National Center for Earth-surface Dynamics

2005 Annual Report

An NSF Science and Technology Center

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Key to acronyms and abbreviations used in this report:

AAPG	American Association of Petroleum Geologists
ACRR	Angelo Coast Range Reserve (NCED field site)
AFDM	Ash Free Dry Mass
AGEP	Alliances for Graduate Education and the Professoriate
AGU	American Geophysical Union
AISES	American Indian Science and Engineering Society
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
BBY	Big Back Yard (Science Museum of Minnesota)
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, Missouri)
CME	Coastal & Marine Environments
CPOM	Coarse Particulate Organic Matter
CRN	Cosmogenic Radionuclide
CSC	College of St. Catherine
CSDMS	Community Surface Dynamics Modeling System
CSIRO	Commonwealth Scientific and Industrial Research Organisation is (Australia)
CUAHSI	Consortium of Universities for Advancement of Hydrologic Science, Incorporated
CUNY	City University New York
CV	Coefficient of variation
DEM	Digital Elevation Model
DLESE	Digital Library for Earth System Education
DNR	Department of Natural Resources
EAB	External Advisory Board (NCED)
ECCOMAS	European Community on COmputational Methods in Applied Sciences
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)
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
EWRI	Environmental & Water Resources Institute (ASCE)
FDLTCC	Fond du Lac Tribal and Community College
FPOM	Fine Particulate Organic Matter
GEM	National Consoritum for Graduate Degrees for Minorities in Engineering and Science
GIS	Geographic Information Systems
GMA	Graduate Museum Assistant (NCED)

GSA	Geological Society of America
GSC	(NCED) Graduate Student Council
HACU	Hispanic Association of Colleges and Universities
HG	Hydraulic Geometry
H/L	Hispanic/Latino
IAS	International Association of Sedimentologists
IGERT	Integrative Graduate Education and Research Traineeship
INSTAAR	Institute of Arctic and Alpine Research
IP	Integrated Project (within NCED)
ISE	Informal Science Education (NSF)
JHU	Johns Hopkins University
KT	Knowledge Transfer
LBNL	Lawrence Berkeley National Laboratory
LES	Large Eddy Simulation
LIDAR	LIght Detection And Ranging
LSAMP	Louis Stokes Alliances for Minority Participation (NSF HRD)
LS LAMP	Louis Stokes Louisiana Alliance for Minority Participation
LTER	Long Term Ecological Research
MIT	Massachusetts Institute of Technology
MNP	Maltby Nature Preserve (now "Science Center at the Maltby Nature Preserve")
MSI	Minority-Serving Institution
MST	Minimal Spanning Tree
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 Center for Airborne Laser Mapping
NCED	National Center for Earth-surface Dynamics
NCHSS	National Center for Hydrologic Science
NDS	Nutrient Diffusing Substrate
NOAA	National Oceanic and Atmospheric Administration
NPR	National Public Radio
NRCEN	National Science Foundation Research Center Educators Network
NRCS NDCSMC	Natural Resources Conservation Service: 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
ONR	Office of Naval Research
PDF	Probability Density Function
PI	Principal Investigator
PR	Puerto Rico or Puerto Rican
QEM	Quality Education for Minorities
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)
SCP	School Contact Program (SMM): now referred to as ESR
SEG	Society of Exploration Geophysicists
SEPM	Society for Sedimentary Geology
SHPE	Society of Hispanic Professional Engineers
SIP	Strategic Implementation Plan
SMM	Science Museum of Minnesota
SPD/AAS	Solar Physics Division - American Astronomical Society
SRPG	Stream Restoration Partners Group (NCED Partners)
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
UCB	University of California Berkeley
UF	University of Florida
UMN or UofM	University of Minnesota
UMN WRS	Univeristy of Minnesota Water Resources Science
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
USIP	Undergraduate Summer Internship Program
VP	(NCED) Visitor Program
XES	eXperimental EarthScapes facility (“Jurassic Tank”)
YSC	Youth Science Center (Science Museum of Minnesota)

1. Cover sheet

Date submitted	May 1, 2005
Reporting period	April 1, 2004 through March 31, 2005
Name of the Center	National Center for Earth-surface Dynamics
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Role of Institution at Center	Research physical and social dynamics of stream restoration

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Role of Institution at Center	Research channel and floodplain dynamics

1b. New Faculty Biographical Information

Three new faculty (Ben Hobbs, Nicholas Flores, and Peter Wilcock) have joined NCED – their biographical data is in Appendix 1.

I. Context

This section is the Context document that links the results reported in the main body of this report to the Center's Strategic and Implementation Plan (SIP). Our SIP is currently being revised, and a major element of the revision is our decision to replace the Focus Questions with three Integrated Projects. We emphasize that this does not represent a change in focus, but a modified way of organizing our research that lends itself to the establishment of specific deliverables and timelines. Given this change, in the Research part of this Context section we present a detailed description of the modified research organization, and incorporate the Context information within it.

Research

NCED began operation with a broad research goal of transforming the science of the Earth's surface environment ("critical zone") by integrating disparate fields including Earth sciences, engineering, hydrology, ecology, and social sciences into a unified, predictive science of Earth-surface dynamics. Such a science would benefit society by providing new and better tools for environmental forecasting, decision-making, and planning; for stream and landscape restoration; and for resource development and management. We group these benefits under the broad heading of *landscape sustainability*. During year 2 we focused our research program on channels and channel networks, the arterial system of the Earth's surface, and developed a set of Focus Questions to guide the research. This focusing effort provided the basis of our current Strategic and Implementation Plan. This year we have worked to improve our focus, better organize our research program, and sharpen our synthesis strategy. We summarize these changes here as an update, annotated with current research topics, to the current SIP.

Our first step was to organize our research around three large-scale research projects designed to show the power of our integrated, quantitative approach to Earth-surface dynamics. All of our research efforts support these three Integrated Projects (IPs). These IPs are not new - they evolved naturally out of center-wide projects described (as "Integrative Activities") in previous documents. The Integrated Projects represent 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.

A major advantage of organizing along Integrated Project lines is that they lend themselves easily to the establishment of goal sets and work clusters that are intermediate in scale between the center's overall mission and individual research projects. The Integrated Projects therefore replace the Focus Questions as the crucial link in maintaining a clear "line of sight" between day-to-day research activities and the center's overall mission. The IPs complement but do not replace the research Focus Areas. The Focus Areas group PIs synergistically by primary interest. The Integrated Projects ensure that the Focus Areas work toward common and specific goals. The relation between Integrated Projects and Focus Areas can be represented via the following matrix (see next page - italicized text represents well-developed connections, plain-text, developing connections):

We are currently in the process of organizing, defining deliverables and providing milestones for, the Integrated Projects: project lists have been drafted, and milestones and timetables will be ready by early summer. In the next sections we present an outline of the three Integrated Projects and an update of our current strategy for research synthesis, annotated with references to current research described in detail in the main body of the Annual Report.

		Integrated projects		
Research Focus Areas		**Desktop Watershed**	**Stream restoration**	**Subsurface architecture**
	Channel Network Dynamics & Scaling	*Network controls on local channel and ecosystem properties*	*Network controls on local channel and ecosystem properties; prediction of fluxes at network scale*	*Application of statistical approaches from terrestrial tributary networks to distributary networks and submarine tributary networks*
	Channel & Floodplain Dynamics	*Hydraulic controls on local channel and floodplain geometry; bedrock & debris flow erosion; sediment flux; channel-floodplain coupling*	*Hydraulic controls on local channel and floodplain geometry; bank stabilization; sediment flux; channel-floodplain coupling*	*Hydraulic controls on channel geometry and sediment flux; channel - floodplain interaction (fluvial and submarine); comparative fluvial-submarine channel dynamics*
	Advanced Mathematical and Observational Methods	*Moving-boundary, upscaling, and adaptive grid methods; image analysis*	*Moving-boundary and upscaling methods; image analysis*	*Moving-boundary methods; parameterization & upscaling methods for long-term fluxes*
		Biological- physical interactions in channels, floodplains,& adjoining hillslopes	*Predictive understanding of ecosystem structure and function*	Biological controls on channel geometry, floodplain dynamics; preserved biologic indicators
	Long-term Dynamics	Long-term and geologic context for present system state; frequency of rare events, long-term evolutionary trends, reach- and network- averaged flux modeling	Long-term and geologic context for present system state; frequency of rare events, long-term evolutionary trends, reach- and network- averaged flux modeling	*Time-averaged depositional channel system models*
	Human Dynamics	Human-behavior 'overlay' on Desktop Watershed model	*Multi-objective tradeoffs, optimal multi-criterion decision-making in stream restoration*	[for future development: social dimensions of resource development and use]

Desktop Watershed Integrated Project

Goal: Develop process-based models using digital topographic and surface attributes (such as geology, vegetation, and landuse) to predict the linkages between terrain, land use and ecosystem function in order to dramatically improve landscape management and decision-making, and provide a basis for forecasting the impact of environmental changes (e.g., climate change) on landscapes and their associated ecosystems.

Rationale: The Desktop Watershed project combines highly resolved topography, spatially-referenced information on material and biological properties, and simple mechanistic models to reach its goal of being able to predict linkages between land use and ecosystem function. Desktop Watersheds can be used to guide local channel restoration decisions, to inform management decisions at the watershed scale, and to predict environmental response to imposed climatic and other changes.

There is no standard method for developing useful real-world models of complex, spatially-extended environmental systems. The Desktop Watershed approach is an adaptive hybrid of techniques ranging from first-principles theoretical models to thoughtful inductive summaries of observed dynamics. While our approach is intended to be flexible and generalizable, to prove the concept we need to apply it to a specific place. This place is the Angelo Coast Range Reserve (ACRR), a site we chose as a field focus for our research last year. Our strategy for developing our Desktop Watershed model comprises three main steps:

1. Develop hypotheses for predicting expected resource properties from topography. We refer to the predicted landscape properties, such as landslide location, river bed grain size, abundance of wood in channel, and stream temperature, as the ***analytical reference state***.
2. Extrapolate site-specific information to entire watersheds. Field observations usually rely on a limited number of sample points at locations where access is possible in a watershed. The analytical reference state will allow field researchers to identify key sample locations, and by spatially registering these observations and relating these properties to topographic controls (and perhaps other features), generalize the observations to the entire watershed.
3. Develop dynamic algorithms, including linkages between land use and reference state, that allow the reference state to evolve in time. This will allow the Desktop Watershed to predict the effects of forest clearing on runoff magnitude; predict sediment production and routing through channel network; and predict fish population response to land use change.

Executing each of these steps requires a sophisticated, integrated understanding of the relationships coupling the spatial structure of the watershed, hill slope - channel interactions, and local physical and biologic processes. At present we are working mainly on the first step in this sequence. Some parallel work is beginning on Step 2. Step 3 is in the stage of assessment of the current state of knowledge and strategic planning.

Stream RestorationIntegrated Project

Goal: Advance the science and policy basis for stream restoration by coordinating and conducting critical research, by working with agencies and practitioners to address knowledge gaps and develop improved tools, and by disseminating this knowledge to practitioners, all in order to enable effective, sustainable restoration projects and avoid costly mistakes.

Rationale: Our coordinated efforts in stream restoration are motivated by the collision of a huge societal demand for restoration projects with a limited understanding of stream disturbance and restoration dynamics. This has led to a situation where annual expenditures for restoration projects in the US exceed $1 billion per year (this figure *excludes* large regional projects), even though it is widely acknowledged that the science and policy bases for this work are weak, and historically these projects have a poorly measured but clearly mixed record of success. NCED is well placed to make a major positive impact on the practice of stream restoration. A number of the activities we've undertaken – establishing a stream restoration partners group, developing a web-based community center, coordinating and developing training courses and materials, coordinating and performing interdisciplinary research– would be unlikely to happen outside of a large Center with an interdisciplinary research focus, a commitment to the practical application of that research, and stable funding. With the recent addition of Wilcock, Flores, and Hobbs to the PI list, NCED brings together a combination of expertise in biological, physical and socials sciences with a research focus spanning the space and time scales needed to understand stream disturbance. Many of the projects listed below would not have developed without NCED funding and depend in essential ways on collaboration among NCED PIs.

Strategy: Our Stream Restoration strategy comprises the following major elements. We are working currently on items 1-3, and expect to begin work on 4 shortly. Items 5 and 6 are for longer-range development, in that they require results from ongoing work on the Desktop Watershed and stochastic geomorphology:

1. Combine physical, biological, and social sciences to comprehensively address stream restoration issues. Better restoration science requires an integration of physical and biological methods and understanding; better identification of restoration priorities and implementation of restoration plans require incorporating economic and decision sciences into the research and method development. It has been repeatedly emphasized that institutional and social obstacles are often as important as knowledge barriers as impediments to effective restoration practice.
2. Collaborate with other researchers within and outside of NCED in order to address the wide range of science needs for restoration in a coordinated fashion. These collaborations include the NCED Stream Restoration Partners group, which includes agency, consulting, and academic partners; allied organizations working on restoration topics including CUAHSI, SAHRA, NRRSS, and the NAS; and a large experimental project funded by CALFED (Dietrich is a PI on that project and Parker and Wilcock serve on its Scientific Advisory Panel). Based largely on interactions with the NCED Stream Restoration partners' group, priority research areas include: steady-state channel geometry; social drivers and decision-making in restoration projects; flux laws for sand and sediment mixtures (especially on reach scales); flow-sediment-biota interactions; stream evolution following dam removal; and channel-vegetation interactions including stream-bank bioengineering.
3. Explicitly link restoration practice, research, methods, and training. A persistent issue in stream restoration is that 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. We strongly believe that stream restoration practice will not be improved without developing improved training and providing broad distribution of methods and models within an organized, open-source framework. Our knowledge transfer program includes a number of efforts designed to meet these needs, including the creation of a stream restoration toolbox of practical open-source algorithms and tutorials, the design of graduate training and short courses, and the coordination of existing training materials and programs. Carrying out this work in the center mode allows for close connection between training materials and new research findings.
4. Make better use of the many existing restoration "experiments" by developing tools to allow for more frequent and more effective evaluations of existing projects. These tools will focus in particular on better defining linkages between geomorphic design and ecological outcomes. A national survey of stream restoration projects (NRRSS) has been completed by a collaborative team led by Margaret Palmer (University of Maryland) and Emily Bernhardt (Duke University) We are working with these investigators to develop the next phase of this work, in which a team of ecologists, geomorphologists, and social scientists will investigate, in detail, restoration project performance to learn general lessons and examine the effect of restoration actions on the ecological function of the stream and riparian zone.
5. Develop techniques to place restoration actions in the larger spatial and temporal context of the watershed.
6. Understand and incorporate uncertainty, both in terms of scientific uncertainty and stochastic processes in the environment, in restoration practice.

Subsurface Architecture

Goal: Couple our understanding of channel dynamics with long-term variation in tectonics, climate, and sea level in depositional systems to predict the geometry and connectivity of subsurface fluid conduits and reservoirs that provide oil, gas, and water for society.

