminars		
Date	Presenter	Title
Mar 21, 2007	Edward Silberman Fellowship Award Ceremony Eric Novotny Speaker: Prof. Aline Cotel Dept. of Civil & Environmental Engineering University of Michigan	*The effect of turbulence on fish habitat choices*
Mar 28, 2007	Bridget Scanlon, Senior Research Scientist Bureau of Economic Geology University of Texas, Austin	*Impacts of changing land use on subsurface water resources in semiarid regions*
Feb 14, 2007	Prof. Satish Kumar Chemical Engineering and Math Sciences University of Minnesota	*Squishy, oily, and frozen interfaces: Instabilities and applications*
Feb 21, 2007	Doug Jerolmack, Post Doctoral Associate National Center for Earth-surface Dynamics St. Anthony Falls Laboratory, UMN	*Quantitative sedimentology on Mars*
Feb 28, 2007	Prof. Brad Murray Coastal Processes and Geomorphology Duke University	*Emergent shapes of sandy coastlines, and their response to climate change*
Feb 7, 2007	Prof. Roberto Ballarini Civil Engineering University of Minnesota	*Cracking the conch conundrum: Tough ceramics at the seashore*
Jan 19, 2007	Thesis Defense: Wonsuck Kim PhD Candidate St. Anthony Falls Laboratory	*Coupled fluvial and shoreline dynamics: Experiments and theory*
Jan 24, 2007	Chris Elvrum Manager, Water Supply Planning Environmental Education Metropolitan Council Environmental Services Minneapolis, MN	*Twin Cities area water supply planning*
Jan 31, 2007	Prof. Robert Sterner Ecology, Evolution, and Behavior University of Minnesota	*Ecological stoichiometry*
Mar. 7, 2007	Distinguished Seminar Series Prof. Peter Kitanidis Environmental Fluid Mechanics and Hydrology, Stanford University	*Biostimulation to immobilize uranium at Oak Ridge National Laboratory: Chemical delivery and mixing*

External Education Activities

Meeting: AAAS: Using Atlas of Science Literacy: AAAS Project 2061 Professional Development Workshop for Educators	
Led by:	Ted Willard, AAAS Senior Program Associate, Project 2061.
Location, Date(s):	Science Museum of Minnesota, January 24-26, 2007

	Attendee Name	Affiliation
1.	Randy Smasal	Anoka-Hennepin - Science Curriculum Coordinator
2.	Sil Pembleton	Maltby Nature Center Education Director
3.	Joe Alfano	Mpls - Science Curriculum Coordinator
4.	Jenn Rose	Mpls - Science Curriculum Coordinator
5.	Karen Campbell	NCED – Education Director
6.	Diana Dalbotten	NCED – Diversity Director
7.	Kate Rosok	NCED – ESTREAM intern

8.	Tony Murphy	NCED, St. Kate's
9.	Anne Mock	Osseo - Science Specialist Edgewood Elem.
10.	Jackie Hoff	SMM - Collections
11.	Tilly Laskey	SMM - Ethnology
12.	Amy Grack-Nelson	SMM - Evaluation
13.	Mark Dahlager	SMM - Exhibits
14.	Keith Braafladt	SMM - Learning Technologies
15.	Laurie Fink	SMM - Museum Enterprises/Biology
16.	Sue Meyer	SMM - Outreach
17.	Larry Thomas	SMM - Outreach
18.	Maija Sedzielarz	SMM - School Visits
19.	Liesl Chatman	SMM - Teacher Programs
20.	Nils Halker	SMM - Teacher Programs
21.	Molly Leifeld	SMM - Teacher Programs
22.	Travis Sandland	SMM - Teacher Programs
23.	Janet Groenert	SMM - Youth and Family
24.	Kit Wilhite	SMM - Youth and Family
25.	Robby Schreiber	SMM - Youth Science Center
26.	Michael Thompson	SPPS - Admin.
27.	Marty Davis	SPPS - Science Curriculum Coordinator
28.	John Olson	SPPS - Science Curriculum Coordinator
29.	Bill Lindquist	SPPS - Science Specialist Crossroads Elem.
30.	Robin Wright	U of MN - College of Biological Sciences
31.	Carrie MacNabb	U of MN - Department of Neuroscience

ESTREAM			
Intended Audience	Middle to High School Earth Science teachers (in service or pre-service)		
Date	Location	Led by	Attendees
Spring – Dec., 2005	SAFL	Campbell	Amy Chen
Amy Chen, recent UMn geology B.S. graduate, joins NCED as a part-time ESTREAM intern. Amy develops 3Dmap manual, assists in development and delivery of NCED Education and Diversity programs such as Earthscapes Teacher Insitute and Fond du Lac camps, partners with other ESTREAM teachers in summer; assists in NCED/SAHRA booth at Fall AGU and presents and assists in Fall AGU "Hands-on Inquiry-Based" all day education session. Begins taking Education courses, but is admitted to Graduate program in Geology and Geophysics, so returns to full time student status in January, 2007.			
June 2006- present	SAFL Uof M	Campbell	Kate Poulter Rosok
Rosok serves as a Graduate Assistants, developing and testing ESTREAM activities. Rosok also assists in development and delivery of NCED Education and Diversity programs such as Earthscapes Teacher Insitute and Fond du Lac camps, partners with other ESTREAM teachers in summer; assists in NCED/SAHRA booth at Fall AGU and presents and assists in Fall AGU "Hands-on Inquiry-Based" all day education session. Rosok simultaneously enrolls in and completes course work for University of St. Thomas, Graduate Teacher Education Initial Licensure Program, Earth/Space Science (9-12) with General Science (5-8) and receives Knowles Science Teaching Foundation, 2007 Knowles Science Teaching Fellow (http://www.kstf.org).			

ESTREAM			
Intended Audience	Middle to High School Earth Science teachers (in service or pre-service)		
Date	Location	Led by	Attendees
June-Aug 2006	SAFL	Campbell	Jon Fults
Jon Fults, undergraduate Earth Science Education major at St. Cloud State University, serves as summer ESTREAM intern. Fults develops classroom version of NCED vegetation and stream morphology experiment, while also completing a series of experimental "runs" in NCED's 25' traveling flume. Fults also joins other ESTREAM teachers in joint activities (below).			
Fall 2006	St. Cloud, MN	Pound	Jon Fults
Fults completes independent study with Dr. Pound, NCED collaborator, on development and use of classroom vegetation and stream morphology experiment.			
June-Aug 2006	SAFL	Campbell	Chen, Rosok, Fults, Emily Horth (GMA)
Four interns work as a team to accomplish several projects. Chief among them are: 1. design, construction, testing and documentation of "Delta Box:" for "NCED Day" at SERC workshop: On the Cutting Edge - Professional Development for Geoscience Faculty Teaching Sedimentary Geology in the 21st Century , University of Utah, Salt Lake City, UT; and 2. designing, leading and documenting a series of river-science field trips for YSC Park Crew Youth and USIP interns.			
Jan. 2007	SMM	Ted Willard, AAAS	SMM and NCED staff, area K-12 science coordinators
Campbell and Rosok attend 3 day NCED sponsored AAAS workshop: Using Atlas of Science Literacy: AAAS Project 2061 Professional Development Workshop for Educators.			

Science Museum of Minnesota Big Back Yard			
Intended Audience	General public, teachers and students		
Date	Location	Led by	Attendees
May 2006	St. Paul, MN	Hamilton	SMM visitors
BBY opens for 3rd season.			
June-Aug 2006	SMM and environs	Horth	Earthscapes YSC Park Crew
NCED GMA Horth designs and delivers training and field trips for 2005 Park Crew.			
June 2006	SMM	Campbell, Liefeld, Sandland	16 K-12 teachers
Portion of Earthscapes Teacher Institute held in BBY.			
Summer 2006	SMM	Hamilton	Fuller, Horth, Park Crew
Fossils program opens in BBY; much of this interactive activity designed by GMAs Fuller and Horth			
August 2006	SMM	Horth	NCED staff and families, UofM admininstrators
GMA Horth and Park Crew guide NCED visitors and guests through the interpretive activities they devised over the summer to expand the engagement of Museum visitors in NCED science			
September 2006	SMM	Hamilton, Thomas	Minnesota teachers and students
SMM opens BBY for school field trips for the first time.			
ongoing	SMM	Hamilton, Campbell, Morin, Schmitt	SMM visitors
"Earthscapes Indoors" exhibit area developed around Science on a Sphere—Dam removal, 3D maps, World map puzzle installed.			
ongoing	St. Paul, MN	Chatman	Minnesota teachers
SMM Teacher Program staff plans and oversees renovation of BBY's Science House into the Teacher Resource Center. Initial items included in the TRC include a set of NCED Dam Removal models, NCED Earthscapes River Monitoring Kits sets of AAAS Project 2061 resources from NCED sponsored AAAS workshop.			
Summer 2006	SMM	Hamilton	SMM Visitors

SMM Evaluation Staff complete "Big Back Yard Studies"; evaluation of how visitors use the Park, what messages they retain and why some museum visitors don't venture into the Park. Major finding is that more promotion of the Park is needed; many visitors are simply unaware it exists.

Meeting: Earthscapes Teacher Institute		
Led by:	Karen Campbell, Molly Liefeld, Travis Sandland	
Location, Date(s):	Minnesota, June 19-23, 2006	
	Attendee Name	Address
1.	Brandi Hansmeyer	Lakeville, MN
2.	Brent Kraske	Rochester, MN
3.	Richard Humble	Lexington, NC
4.	Nicole Kunkel	Royalton,, MN
5.	Melissa Huseth	Cannon Falls
6.	Eric Lindberg	Minneapolis
7.	Jessica Just	Lakeville, MN
8.	Alissa Naymark	Rochester, MN
9.	Jennifer Perry	Prior Lake MN
10.	Margaret Schmitz	Willmar, MN
11.	Kevin Presler	Royalton, MN
12.	Susie Schrader	Bloomington, MN
13.	Chad Schmeising	New London, MN
14.	Roxanne Schmeising	New London, MN
15.	Lynell Senden	Mankato, MN
16.	Tom Yellowman	Cloquet, MN

Earthscapes Teacher Institute			
Intended Audience	Middle to High School teachers, primarily Science teachers		
Date	Location	Led by	Attendees
Spring 2006	Cloquet, MN	Campbell	Campbell, Chen
E-STREAM teacher Chen and Campbell review Cloquet site to prepare Chen to lead geology field trip/discussion			
June 19-24, 2006	SAFL, SMM, Randolph and Cloquet, MN	Campbell, Leifeld, Pembleton	16 ETI teachers
Year 3 ETI conducted.			
July 2006	SAFL	Campbell	
Action plans and field books graded for those who wished graduate credit.			
September, 2006	various		
ETI teachers carry out action plans. Many receive coverage in local newspapers.			
February , 2006	SMM	Leifeld	ETI teachers
Teachers meet to present results of class river investigations, share ideas, ESTREAM intern Rosok presents Delta Box, SMM Watershed Research Station staff give teachers tour of that facility and presentation on water quality issues in MN.			
ongoing	SMM	Campbell	SMM staff
Appropriate materials from ETI (dam removal models, river monitoring kits) selected and packaged for SMM's new Teacher Resource Center.			

Earthscapes School Contact Program (River Restoration Residency)			
Intended Audience	Middle-to-high school Earth-science students		
Date	Location	Led by	Attendees
Fall 2006 and Spring 2007	Minnesota	Travis Sandland	Classrooms of ETI teachers
Sandland visits schools from 05 and 06 ETI.			
June 2006	St. Paul, MN	Travis Sandland	16 2005 ETI teachers
Sandland leads 2006 teachers through the River Restoration Residency he will deliver to their classes.			
Winter 2007	Minnesota	Sandland	
RRR models identified as important resource for SMM's new Teacher Resource Center.			
Ongoing	Minneapolis, MN	Sandland, Amy Grack Nelson	
Summative evaluation of RRR conducted and completed at SMM.			
December 2006	San Francisco, CA	Sandland	AGU attendees
Sandland presents poster on RRR evaluation at Fall AGU.			
ongoing	Minnesota	Campbell	Undergraduates and K12 students
Individual RRR models or sets used a science outreach days, seminars or undergraduate classes from Macalester., College of St. Catherine, University of Minnesota, University of Wisconsin-Eau Claire, University of Wisconsin-River Falls.			

Individual Education Activities			
Intended Audience	Wider education formal and informal community of learners		
Date	Location	Led by	Attendees
ongoing	California	Banfield	High school students, Oakland,CA
Collaboration with two science educators: Kevin Cuff and Herb Their to develop a program to involve high school and after school students (Oakland, CA) in ongoing scientific research with the expectation that participation in research (specifically the excitement of scientific discovery) will inspire participants to pursue careers in science. The focus of the program is in the area of environmental microbiology and is designed to demonstrate how DNA sequence data can be used to uncover details of the makeup of natural microbial consortia and establish their relatedness and ecosystem function. One component is designed to reveal systematic relationships among DNA sequences from different lineages with the explicit goal of demonstrating the footprints of the evolutionary process.			
Summer 2006	SAFL	Paola	Undergraduate interns (see also Diversity)
Mentor undergrad visiting interns John Shaw (Oberlin) and Andy Wickert (MIT)			
Summer 2006	SAFL	Foufoula	Summer interns
Advise Summer Interns: Elizabeth Barnes (Valley morphology and upscaling of biotic transport laws) and Debbie Chasman (High resolution topography: computation aspects in extracting river networks). See also Diversity.			
Dec. 16, 2006	California	Paola	Gilbert Club attendees
Keynote talk, Gilbert Club, University of California, Berkeley			
July 13-16, 2006	Utah	Paola	Undergraduate faculty from around the U.S.
Co-organizer and lead presenter, Cutting edge sedimentary geology teaching workshop, Utah			
March 2006	NSF	NSF	Education Directors of Centers funded through GEO
Campbell invited attendee at NSF meeting of Education Directors of Centers funded through GEO to set direction for Education funded out of GEO directorate. Led by Jill Karsten (NSF) and UNAVCO Education Director, Susan Ericksson.			
ongoing	Minnesota	Voller	Students in SRSE Certificate program
Voller serves as Director of Graduate Studies for the Stream Restoration Science and Engineering certificate at the UMN			
ogoing		Campbell	CUAHSI
Campbell serves on CUAHSI Education and Outreach Committee			

Knowledge Transfer Activities

Meeting: Fluid and Granular Flow Dynamics Workshop		
Led by:	Jeff Marr	
Location, Date(s):	SAFL, April 4-6, 2006	
	Attendee Name, Affiliation	Address
1.	Lincoln Pratson	Duke University
2.	Homa Lee	USGS
3.	Matteo Pagliardi	University Pavia, Italy
4.	Dieter Issler	International Center for Geohazards, Norway
5.	Jose Cepeda	University of Oslo
6.	A Zakeri	University of Oslo
7.	Anders Elverhoi	University of Oslo
8.	Hedda Breien	University of Oslo
9.	Jeff Marr	NCED – University of Minnesota
10.	Alessandro Cantelli	University of Illinois, Urbana-Champaign

Meeting: StreamLab All-Hands Meeting		
Led by:	Peter Wilcock, Jeff Marr	
Location, Date(s):	SAFL, April 19-20, 2006	
	Attendee Name	Affiliation
1.	Peter Wilcock	Johns Hopkins University, PI
2.	Jeff Marr	University of Minnesota, PM
3.	Jeff Clark	Lawrence University, CI
4.	Cailin Orr	University of Minnesota, PostDoc
5.	Nancy Brown	University of Minnesota, PostDoc
6.	Ben O'Conner	University of Minnesota, Grad student
7.	Miki Hondzo	University of Minnesota, PI
8.	Jacques Finlay	University of Minnesota, PI
9.	Mike Limm	UC Berkeley, Grad student
10.	Jeremy Venditti	UC Berkeley, PostDoc
11.	Peter Nelson	UC Berkeley, Grad student
12.	Rebecca Leonardson	UC Berkeley, Grad student
13.	Anne Jefferson	Oregon State University, Grad student
14.	Efi Foufoula	University of Minnesota, PI

NCED Graduate Short Course: Low-Slope Sand-Bed Rivers		
Led by:	William Dietrich, Marcelo Garcia, J. Wesley Lauer, David Mohrig, Chris Paola, Gary Parker, Robert Twilley	
Location, Date(s):	Johns Hopkins University	
	Attendee Name , Affiliation	Position
1.	Scott Ensign, UNC Chapel Hill	PhD student
2.	Jason Julian, UNC Chapel Hill	PhD student
3.	Nikki Strong, Macalester College and UMN	NCED PhD student
4.	Katherine Skalak, University of Delaware	PhD student

NCED Graduate Short Course: Low-Slope Sand-Bed Rivers		
Led by:	William Dietrich, Marcelo Garcia, J. Wesley Lauer, David Mohrig, Chris Paola, Gary Parker, Robert Twilley	
Location, Date(s):	Johns Hopkins University	

	Attendee Name , Affiliation	Position
5.	Jorge Abad, University of Illinois	PhD student
6.	Liz Hajek, University of Wyoming	Grad student
7.	Heather Jones, University of Wyoming	Grad student
8.	Jason Alexander, Utah State University	Grad student
9.	Susannah Erwin, Utah State University	Grad student
10.	Brendan Yuill, Arizona State University	Grad student
11.	Christian Braudrick, UC Berkeley	NCED PhD student
12.	Inci Guneralp, University of Illinois	Grad student
13.	Wes Lauer, Unversity of Minnesota	NCED PhD student
14.	Nick Nelson, Utah State University	Grad student
15.	Brandon McElroy, MIT	NCED PhD student
16.	Anne Jefferson, Oregon State University	Grad student
17.	Allen Gellis, USGS – Baltimore	Researcher
18.	Kathleen Swanson, UC Berkeley	NCED PhD student
19.	Matt O’Connor, O’Connor Enviromental, Inc.	PhD consultant
20.	Andrew Wilcox, USGS	PostDoc Research Associate
21.	Kris Bass, North Carolina State University	Faculty
22.	Michal Tal, University of Minnesota	NCED PhD student
23.	Ben O’Connor, University of Minnesota	NCED PhD student
24.	Brendan DeTemple, Johns Hopkins University	NCED PhD student
25.	Ellen McClure, Biohabitats, Inc.	Consultant
26.	Vincent Sortman, Biohabitats, Inc.	Senior Fluvial Geomorphologist
27.	Laurel Larsen, University of Colarado	Grad student
28.	Michael O’Driscoll, East Carolina University	Junior Faculty
29.	Boris Lau, Northwestern University	PostDoc
30.	Jeff Nittrouer, Tulane University	Grad student
31.	Dale White, Ohio State University	Grad student
32.	Philip Berger, US Environmental Protection Agency	Geologist/Hydrologist
33.	Javier Ancalle, University of Illinois	NCED PhD student
34.	Mohamend Habib, University of Louisiana	Grad student
35.	William Veseley, University of Louisville	Grad student