Rationale: The Subsurface Architecture Project focuses on channel dynamics over planetary time scales: thousands of years and up. It is built around applications that involve understanding heterogeneity in sedimentary deposits, i.e., problems involving conduits and reservoirs for subsurface fluids like water and hydrocarbons. The deep-time view offers us a different perspective on channel dynamics than either of the two environmental projects, which are mainly focused on human time scales. Integration over long time scales brings tectonic, climatic, and sea-level controls on channel patterns into clear focus; reveals connections among different parts of the system that are obscured at short time scales; and makes rare events commonplace. In addition, the "deep time" record holds our only direct evidence of changes in the earth surface system tied to climate conditions substantially different than today. The Subsurface Project includes both fluvial and submarine channels, the latter both because of their fascinating similarity to fluvial channels and because they are extremely important but high-risk prospecting targets in the oil industry. The subsurface channel work also plugs NCED into the research core of the largest commercial surface-dynamics enterprise on Earth: the oil industry. Our contacts there include experts in topics ranging from analogies between fluvial and submarine meandering to carbon storage in floodplains to broad climatic effects on sediment supply and discharge variability. This industrial expertise is built on a base of data that academic researchers generally cannot access: a unique, global, time-integrated perspective on channel-system dynamics. Thus the industrial connection provides NCED with a number of benefits: new questions; new insights; an enormous inventory of data including global compilations of modern process data; a pragmatic, market-driven (as opposed to regulation-driven) perspective on applied research; our only significant commercial source of leveraged research funding; and job and internship opportunities for our students.

Overall, our strategy for the Subsurface Architecture project comprises the following main steps, of which 1-3 are being done in parallel, to be followed by 4:

1. Test and refine existing hypotheses for how sedimentation rate, sea-level variation and other factors control the stacking of channels and related deposits in alluvial deposits. These models are now in transition from 2D to 3D, and use experimentation for model testing and refinement, supplemented by real-world data, primarily from the oil industry. This effort depends particularly on understanding physical and biological controls on channel pattern and morphology and channel-floodplain interaction and how these local processes are influenced by external forcing such as subsidence, sediment supply, and sea-level change.
2. Understand the comparative physics of terrestrial and submarine channels and channel networks. The goal here is to provide a means by which results from step 1 can be adapted to submarine systems to catalyze rapid progress in understanding and predicting subsurface characteristics of submarine channel deposits.
3. Adapt methods and insights from analysis of subaerial tributary channel networks to subaerial distributary networks (mainly deltas) and to submarine networks of both types. The goal again is to catalyze rapid progress in the depositional realms by injecting a set of methodologies that have revolutionized the study of terrestrial landscapes, revealing spatial structure and providing a predictive understanding of how the landscape is organized.
4. Develop a unified, predictive fluvial-submarine channel-architecture model that includes process-based understanding of channel geometry, the relative roles of critical common sedimentation elements (channels, lobes, floodplains), controls on channel shifting (gradual and abrupt), and external drivers such as sediment supply, subsidence, and sea level.

At present we are working in parallel on Steps 1-3. Steps 1 and 2 have been in progress since NCED's inception, and Step 3 began this year.

Synthesis Across Research Focus Areas

One of the main motivations for developing the three Integrated Projects was to promote integration across the six research Focus Areas (see the criteria listed above). Specific ways in which they serve this purpose are indicated by the matrix of connections between Focus Areas and projects shown in Table 1. This IP structure for our research is new this year, so this annual report is organized according to the system we had for most of the year. Nonetheless, each Focus Area section in the annual report includes discussion of how the research contributes to the three Integrated Projects. In the coming year, the IPs will be the main element in structuring our research; this will also be reflected in an updated Strategic and Implementation Plan to be completed early this summer.

NCED management maintains connection diagrams, inspired by the work of Diana Rhoten, that show the connections among NCED's researchers and thus its research Focus Areas. These diagrams are presented in the main body of this report. In the coming year, the three Integrated Projects will help strengthen and increase these connections.

Synergy Across Integrated Projects

As discussed earlier, the three Integrated Projects were chosen as the major application areas of NCED's core science: the dynamics of channels and channel networks. This common 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. As discussed below, some of these can be used to link education and research as well. The second general synthesis strategy is to insure that each IP can *incorporate and build on results* from the other IPs.

Common concepts and methods

This section presents an outline of major elements of NCED's common scientific core; applicable research themes from Focus Areas are in italics; Integrated Projects that make intensive use of each element are listed in braces [D=Desktop Watersheds. R=Stream restoration, A=Subsurface architecture].

1. Process analogies.

One of the most fascinating aspects of surface dynamics is the appearance of common morphologic elements and processes repeatedly over a wide range of scales and environments, and a key goal of NCED since its inception has been to exploit these analogies. These are not just superficial resemblances; in case after case, *the basic physics is the same*. Specific examples include:

1.1. **Tributary and distributary networks.** River channel networks represent one of the most common self-organized patterns on the Earth's surface. (These networks also show strong self-similarity and so appear below under Channel Network Dynamics and Scaling.) The most common terrestrial type is the tree-like tributary network visible on eroding landscapes. One of the major themes developing across IPs is the critical role of tributary network structure in setting a wide range of local conditions, from channel geometry and grain size to algal productivity and habitat quality. Current work on network structure and controls on local physical and ecologic conditions is reported under the Channel Network Dynamics and Scaling Focus Area (*Geomorphologic controls on the scaling of floods and hydrologic response; Hydrologic, geomorphologic and ecologic dynamics of vegetation along channel networks*) and the Ecogeomorphology Focus Area

(*Landscape controls on nutrient and carbon flux; Landscape controls on ecosystem processes; Landscape geomicrobiology*) Another major effort, reported under Channel Network Dynamics and Scaling (*Morphology and eco-hydrology of braided river systems and deltas*), is that involving Rodríguez-Iturbe and Paola, along with non-NCED colleagues, to investigate the spatial structure and scaling properties of deltaic (distributary) networks. [D, R, A]

1.2. **Meandering and braiding.** River channels show a variety of planforms of which two common ones are highly sinuous single meandering channels that migrate slowly and networks of highly interconnected (braided) channels that shift rapidly. The meandering pattern seems to have considerable public appeal: many stream restoration projects have created artificial meanders, in some cases in streams whose natural tendency was to braid. Better understanding of conditions that produce stable meandering would help avoid costly restoration mistakes; better understanding of braiding would help restore sand-bank habitat crucial to migratory birds. Within the last two decades, high-resolution sonar has revealed analogous channel patterns in the deep ocean and at present deposits from these systems present some of the most intensive targets for hydrocarbon exploration, with risks on the order of a hundred million dollars for a single deep-water well and potential payoffs well above that. Work on meandering is reported in the Channel and Floodplain Dynamics Focus Area (*Meandering*). Parker and Mohrig are developing plans for a comparison of subaerial and submarine meandering; work on braiding by Foufoula and Paola is reported under the Channel Network Dynamics and Scaling Focus Area (*Morphology and eco-hydrology of braided river systems and deltas*). [R, A]

1.3. **Valley evolution.** There is a close analogy between sediment transfer and morphologic evolution when a reservoir is drawn down and the response of continental margins to eustatic sea-level lowering. As a result, methods we are developing now for analyzing dam removal scenarios – which will be a key issue in stream restoration for the next several decades – draw on experiments and analytical tools (moving-boundary methods) initiated to study the stratigraphic signature of eustatic base-level cycles. In a joint effort, Parker (Channel and Floodplain Dynamics *Dam removal*), Paola (Long-term Dynamics *Fluvial response to changes in sea level, sediment supply, and tectonics*), and Cantelli (Synthesis postdoc) are developing a common valley-evolution model that will apply with minor modification to both cases. [R, A]

1.4. **Bedforms.** The bed roughness of sand-bed streams is typically set by self-organized transverse ridges of sand that migrate downstream. These features recur on scales from decimeters to hundreds of meters in environments from river bottoms to deep-sea submarine channels. Because of their dominant influence mediating sediment flow, their depositional products are also key indicators of flow regime and sediment flux in preserved channel deposits. Current work on this topic is being led by PIs Mohrig (Long-term Dynamics *Characterization and averaging of short-term fluctuations*) and Voller (Advanced Mathematical and Observational Methods *Moving boundaries*). [D, R, A]

1.5. **Scour-lobe couplets.** Recent work has shown the fundamental importance of local scours driven by flow narrowing and acceleration and their coupled depositional lobes driven by expansion and deceleration in localizing sediment transfer. Researchers at NCED partner ExxonMobil have hypothesized that the expansion is jet-like in nature and that as a result the associated lobe possesses a common, scale-independent geometry. Work by Paola's group (Long-term Dynamics *Characterization and averaging of short-term fluctuations*) has shown strong localization of deposition and erosion by these features, and joint work with industrial partners and PI Mohrig has established their relevance to submarine channel systems as well. [D, R, A]

1.6. **Cyclic steps.** Recent work by Parker (Channel and Floodplain Dynamics *Steep Landscapes and Mountain Rivers*) has shown that a variety of upstream-migrating morphologic features in environments from mountain rivers to the deep ocean are manifestations of a single fundamental instability in which flow cycles between subcritical and supercritical states. Where present, these features appear to dominate local sediment transport

and may be a primary morphometric control on the nutrient and ecological 'hot spots' that PIs Hondzo and Power (Ecogeomorphology) have recently identified at our ACRR field site. [D, R, A]

1.7. **Channel-floodplain interaction.** Most channels, from mountainous erosional settings to the deep ocean, develop some form of adjoining flats, which are often vegetated (in rivers) and/or trap fine sediments. Neither the scales nor the precise mechanisms by which these features develop are well understood at present. But it is a critical fundamental issue. In all types of channel systems, floodplain development plays a major role in constraining the overall channel pattern and influences the overall sediment budget through the trapping of fines, which in turn are often associated with organic carbon, nutrients, and contaminants. There is evidence that the onset of floodplain formation is revealed by a break in scaling properties of local channel and bankfull-flow geometry in river networks. NCED work on channel-floodplain interaction, including vegetation, is being done by Parker, Dietrich, and Wilkerson (Channel and Floodplain Dynamics *Channel-Floodplain Interaction*); Foufoula (Channel Network Dynamics and Scaling *Geomorphologic controls on the scaling of floods and hydrologic response*); and Paola (Long-term Dynamics *Fluvial response to changes in sea level, sediment supply, and tectonics*). [D, R, A]

1.8. **Abrupt channel changes.** It has been known for some time that channelized systems in all settings and environments are prone to abrupt changes in discharge and channel course. At least in some cases the shift can occur over a single flood. The mechanisms of shifting vary: in erosional settings the mechanism is stream capture, in which erosion through drainage divides leads to dramatic changes in drainage area and discharge. In depositional settings, major changes in the dominant flow pathway are known as avulsions, and are often governed by changes in channel elevation relative to the floodplain and other channels. It is now clear that avulsions occur in deep-marine channel systems as well though relatively less frequently. Previous work by Paola has investigated controls on avulsion frequency in fluvial channels; this work was applied to submarine channel dynamics by Mohrig as reported in last year's annual report. [D, R, A]

2. Network Dynamics and Scaling

Fractal geometry is the most common manifestation of scale invariance in nature. The original "type" example of a natural fractal was drawn from topography (the coastline of Great Britain, a contour line) so it is not surprising that fractality is ubiquitous in Earth-surface dynamics. Fractality and scaling provide a powerful set of tools for understanding both how the parts of landscapes relate to the whole system, and how small systems relate to large ones. Since Channel Network Dynamics and Scaling is a research Focus Area, current work on this is reported there; this year's results focus on scale controls on flooding, channel morphology, floodplain development, and vegetation, plus initial work on scaling relations in deltaic (distributary) systems. Specific applications of scaling methods across the three Integrated Projects include:

2.1. Extending information obtained from ground-based field measurements to the whole watershed via a scaling-based framework. [D, R, A]

2.2. Using scaling techniques to understand how network structure controls vegetation and local discharge and flooding. [D, R, A]

2.3. Application of scaling techniques developed for subaerial tributary channel networks to terrestrial distributary and submarine tributary and distributary networks, as discussed above. [D, A]

3. Biological-physical connections and the geomorphic signature of life.

How does the ubiquitous presence of life on and within the surface environment influence surface evolution? How does surface morphology in turn influence life and habitat? Recent NCED research has revealed how the morphologic structure provides a kind of template for the spatial structure of the ecosystem. The strong coupling

between biological and geomorphic processes appears as a theme in all three IPs. Current examples are reported under the Channel Network Dynamics and Scaling (*Hydrologic, geomorphologic and ecologic dynamics of vegetation along channel networks*); Channel and Floodplain Dynamics (*Channel-floodplain interaction; Bank stabilization and vegetation*); and Ecogeomorphology (*all*) Focus Areas. An especially noteworthy step this year is completion of a manuscript on the geomorphic signature of life led by Dietrich. Major cross-cutting themes include:

3.1. The strong control of drainage network structure on vegetation, metabolism, and even microbial ecology being revealed by NCED research at ACRR. [D, R]

3.2. The strong but still poorly understood influence of organisms, especially vegetation, on hillslope and channel bank stability, and floodplain evolution. [D, R, A]

3.3. The role of physical processes such as sediment movement and turbulence in controlling local algal and in-stream predator populations, with concomitant effects across the food web, revealed as localized "hot spots" and "hot moments" of productivity and population change. [D, R]

4. Statistical methods and uncertainty.

One of the hallmarks of a mature, quantitative science is the routine incorporation of uncertainty into research findings and applications. Estimation of uncertainty is still relatively rare in Earth-surface dynamics generally, and one of NCED's specific goals is to change that. Our expertise in uncertainty comes largely from stochastic hydrology. This year our main work on uncertainty involved study of stochastic aspects of stream braiding, reported under Channel Network Dynamics and Scaling(*Morphology and eco-hydrology of braided river systems and deltas*) and effects of stochastic erosion on sediment flux estimation using cosmogenic radionuclides reported under Long-term Dynamics (*Long-term sediment production and flux: mean and variability*) ; in addition, decision-making under uncertainty is a major focus of the new Human Dynamics Focus Area. Specific applications across the three IPs include:

4.1. Understanding the natural space-time variability of geomorphologic and hydrologic variables (such as meander sinuosity, channel morphometry, discharge and riparian vegetation) and using this information, understand the probability density functions (PDFs) of key local variables such as water discharge, and using this information to begin providing physically based constraints on uncertainty of outcomes for environmental forecasts and restoration projects. [D, R]

4.2. Application of statistical methods to understanding and predicting how natural variability in channel network properties, including rivers with high natural variability (such as braided rivers), changes as a function of scale and climatologic regime for transferability studies and increasing the reliability of predictions via regionalization. [D, R, A]

4.3. Understanding how natural channel variability is recorded in the stratigraphic record and how natural variability can be distinguished statistically from records of external events. [R, A]

4.4. Understanding how scientific uncertainty affects decision-making. [D, R, A]

5. Humans as geomorphic agents.

Recent research suggests that humans have become the main agent of geomorphic change in Earth today, in terms of total volumetric rate of material transfer. Human dynamics, including understanding of incentives, drivers, and decision-making, is thus an essential element in present-day surface dynamics. The home for NCED work on these topics is our new Human-dynamics Focus Area, but we expect this work to connect with research broadly across the center. Examples of human-dynamics issues that cross the IPs include:

5.1. Watershed-scale land-use decisions (e.g., clear-cutting, road construction, reforestation) that strongly influence natural processes like hillslope stability, sediment yield, and delivery of woody debris to streams [D, R]

5.2. Human priorities in esthetics, commercial, and recreational use of landscapes and rivers that affect decisions and ultimately the fate of these landscapes and their associated ecosystems. [D, R]

5.3. It now appears that the human influence on surface dynamics is not only large, but also long-term; through deforestation and farming, humans may have been a major factor in surface dynamics since the spread of agriculture some 8,000 years ago. This raises the possibility that the reference time for pre-anthropogenic conditions may be early enough to require application of deep-time methods for constraining variables such as sediment flux and stream geometry. [D, R, A]

6. *Mathematics of pattern formation and evolution.*

Channels and channel networks represent the most spatially significant instance of spontaneous pattern formation and self-organization on Earth. Thus it is not surprising that the ability to understand and model the formation and evolution of patterns in landscape systems is a common theme across the IPs. Work in this area for this year has focused on modeling front evolution, developing new equations for sedimentary interfaces, and on subgrid methods for nonlinear landscape systems. Current work is reported under the Advanced Mathematical and Observational Methods (*all*) and Long-term Dynamics (*Characterization and averaging of short-term fluctuations*) Focus Areas, but involves a broader group of PIs including Voller, Porté-Agel, Mohrig, Foufoula, Parker, and Paola. Examples include:

6.1 Numerical techniques for tracking moving boundaries in sediment transport systems including shoreline and sediment movement following dam removal. [D, R, A]

6.2. Development and application of surface evolution equations to model the evolution of landscape surfaces at all scales (bed forms through to watershed scale topography). [D, R, A]

6.3. Applications of turbulence analogies (in particular LES) to develop multi-scale surface evolution models. [D, R, A]

6.4. Development of appropriate reaction diffusion models aimed at predicting patterns in eco-geomorphic systems. [D, R]

Direct incorporation of results across IPs

The first two Integrated Projects (Desktop Watershed and Stream Restoration) address environmental management. The third, Subsurface Architecture, is oriented toward subsurface prediction and resources. The direct incorporation of results among the three projects comes in two flavors: results synergies between the first two (environmental) IPs, and then result synergies between the subsurface IP and the environmental IPs.

Part 1: Results Synergies Between Environmental IPs.

One of the long-term trends in stream restoration and management is an increasing realization that individual stream reaches, the typical targets for individual restoration projects, must be understood in the context of the basins that supply them with water, sediment, nutrients, organisms, etc. Present-day stream management represents a more holistic and environmentally informed approach than the “hard” engineering of the past. As stressed above, a major goal of our overall Stream Restoration strategy is to support this new understanding by developing tools and methodologies that place local management and restoration projects in a whole-basin context. Thus our strategy for synthesis between the first two projects is based on using watershed models to provide critical

context information for local restoration projects. Along the way, the Desktop Watershed project will provide a steady supply of tools for the Stream Restoration toolbox; eventually, watershed models may become 'tools' in themselves. In addition, as appropriate, outcomes of Stream Restoration studies (e.g., effects of woody debris on channel evolution and habitat) will be incorporated into the Desktop Watershed.

Tactics: Desktop Watershed ↔ Stream restoration:

1. Understand how location in the drainage network controls key local ecogeomorphic variables such as water and sediment discharge, channel geometry, stream temperature, nutrient dynamics (e.g., nitrate), suspended sediment, algal productivity, and populations of key organisms such as insects and fish. These variables are generally stochastic, so we work to constrain not only mean values but variability and, eventually, complete probability density functions.
2. Make prediction of restoration-critical local variables (e.g., fish populations, dissolved oxygen, sediment loading) a high priority in development of the Desktop Watershed model.
3. As part of our general study of how decisions are made about restoration projects, investigate how sites are chosen relative to the whole watershed, and the role of economic and other social factors in determining the scales of individual projects.
4. In collaboration with related efforts to investigate outcomes of restoration projects, determine how watershed-scale information could have been used to understand external controls on individual restoration projects and avoid failures.

Part 2: Direct Incorporation of Results Between the Subsurface Architecture and The Environmental IPs.

Since the stratigraphic record is in effect a time integration of short-term dynamics, it is easy to see how research on short-term processes supports long-term research. Reconstructing past system dynamics recorded in preserved deposits is based on understanding how modern systems work. So deep-time research is *based on* synthesis and integration of short-term processes, accounting for time averaging and the filtering effects of stratigraphic preservation. Specific examples include application of work on channel geometry, stream braiding, channel-floodplain interaction, valley evolution, sediment flux, and bedforms being done in the Stream Restoration IP; adaptation and application of scaling work being done in the Desktop Watershed IP; and application of Desktop Watershed models themselves to submarine channel networks.

The transferabilty of results from the Subsurface Architecture IP to the Environmental IPs is subtler but present. Sustainability, the heart of NCED's vision, involves understanding and working with long-term trends in managing the environment so as to minimize the need for human interference. In general, the response time of channel systems increases strongly with system size. As we consider whole systems rather than individual small reaches, slow processes like tectonic uplift and subsidence or sea-level change become important. Major aspects of river geometry, such as long profile, slope distribution, and avulsion frequency, are set by long-term balances between net erosion or deposition and tectonic uplift or subsidence, and by disequilibrium system response to changes in tectonics and other long-term influences like sea-level change. These system characteristics in turn control more local variables such as sediment flux and floodplain development that are important for short-term management problems. For instance, the current large-scale effort to restore coastal marshes in the Mississippi Delta and protect New Orleans from storms is necessitated by human alteration in the natural long-term balance between subsidence and sedimentation in the delta.

Similarly, Subsurface Architecture results can support environmental science by providing information on natural variability. On long time scales, the distinction between natural ("autogenic") variability and response to external forcing (e.g., sea-level rise) becomes clear. Stochastic events become frequent enough that their

statistical properties (probability distribution functions) can be measured. Rare, catastrophic events like major channel avulsions become commonplace so that their distribution in time and sensitivity to external forcing can be estimated.

Because it represents the integrated behavior of net-depositional environments, stratigraphic information is most relevant to environmental-management issues in depositional settings. For net-erosional systems, the stratigraphic record provides a time-integrated history of sediment yield, and thus can complement other techniques (e.g., cosmogenic radionuclides) for estimating the history and variability of long-term and especially pre-anthropogenic sediment yield.

Tactics: Subsurface architecture ↔ Desktop Watershed and Stream restoration

1. Continuously adapt results from short-term research (e.g., controls on channel geometry, floodplain-channel coupling, channel migration dynamics, bedform dynamics) to analyze long-term evolution, emphasizing advanced techniques for averaging and parameterizing nonlinear and highly localized short-term transport processes.
2. Adapt Desktop Watershed models to predict the spatial properties of submarine channel networks.
3. Use experience from the ACRR site to develop a second NCED field site in a depositional setting that is useful both for study of stratigraphic evolution and stream restoration science, e.g., a depositional restoration problem. A site in the Mississippi Delta is one possibility under consideration.
4. Use the archival properties of the stratigraphic record of preserved channel deposits to understand the statistics of natural (autogenic) variability and rare large transport events to help constrain the uncertainty of environmental forecasts. Use laboratory experiments to understand how autogenic effects are recorded and how they can be distinguished from externally driven events
5. Use the depositional record off the mouth of the Eel River, already investigated as part of the ONR STRATAFORM program, to provide information on long-term and pre-anthropogenic sediment flux from the Eel Basin, of which ACRR is a part.
6. Organize an NCED working group in *environmental stratigraphy* (applications of stratigraphy in environmental science and landscape management).
7. Work with environmental partners to understand how long-term context information (e.g., tectonic controls on river long profile and sediment budget; long-term trends in river evolution) can support stream restoration design and decision-making.
8. Work in partnership with the larger stratigraphic community to improve access to industrial high-resolution 3D seismic data. Existing datasets, gathered over many years at great cost, would give a much more complete picture of the behavior of channelized depositional systems through time. Indeed, broad access to high-resolution 3D seismic data could revitalize sedimentary geology in much the same way that high-resolution topographic data has revitalized geomorphology in the last 10-15 years. The combination of high-resolution surface topographic data (e.g., LIDAR) and subsurface seismic topographic data could be truly explosive in terms of catalyzing the development of surface-process science.
9. Use the community-forum model we are developing with NSF to energize and organize the sedimentary-geology community internationally to promote environmental stratigraphy.

Special Initiatives We have developed the three IPs to improve the integration of our research by focusing it on three interconnected large-scale projects that each have significant societal benefit. All mainline PI research must fit into this structure. To keep NCED vital and growing, however, we consider it important to continually probe

for new areas where our collective expertise in channel dynamics could be used to good effect. We do this via Special Initiatives. PIs who want to use NCED funds for a special initiative outside the project structure must make a request to the Director. At present we have two small but exciting and potentially high-impact initiatives; note that the Mars work is mainly funded from non-NCED (leverage) sources:

1. Channels on Mars. Application of our collective expertise on channel systems can help maximize benefit from the exciting new data coming from Mars. We have two Mars channel projects: one by Dietrich and Banfield to investigate the possibility that Martian channel heads may be optimal sites to explore for Martian life; and the other by Mohrig to estimate the minimum amount of time needed to construct a recently discovered channelized fan on Mars, to constrain the fan's implications for past climate.

2. Depositional floodplains and carbon storage. We have set up a working group to study the role of river floodplains in depositional settings in the carbon cycle, and in particular in removing it from the atmosphere. There is preliminary evidence that floodplain storage could be a significant carbon sink and that the carbon burial rate is influenced by climatic cycles such as ENSO and rare large events like river avulsion. The working group starts in June.

Conclusion: NCED's synthesis strategy is one of the things that distinguishes it from other cross-disciplinary environmental research centers (e.g., LTER sites or CUAHSI hydrologic observatories). These centers seek integration through place, assembling a multidisciplinary group to understand the dynamics of the hydro- or ecosystem in a particular geographic structure (e.g., a watershed). NCED's overall strategy is to focus instead on a *fundamental component* of the Earth-surface system – channel networks – that recurs in varying but fundamentally related forms across a wide range of environments and scales. Our synthesis strategy is analogous to that of a center that focuses on a particular technology (the science of channels and channel networks) but applies it to a wide range of problems (the deliverables from our three Integrated Projects). All NCED research is focused on channel systems, but we seek to apply our understanding of channel systems broadly, because studying a phenomenon in all its diverse manifestations is the only way to be sure of understanding it. We believe that our work has already shown how much channel systems have in common across environments, locations, disciplines, and scales. Fundamentally, it is this common research core that provides the main vehicle for synthesis of NCED research.

Education

There has been less refinement of the Strategic Plan for Education, Knowledge Transfer, and Diversity so these sections focus more on summarizing accomplishments this year than the Research section did. The only major refinement of our Education program from the current Strategic Plan has been to improve the connection between education and research by identifying "linking concepts and technologies" (discussed above in the Research section) that apply across Research and Education. Specific examples that we are currently developing to better integrate Research and Education include:

1. Landscapes as interconnected systems from source to sink, the basic theme of our Earthscapes outdoor science park and its companion Earthscapes programs for teachers and students;
2. 3D visualization as an aid to understanding;
3. Humans as geomorphic agents;
4. Life and surface dynamics, the Earth's surface as a "living skin";
5. Wireless environmental sensing; and
6. Spontaneous pattern formation.

Examples of these linking concepts and technologies in action are given below, and we will work to expand their application in the coming year.

Significant Year Three Education Accomplishments

In Year 3, we made substantial progress toward meeting **our first Education Goal**, ensuring that students at our institutions benefit from the unique educational opportunities presented by participating in a Science and Technology Center, through the following programs:

1. Graduate Museum Assistantships: We established this new program last year. Two NCED students completed successful assistantships at the Science Museum of Minnesota, teaching the SMM's Youth Science Center Park Crew Youth sufficient NCED science to help them devise activities that they in turn used to involve BBY visitors in our interactive outdoor science park. This experience was so successful that the YSC routinely models new programs around it. All six of the Education to Research linkages can be found in this very rich interaction.

2. Graduate Student Council: formed at our 2004 annual retreat, the GSC elected a slate of three officers in Year 3. These students serve as "connectors" between our multiple institutions, students and PIs. The Council developed and implemented several initiatives, including a web-based listing of NCED equipment available for use across institutions and an award program for student-initiated NCED travel.

3. Graduate Program in Applied River Restoration: PI Voller, working with an undergraduate assistant, Christina Omdahl, designed a framework for an integrative program in stream restoration. The program will begin as a certificate to be added to existing degree programs at Minnesota, developing over time into a degree program with online components for broader dissemination. This design benefited from input by our Environmental Partners at the 2005 Stream Restoration Partners Meeting, thus providing a link to Knowledge Transfer, as well as the clear link between this program and our two environmental PIs.

4. Additional value-added activities for NCED's internal students: (i) graduate students regularly attended and presented at weekly video-conferences.(ii) Multiple examples of collaborative work between NCED students, PIs and other stakeholders occurred, especially at the ACRR and in NCED's Stream Restoration and Subsurface Architecture activities. (iii) A new integrative graduate seminar, involving six NCED students from multiple departments, addressed universality in moving boundary problems; student projects addressed NCED research and application cases. (iv) our students were integrally involved in planning and delivering Partner meetings, short courses and NCED workshops, resulting in the placement of one NCED student in a Stratigraphic Partner internship and another in permanent employment with an NCED Partner. (v) We sponsored a pre-workshop for the NSF-sponsored "Preparing for an Academic Career" workshop in summer 2005. Two NCED students attended the entire workshop; they and NCED staff and collaborators planned and delivered the one-day pre-workshop to provide future faculty with inquiry-based laboratory activities and inspiration in finding ways to connect undergraduate students to cutting-edge research. (vi) Finally, in collaboration with the departments of Civil Engineering and Ecology, Evolution and Behavior, we proposed an NSF IGERT (Integrative Graduate Education and Research Traineeship) award on non-equilibrium dynamics across time and space scales. The project will prepare scientists across the interfaces of ecology, civil engineering and the earth sciences to develop a conceptual framework for understanding how physical, chemical, and biological processes integrate across spatial and temporal scales. This framework will provide the foundation to address many pressing environmental problems, including water and air pollution, habitat restoration, hazardous waste management, that are the applications of ecological or environmental engineering. Two NCED PIs, Paola and Hondzo, are PIs on the grant, which dramatically expands the scope of NCED's integrative philosophy across the University of Minnesota community. Since it is conceptually based upon NCED's mission, this proposed program exists because of

its strong ties to all three NCED PIs. We hope it will offer NCED a model to extend beyond the University of Minnesota.