NCED Graduate Short Course: Low-Slope Sand-Bed Rivers		
Led by:	William Dietrich, Marcelo Garcia, J. Wesley Lauer, David Mohrig, Chris Paola, Gary Parker, Robert Twilley	
Location, Date(s):	Johns Hopkins University	
	Attendee Name , Affiliation	Position
36.	J. Stephen Fries, Institute of Marine Sciences	PostDoc Associate
37.	Joel Rowland, UC Berkeley	NCED PhD student
38.	Sean Smith, Johns Hopkins and Maryland DNR	Grad student
39.	Scott Bell, Limno-Tech, Inc.	Environmental Engineer
40.	Scott Lowe, McCormick Taylor, Inc.	Environmental Scientist
41.	Pramenath Narinesingh, University of Delaware	Grad student

Meeting: NCED Stream Restoration Partners Group		
Led by:	Peter Wilcock, Peter Downs	
Location, Date(s):	UC Berkeley Richmond Field Station, Richmond, CA July 6-8, 2006	
	Attendee Name	Affiliation
1.	Carlos Alonso	National Sedimentation Lab
2.	Drew Baird	Stewart Engineering
3.	Paul Bakke	Fish and Wildlife Service
4.	Jerry Bernard	USDA
5.	Derek Booth	University of Washington
6.	Michael Bowen	Coastal Conservancy
7.	Christian Braudrick	UC Berkeley – Grad student
8.	Matt Brown	USFWS
9.	Koll Buer	CalFed
10.	John Buffington	Forest Service
11.	John Cain	Bay Institute
12.	Margie Caisley	Calofornia Department of Water Resources
13.	Jeff Clark	Lawrence University
14.	Brian Cluer	NOAA Fisheries
15.	Yantao Cui	Stillwater Sciences
16.	Bill Dietrich	NCED - UC Berkeley
17.	Peter Downs	Stillwater Sciences
18.	Martin Doyle	University of North Carolina
19.	John Elliott	USGS
20.	Mike Ellis	NSF
21.	Craig Fischenich	U.S. Army Corps of Engineers
22.	Nick Flores	NCED - University of Colorado
23.	Jon Fripp	USDA
24.	Karen Gran	NCED - PostDoc
25.	John Gray	USGS

Meeting: NCED Stream Restoration Partners Group		
Led by:	Peter Wilcock, Peter Downs	
Location, Date(s):	UC Berkeley Richmond Field Station, Richmond, CA July 6-8, 2006	
	Attendee Name	Affiliation
26.	Blair Greiman	USBR
27.	Ed Herricks	University of Illinois, Urbana-Champaign
28.	Bill Jackson	National Park Service
29.	Peggy Johnson	Portland State University
30.	Meg Jonas	US Army Corps of Engineers
31.	Steve Kite	West Virginia University
32.	Craig Kochel	Bucknell University
33.	Matt Kondolf	UC Berkeley
34.	Andreas Krause	USBR
35.	Roger Kuhnle	USDA
36.	Frank Ligon	Stillwater Sciences
37.	Tom Lisle	USDA
38.	Jim MacBroom	Milone & MacBroom, Inc.
39.	Jeff Marr	NCED – University of Minnesota
40.	Jerry Miller	Western Carolina University
41.	Bruce Orr	Stillwater Sciences
42.	Gary Parker	NCED - University of Illinois, Urbana-Champaign
43.	John Potyondy	US Forest Service
44.	Mary Power	NCED - UC Berkeley
45.	Hal Pranger	National Park Service
46.	Karen Prestegaard	NSF
47.	Tim Randall	USBR
48.	Bruce Rhoads	University of Illinois, Urbana-Champaign
49.	Kerry Robinson	USDA
50.	Dave Rosgen	Wildland Hydrology
51.	Jack Schmidt	Utah State University
52.	Tom Schueler	Center for Water Protection
53.	Conor Shea	US Fish and Wildlife Service
54.	Andrew Simon	USDA
55.	Elise Striz	Environmental Protection Agency
56.	Michal Tal	NCED – Grad student
57.	Peter Wilcock	NCED – Johns Hopkins University
58.	Greg Wilkerson	NCED - University of Illinois, Urbana-Champaign

Meeting: Bedload Research International Cooperative (BRIC)		
Led by:	Jeffrey Marr, John Gray, Jonathan Laronne	
Location, Date(s):	SAFL, April 11-14, 2007	
	Attendee Name	Address
1.	Jonathan Barton	293 Stillwater Drive Horseheads, NY 14845
2.	Ramon Batalla	University of Lleida Alcalde Rovira Roure, 191 Lleida, 25002 SPAIN
3.	Jim Bogen	Orwegian Water Resources PO Box 5091 Majorstua Oslo, 0301 NORWAY
4.	Kristin Bunte	Colorado State University Engineering Research Center Fort Collins, CO 80523
5.	Karen Campbell	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota
6.	James Chambers	University of Mississippi 1 Coliseum Drive University, MS 38677
7.	Francesco Comiti	Via Vergerio 4 Padova, 35126 ITALY
8.	Broderick Davis	WES/FISP 3909 Halls Ferry Rd. Vicksburg, MS 39180
9.	Panos Diplas	Civil and Environmental Engineering 220B Patton Hall Blacksburg, VA 24061
10.	William Emmett	5960 S. Wolff Ct. Littleton, CO 80123-6734
11.	Kurt Fienberg	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota
12.	Efi Foufoula-Georgiou	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota
13.	Wojciech Froehlich	Polish Academy of Sciences Krolowej Jadwigi 33/22 P.O. Box 72 Nowy Sacz, 33-300 POLAND
14.	David Gaeuman	U.S. Bureau of Reclamation 16349 Shasta Dam Blvd. Trinity River Restoration Project Shasta Lake, CA 96019
15.	Allen Gellis	U.S. Geological Survey 8987 Yellow Brick Road Baltimore, MD 21237

16.	John Gray	US Geological Survey 415 National Center 12201 Sunrise Valley Drive Reston, VA 20192
17.	Helmut Habersack	Universitaet Fuer Bodenkultur Muthgasse 18 Vienna, 1190 AUSTRIA
18.	Marwan Hassan	University of British Columbia 1984 West Mall Vancouver, BC, V6T 1Z2 CANADA
19.	Rob Hilldale	U.S. Bureau of Reclamation Denver Federal Center Bldg. 67, 86-68540 Denver, CO 80225
20.	Robert Holmes	U.S. Geological Survey 1201 W. University Avenue Urbana, IL 61801
21.	Jonathan Laronne	Ben Gurion University of the Negev P.O. Box 653 Beer Sheva, 84105 ISRAEL
22.	Jeff Marr	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota
23.	Stuart McLelland	University of Hull Department of Geography Cottingham Road Hull, UH67RX UNITED KINGDOM
24.	Takahisa Mizuyama	Kyoto University Shinjo-Cho 3-14 Ibaraki Osaka 5670884, JAPAN
25.	Knut Moen	P.O. Box 5091, Majorstua Oslo, 0301 NORWAY
26.	Omid Mohseni	St. Anthony Falls Laboratory University of Minnesota
27.	Mary Nichols	USDA-ARS 2000 E. Allen Road Tucson, AZ 85719
28.	Michinobu Nonaka	Hydrotech Company, Ltd. 876 Kouzukeda Hino-cho Gamou-gun Shiga 529-1642 JAPAN
29.	Akira Oda	Civil Engineering Research Lab 904-1 Tohigashi Tsukuba City Ibaraki, 300-2633 JAPAN
30.	Rolf Tore Ottesen	Geological Survey of Norway N-7491 Trondheim NORWAY
31.	Chris Paola	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota

32.	Thanos Papanicolaou	University of Iowa 100 Hydraulics Lab Iowa City, IA 52242
33.	Tim Randle	US Bureau of Reclamation Technical Service Center PO Box 25007 Mail Code: 86-68540 Denver, CO 80225-0007
34.	Ian Reid	Loughborough University High Wood Cottage Kilnwick Driffield, Y025 9JF UNITED KINGDOM
35.	Colin Rennie	University of Ottawa 161 Louis Pasteur St. Ottawa, On K1N 6N5
36.	Dieter Rickenmann	Swiss Federal Res. Inst. WSL Zuercherstrasse 111 Birmensdorf, CH-8903 SWITZERLAND
37.	Alberto Rovira	UEA-IRTA Apartat de Correus 200 St. Carles Rapita, 43540 SPAIN
38.	Josef Schuler	313 W. Knapp Street Rice Lake, WI 54868
39.	Hugo Seitz	Universitaet Fuer Boden Kultur Muthgasse 107 Vienna, 1190 AUSTRIA
40.	Arvind Singh	National Center for Earth-surface Dynamics St. Anthony Falls Laboratory University of Minnesota
41.	Wesley Smith	P.O. Box 4485 Arcata, CA 95518
42.	Rebecca Soileau	U.S. Army Corps of Engineers 190 5th Street East, Suite 401 St. Paul, MN 55101
43.	Fotis Sotiropoulos	St. Anthony Falls Laboratory University of Minnesota
44.	Kurt Swingle	630 Iris Avenue Boulder, CO 90304-1754
45.	Damian Vericat	UWA-IGES Llandinam Building Penglais Campus Aberystwyth, Sy23 3DB UNITED KINGDOM
46.	Peter Wilcock	Dept. of Geography & Environmental Engineering 305 Ames Hall Johns Hopkins University 3400 N. Charles Street Baltimore, MD 21218-2686
47.	Andre Zimmermann	UBC 3529 W 6th Avenue Vancouver, BC V6R 1T5