Progress toward achieving our **second Education Goal –** improving the teaching of NCED science to K-16 students through research-education collaboration **–** included these accomplishments:

1. Undergraduate education: (i) Paola developed and taught a new U of M first-year seminar, "The Skin of the Earth", entirely based on NCED research topics. (ii) Foufoula and Rodríguez-Iturbe incorporated NCED themes into existing courses. These efforts connect to NCED research primarily through the "living skin", 3D visualization and spontaneous pattern formation linkages.

2. Materials for K-16 education in Earth-surface dynamics: This program has focused on the source to sink, 3D visualization and humans as geomorphic agents research linkages. Morin and Campbell, working with NCED's pre-service teacher interns, external colleagues and classroom teachers, developed, tested, and nationally promoted new course materials for K-16 teachers based on NCED's research visualizations; Morin's work on 3D visualization was recognized in the *New York Times* in March of this year.

3. Professional Development for Teachers: (i) Campbell and SMM staff delivered NCED's first field, laboratory and museum-based two-week Earthscapes Teacher Institute to 11 teachers who used their Institute experience to design new field- and lab-based learning experiences for their students. (ii) An integrative team of three Fond du Lac Ojibwe School science and mathematics teachers and two pre-service Earth Science teachers successfully completed ESTREAM internships, designing and documenting NCED-based activities and materials for NCED's website and (iv) Campbell, Marr and ESTREAM teacher Friesen worked with SMM and dam-removal researchers to develop a set of 7 dam-removal streamtables and accompanying visualizations and activities to be presented in SMM's K-12 School Contact program. SMM staff presented this "residency" activity (a staff member visits classrooms with the models and activities) to Earthscapes Teacher Institute teachers for suggestions, the program was tested in classrooms in late Year 3, and it will begin touring early in Year 4. As with our instructional materials, this program area links to research primarily through the source to sink, 3D visualization and humans as geomorphic agents linkages.

Some of our most exciting achievements in Year 3 advanced our **third Educational Goal,** to create unique and stimulating educational experiences, based on NCED science, for the general public, and communicate these via the national science museum community and included:

1. Earthscapes Big Back Yard (BBY): (i) We opened our 1.75-acre outdoor science park, Earthscapes exhibits and miniature golf in the SMM's BBY, to the public in June 2004. Over 53,000 people explored the Big Back Yard before it closed for the season on October 3, 2004. (ii) The park received extensive media coverage throughout the summer, including a full episode of the nationally-broadcast *DragonFly* children's science television program, filmed in the park and the field. (iii) NCED evaluator Mary McEathron and colleagues completed a formal summative evaluation of visitor experiences, using interviews and observations to track and evaluate the experiences of 323 individuals and 92 groups in the Park. (iv) SMM's Youth Science Center's Park Crew, trained by our GMAs in NCED-related science, then educated BBY visitors and delivered NCED-related activities at local community learning centers. As mentioned above, source to sink is the primary link between the BBY and NCED research, but aspects of the park address all six linkages.

2. Communicating NCED science via the national museum community: (i) NCED's 3D visualizations are gaining increasing attention. In Year 3, Morin designed an Earth-surface visualization for use by the Geological Society of America, which has been regularly requested for teaching purposes, in K-12 and undergraduate classrooms, as well as in museums. Additional visualizations are being developed for museums, including a large-scale 3D visualization to be installed in a new museum building at the University of Utah. (ii) Working with SMM staff,

Morin has designed a Summer 2005 program to prototype the use of GeoWall2 in a museum setting; part of a large-scale initiative to promote the use of 3D Earth-surface computer- and paper-based visualizations nationally. Clearly, this program has a strong link to Research through its use of 3D visualization.

Diversity

As with Education, there are no significant changes to our Diversity program from the current Strategic Plan. Again, we are working to improve connections to Research by using the linking concepts and technologies idea. Since our Diversity Program is primarily aimed at recruiting more diverse students, Diversity shares Education's linkages to Research.

Significant Year Three Diversity Accomplishments

Progress toward our **first Diversity Goal**, to increase the participation level in NCED by underrepresented groups until participation rates are proportional to the general U.S. population was made by:

1. Graduate and Professional Recruiting: (i) We presented minority student-faculty research at recruiting conferences and actively participated in STC-wide recruiting efforts. (ii) We have the first major successes of our minority recruiting strategy: one new minority graduate student and one new minority PI in Year 3, and as many as three underrepresented graduate students recruited to join NCED in Year 4. (iii) Six diverse students joined NCED for Undergraduate Summer Internships in Year 3, with one returning for additional undergraduate research in Summer 2005, before he joins us to begin graduate research in Year 5.

2. Faculty-to-faculty research partnerships: The first concrete steps to implementing our strategy of developing long-term ties to MSIs by supporting and mentoring junior faculty were made in Year 3. Two faculty members from MSIs began planning collaborative research with NCED PIs, with plans underway for joint research with these faculty and their students early in Year 4. In meeting our recruiting goals, we link Diversity programs to research; we seek to promote the aspects of NCED research that are most appealing to a broad number of potential students. Both environmental IPs show promise in this area, as does the concept of wireless environmental technologies.

In Year 3, we advanced our **second Diversity Goal**, to increase the matriculation of Native American students into environmental science higher education programs through:

1. gidakiimanaaniwigamig: (i) We realized our goal of a fully year-round camp by conducting 4 *gidakiimanaaniwigamig* (Our Earth Lodge) seasonal science immersion camp sessions in which 84 middle-school Native American youths and their teachers participated. (ii) The first annual NCED/FDLTCC sponsored American Indian Regional Science Fair for Native American K-12 students resulted in 12 students being chosen to represent NCED and FDLTCC at the AISES National American Indian Science and Engineering Fair in Albuquerque, NM, where they won 7 medals and earned 3 of 8 coveted spots to represent NAISEF at the Intel International Science Fair. One of these students will be a freshman at a university (hasn't chosen yet but has been accepted) this fall. (iii) NCED's Fond du Lac staff, Holly Pellerin and Lowana Greensky, received invitations to report on gidakiimanaanawigamig as keynote speakers at NRCEN 2005, the annual meeting of education staff of NSF sponsored centers. (iv) Building on our successful experiences with the Fond du Lac community, NCED launched an urban *gidakiimanaanawigamig* program in Minneapolis in Year 3.

2. ando-giikendaaswin: Our ando-giikendaaswin high school camp focused on Earth, water and wildlife continued; in Year 3, 15 Native American youth from around the country participated in the NCED track of this multi-year camp. As with our Earthscapes programs at SMM, source to sink is a unifying link to Research, but elements of all six research-education links are also present in our camp programs.

3. Undergraduate education: To ensure that more FCLTCC students are prepared to transition to graduate careers at NCED and other graduate programs in environmental sciences, we are collaborating with FDLTCC, Southwestern Indian Polytechnic Institute, and Itasca Community College to develop an Associate in Science degree in Civil Engineering at FDLTCC. FDLTCC is in the search process to hire a new faculty member to develop this program.

Knowledge Transfer

There are no changes to our Knowledge Transfer program from the current Strategic Plan. In this program area, linkages to Research are emerging rapidly and abundantly**.** All three IPs have strong applied research components. Our Subsurface Architecture IP benefits from a dynamic tradition of shared research, education and employment with our Stratigraphic Partners; this experience is invaluable in informing our emerging initiatives with Environmental Partners in the linked Environmental IPs. Year 3 also brought growing opportunities for our Graduate Students to interact with partners across all Knowledge Transfer programs.

Significant Year Three Knowledge Transfer accomplishments

In Year 3, we realized **our first Knowledge Transfer Goal**, to ensure that our research is informed by Partner needs by: (i) We hosted an Environmental Partners meeting focused on Stream Restoration at which 29 researchers from agencies and institutions outside NCED discussed shared applied research and training needs with NCED PIs and graduate students, developing a full and thoughtful agenda to inform our ongoing work in the Stream Restoration IP. (ii) We began a collaboration with the USFS to showcase USFS research in an experimental flume at the Smithsonian Folklife Festival in Washington DC, summer 2005. When the festival opens, we will bring a USFS research project inspired by the work of NCED graduate student Michal Tal to the up to 1 million visitors to the festival. (iii) In Year 3, our PIs and graduate students again designed and delivered our Annual Meeting and two shortcourses with Stratigraphic Partners. Three exciting new developments included completing a joint research experiment planned at the 2003 Annual meeting and securing an internship for one NCED graduate student and a job placement for a Year 3 graduate with our Stratigraphic Partners.

We made progress on our **second Knowledge Transfer Goal** by: (i) We added new features, data and content to our website and data archive, including a Stream Restoration portal, a current-awareness service to let colleagues know of updates to our data archive, and a semi-automated system to make our meta-data available for data-mining. (ii) We organized a special session, River Restoration From Boundary Layer to Watershed: Integrating Physical and Biological Science Over Space and Time, to be held at the Joint Assembly of AGU, SEG, NABS and SPD/AAS, in May 2005. (iii) We hosted a workshop, the National Workshop on Sediment Remobilization and Channel Morphodynamics in March, 2005, focusing on dam removal, at which members of our Environmental Partners community and larger research community planned a research agenda for this important aspect of Stream restoration. (iv) We hosted our first Working Group, Numerical Methods Working Group held May, 2004; the momentum from this meeting has led to plans for a second meeting of the group early in Year 4. (v) We hosted three Visitor teams, all involving members or data from our Environmental Partners, and planned, with our Partners, a suite of gravel-bed transport experiments to begin in Year 4.

Finally, we made substantial progress toward meeting **our third and fourth Knowledge Transfer Goals**, to become a significant force in bringing together the Stream Restoration community in strengthening the scientific basis for Stream Restoration and to maximize the societal impact of our research through effective communication of our science to policy makers in three activities of our Stream Restoration IP. (i) We hosted the 2005 NCED Partner meeting on Stream Restoration. The overwhelming level of interest and enthusiastic participation in this meeting, by Partners and academic colleagues, NCED PIs and NCED graduate students, clearly demonstrated the need for the roles we can fill in providing tools, training, research, and a meeting place for the Stream Restoration

community. (ii) After a thorough consideration of the best way to accomplish our goal of communicating to policy makers, we added three PIs to NCED: Peter Wilcock is a researcher with a strong commitment to Stream Restoration training and practice; Ben Hobbs and Nick Flores have both worked on decision-making in environmental policy. Wilcock led the Partners meeting and co-led our dam removal workshop, Hobbs and Flores launched their NCED careers by conducting research in stream restoration policy making AT the 2005 Partners meeting. (iii) Finally, we established a Stream Restoration web portal and began assembling the first edition of our stream restoration newsletter; we hope both will play major roles in maintaining the positive Knowledge Transfer momentum of Year 3's launch of the Stream Restoration IP.

II. Research

This year we have worked to improve our focus, better organize our research program, and sharpen our synthesis strategy. A full description of this process can be found in the introductory document to this report. In summary:

We have adopted a project management approach to organizing our research. Our research is focused on the core science of channels and channels systems, and supports three Integrated Projects (IPs): Desktop Watershed, Stream Restoration, and Subsurface Architecture (we also have a small number of Special Initiative projects that don't fall under the three IPs: in these projects, NCED researchers are encouraged take risks and "push the envelope" of our core science). The IPs evolved naturally out of center-wide projects previously described as "Integrative Activities".

Our PIs remain organized by Focus Area, which encourages synergy among researchers through their common interests. The Integrated Projects achieve synergy among researchers through work toward common deliverables.

The Integrated Projects

These projects and their rationale are described fully in the accompanying introductory document. Briefly:

The Desktop Watershed Project will develop process-based models that use digital topography and spatially-referenced surface attributes (such as geology, vegetation, and landuse) to predict the linkages between external disturbances (such as climate change or land use decisions) and ecogeomorphic function within the watershed. Our development approach is an adaptive hybrid of techniques ranging from first-principles theoretical models to thoughtful inductive summaries of observed dynamics. The model will be field-tested and calibrated based on extensive data gathering and analysis at our common field site in the Angelo Coast Range Reserve.

Development will proceed in three somewhat overlapping phases:

1. Develop hypotheses for predicting expected resource properties from topography. We refer to the predicted landscape properties, such as landslide location, river bed grain size, abundance of wood in channel, and stream temperature, as the ***analytical reference state***.
2. Extrapolate site-specific information to entire watersheds. Field observations usually rely on a limited number of sample points at locations where access is possible in a watershed. The analytical reference state will allow field researchers to identify key sample locations and, by spatially registering these observations and relating these properties to topographic controls (and perhaps other features), generalize the observations to the entire watershed.
3. Develop dynamic algorithms, including linkages between land use and reference state, that allow the reference state to evolve in time. This will allow the Desktop Watershed to predict the effects of forest clearing on runoff magnitude; sediment production and routing through channel network; and fish population response to landuse change.

As the detailed reports of research accomplishments and near-term plans below will show, we are well into the work of phase 1, and have taken initial steps in pursuing phase 2. Phase 3 is in the initial stage of assessing the current state of knowledge.

The Stream Restoration Project will advance the scientific and policy bases for stream restoration by: (a) working with our Partners to identify critical gaps in scientific knowledge, applied methods, and policy decision-making, (b) conducting and coordinating the research necessary to fill the most critical gaps, and

(c) working with our Partners to ensure that our results are translated into widely available (and accepted) practical tools and training curricula to guide stream restoration decision-making and practice.

This project comprises the following major elements:

1. Collaboration with other researchers within and outside of NCED in order to address the wide range of science needs for restoration in a coordinated fashion. These collaborations include the NCED Stream Restoration Partners group, which includes agency, consulting, and academic Partners; allied organizations working on restoration topics including CUAHSI, SAHRA, NRRSS, and the NAS; and a large experimental project funded by CALFED (Dietrich is a PI on that project and Parker and Wilcock serve on its Scientific Advisory Panel). Based largely on interactions with the NCED Stream Restoration partners' group, priority research areas include: steady-state channel geometry; social drivers and decision-making in restoration projects; flux laws for sand and sediment mixtures (especially on reach scales); flow-sediment-biota interactions; stream evolution following dam removal; and channel-vegetation interactions including stream-bank bioengineering.
2. Truly inter-disciplinary research combining physical, biological, and social sciences to comprehensively address stream restoration issues. Better restoration science requires an integration of physical and biological methods and understanding; better identification of restoration priorities and implementation of restoration plans require incorporating economic and decision sciences into the research and method development. It has been repeatedly emphasized that institutional and social obstacles are often as important as knowledge barriers as impediments to effective restoration practice.
3. Linking basic scientific research with stream restoration tools, methods, and training. A persistent issue in stream restoration is that 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. We strongly believe that stream restoration practice will not be improved without developing improved training and providing broad distribution of methods and models within an organized, open-source framework. Our knowledge transfer program includes a number of efforts designed to meet these needs, including the creation of a stream restoration toolbox of practical open-source algorithms and tutorials, the design of graduate training and short courses, and the coordination of existing training materials and programs. Carrying out this work in the center mode allows for close connection between training materials and new research findings.
4. Developing project evaluation tools and methods that provide for more frequent and more effective evaluations of the many existing restoration "experiments," institutionalizing their use, and providing a forum for sharing this information among scientists and practitioners. The evaluation tools will focus in particular on better defining linkages between geomorphic design and ecological outcomes. In terms of results sharing, a national survey of stream restoration projects (NRRSS) has been completed by a collaborative team led by Margaret Palmer (University of Maryland) and Emily Bernhardt (Duke University). We are working with these investigators to develop the next phase of this work, in which a team of ecologists, geomorphologists, and social scientists will investigate, in detail, restoration project performance to learn general lessons and examine the effect of restoration actions on the ecological function of the stream and riparian zone.
5. Develop techniques to place restoration actions in the larger spatial and temporal context of the watershed.
6. Understand and incorporate uncertainty, both in terms of scientific uncertainty and stochastic processes in the environment, in restoration practice.

As the detailed reports of research accomplishments and near-term plans below will show, we are well into the work on items 1-3, and expect to begin work on 4 shortly. Items 5 and 6 are for longer-range development, in that they require results from ongoing work on the Desktop Watershed and stochastic geomorphology.

The Subsurface Architecture Project will develop a model or models of the interaction of channel dynamics, tectonics, and sea level in depositional systems in order to predict the geometry and connectivity of subsurface fluid conduits and reservoirs. These models will, in effect, integrate much of the work being performed by the other two IPs across planetary time scales. Our approach combines our own laboratory research and collaborative research with our industrial partners that will let us tap into their extensive (and generally unavailable) research on subsurface conditions around the globe. In turn, this project will provide valuable data to the other IPs on the natural variability in channel system behavior, as well as enhance their ability to incorporate the local effects of long-term trends into short-term environmental forecasting.

The major research efforts of the Subsurface Architecture project are:

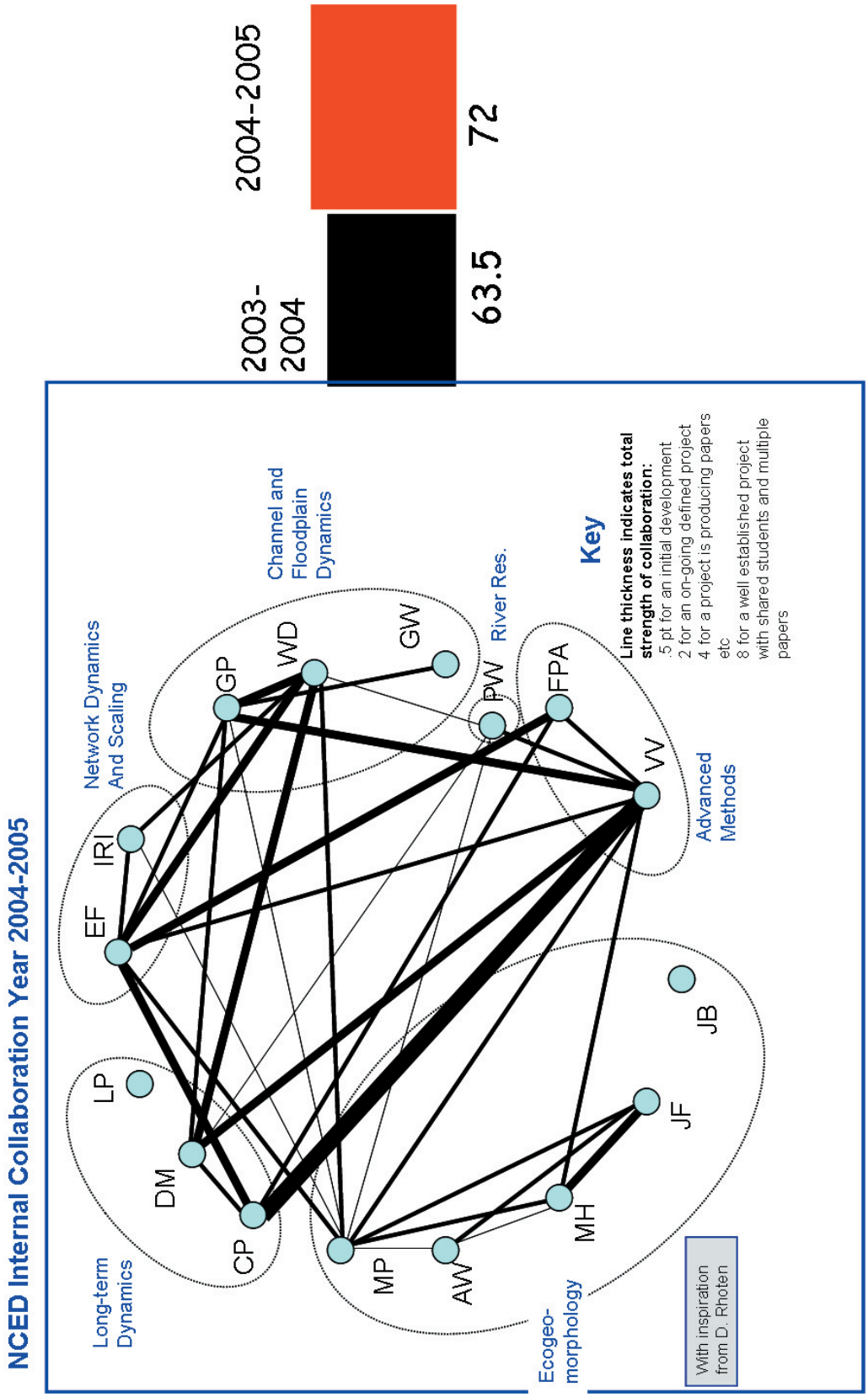
1. Test and refine existing hypotheses for how sedimentation rate, sea-level variation and other factors control the stacking of channels and related deposits in alluvial deposits. These models are now in transition from 2D to 3D, and use experimentation for model testing and refinement, supplemented by real-world data, primarily from the oil industry. This effort depends particularly on understanding physical and biological controls on channel pattern and morphology and channel-floodplain interaction and how these local processes are influenced by external forcing such as subsidence, sediment supply, and sea-level change.
2. Understand the comparative physics of terrestrial and submarine channels and channel networks. The goal here is to provide a means by which results from step 1 can be adapted to submarine systems to catalyze rapid progress in understanding and predicting subsurface characteristics of submarine channel deposits.
3. Adapt methods and insights from analysis of subaerial tributary channel networks to subaerial distributary networks (mainly deltas) and to submarine networks of both types. The goal again is to catalyze rapid progress in the depositional realms by injecting a set of methodologies that have revolutionized the study of terrestrial landscapes, revealing spatial structure and providing a predictive understanding of how the landscape is organized.
4. Develop a unified, predictive fluvial-submarine channel-architecture model that includes process-based understanding of channel geometry, the relative roles of critical common sedimentation elements (channels, lobes, floodplains), controls on channel shifting (gradual and abrupt), and external drivers such as sediment supply, subsidence, and sea level.

As the detailed reports of research accomplishments and near-term plans below will show, we are well into the work on items 1 and 2, and will begin work on item 3 this year. Item 4 will begin as the results from items 1-3 take shape.

Research Performance Indicators

See table on next page

Goal			Measurement #1		Measurement #2	
			Description	Value	Description	Value
1	Research:					
	a.	Scientific output: Number of peer-reviewed publications and conference proceedings	Papers	47	Conference Proceedings	8
	b.	Interdisciplinary work: collaboration measures include participation in Center-wide discussions, joint publications and talks, and shared graduate students and postdocs	Collaboration metrics	See Vaughan Diagram next page		
2	Scientific Community (metrics shared with Knowledge Transfer)					
	a.	PI Participation in Working Groups	Number	9	Percent of PIs	50%
	b.	PI and student involvement with visiting scientists	Number/visitor	2 PIs and their research groups worked with all Yr 3 visitors		
	c.	PI and student involvement with community initiatives	Number of initiatives	2	Percent of PIs	10%
3	PI Participation in Knowledge Transfer Activities (metrics shared with Knowledge Transfer)					
	a.	Joint publications with partners	Number (in press)	2		
	b.	PI involvement in partner meetings and other joint activities	Percent	50%		
	c.	PI contributions to web site and other KT venues	Number of contributions	7	Number data sets or papers	9



"Vaughan Diagram" showing measures of internatal collaboration between NCED reseaarchers.

Research Focus Area 1: Channel Network Dynamics and Scaling

Lead PIs: Rodríguez-Iturbe and Foufoula-Georgiou

Mission: to understand the space-time organization of channel networks, including morphology, hydrology, and ecology, in order to:

1. Determine how small-scale processes interact to produce large-scale self-organized patterns;
2. Extend and integrate existing understanding by exploiting similarity and scaling; and
3. Gain insight into physical and ecologic processes and couplings that manifest themselves via spatial patterns, similarity and scaling.

Strategy and synthesis

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. Focus group leaders Foufoula and Rodríguez-Iturbe have organized the Scaling group's research around four complementary themes that provide critical insight to NCED's three Integrated Projects (IPs):

Major research themes:

1. Geomorphologic controls on the scaling of floods and hydrologic response. Here we investigate the influence of spatial structure and scale on floodplain geometry and flooding. This activity is central to the Desktop Watershed Integrated Project in that it provides an avenue for relating flooding and hydrologic response to watershed structure.
2. Hydrologic, geomorphologic and ecologic dynamics of vegetation along channel networks. The role of the landscape in influencing ecosystem organization supports another major NCED goal, that of connecting ecology with surface morphology. The Scaling group's work on this topic provides a strong connection to the Ecogeomorphology group, and is also central to the Desktop watershed IP as explained in the Context section of this report.
3. Morphology and eco-hydrology of braided river systems and deltas. Work on scaling in drainage basins, such as that described above, has shown how this approach can provide critical insights about underlying regularities in the spatial structure and statistics of basin hydrology, geomorphology, and ecology. One of our ongoing activities in NCED is to adapt these techniques to other types of river networks, such as braided rivers and deltas, that are typical of depositional environments. Both network types are important for Stream Restoration (e.g., restoration activities in the Platte River and Mississippi Delta) and for Subsurface Architecture (braiding is favored by net depositional conditions and deltas are major depositional sites worldwide).
4. Advances in modeling tools for hydro-eco-geomorphologic studies. A major long-term goal of the Desktop watershed NCED Integrated Project is to answer questions related to climate change. A critical element in this work is the development of advanced hydrological modeling tools that account for coupling with geomorphology and ecology.

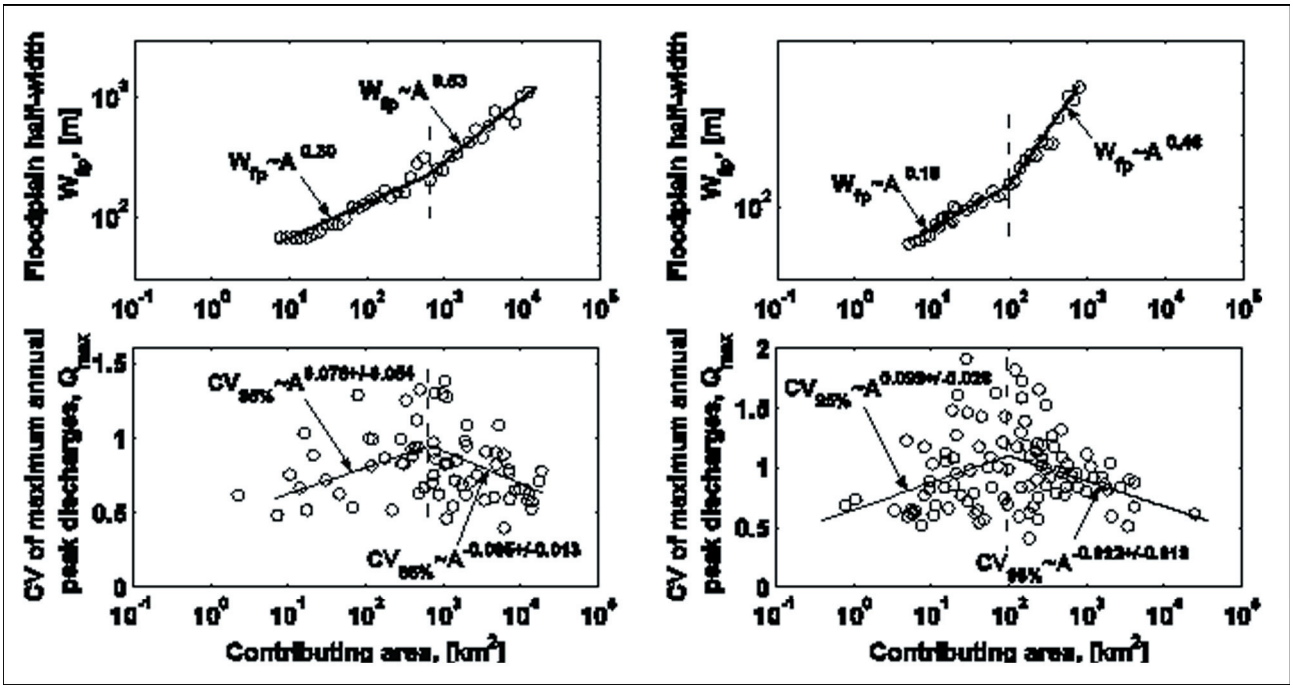


Figure 1. Comparison of floodplain geometry analysis from DEM and CV of maximum annual floods from USGS stations in Oklahoma and Kansas (left), and the Appalachian Piedmont (right). It is observed that the scaling break in floodplain geometry carries over to a scaling break in the frequency of floods.

Research Accomplishments:

Geomorphologic controls on the scaling of floods and hydrologic response

Effect of channel/floodplain geometry on the frequency of floods

In *Dodov and Foufoula-Georgiou* (2005a) the hypothesis was put forward that streamflow statistics are significantly affected by the scale-dependent channel/floodplain interactions. Specifically, they documented via extensive analysis of hydrologic, geomorphologic and sedimentologic observations in the Midwestern U.S. (Kansas-Oklahoma region) that the break in the scaling of floods (namely, an increase in the coefficient of variation *CV* up to some critical scale A_C and a decrease afterwards) is strongly connected to the scaling break in channel/floodplain geometry (see Figure 1). This was attributed to a transition from an overall mildly erosional regime upstream (i.e., scales smaller than 700 km^2) which suppresses floodplain development, to a more depositional regime downstream, which enhances floodplain development and thus induces significant retardation effects and, respectively, decrease in peak flow variability at large contributing areas. Scaling break in floods has been reported in other regions of the U.S., e.g., in the Appalachian highlands, where the scaling break was found to occur at a scale of approximately 100 km^2 (*Smith*, 1992 and *Gupta et al.*, 1994). To further test our hypothesis that the scaling break of floods relates to the scaling break in the channel/floodplain geometry, we performed a geomorphologic analysis of the Appalachian Piedmont region. Figure 1 shows that indeed, for that region too, the scaling break of floods coincides with the scale at which a scaling break occurs in the channel/floodplain geometry, providing further support for the tight connections between channel/floodplain dynamics and frequency of floods. Such quantitative connections between geomorphology and hydrology are of practical interest as they provide the means to infer the scale-dependency of flood frequency distributions in ungauged basins from a geomorphologic analysis of readily available DEMs.