2006 Shallow-Water Short Course for ExxonMobil Students	
Led by:	ExxonMobil: Penny Patterson and Ben Sheets NCED Affiliated: John Martin, Sara Johnson, Chris Paola and Chris Ellis
Location, Date(s):	SAFL, May 3-5, 2006
	Twelve Students, 2 instructors

2007 Shallow-Water Short Course for Chevron Students	
Led by:	Chevron: Martin Perlmutter and Morgan Sullivan NCED Affiliated: Craig Hill, Chris Paola, and Chris Ellis
Location, Date(s):	SAFL, April 18-20, 2007
	9 Students, 2 instructors

2007 Shallow-Water Short Course for ExxonMobil Students	
Led by:	ExxonMobil: Penny Patterson, Ben Sheets (NCED alum), and John Martin (NCED PhD student interning at EM) NCED Affiliated: Craig Hill, Chris Paola, and Chris Ellis
Location, Date(s):	SAFL, May 2-4, 2007
	10 Students, 3 instructors

St. Anthony Falls Laboratory Industrial Consortium Site Visit	
Description:	Presentations of yearly results on experimental, seismic, and numerical modeling efforts along with observed stratigraphic peel data for general discussion of the resultant stratigraphy.
Led by:	Chris Paola and John Martin
Location, Date(s):	SAFL, August 17-18

	Organization attending
1.	ExxonMobil
2.	Chevron
3.	ConocoPhilips
Total attendees	10

Visitors Program		
Intended Audience	Research community outside NCED PIs	
Visitor	Affiliation	Research Topic
Collin Rennie	Civil Engineering, University of Ottawa	Acoustic Doppler measurement of bedload
Noah Finnegan	Earth and Space Sciences, University of Washington	Controls on the channel width of bedrock rivers
Elizabeth Hagen	School of Life Sciences Arizona State University	Effects of river channel geomorphology and terrestrial vegetation structure on bat foraging ecology within the South Fork Eel watershed, Mendocino County, California.

Digital Visualization			
Intended Audience	Educators, Researchers, Partners		
Date	Location	Led by	Attendees
Ongoing		Morin	McGraw-Hill, other authors
Co-author and art director for undergraduate textbook, "Visualizing Geology"			
Ongoing	Minneapolis	Morin	Kent Kirkby, undergraduates
Ongoing study of effectiveness of 3D visualization in undergraduate instruction.			
Ongoing	St. Paul	Morin	Hamilton
PI and visualization director for WaterPlanet traveling exhibit.			
Ongoing	Washington, D.C.	AGU	
Member, AGU IT Committee			
Ongoing	U.S.	Morin	Undergraduates
Morin, as NAGT Distinguished Lecturers, brings NCED visualization and research to Western Michigan University, DePauw University, and Indiana University.			
Ongoing	Minneapolis	Morin	Northeast section, Geological Society of America
Supervise GMA Sivistula in development of "Water Table" an interactive watershed exhibit component and classroom tool for WaterPlanet			
October 2006	Minneapolis	Morin	Colorado students
Posters at annual meeting of Geological Society of America on 3D maps in undergraduate and informal education.			
Ongoing	St. Paul	Morin	Dimitri Sivistula
Development of Corewall software with partners at ANDRILL, IODP, LacCore, PetroBras, JOI, JAMTEC, for description, visualization and analysis of SA.			

River on the Road (public interactive exhibits about rivers)			
Intended Audience	Public		
Date	Location	Led by	Attendees
June, 2006	LaCrosse, WI	Campbell	Conference attendees
Campbell delivers invited talk, staffs booth and 3rd International Conference on Rivers and Civilization http://www.rivers2006.org/ featuring NCED's dam removal model and the various formal and informal education activities that have featured it.			
June 7-8, 2006	Washington, DC	Campbell	Congressional staff and interns, NSF staff
Campbell, Hobbs, JHU grad student Jenn Bassman and SAHRA staff present booth and annual CNSF Exhibition on Capitol Hill, featuring Elwha Dam Removal Model (see http://www.cnsfweb.org/exhibition.html)			
Summer 2006	SAFL	Campbell/Marr	Gordon Grant, Jim Roe
Discussions begin on NCED research and outreach involvement with removal of Marmot Dam, Sandy River, OR.			
Summer 2006	SAFL and Oregon	Campbell/Roe	Jeff Gersch, filmmaker
Discussions about linking Oregon Museum of Science and Industry to Marmot removal			
Sept. 2006	Minnesota	Campbell, Rosok	Attendees of Annual AIPG meeting
Campbell and Rosok organize joint NCED/AWG booth at Annual AIPG (American Institute of Professional Geologists) meeting, featuring Elwha Dam Removal model			
April 2006	SAFL	Marr/Campbell	Gersch, Grant
Contract signed between Portland General Electric (dam owner) and SAFL/NCED to construct physical model of Marmot Dam for documentary film and ongoing research.			
April 2006	SAFL/Oregon	Campbell	Gersch, OMSI
Serious discussions begin with OMSI about possible outreach, modeled on NCED's Elwha dam removal experience			

Hobbs
Participation in the Spring 2006 open house for Congressional staff (House Office Building, Washington, DC) with Karen Campbell

Website and Data Repository			
Intended Audience	NCED internal and external community		
Date	Location	Led by	Attendees
Spring 2006	Minneapolis	Campbell, Homstad	Urban Planet, LLC
Graphic redesign of NCED website implemented May 2006.			
Summer 2006	Minneapolis	Campbell, Nguyen	
NCED's internal collection of photos migrated to password-protected web-based image gallery for use in talks, papers by NCED members.			
Summer 2006	Minneapolis	Horth	
E-STEAM teachers use private section of NCED website to document joint work with SMM Youth			
ongoing	Minneapolis	Nguyen	
Ongoing meetings with NCED Partner, Minnesota Super Computing institute, to seek new solutions for NCED Data repository and eventual archive.			
Winter7 2006-2006	Minneapolis	Marr, Lord-Van Slyke	SR Community
Significant revision of SR "portal" portion of NCED website			
ongoing	Minneapolis	John Gray	Nguyen, Campbell
On going development of BRIC (Bedload Research International Cooperative) website			
Spring 2007	Minneapolis	Nguyen, Marr	BRIC Symposium attendees world wide
NCED implements Macromedia BREEZE technology to allow live streaming and interactive discussion of BRIC Symposium, held at SAFL, internationally.			
Spring 2007	Minneapolis	Nguyen, Campbell	
NCED designs new data repository solution, based on research done in Year 4. SQL-based, php database will be much more flexible than NCED's current data repository and incorporate lessons learned from LTERs and the repository at Oak Ridge National Laboratory.			
ongoing	Minneapolis	Nguyen	
Ongoing work to convert archived "streams" of NCED video conferences to more user-friendly viewing technology and display and obtain permissions, where needed, to make these NCED research talks publicly-available.			

Individual Knowledge Transfer Activities			
Intended Audience	Wider research community and practitioners in industry, consulting, agencies and non-profits		
Date	Location	Led by	Attendees
May 31-June 2, 2006	Florida	Power	NSF Site Review Committee, NCALM
"Flood webs in river networks: Towards Predictive Mapping" NCALM site review, St. Augustine, Florida.			
May 2006	SAFL	Paola	Oil industry scientists
ExxonMobil shallow-water intern course, co-instructor			
May 30 – June 8, 2006	Utah	Wilcock, Schmidt	Short course attendees
The principles and practice of stream restoration. Wilcock primary instructor in two-week short course convened by J.C. Schmidt, Utah State University.			