Effect of channel/floodplain interactions on hydrologic response

Preliminary evidence that the channel morphology exerts a significant control on the hydrologic response of a basin was presented in *Dodov and Foufoula-Georgiou* (2004a). In that study, a simple Hydraulic Geometry (HG), i.e., channel cross-sectional area versus discharge relationship with constant parameters as in *Leopold and Maddock* (1953), versus a scale-dependent HG, i.e., the generalized relationships proposed by *Dodov and Foufoula-Georgiou* (2004a), were used in a semi-lumped modeling framework to study how the properties of the hydrologic response (time to peak, peak magnitude, skewness of the hydrograph and relaxation time) change as a function of scale. The results demonstrated that ignoring the scale-dependence of HG introduces significant errors in the modeled hydrographs and prompted us to further study the effect of the "extended channel", i.e., the floodplain, on the modeled hydrologic response of a basin. The scheme of introducing the floodplain into an "extended HG" framework relied on using a bivariate multiscaling mixture model of cross-sectional area and discharge (see *Dodov and Foufoula-Georgiou,* 2004a). Once the parameters of this extended HG model were estimated, the expectation of cross-sectional area conditioned on discharge was employed as a momentum equation in a nonlinear reservoirs in network scheme for runoff routing (see *Dodov and Foufoula-Georgiou,* 2004a for details). Pulses of different exceedance intensity and over basins of increasing Strahler stream order (scale) were simulated to study the effect of geomorphologic controls on hydrologic response. In Figure 2, we show the result of these simulations. Clearly, the effect of geomorphologic controls (channel, floodplain on geomorphic response) is quite strong, making it imperative to introduce the channel/floodplain interactions in any hydrologic routing scheme.

Stream corridor geometry: morphologic signature and implications for riparian vegetation and flooding

The availability of very high resolution DEMs (1mx1m from LIDAR) in the Angelo Coast Range Reserve allows analysis of the stream corridor morphology in terms of its scaling relationships, inference of the geomorphologic processes that contributed to the formation of this geometry and the implications for flooding and riparian vegetation dynamics. The analysis was conducted by means of a procedure similar to the one used in *Dodov and Foufoula-Georgiou* (2005b) for floodplain extraction but with improved accuracy and performance. To avoid spurious statistical effects at the junctions of very small and very large streams (e.g., where the stream corridor of a small tributary is actually a part of a terrace belonging to a stream with much larger contributing area) we divided the stream network into ten equal intervals of log-area (see Table 1, next page). Subsequently, the extraction of stream corridor and its analysis was conducted for each group separately.

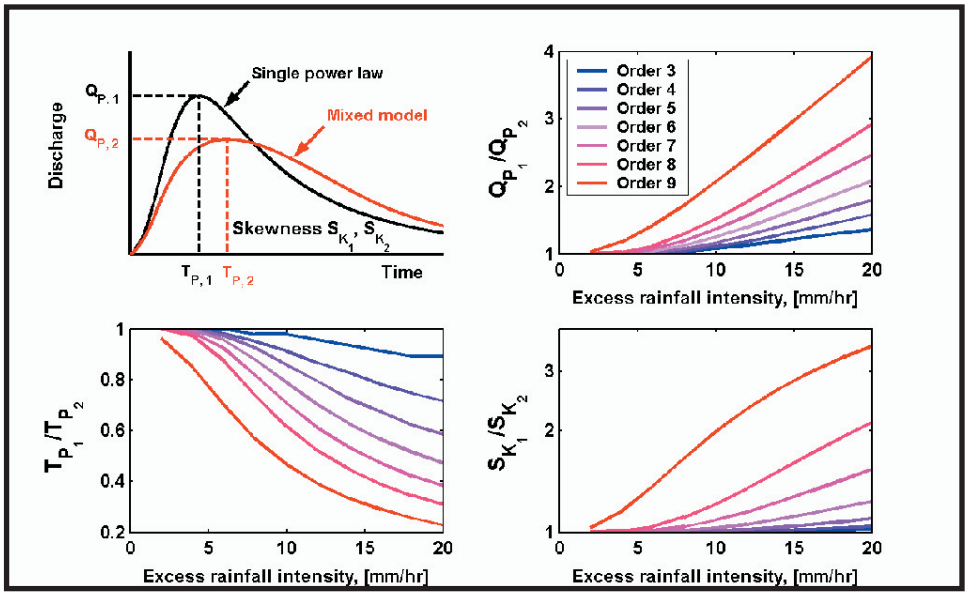


Figure 2. The effect of transition to overbank regime on hydrologic response quantified via numerical simulations. Top left is a schematic of the simulated hydrograph when a single power law HG which ignore the floodplain (index 1) versus a mixed model of HG which incorporates the floodplain (index 2) is used. The other panels show the ratio of QP,1 / QP,2, TP,1 / TP,2 and SP,1 / SP,2 for streams of order □ = 3 to 9 as a function of excess rainfall intensity. It is observed that the larger the area of the basin and the larger the rainfall intensity, the larger the effect of the floodplain on hydrologic response

In Figure 3 (next page) we plot the width to depth ratio respectively as function of elevation above the water level and as a function of scale (group). It is obvious that there is a major change in the stream corridor cross-sectional geometry occurring at the scale of approximately 1-2 km^2. This was attributed to a transition from a debris flow dominated zone to a zone where the incision into the bedrock is dominated by lateral erosion acting in a way similar to the formation of a floodplain in a depositional fluvial environment. Further analysis to better understand this transition locally along the stream network and, particularly, its effect on the formation of riparian vegetation community and streamflow variability is the subject of an intensive ongoing research.

Group	From area km^2	Geom. mean km^2	To area km^2
1	0.010	0.016	0.027
2	0.027	0.044	0.072
3	0.072	0.117	0.191
4	0.191	0.313	0.512
5	0.512	0.837	1.369
6	1.369	2.239	3.663
7	3.663	5.990	9.797
8	9.797	16.023	26.205
9	26.205	42.858	70.094
10	70.094	114.637	187.489

Table 1. Upstream area partitioning intervals.

Hydrologic, geomorphologic and ecologic dynamics of vegetation along channel networks

Dynamics of vegetation in riparian corridors

The work reported here represents the final phase of our study of geomorphology and vegetation in the Rio Salado Basin, New Mexico. This work began before NCED started. As discussed below under Plans, our plan is to adapt the techniques we developed at Rio Salado to the NCED common field site at the Angelo Coast Range Reserve (ACRR). The fundamental scientific focus remains the same: to relate the spatial structure of ecosystems to the spatial structure of the landscape. To study the interaction between the geomorphology of channel networks and the ecological dynamics of the riparian vegetation, i.e., the vegetation along channel networks, we constructed a model of structured metapopulation type, which allows for the dynamics of the riparian vegetation to take

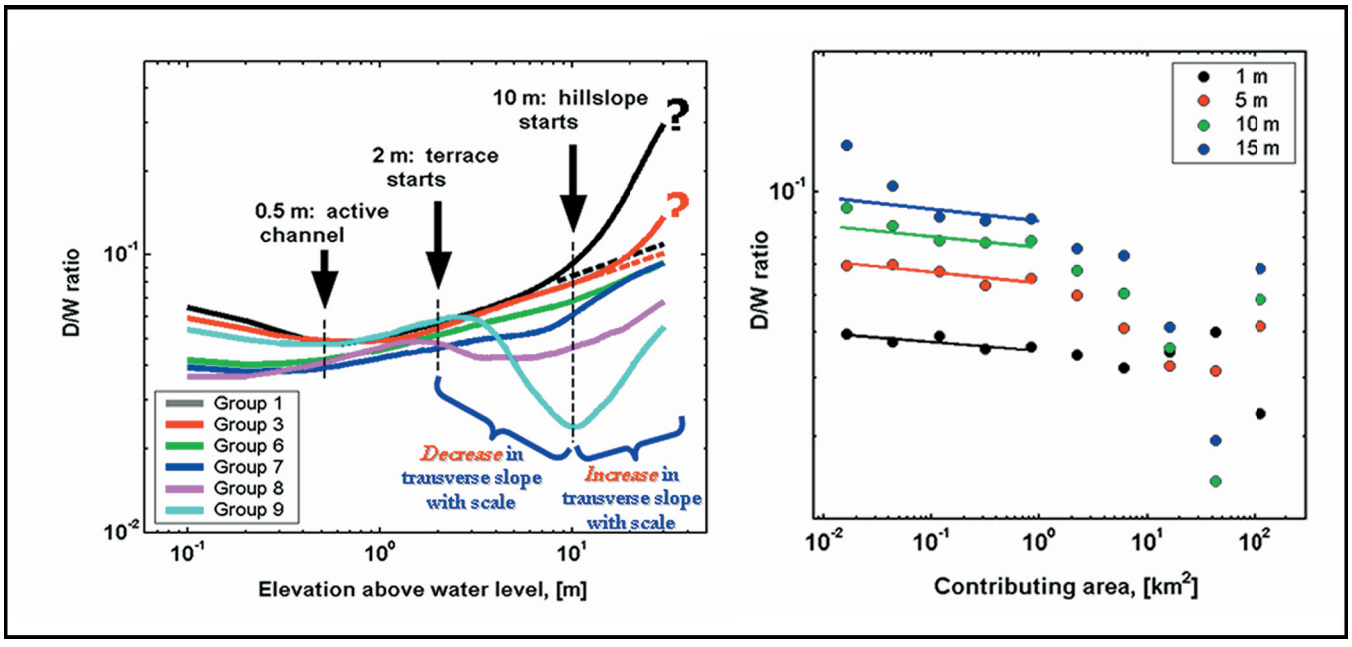


Figure 3. Analysis of stream corridor geometry: depth/width ratio as a function of elevation above water level at a given scale (see groups in Table 1) [left] and as a function of scale at a given elevation above the water surface [right]. Observe the appearance of terraces at the scale of approximately 1-2 km^2 (between groups 6 and 7).

place in channel networks. The model has been applied to various types of channel networks, including comb-like, Scheidegger, area-filling branching, and a real river network (Rio) (see Figure 4) to examine the effects of the network structure on the riparian vegetation dynamics; note that these networks are topologically distinct from one another.

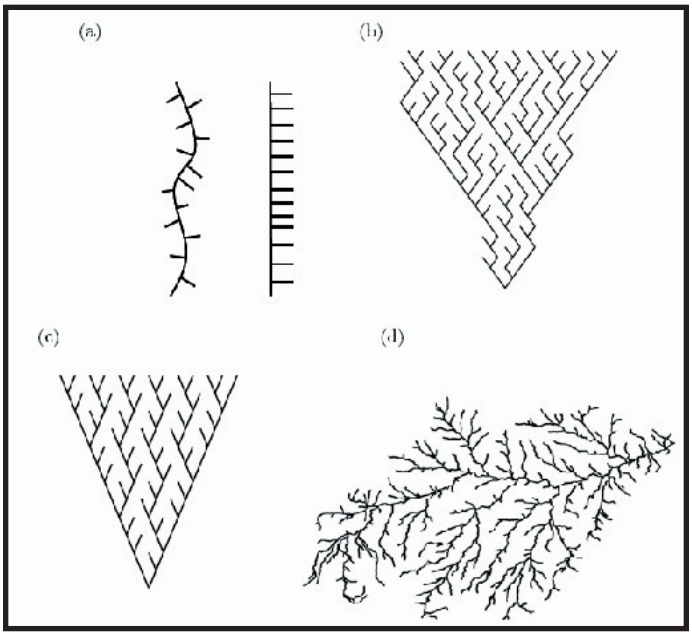


Figure 4. Examples of topologically distinct river network structures: (a) comb-like, (b) Scheidegger, (c) area-filling branching, and (d) a real river network: Rio Salado.

We found that some static properties of river networks, i.e., those that can be obtained without running simulations, could imply certain characteristics of the vegetation dynamics. Examples of the static network properties include the "diameter", <L>, of the network (i.e., the average distance, in unit of link, between any pair of stream links in the network), mean ecological distance, <φ>, (i.e., the distance between any pair of stream links in the network, modified by ecologically relevant parameters), and mean dispersal probability, <K>, (i.e., the probability that a propagule from a currently occupied stream link disperses to and occupies another link). Some interesting results immediately arose. All of the three static network properties mentioned, namely, <L>, <φ>, and <K>, exhibit power law relationships with basin size. In the cases of Rio Salado (a real network) and Scheidegger networks, the power law exponents of <L> are very close to their well-established Hack's exponents, ~0.52-0.62 and 2/3, respectively. An important implication of these observations is that the ratio between <L> and the length of the longest stream in the network is constant. This will likely have consequences in subsequent analysis and future fieldwork.

There are several ways to represent the riparian vegetation dynamics. In the past year, we started with a simplest setting: the vegetation at each stream link is represented as being either present or absent, and the interspecific interaction is of strictly hierarchical competition type; we of course plan to explore other interaction schemes in the coming year (see Research Plans, below). Embedded in this model setting is the notion of the classic competition-colonization tradeoffs, in which the superior species is better at competing and the inferior species is better at colonizing. The results indicate that parameters related to dispersal, birth, and death of the vegetation have thresholds below which the network is essentially barren all the time, and above which the fraction of the stream links occupied by the vegetation soars rapidly. Furthermore, given the same parameters for dispersal, birth, death, and immigration, the superior species in the comb-like network occupies a higher fraction of stream links than that in the more branching networks. The biodiversity, on the contrary, is usually higher in the more branching networks than in the comb-like one at all sub-basin scales.

One of the unique traits of Rio Salado, the only real river network considered, is bottleneck effect. A bottleneck is referred to as a stream link coinciding with a local minimum of the network's width function, and is thus likely a confluence of two sub-networks. As the dispersal of riparian vegetation is downstream-biased, primarily due to river flows, such location has relatively more incoming propagules than other locations, and thus higher probability of having vegetation present. This effect is absent in the comb-like and another artificially constructed branching network used in the model due to their unnaturally well-organized structures in which the only bottlenecks are the outlet links. We also have preliminary results regarding the effects of network structure on the resilience of riparian vegetation. The model indicates that there exist disturbance thresholds above which the average fraction of occupied stream links decreases at a faster rate as response to additional disturbance. Interestingly, these

thresholds seem to be higher in Rio Salado, possibly implying better resilience in real river networks. Some of the results reported here are included in an article being prepared for publication. It is important, however, to note that these conclusions are specific to this particular setting, and would be different if, for instance, the interspecific interaction changed.