Individual Knowledge Transfer Activities			
Intended Audience	Wider research community and practitioners in industry, consulting, agencies and non-profits		
Date	Location	Led by	Attendees
June 2006	Germany	Parker	Short course attendees
Summer course, environmental fluid dynamics, Karlsruhe, Germany, June 16, 19, 21, 2006			
June 12-16, 2006	Maryland	Wilcock, Palmer	Short course attendees
Ecological and geomorphic principles of stream restoration. One-week short course co-convened with Margaret Palmer, University of Maryland.			
July 2006	Snowbird, UT	Paola	SEPM (Society for Sedimentary Geology) members
Keynote talk, SEPM Snowbird sedimentary systems meeting			
August 10-14, 2006	California	Wilcock, Kondolf, Power	Short course attendees
River restoration: Application of fluvial geomorphology. Wilcock primary instructor in one-week short course convened by G.M. Kondolf, UC-Berkeley. Truckee, CA. Power also instructor.			
August 2007	Japan	Parker	Conference attendees
Short course, turbidity currents, International Sedimentological Congress, Fukuoka, Japan, August 27, 2006			
September 2007	Portugal	Parker	Short course attendees
Short course, river morphodynamics, Lisbon, Portugal, September 4, 2006			
September 27, 2006	Montana	Wilcock	Short course attendees
Sediment transport in stream channel design. One-day short course. Northwest Environmental Training Center, , Missoula MT			
September 2006	Montana	Wilcock	Conference attendees
Center for Riverine Science and Stream Re-naturalization 2006 Conference, University of Montana, Keynote Address, Sediment Transport and Stream Renaturalization Success.			
September 2006	Minnesota	Wilcock, Marr, Campbell	Attendees of Annual EPA national Monitoring Workshop
Campbell, Marr and Wilcock organize NCED half – day session: NCED Stream Restoration research, training and tools; tours of StreamLab			
October 2, 2006	North Carolina	Wilcock	Workshop attendees
Pre-conference Workshop: Sediment Transport in Natural Streams, North Carolina Stream Restoration Conference, , Charlotte NC			
October 2006	North Carolina	Wilcock	Conference attendees
North Carolina Stream Restoration Conference, Keynote Address, *Understanding Sediment Transport.*			
November 2006	Maryland	Wilcock	Workshop attendees
Chesapeake Bay Program, Science and Technical Advisory Group, Workshop on Quantifying the Role of Stream Restoration in Achieving Nutrient and Sediment Reductions. Streambank stabilization – problem or solution?			
November 2006	Maryland	Wilcock	Workshop attendees
Maryland Stream Restoration Interest Group. Sediment Transport in Stream Channel Planning and Design.			
December 7, 2006	Washington	Power, Post-doc Palen, Grad student Limm and others	Symposium attendees
"Changes to salmon habitats, environments, and ecosystems: Pulses, presses, and spatial extent" for NOAA Fisheries Symposium on Evolutionary Changes and Salmon Symposium Seattle, WA			
January 5, 2007	Switzerland	Power	Meeting attendees
"Flood webs in river networks: Towards Predictive Mapping" EAWAG, The Swiss Federal Institute of Aquatic Science and Technology,.			

Individual Knowledge Transfer Activities			
Intended Audience	Wider research community and practitioners in industry, consulting, agencies and non-profits		
Date	Location	Led by	Attendees
February 6-9, 2007	Alaska	Power and post-doc Palen	Symposium attendees
"Regime changes down drainage networks: towards predictive mapping" for the symposium on Sustainability of the Arctic-Yukon-Kuskokwim Salmon Fisheries /, Anchorage, Alaska. Sponsored by the Bering Sea Fishermen's Association Arctic-Yukon-Kuskokwim Sustainable Salmon Initiative.			
April 2007	SAFL	Paola	Oil industry scientists
Chevron shallow-water intern course, co-instructor			
May 2007	SAFL	Paola	Oil industry scientists
ExxonMobil shallow-water intern course, co-instructor			
ongoing		Power	NOAA
NOAA-Fisheries Salmon Recovery Science Advisory Panel, 2004-present			
2006	NA	Wilcock	Agency employees
Sediment transport model developed by Wilcock and Crowe (2003, *J. Hydraulic Engineering*) incorporated into HEC-RAS, standard hydraulic model developed by the US Army Corps of Engineers.			
Ongoing	CA	Dietrich	Parker, Wilcock, various graduate students
Collaborations with Stillwater Sciences on several California-based river restoration projects.			
2006	UMN	Finlay, Orr	
Produce an article on Streamlab for the UMN Water Resources Center publication *Minnegram*.			
ongoing	UIUC	Wilkerson	Stream Restoration Community
Preliminary version of a tool for stream restoration toolbox, titled "Willow Post Analyzer," developed. This tool facilitates prediction of velocity distributions in rectangular and trapezoidal channels with vegetation for user specified conditions. A manuscript describing theoretical foundation and computational procedure for implementing the model will be published in the *Journal of Hydraulic Engineering* in May 2007. A final version of this tool, to be posted on NCED website, will be developed in 2007.			
ongoing	UIUC	Parker	
Research with industry: ExxonMobil: long-runout turbidity currents and gravel transport by turbidity currents			
ongoing	UIUC	Parker	
Research with industry: Shell Oil: channelization of turbidity currents			
ongoing	UIUC	Parker	
Research with industry: Iron Ore Company of Canada: tailings basin of Lake Wabush, Labrador			

Meeting: STC Directors Meeting		
Led by:	Chris Paola, Rochelle Storfer, Deb Pierzina	
Location, Date(s):	University of Minnesota, September 18-19, 2006	
	Attendee Name, Affiliation	Address
1.	Elliott Albers	Center for Behavioral Neuroscience
2.	Neal Armstrong	Center for Materials and Devices for Information Technology Research
3.	David Avery	Center for Embedded Networked Sensing
4.	Ruzena Bajcsy	Team for Research in Ubiquitous Secure Technologies
5.	Antonio Bapista	Center for Coastal Margin Observation and Prediction
6.	Everett Baucom	Center for Environmentally Responsible Solvents and Processes
7.	Mary Bellamy	Center for Environmentally Responsible Solvents and Processes

Meeting: STC Directors Meeting		
Led by:	Chris Paola, Rochelle Storfer, Deb Pierzina	
Location, Date(s):	University of Minnesota, September 18-19, 2006	
	Attendee Name, Affiliation	Address
8.	David Braaten	Center for Remote Sensing of Ice Sheets
9.	Dragana Brzakovic	NSF
10.	Cindy Carrick	Center for Multi-Scale Modeling of Atmospheric Processes
11.	Leyla Conrad	Materials and Devices for Information Technology Research
12.	Stephen Craig	Center for Environmentally Responsible Solvents and Processes
13.	Larry Dalton	Center for Materials and Devices for Information Technology Research
14.	Allan Denning	Center for Multi-Scale Modeling of Atmospheric Processes
15.	Deborah Estrin	Center for Embedded Networked Sensing
16.	Kristen Gates	Team for Research in Ubiquitous Secure Technologies
17.	Siva Prasad Gogineni	Center for Remote Sensing of Ice Sheets
18.	Jeffrey Goldman	Center for Embedded Networked Sensing
19.	Nicholas Gross	Center for Integrated Space Weather Modeling
20.	Margaret Harden	Materials and Devices for Information Technology Research
21.	Susan Herricks	Center for Advanced Materials for Water Purification
22.	Melissa Higgins	Sustainability of semi-Arid Hydrology and Riparian Areas
23.	Harvey Hoch	Nanobiotechnology Center
24.	Larry Howard	Team for Research in Ubiquitous Secure Technologies
25.	Jeffrey Hughes	Center for Integrated Space Weather Modeling
26.	Lisa Hunter	Center for Adaptive Optics
27.	Deborah Illman	NSF
28.	Stephen Ingalls	Center for Remote Sensing of Ice Sheets
29.	David Karl	Center for Microbial Oceanography: Research and Education
30.	Graham Kerslick	Nanobiotechnology Center
31.	Karen Kim	Center for Embedded Networked Sensing
32.	Alvin Kwiram	Materials and Devices for Information Technology Research
33.	Richard Lane	NSF
34.	Christopher Lemaistre	Center for Adaptive Optics
35.	James Lightbourne	NSF
36.	Seth Marder	Center for Materials and Devices for Information Technology Research
37.	Alina Martinez	ABT Associates
38.	Dennis Matthews	Center for Biophotonics
39.	Claire Max	Center for Adaptive Optics
40.	William McHenry	NSF
41.	Marco Molinaro	Center for Biophotonics
42.	Keith Oden	Materials and Devices for Information Technology Research
43.	Suzanne Papamichail	Center for Biophotonics
44.	Brian Pianfetti	Center for Advanced Materials for Water Purification
45.	Nathaniel Pitts	NSF
46.	Kelly Powell	Center for Behavioral Neuroscience
47.	Jack Quinn	Center for Integrated Space Weather Modeling

Meeting: STC Directors Meeting		
Led by:		Chris Paola, Rochelle Storfer, Deb Pierzina
Location, Date(s):		University of Minnesota, September 18-19, 2006
	Attendee Name, Affiliation	Address
48.	David Randall	Center for Multi-Scale Modeling of Atmospheric Processes
49.	Shankar Sastry	Team for Research in Ubiquitous Secure Technologies
50.	Mark Shannon	Center for Advanced Materials for Water Purification
51.	James Shuttleworth	Center for Sustainability of semi-Arid Hydrology and Riparian Areas
52.	Kenneth Singer	Center for Layered Polymeric Systems
53.	Mary Sprinkle	Team for Research in Ubiquitous Secure Technologies
54.	Richard Sustich	Center for Advanced Materials for Water Purification
55.	James Washburne	Center for Sustainability of semi-Arid Hydrology and Riparian Areas
56.	Gary Webber	Center for Remote Sensing of Ice Sheets
57.	Walter Wilczynski	Center for Behavioral Neuroscience
58.	Gary Woodard	Center for Sustainability of semi-Arid Hydrology and Riparian Areas

Meeting: External Advisory Board		
Led by:		Chris Paola, Efi Foufoula
Location, Date(s):		SAFL, October 31 – November 1, 2006 (Videoconference)
	Attendee Name	Address
1.	Dhamo Dhamotharan	Sr. Vice President & Regional Manager URS Corporation 9801 Westheimer, Suite 500 Houston, TX 77042
2.	David Jon Furbish	Department of Earth and Environmental Sciences Vanderbilt University VU Station B #351805 2301 Vanderbilt Place Nashville, TN 37235-1805
3.	Richard P. Hooper	CUAHSI 2000 Florida Avenue, NW Washington, DC 20009
4.	Matthew Larsen	Chief Scientist for Hydrology Water Resources Division U.S. Geological Survey 436 National Center Reston, VA 20192
5.	Jean Moon	Director, Board on Science Education The National Research Council 500 Fifth Street, NW Washington, DC 20001
6.	Anthony Paul Murphy	College of St. Catherine 2004 Randolph Avenue St. Paul, MN 55105
7.	William Schulze	Applied Economics & Management Cornell University 301 Warren Hall Ithaca, NY 14853

Meeting: External Advisory Board		
Led by:	Chris Paola, Efi Foufoula	
Location, Date(s):	SAFL, October 31 – November 1, 2006 (Videoconference)	
	Attendee Name	Address
8.	David V. Taylor	Provost and Senior Vice President for Academic Affairs Morehouse College 830 Westview Drive Atlanta, GA 30314-3773
9.	Chris Paola	NCED – University of Minnesota
10.	Efi Foufoula	NCED – University of Minnesota
11.	Karen Campbell	NCED – University of Minnesota
12.	Diana Dalbotten	NCED – University of Minnesota
13.	Jeff Marr	NCED – University of Minnesota
14.	David Mohrig	NCED - MIT
15.	Nicholas Flores	NCED – University of Colorado
16.	Bill Dietrich	NCED – UC Berkeley

Diversity Program Activity Tables

Diversity Activity Table			
Date	Location	Led By	Attendees
Description of activity			
Date	Location	Led by	Attendees
2006/07	ACCR	Power	Jesse De Wolf, Shayla Workman, Angela Dombrowski
NCED PI Mary Power supervises three undergraduate students (two Native American and one African American) on independent research and technical field work at ACCR			
2006/07	FDLTCC	Wold	Sharon O’Leary
NCED PI Andrew Wold supervises an undergraduate student (Native American) on independent research.			
April 2007	Forestry Center, Cloquet, Minnesota	Pellerin and Greensky	28 students; 3 mentors, 1 pre-service teacher, 5 teachers, 2 elders, partner scientists 6
A three day seasonal experiential science educational experience where underrepresented students in grades 4-8 explore science in their local area.			
May 2006	Indianapolis, IN	Dalbotten	Aurelia DeNasha
gidakiimanaaniwigamig student Aurelia DeNasha represented AISES at the Intel International Science and Engineering Fair in May 2006.			
Summer 2006	U of MN TC	Finlay/Orr	Alyxis Feltis
NCED PI Finlay and post-doc Orr supervise USIP student.			
Summer 2006	U of MN TC	Clark	Jorden Theissen
NCED visiting researcher Jeffrey Clark supervises USIP student.			
Summer 2006	U of MN TC	Hill	Hallie Boyer
NCED affiliated researcher Kimberly Hill (SAFL, U of MN) supervises USIP student.			
Summer 2006	U of MN TC	Porte-Angel and Stefan	Angel Santiago
NCED PI Porté-Agel and and affiliated researcher Heinz Stefan supervises Angel Santiago, here for his third summer internship with NCED.			

Diversity Activity Table			
Date	Location	Led By	Attendees
Description of activity			
Summer 2006	SAFL	Dalbotten	USIP interns, other summer interns at SAFL
Dalbotten led weekly research meetings and end-of-summer poster session for NCED undergraduates and other undergraduates doing research during Summer 2006 at the St. Anthony Falls Laboratory.			
June 2006	Taylor's Falls	Poulter-Rosok, Horth	USIP interns, BBY YSC participants
Kate Poulter Rosok and Emily Horth, NCED ESTREAM teachers, led a field trip to study the geology of Taylor's Falls and the research on biodiversity taking place at the Cedar Creek Natural History Center for NCED undergrad summer interns and high-school students working in the SMM Big Backyard.			
July 2006	Chicago, IL	Dalbotten	Wilkerson, Podoluk, Ancalle
Dalbotten, NCED PI Wilkerson, NCED grad students Podoluk and Ancalle attended the GEM Consortium National Conference. GEM partners with NCED to recruit and retain diverse graduate students.			
July 2006	SMM	Dalbotten	Division of Indian Works summer participants (K-6)
Students in the summer program for the Division of Indian Works visit the Big Backyard at the Science Museum of Minnesota and are hosted by the YSB BBY Park Crew.			
July 2006	Fond du Lac Tribal and Community College, Cloquet, Mn	Pellerin and Greensky	27 students; 7 teachers, 2 pre-service teacher,12 partner scientist, 10 mentors, and 3 elders
Ten days of a residential experiential science experience at the college housing facility. We ran several classes per day including a visit to the Science Museum of Mn classes on computer animation, plot sampling on the Fond du Lac Reservation, geo-caching, journaling and writing, where underrepresented students in grades 4-8 explore science in their local area.			
July 2006	Fond du Lac Reservation	Dalbotten/Pellerin	Diana Dalbotten, Diversity Director, NCED; Rick Hooper; Executive Director CUAHSI, on NCED Advisory Board; Vern Zacher; K12 American Indian Education Director, Cloquet Schools; Ferd Martineau, Secretary/Treasurer, Fond du Lac Reservation; Betty Martineau; Lowana Greensky; K-12 American Indian Education Director, St. Louis County Schools and gidakiimanaaniwigamig program staff; Margaret King, Fond du Lac Tribal and Community College Student Advisor; Holly Pellerin, gidakiimanaaniwigamig
NCED advisory board member, Rick Hooper, CUAHSI and Diana Dalbotten, NCED Diversity Director, met with Fond du Lac tribal board members to discuss NCED's gidakiimanaaniwigimig program and ways the reservation could partner with us to support our efforts.			
July 2006	Hastings, MN	Horth, Jazdzewski	ESTREAM teacher, grad student, USIP interns, BBY YSC participants
Emily Horth, NCED ESTREAM teacher and Jeremiah Jadzewski, SAFL grad student, led a field trip to the Vermillion River to demonstrate river field research to NCED undergrad summer interns and high-school students working in the SMM Big Backyard.			
August 2006	U of MN TC	Santiago	
NCED Undergraduate Summer Intern Angel Santiago becomes a first time father with birth of his son, Angel Jr., home in Puerto Rico, while Angel continues his research at SAFL.			

Diversity Activity Table			
Date	Location	Led By	Attendees
Description of activity			
August 2006	FDLTCC	Dalbotten/Pellerin	Meeting with Sam Moore to meet with Mick Gillespie Fond du Lac Tribal and Community College
NCED diversity staff met with UMN Institute of Technology APEXES Director and FDLTCC faculty to discuss development of pre-engineering program at Fond du Lac and the University of Mn IT support of pilot undergrad students program. This supports the mission of NCED of bringing more FDLTCC students into science and engineering careers.			
August 2006	Las Vegas, NV	Pellerin	Pellerin and Patricia Petite, Chairman, Fond du Lac Reservation
Holly Pellerin, Program Director, gidakiimanaaniwigimag and Patricia Petite, Chairman, Fond du Lac Reservation, attend the American Competitive Initiative Strengthening Math and Science Education Technical Service Workshop sponsored by NSF and other government agencies.			
September 2006	U of MN	Dalbotten	STC Education and Diversity Directors
Dalbotten coordinated and led sessions on Diversity at STC Director's Meeting.			
September 2006	FDLTCC	Dalbotten/Pellerin	Alyssa Burger and Will Durfee, Center for Compact and Efficient Fluid Power Mick Gillespie, Ted Weatherby, Fond du Lac Tribal and Community College
Meeting with new center at Univ of Minnesota, NCED staff, and Fond du Lac Tribal and Community College Faculty to discuss development of pre-engineering program at Fond du Lac and the University of Mn IT support of pilot undergrad students program.			
September 2006	FDLTCC	Dalbotten/Pellerin	Aurelia DeNasha, Clint Northrup, Julia Lone
Three NCED gidakiimanaaniwigamig participants begin taking courses as undergraduates at the Fond du Lac Tribal and Community College—Aurelia DeNasha as a PSEO student (high school student taking courses for college credit). Northrup and Lone graduated high school early and are now FDLTCC undergraduates.			
October 2006	Columbus, OH	Dalbotten	graduate school diversity personnel
Dalbotten attended CIC conference on Recruiting and Retention of Diverse Graduate Students to represent University of Minnesota and NCED in developing best practices.			
October 2006	Tampa, FL	Dalbotten	Dalbotten and other STC education and diversity representatives
Dalbotten and other STC diversity and education representatives led a session at the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) National Conference entitled "New Approaches, Techniques and Tools for Understanding the Environment. The STC's also shared a booth for recruiting undergraduate and graduate schools in the SACNAS Research Fair.			
October 2006	Detroit, MI	Greensky	Lowana Greensky
Dalbotten, Pellerin, Greensky, and Bellcourt led a session at the Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) National Conference entitled "Setting Up and Running Native American Math and Science Camps."			
October 2006	Detroit, MI	Greensky	Lowana Greensky
Lowana Greensky participates in a workshop on curriculum development for Native American students at the American Indian Science and Engineering Society (AISES) National Conference.			
October 2006	Detroit, MI	Dalbotten	Aurelia DeNasha
NCED gidakiimanaaniwigamig participant Aurelia DeNasha, whose research has been advised by NCED PI Andrew Wold, is recognized at the 2006 American Indian Science and Engineering Society (AISES) National Conference for her participation in the 2006/2007 Intel International Science Science and Engineering Fair.			
Oct 2006	SAFL	Dalbotten	Assefa Melessea
As part of the Faculty-to-Faculty Program, Assefa Melessea visited the St. Anthony Falls Laboratory, met with NCED PI's, Post-Docs, and Graduate Students, and gave an NCED videoconference.			