Patterns and organization of vegetation communities within river basins

Research during the last 10 years has conclusively shown an increasing degree of organization and unifying principles behind the structure of the drainage network and the 3-dimensional geometry of river basins. This cohesion exists despite the infinite variety of shapes and forms one observes in natural watersheds. What has been relatively unexplored is the question of whether or not the interaction of vegetation, soils, and climate also display a similar set of unifying characteristics among the very different patterns these are found to exhibit within river basins. A recently formulated framework for the water balance at the daily level links the observed patterns of basin organization to the soil moisture dynamics. Using available geospatial data, we assign soil, climate, and vegetation properties across the basin and analyze the probabilistic characteristics of steady-state soil moisture distribution. We investigate the presence of organization through the analysis of the spatial patterns of the steady-state soil moisture distribution, as well as the distribution of observed vegetation patterns, simulated vegetation dynamic water stress and hydrological fluxes such as transpiration. We show that the drainage network acts as a template for the organization of both vegetation and hydrological patterns, which exhibit self-affine characteristics in their distribution across the river basin. Our analyses suggest the existence of a balance between the large-scale determinants of vegetation patterns reflecting optimality in the response to water stress, and the random small-scale patterns that arise from local factors and ecological legacies such as those caused by dispersal, disturbance, and founder effects.

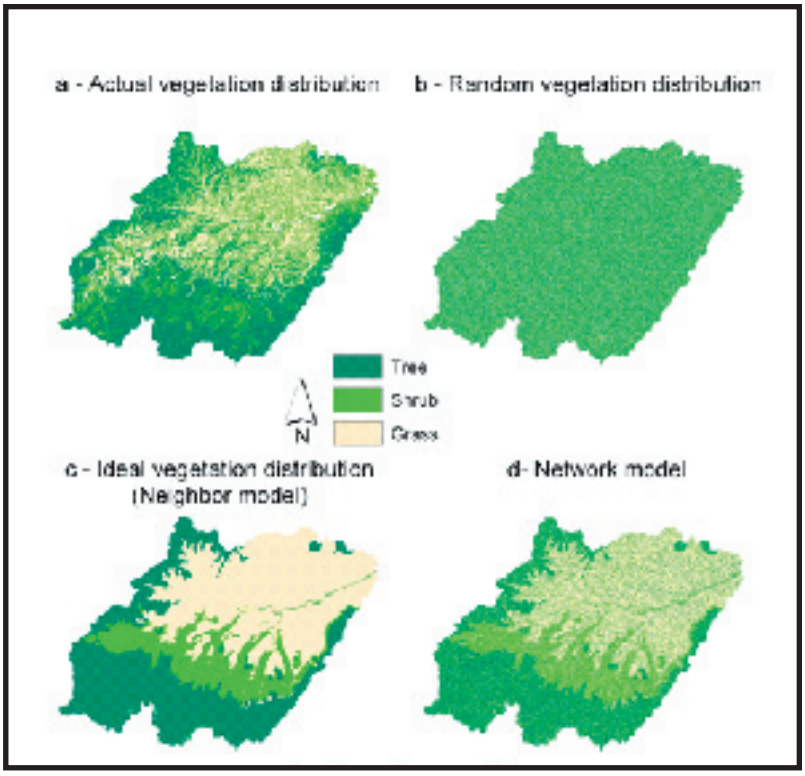


Figure 5. Spatial distribution of land cover within the Rio Salado basin. a, Actual vegetation distribution in the upper Rio Salado river basin. b, A random distribution of vegetation representing equal amounts of each land cover type. c, The pattern of land cover corresponding to an ideal (optimal) pattern that minimizes water stress at each location. d, A feasibly optimal pattern of vegetation that arises from local optimization within the network flow path starting from an initially random condition.

We have also examined mechanisms leading to organization of vegetation patterns within the channel network structure of a semiarid New Mexico river basin under the controlling influence of water stress (Figure 5). We compare the actual pattern of water stress within the basin to patterns resulting from two algorithms of local stress optimization that proceed from an initial fully random vegetation distribution. Our results show that the distribution of vegetation and basin water stress derived from an algorithm that maintains local optimization within the network flow path exhibits considerably better agreement with the actual distribution than one that allows for local interactions that ignore the network structure of the basin. These results suggest that the pattern of actual vegetation observed within the basin corresponds to a condition of "feasible optimality"

in which large-scale organization is constrained by the stochastic nature of local interactions mediated by the network configuration. The principles of such organization have important consequences regarding the impact of land cover change on hydrological dynamics in river basins, as well as the geomorphological and biogeographical evolution of landscapes under varying climate and disturbance regimes.

Morphology and hydrology of braided river systems and deltas

Braided river systems

The spatial and temporal (dynamic) scaling relationships of braided river systems (established by previous research of our group at the St. Anthony Falls Laboratory -- *Sapozhnikov and Foufoula-Georgiou*) have provided information on the planform morphology of channel patterns and the evolution of those patterns over a range of spatial scales. Of additional interest is information on the scaling of hydrologic parameters of these complex systems such as channel depth, velocity, and flow. Scaling relationships of this type could assist in field prediction of channel cross-sectional properties, such as mean depth given the channel width which is easier to observe from area photographs, and also assist in the validation of braided river models. Hydrologic parameters, however, are difficult to measure in a comprehensive manner in the field due to the spatial and temporal variability of braided river systems. Several experimental braided river systems were produced at SAFL which allowed collection of a comprehensive data set of water depths over the evolution of an entire system. The scaling of the probability density functions of mean and maximum channel depths (where scale here is the depth) was studied and power law relationships were established (see Figures 6 below and 7 on next page). These relationships imply that a channel that is five times wider than another is expected to have an average channel depth that is 1.45 times deeper and a maximum channel depth that is 1.78 times deeper. A comparison of the braided river depth-to-width scaling relationships to the scaling relationships found for meandering rivers suggests that braided rivers have characteristics that lie between those of erosional and depositional meandering systems, but are more closely related to depositional systems such as those found in areas with well established floodplains. This work is in collaboration with the group of Chris Paola. A manuscript describing the research in detail is near completion (*Tilman et al.*), and the MS thesis of Lisa Tilman has been completed and defended (*Tilman, April 2005*).

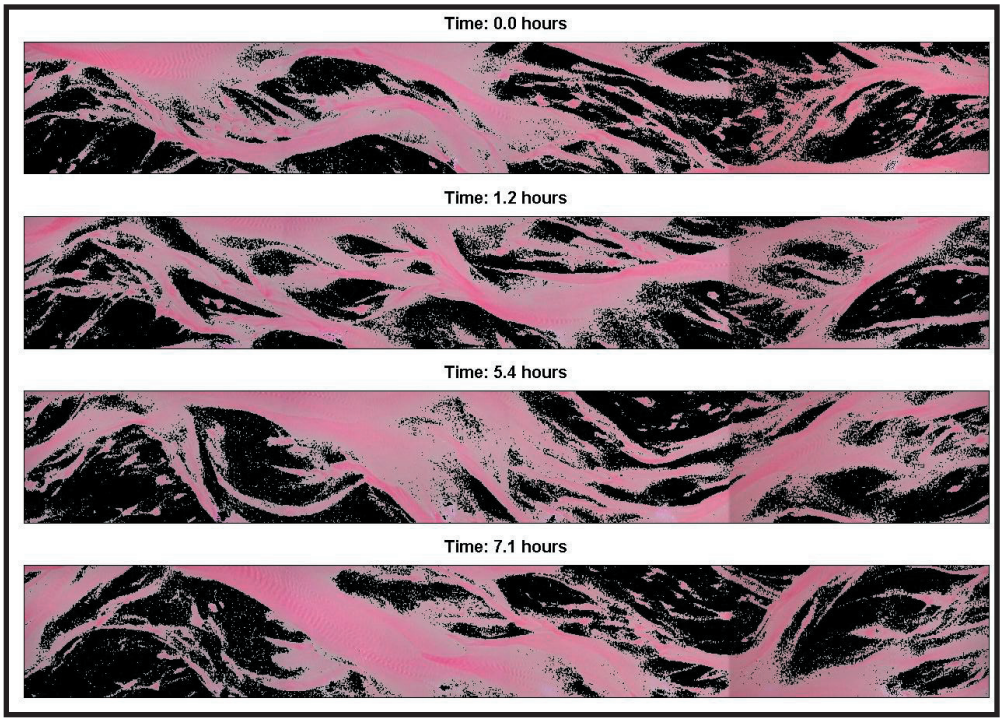


Figure 6. Photographs of the experimental braided river at four time instances display the evolution of the braided system. Islands are shaded black for clarity.

Deltas

We have recently begun an investigation of the geomorphological pattern of river deltas, and the interaction between pattern and process in distributary river networks. This is a joint collaboration of the Princeton group with Prof. Chris Paola at the University of Minnesota as well as with Prof. Andrea Rinaldo in his capacity as adjunct professor of Civil and Environmental Engineering at Princeton University. Although this work is still in its initial phases, we have already developed a set of tools for extracting and analyzing the

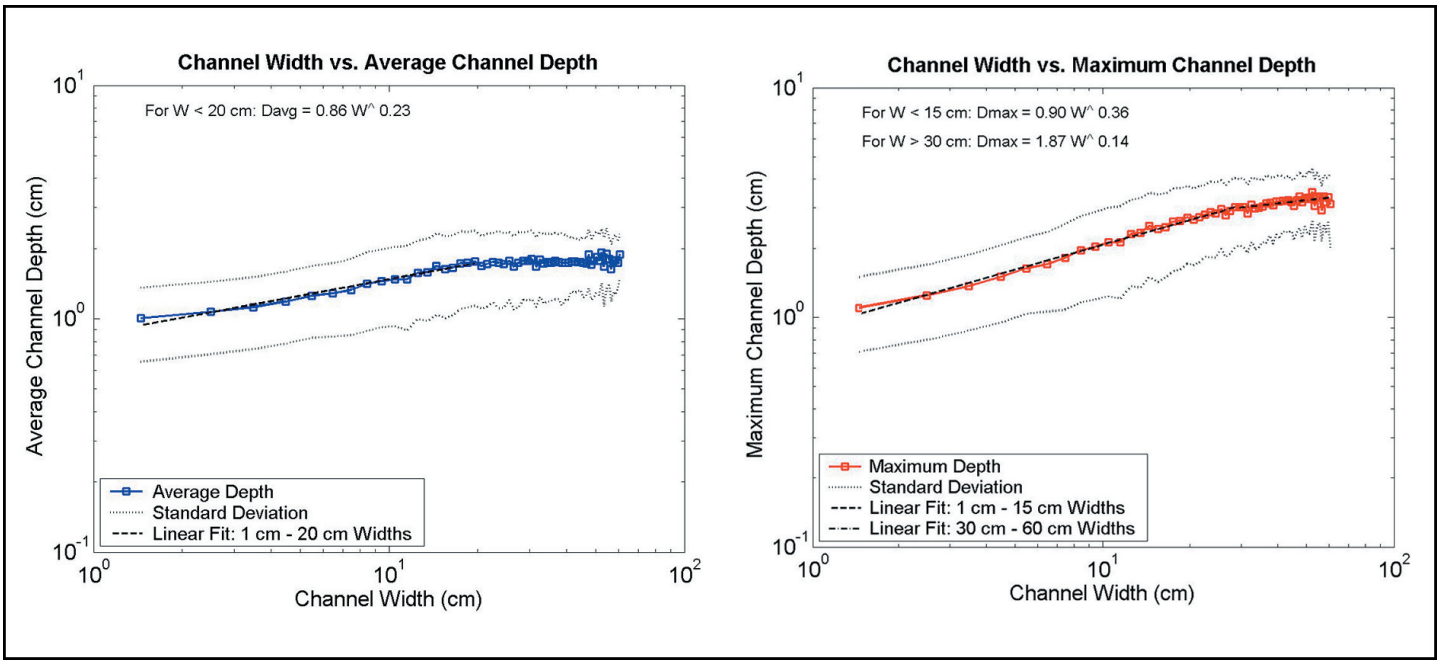


Figure 7. Log-log scaled plot of the bin averaged relationship between channel width and mean and maximum water depth within the channel. The solid line marked with squares shows the bin averaged values. The log-log linear fit is shown as the heavy dashed line. The lighter dotted lines show the standard deviation. This suggests a power law relationship between channel width and mean channel depth of $D_{mean} = 0.86W^{0.23}$ for channels with width less than 20 cm. The power law relationship between maximum channel depth and channel width is $D_{max}=0.90W^{0.36}$ for channels with width less than 30 cm and is $D_{max}=1.87W^{0.14}$ for channels with width greater than 30 cm.

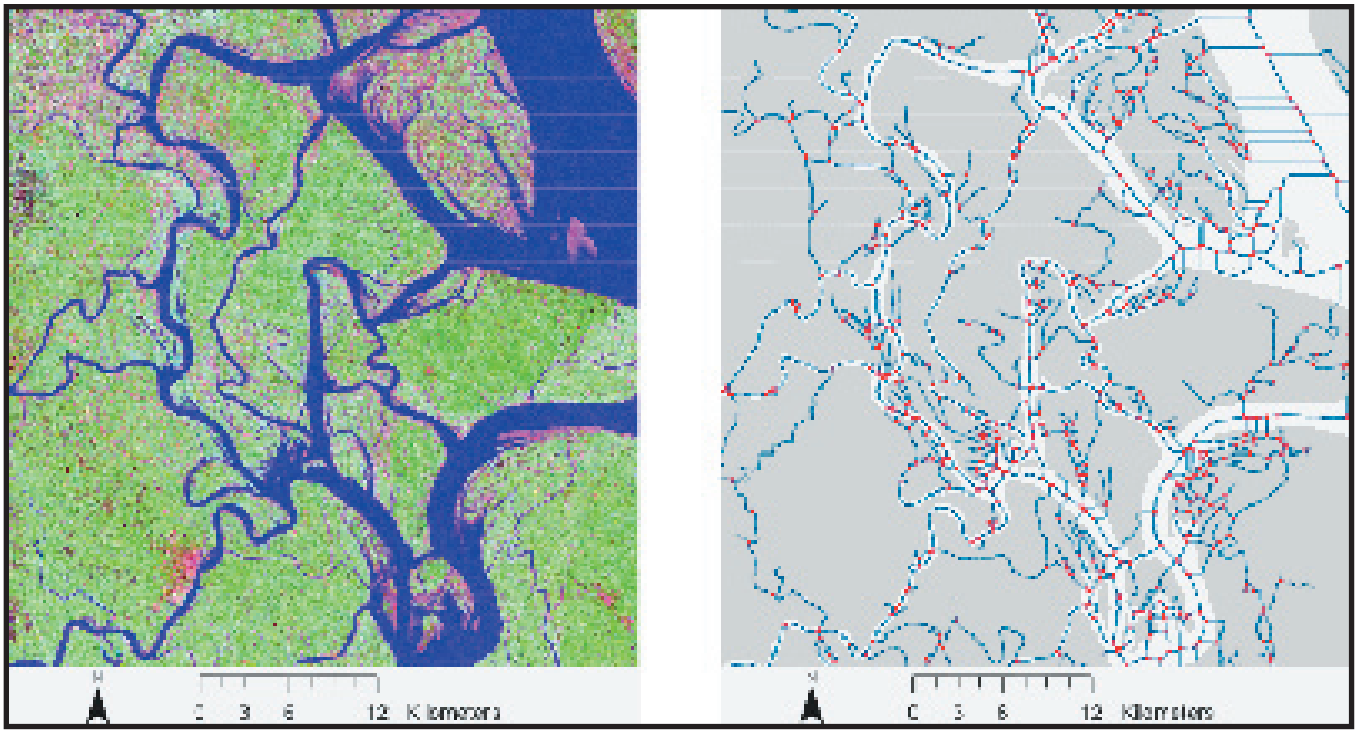


Figure 8. Original 28.5-meter false color-composited landsat image (left panel) and extracted network topology (right panel) for a small subset of the Brahmaputra river delta. The topology in the right panel is represented as a series of 1-dimensional channel segments (blue lines), which intersect at zero-dimensional nodes (red points). The bottom plots show the PDFs of island areas and channel lengths.

complex network structure of the Brahmaputra river delta (Figure 8, previous page). Through the extraction of a coherent topological network, we are now able to investigate the geometric properties of channel structure, such as the distribution of channel lengths and the distribution of channel widths throughout the delta network. We anticipate linking our efforts to ongoing research on deltaic formations being conducted through NCED at the eXperimental EarthScape facility (XES) at the St. Anthony Falls Laboratory.