Diversity Activity Table			
Date	Location	Led By	Attendees
Description of activity			
October 2006	Forestry Center, Cloquet, Mn	Pellerin and Greensky	29 students, 6 teachers, 2 pre-service teachers, 2 elders and 8 mentors
A three day experiential science experience for area students, theme was eskers, content areas covered were glaciers, rock identification. Abstract math thinking, journaling, and public presentation of their research.			
November 2006	FDLTCC	Dalbotten/Pellerin	Fred Norwood, Southwestern Polytechnic Institute; Mick Gillespie, Fond du Lac Tribal and Community College
Meeting to discuss development of pre-engineering program at Fond du Lac and the Southwestern Polytechnic Institute and faculty from the Fond du Lac Tribal and Community College.			
November 2006	SAFL	Dalbotten	Judy Haschenburger
As part of the Faculty-to-Faculty Program, Judy Haschenburger visited the St. Anthony Falls Laboratory, met with NCED PI's, Post-Docs, and Graduate Students, and gave an NCED videoconference.			
January 2007	SMM	Campbell	Science educators from SMM, NCED and others
Dalbotten participated in AAAS Atlas of Science Literacy workshop to learn to apply AAAS standards in our Native Youths Science Immersion programs.			
January 2007	Univ of New Orleans	Dalbotten	Mark Kulp, Denise Reed
Dalbotten visited the University of New Orleans to speak with Dept of Earth and Environmental Sciences faculty about NCED's Faculty-to-Faculty program and opportunities for students and researchers from UNO to participate in NCED research.			
January 2007	University of Louisiana, Lafayette	Dalbotten	Emad Habib
Dalbotten visited the University of Louisiana, Lafayette to speak with Emad Habib, Dept of Civil Engineering, about NCED's Faculty-to-Faculty program and opportunities for students and researchers from UL to participate in NCED research.			
February 2007	San Francisco, CA	Dalbotten	STC Education and Diversity Directors
Dalbotten joined others from NSF STC's on a panel on Identifying Pathways for Underrepresented Students in Science and Engineering at the AAAS Annual Meeting. Dalbotten spoke on NCED's Faculty-to-Faculty Program.			
February 2007	Fond du Lac Tribal and Community College	Pellerin	65 students; area middle schools and teachers; various NCED staff and other scientists and community leaders served as judges;
The Third Annual Regional Science Fair sponsored by the Fond du lac Tribal and Community College, 16 projects were selected to attend the National American Indian Science and Engineering Fair.			
February 2007	Forestry Center, Cloquet, Minnesota	Pellerin and Greensky	28 students; 3 mentors, 1 pre-service teacher, 5 teachers, 2 elders, partner scientists 6
A three day seasonal experiential science educational experience where underrepresented students in grades 4-8 explore science in their local area. With the assistance of UMN, Limnological Research Center and Fond du Lac Dept. of Natural Resources students were able to core two lakes: one that grows wild rice and one that does not. They examined the core samples and documented their learning. All camp activities pertained to the coring the Earth.			
March 2007	UMN	Dalbotten/Campbell	UMN IT faculty and staff interested in diversity, education, and outreach
Dalbotten and Campbell organizers for a committee in the Institute of Technology, University of Minnesota, of staff and faculty interested in Education, Diversity, and Outreach.			
March 2007	U of MN	Dalbotten	Kimberly Hill, Cailin Orr, Chris Ellis

Diversity Activity Table			
Date	Location	Led By	Attendees
Description of activity			
NCED participants Kimberly Hill, Cailin Orr, and Chris Ellis demonstrated NCED's dam removal model at the IT Center for Educational Program's Fun Fair, demonstrating hands-on science to local families.			
March 2007	Albuquerque, New Mexico	Dalbotten/Pellerin	16 students, 3 NCED Staff, 4 teachers,
Students attended the American Indian Science and Engineering Sciety (AISES) National American Indian Science and Egineering Fair. In their disciplinary categories gidaakiimaniwiigamig students were awarded four 1st place medals (Elizabeth Rilea, Biochemistry; Dominic Johnson-Fuller, Medicine and Health; Cori Sullivan, Biochemistry; Christopher Johnson-Fuller, Medicine and Health), four 2nd place medals (Charlie Nahgahnub, Botany; Jeremy Ammesmaki, Engineering; Corey McCloskey, Zoology; Jamie Bluebird, Physics), and four 3rd place medals (Brittany Bird, Behavioral and Social Sciences; Valerie Ross, Chemistry; SaShawna Lone, Behavioral and Social Sciences; Aliza Gingras, Medicine and Health); students also won eight special awards: two IBM Innovations (Jeremy Amesmaki and Samantha Ledeaux); a Women in Science Award (Valerie Ross); and five Math Awards.			

Appendix N: Acronyms

Key to acronyms and abbreviations used in this report:

1D	one dimensional
2D	two dimensional
3D	three dimensional
4D	four dimensional
AAAS	American Association for the Advancement of Science
AAPG	American Association of Petroleum Geologists
ACRR	Angelo Coast Range Reserve (NCED field site)
ADV	Acoustic Doppler Velocimeter
AGEP	Alliances for Graduate Education and the Professoriate
AGU	American Geophysical Union
AISES	American Indian Science and Engineering Society
ALSM	Airborne Laser Swath Mapping
AMNH	American Museum of Natural History (New York)
ANAMS	*ando-giikendaasowin* Native American Math and Science Camps
ASCE	American Society of Civil Engineers
ASTC	Association of Science and Technology Centers
AWG	Association for Women Geoscientists
BACI	before, after, control, impact
BBY	Big Back Yard (Science Museum of Minnesota)
BRIC	Bedload Research International Consortium
CALFED	25 state and federal agencies working cooperatively to improve the quality and reliability of California's water supplies while restoring the Bay-Delta ecosystem
CENS	Center for Embedded Network Sensing (NSF STC)
CERC	Columbia Environmental Research Center (USGS research facility located in Columbia, MO)
CERP	Comprehensive Everglades Adaptive Management Program
CFD	Computational Fluid Dynamics
CFE	Center for Future Earth (Science Museum of Minnesota)
CFS	cubic feet per second
CLEANER	Collaborative Large-scale Engineering Analysis Network for Environmental Research (NSF)
CLEAR	Coastal Louisiana Ecosystem Assessment and Restoration
CME	Coastal & Marine Environments
CNSF	Coalition for National Science Funding
CPOM	Coarse Particulate Organic Matter
CRN	Cosmogenic Radionuclide
CREST	Centers of Research Excellence in Science and Technology
CSC	College of St. Catherine
CSDMS	Community Surface Dynamics Modeling System
CSIRO	Commonwealth Scientific and Industrial Research Organisation (in Australia)
CUAHSI	Consortium of Universities for Advancement of Hydrologic Science Inc.

CUNY	City University New York
CV	coefficient of variation
CZEN	Critical Zone Exploration Network
CZO	Critical Zone Observatories
DEM	Digital Elevation Model
DLESE	Digital Library for Earth System Education
DNR	Department of Natural Resources
DO	dissolved oxygen
DRB	Director's Review Board
DSL	Digital Subscriber Line (internet access method)
DW	Desktop Watersheds
DW IP	Desktop Watersheds Integrated Project
DWPG	Desktop Watersheds Partners Group
EAB	External Advisory Board (NCED)
ECCOMAS	European Community on Computational Methods in Applied Science
EGS	European Geological Society
ENSO	El Niño/Southern Oscillation
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center (U.S. Army Corps of Engineers)
ESA	Ecological Society of America
ESR	Earthscapes School Residency (SMM): previously referred to as School Contact Program
ESTREAM	Earth Science Teacher Researchers Exploring Active Modeling
ETI	Earthscapes Teacher Institute (SMM)
EUG	European Union of Geosciences
EVL	Electronic Visualization Laboratory (Univeristy of Illinois, Chicago)
EWRI	Environmental & Water Resources Institute (ASCE)
F2F	Faculty to Faculty Program
FDLTCC	Fond du Lac Tribal and Community College
FPOM	Fine Particulate Organic Matter
GCMRC	Grand Canyon Monitoring and Research Center
GEM	National Consoritum for Graduate Degrees for Minorities in Engineering and Science
GIS	Geographic Information Systems
GLOBE	Global Learning and Observations to Benefit the Environment
GMA	Graduate Museum Assistant (NCED)
GPM	Global Precipitaion (satellite) Mission (a new NASA mission)
GSA	Geological Society of America
GSC	(NCED) Graduate Student Council
HACU	Hispanic Association of Colleges and Universities
HD	high definition (in video)
HEC-RAS	Hydrologic Engineering Centers River Analysis System (see also USACE)
HG	Hydraulic Geometry
H/L	Hispanic/Latino

HSC	Headwaters Science Center
IAS	International Association of Sedimentologists
IBSMW	International Bedload Surrogates Monitoring Workshop
ICG	International Center for Geohazards
IGERT	Integrative Graduate Education and Research Traineeship
INSTAAR	Institute of Arctic and Alpine Research
IP	Integrated Project (within NCED)
IREP	International Research Experience Program
ISE	Informal Science Education (NSF)
ISEF	Intel International Science and Engineering Fair
iSURF	inverse surface-based transport calculations (an NCED SR Toolbox tool)
IUH	instantaneous unit hydrograph
JHU	Johns Hopkins University
KT	Knowledge Transfer
LBNL	Lawrence Berkeley National Laboratory
LES	Large Eddy Simulation
LIDAR	LIght Detection And Ranging (an optical remote sensing technology)
LPM	long-profile model
LSAMP	Louis Stokes Alliances for Minority Participation (NSF HRD)
LS LAMP	Louis Stokes Louisiana Alliance for Minority Participation
LTER	Long Term Ecological Research
MAST	Multi-Axial Subassemblage Testing
MD-SWMS	USGS's Multidimensional Surface-Water Modeling System
MF	Multifractal
MIT	Massachusetts Institute of Technology
MNP	Maltby Nature Preserve (now "Science Center at the Maltby Nature reserve")
MRSEC	The University of Minnesota Materials Research Science and Engineering Center
MSI	Minority-Serving Institution
MST	Minimal Spanning Tree
MYRES	Meeting of Young Researchers in Earth Science
NABS	North American Benthological Society
NAGT	National Association of Geoscience Teachers
NAISEF	National American Indian Science and Engineering Fair
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCALM	NSF supported Natioanl Center for Airborne Laser Mapping
NCED	National Center for Earth-surface Dynamics
NCEAS	National Center for Ecological Analysis and Synthesis
NDS	Nutrient Diffusing Substrate
NEES	Network for Earthquake Engineering Simulation
NEMO	Nonpoint Education for Municipal Officials
NIWA	National Institute of Water and Atmospheric Research, New Zealand

NOAA	National Oceanic and Atmospheric Administration
NPR	National Public Radio
NRC	National Research Council
NRCEN	National Science Foundation Research Center Educators Network
NRCS	Natural Resources Conservation Service
NDCSMC	National Design, Construction, and Soil Mechanics Center
NRRSS	National River Restoration Science Synthesis
NSBE	National Society of Black Engineers
NSF	National Science Foundation
OCN	Optimal Channel Networks
OLERR	Outdoor Laboratory for Ecogeomorphology and River Restoration
ONR	Office of Naval Research
OSL	Outdoor StreamLab
PAR	photosynthetically active (solar) radiation
PDE	partial differential equation
PDF	Probability Density Function
PGE	Portland General Electric
PI	Principal Investigator
PIV	particle image velocimetry
PR	Puerto Rico or Puerto Rican
QEM	Quality Education for Minorities
R2	R2 Resource Consultants
REU	(NSF funded) Research Experience for Undergraduates
RFID	Radio Frequency Identification
RFS	Richmond Field Station (University of California, Berkeley)
RCW	River Corridor Width
SA	Subsurface Architecture
SACNAS	Society for the Advancement of Chicanos and Native Americans in Science
SAFL	St. Anthony Falls Laboratory
SAHRA	Sustainability of Semi-Arid Hydrology and Riparian Areas (NSF STC)
SA IP	Subsurface Architecture Integrated Project
SAPG	Subsurface Architecture Partners Group
SCP	School Contact Program (SMM): now referred to as ESR
SEG	Society of Exploration Geophysicists
SEPM	Society for Sedimentary Geology
SERC	Science Education Resource Center
SHIRAZ	a computer model developed at the University of Washington to incorporate fish habitate relationships into conservation planning. Part of the Puget Sound Regional Synthesis Model.
SHPE	Society of Hispanic Professional Engineers
SIP	Strategic Implementation Plan
SMC	Seven Mile Creek
SMM	Science Museum of Minnesota

SOS	Sceince on a Sphere
SPD/AAS	Solar Physics Division - American Astronomical Society
SPM	Salmon Population Model
SR	Stream Restoration
SRES	Stream Restoration Certificate Program
SR IP	Stream Restoration Integrated Project
SRN	Stream Restoration Networker
SRPG	Stream Restoration Partners Group (NCED Partners)
SRSE	Stream Restoration Science and Engineering
SRTT	Stream Restoration Training Team
SRTWG	Stream Restoration Training Working Group
STC	Science and Technology Center
STEM	Science Technology Engineering Mathematics
SURGE	Support for Under-Represented Groups in Engineering Fellowship Program at the University of Illinois at Urbana-Champaign
TNC	The Nature Conservancy
TR2	Toutle River II
TRC	Teacher Resource Center (Science Museum of Minnesota)
TRRP	Trinity River Restoration Program
UC	University of California
UCB	University of California Berkeley
UF	University of Florida
UIUC	University of Illinois at Urbana-Champaign
UMN	University of Minnesota
UMNTC	University of Minnesota Twin Cities
UMN WRS	University of Minnesota Water Resources Science
USACE	U.S. Army Corps of Engineers (see also HEC-RAS)
USBR	U.S. Department of the Interior, Bureau of Reclamation
USDA	United States Department of Agriculture
USARS	United States Agricultural Research Service
USBR	United States Bureau of Reclamation
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USIP	Undergraduate Summer Internship Program
VOIP	Voice Over Internet Protocol (internet access method)
VP	(NCED) Visitor Program
WaterCAMPWS	The Center of Advanced Materials for the Purification of Water with Systems
WLD	Wax Lake Delta
WSL	Swiss Federal Institute for Forest, Snow and Landscape Research (“Wald, Schnee und Landschaft”)
XES	eXperimental EarthScapes facility (“Jurassic Tank”)
YSC	Youth Science Center (Science Museum of Minnesota)

Key to Sub-Projects:

Diversity (DV)

Project	Project Name
DV01	Faculty-to-Faculty: building durable connections to Minority-Serving Institutions
DV02	Direct recruiting of under-represented students to NCED graduate and postdoc program
DV03	Undergraduate Summer Internship Program
DV04	Gidakiimanaaniwigamig (Our Earth Lodge) and Ando-giikendaasowin (Seek To Know) science camp programs
DV05	Earthscapes in the SMM Youth Science Center (YSS)

Desktop Watersheds Integrated Project (DW)

Project	Project Name
DW01	Numerical techniques for feature extraction
DW02	Exploit topographic signatures to estimate properties of and processes in the environment
DW03	Predictive mapping of key biotic populations: relationships to habitats
DW04	Understand linkages among solutes, soil production, and biota
DW05	Controls on rate of landslide transport to channels
DW06	Sediment routing; coarse sediment transport in shallow flow; fine sediment interaction with coarse bed
DW07	Develop predictive models for channel incision
DW08	Upscaling transport laws and biotic processes
DW09	Link food webs and channel networks, including dynamic response
DW10	DW model code development
DW11	Use the Desktop Watershed models in landuse management decisions

Education (ED)

Project	Project Name
ED01	Bring surface dynamics to informal education with the Science Museum of Minnesota
ED02	Provide unique center-based experience for graduate students
ED03	Stream Restoration certificate program
ED04	NCED enhancements to undergraduate education
ED05	K-12 teacher development
ED06	Visualization tools to enhance Earth-science education

Knowledge Transfer (KT)

Project	Project Name
KT01	Desktop Watershed Partner Group
KT02	Make components of the Desktop Watershed available to practitioners and the public
KT03	Collaborative DW research with non-NCED researchers
KT04	NCED Stream Restoration Partner Group
KT05	Stream Restoration website
KT06	Stream Restoration Newsletter
KT07	Stream restoration “toolbox” containing useful numerical models, equations, and guidance for practitioners
KT08	Education and training programs in stream restoration

Project	Project Name
KT09	Establish regular communication between NCED and Subsurface Architecture Partner Group
KT10	Develop website content for Subsurface Architecture goals, current progress, and future direction
KT11	Conduct short courses and workshops

Subsurface Architecture Integrated Project (SA)

Project	Project Name
SA01	Current sediment budget and subsidence distribution in Mississippi Delta
SA02	Behavior and deposition of cohesive sediment
SA03	Vegetation-sedimentation interaction in island & marsh development & maintenance
SA04	Reconstructing delta dynamics from seismic records
SA05	Reconstructing delta dynamics from cores and other records
SA06	Modeling land buildling; integration with LSU CLEAR
SA07	Self-organization of distributary systems including elevation statistics
SA08	Upscaling short-term rates and small-scale geometries
SA09	Coastal system response to rising relative sea level
SA10	Social tradeoffs in Delta restoration

Stream Restoration Integrated Project (SR)

Project	Project Name
SR01	Channel geometry, including variability in space and time
SR02	Dynamics of mixed-size sediment
SR03	Channel-floodplain interaction
SR04	Design stream restoration projects to optimize net primary productivity
SR05	Define physical channel attributes and flows that control nutrient processing
SR06	Specify structure, inputs, and disturbance regime from species recovery
SR07	Develop improved sediment storage and sediment routing models
SR08	Sediment sourcing and yield
SR09	Stream restoration objectives, tradeoffs, and decision-making under uncertainty
SR10	Dam removal, dam management