Advances in modeling tools for hydro-eco-geomorphologic studies

A hydrologic routing scheme based on physically-derived HG and probabilistic upscaling along the river network

Most of the hydrologic routing schemes do not explicitly account for the effect of overbank flows and thus much more computationally demanding hydraulic models (such as HEC-RAS, U.S. Army Corps of Engineers, MIKE11, Danish Hydrologic Institute, SWMM-EXTRAN, U.S. Environmental Protection Agency, etc.) need to be implemented for accurate prediction of flood hydrographs. Such models, however, become computationally infeasible over large areas and also for very long-term simulations of the hydrologic, ecologic, and geomorphologic dynamics of a watershed, say under perturbed climatic conditions. We have proposed a semi-lumped hydrologic routing scheme which explicitly accounts for the channel-floodplain geometry by using as momentum equation the scale-dependent extended HG (cross-sectional channel/floodplain area vs. discharge relationship) derived from a mechanistic model (*Johannenson and Parker*, 1987) along meander bends of particular order. These local HGs are then probabilistically upscaled along the river network via a nonlinear reservoirs in network model.

This framework was implemented in a simulation mode to quantify the effect of overbank flows on hydrologic response (shown in Figure 3) and is currently used to numerically derive the flood frequency distribution of floods over a range of scales.

A rainfall generator for long-term simulations of eco-geo-hydrologic studies

The seasonality and space-time intermittency of precipitation are known to play a crucial role in practically all aspects of the hydrologic cycle from flood frequency scaling, to nonlinearity in hydrologic response, to landscape formation, to ecological dynamics. Due to limited observations, quantifying this role is best approached through a "numerical laboratory" where long series of spatial rainfall fields over large areas (covering basins of several orders of magnitude for a proper scaling analysis) are converted to runoff via hydrologic transformations. This approach requires simulators that mimic the observed rainfall multiscale statistical structure, including intermittency over a large range of scales, and the evolution of this structure with the time of the year. We have a proposed space-time rainfall simulator which is based on: (i) a parsimonious parameterization of the scale- and season-dependent interstorm period and the scale- and season-dependent joint mean intensity-duration PDFs of "storms" and, (ii) disaggregation of each "storm" using a 3D variant of the recently developed constrained Fourier randomization procedure. The proposed approach can be seen as a data-learning simulator and it is shown to yield simulated rainfall fields which are both visually similar and statistically indistinguishable (in terms of the rainfall anisotropic multiscaling structure as it changes over seasons) to observed fields. The simplicity of the proposed approach makes it appealing for application to very large basins or over the whole U.S using the mosaic of hourly radar scans available since 1996. A manuscript near completion describes this research in detail (*Dodov and Foufoula-Georgiou*, 2005). Future research will include the application of this model to simulate the geomorphologic and ecologic evolution of a basin and study the statistical properties of the resulting floods over a large range of scales.

References:

Tilman, L., E. Foufoula-Georgiou, M. Tal and C. Paola, "Depth-width relationships and scaling in braided river channels", to be submitted, 2005.

Tilman, L., "Scaling in depth-width relationships in braided river channels", MS Thesis, University of Minnesota, 2005.

Dodov, B. and E. Foufoula-Georgiou, "Space-time rainfall generators for hydro-climatological studies: Learning from and randomizing large rainfall data sets", to be submitted.

Research Plans

Vegetation dynamics arising from ecohydrological and biogeochemical interactions

In the coming year, our research will continue to focus on the manner by which geomorphological drainage networks act as a template for the organization of ecohydrological and biogeochemical interactions that determine vegetation pattern within landscapes. With regards to the role of network structure on patterns of riparian vegetation, we will further establish the relationship between the static network properties and the statistics describing the vegetation dynamics. In addition to the presence/absence representation scheme of the vegetation we used in the past year, we will explore another scheme, namely population dynamics, in which vegetation at a stream link is represented by an actual number of individuals. This naturally calls for different interspecific interaction schemes. We plan to examine two such schemes, namely resource competition and neutral models. We expect the results, including the metapopulation statistics and their relationship with static network properties, to differ significantly.

Our modeling approach will also be used to couple the evolution of river network properties with the pattern of riparian vegetation dynamics within the river network via the framework of optimal channel networks (OCN)**.** Starting from an arbitrary initial network configuration, energy expenditure in the network is minimized through a simulated annealing mechanism. During the course of the network evolution towards the OCN configuration, a number of the transient configurations will be used to obtain the distance matrix for the dispersal processes of the riparian vegetation, and the analyses will be repeated for different values of parameters. In this way, we can investigate how the statistical descriptions of the riparian vegetation patterns evolve when the river network evolves. Another topic of interest is the relative role of 'network' versus 'cross-basin' dispersal, where cross-basin dispersal occurs not through the network structure, but across basin divides due to the actions of wind and animals. We suspect that the amount of 'cross-basin' dispersal may have an effect similar to the "small-world" effect so at some threshold level, the cross-basin dispersal would effectively make inoperative the dispersal through the drainage network.

Finally, we will couple the river network modeling approach described above to the upland surroundings, based on 3-dimensional evolutionary geomorphic models which, starting from arbitrary initial 3-D landscapes and associated drainage networks, evolve to a statistically steady-state interlocked system of hillslopes and river channels, i.e., the network becomes non-distinguishable from an OCN although it was not derived by the explicit minimization of the Hamiltonian. We will then repeat all the analyses described above for the riparian vegetation associated with the evolution of the 3-D system.

This work will be performed by Rodríguez-Iturbe's group with input from Dietrich and Power.

Morphology and eco-hydrology of deltas and braided rivers

We will continue the investigation of the geomorphological patterns manifested in river deltas, as the signature of the underlying organization characteristic of these distributary systems is not as well-advanced as that for river basins. Therefore, we will first seek to characterize the patterns of deltaic landscapes, particularly the organization of channel networks and islands within the active delta region. Our interest is in understanding how the interactions between boundary conditions (i.e., tidal amplitude and near-shore currents) and sediment supply lead to particular signatures in the distributions of landform properties such as island sizes and channel widths within large delta systems. The implications of these patterns on the distribution of vegetation communities as well as the dynamic

interactions between vegetation communities and landform evolution will be investigated. It is hoped that this work will lead to insights regarding the nature of pattern formation in delta systems as well as a suite of new metrics for investigating landform structure which have a generality applicable to the great diversity of deltas found throughout the world. Similarly, we will continue advancing our understanding of how the width to depth relationships in braided rivers change as a function of vegetation maturity, density and flooding level, with new experiments that will be performed at the St. Anthony Falls Laboratory.

The work on deltas will be performed by Rodríguez-Iturbe's group in collaboration with Paola and the braided river research by Foufoula's group in collaboration with Paola.

Stream corridor geometry and bio-eco-hydrologic interactions in the Eel River basin

In the next year we plan to adapt the techniques we developed in the Rio Salado Basin to the stream corridor geometry of ACRR and the larger Eel Basin in order to: (i) infer the scale-dependent valley-forming processes, and (ii) explore possible connections between stream corridor geometry and network topology, and (iii) link observed patterns in vegetation organization with the hydrological dynamics operating in the South Fork Eel River.

We will also seek to define an integrative approach to understanding hillslope-riparian-stream interactions that may be called 'catchment ecology'. An example of the type of integrative dynamics contemplated include the finding that in some western rivers, the contribution of marine derived N from salmon can account for up to 25% of the riparian vegetation foliar N. It is apparent that in order to assess the strength of feedbacks existing between the structure and function of riparian vegetation and the dynamics of salmon populations, it is necessary to investigate the role of riparian vegetation structure in modifying stream conditions (temperature) and flow regime, as well as the effect of flow regime on the dynamics of riparian vegetation structure. These types of two-way feedbacks exemplify the need for approaches that fully integrate geomorphological, hydrological, biogeochemical and ecological perspectives of catchments. In numerous locations within the South Fork Eel river, the near-stream and in-stream vegetation appears to be locally dominated by red alder (or a hybridized white/red alder), which is commonly associated with nitrogen fixing bacteria. A reasonable hypothesis for the presence of these species in near-stream riparian zones is their ability to tolerate areas with thin, nutrient-poor soils. In the absence of scouring floods, the presence of the alder will build up both the soil itself as well as soil N levels, eventually allowing other vegetation to colonize these areas. In this respect, the fluctuation of water levels may be very important as such fluctuations would control the development of alder and the formation of 'riparian' soils. In many ways, the small-scale process of scour by the river, establishment by alder, soil development and then eventual riparian community maturation is analogous to the large-scale process of primary succession in terrestrial ecosystems after glacial retreat. The presence of former riparian 'terraces' within the Eel provide glimpses of abandoned riparian zones of different ages, which may be compared to the current riparian zone in microbial and vegetation composition as well as N-cycle dynamics and N-sources (N-fixing vs. Ammonia/Nitrate). We hypothesize that there will exist correlations between the composition of vegetation, N-sources and N dynamics associated with terraces of different ages as well as with the specific spatial configuration of existing riparian corridors.

The stream corridor geometry research will be performed by Foufoula's group in collaboration with Dietrich and Rodríguez-Iturbe and the vegetation-ecosystems research by Rodríguez-Iturbe's group with input from Power and Hondzo (on nutrient cycling) and shared observations from the Angelo Coast Range Reserve.

Dynamic interplay of fluvial and hydrologic processes

The research on better understanding the connection between fluvial and hydrologic processes will continue during the next year. More specifically, we plan to introduce realistic space-time rainfall variability into a distributed fluvial-hydrologic model and study the scaling properties of hydrographs and floods as well as the transition to

overbank flows. From this numerical laboratory, we plan to study the frequency of occurrence of overbank flows at any junction along the stream network and, thus, explore a possible connection between network topology and channel/floodplain morphology (assuming that longer-lasting overbank flows produce wider floodplains). Such a connection was already inferred from a floodplain geometry analysis from DEM showing that, within a region of similar geology, wide floodplains occur predominantly at the vicinity of junctions of large tributaries. This trend seems to be magnified at the junctions of tributaries whose basin elongations are particularly oriented with respect to the most frequent direction of storm cell movement. This fact suggests that the channel/floodplain morphology is in addition affected by the dynamics of space-time rainfall over a basin.

This research will be pursued by Foufoula's group with input from Dietrich, Parker and Paola.

Inferences on mechanisms of landscape dissection

Over the past year, we have explored wavelet-based multifractal formalisms and have pointed out the shortcomings of the traditionally used methods (structure function and moment analysis) for scaling analysis of processes that are non-stationary, have non-stationary increments and exhibit a wide spectrum of singularities (*Venugopal et al.*, 2005; and *Rioux et al*., 2005, in preparation). In geomorphology, the width function of a river network W(x), defined as the number of streams crossed at distance x from the outlet (distance considered along the stream) versus distance x, has received considerable attention and the multifractal properties of this function have been attempted to be linked to the mechanism by which the river network dissects the landscape. We believe that a proper analysis of the width and other similar ecogeomorphic functions of the river network (such as the vegetation functions introduced by Kelly Kaylor and Ignacio Rodríguez-Iturbe), as well as the analysis of 2D river network topology itself under the more general wavelet-based multifractal or extended scale-invariance formalism will reveal interesting information about the nature of the mechanisms that dissect the landscape and give rise to the self-similar river networks.

This research is exploratory in nature and will be pursued by Foufoula's group in collaboration with Rodríguez-Iturbe, Dietrich, Paola, and Fernando Porté-Agel.

Collaborations Outside NCED

Foufoula-Georgiou with Kelvin Droegemeier, Center for Analysis and Prediction of Storms, University of Oklahoma (Collaboration on multiscale methods for verification of numerical weather model predictions and on multiscale, multisensor data merging methodologies.

Foufoula-Georgiou has participated as an executive committee member of CUAHSI in several community-related activities related to Hydrologic Observatories and the science that can be performed in understanding the coupled geomorphologic-hydrologic-ecologic-biologic system via observations, analysis and modeling at all scales.

Foufoula-Georgiou: A contract with the National Weather Service on implementing a Hydraulic-Geometry-based routing approach over large areas accounting for the channel and floodplain has led to knowledge transfer from academia to the federal agencies responsible for flood prediction over the U.S.

Foufoula-Georgiou: Undergraduate students from the "Hydrology and Hydrologic Design" course were recruited to perform undergraduate research related to NCED (Kristina Omdahl working on Stream Restoration with Vaughan Voller and Carl Peterson who will work with Foufoula as an MSI summer intern)

Foufoula-Georgiou: One lecture is devoted in the undergraduate "Hydrology and Hydrologic Design" course to introduce students (60 in the spring of 2004) to the complex problems encountered in observation and modeling of surface-water interactions. Introduction to the scope of NCED and its research and practical activities is given.

Foufoula-Georgiou: "Geomorphologic controls on the scaling of floods", invited talk at the EGS meeting, Vienna, April 2005.

Foufoula-Georgiou: "A new space-time rainfall generator for applications over a large range of space and time scales", talk at the EGS meeting, Vienna, April 2005.

Foufoula-Georgiou: Invited seminar entitled "New insights on the hydrology of the channelized systems" in EPFL (L'Ecole Polytechnique Fédérale de Lausanne), February, 2005.

Foufoula-Georgiou: Invited to contribute a vision paper for publication in Water Resources Research as a collection of papers that will drive the science of the new NSF-funded National Center for Hydrologic Science Synthesis (NCHSS).

Foufoula-Georgiou: Invited to act as a guest-editor in Water Resources Research for the collection of vision papers that will drive the science and observatories of CUAHSI.

Rodríguez-Iturbe: Taught full course in Ecohydrology (CEE/ENV 505) at Princeton University. Winter term 2004, winter term 2005.

Rodríguez-Iturbe: Lectured to postdocs and graduate students from different countries-including USA- on geomorphohydrology and ecohydrology at the International Workshop in Venice promoted by the Istituto Veneto di Scienze,Letter ed Arti. Summer 2004.

Rodríguez-Iturbe: Taught a short course at Universitá di Basilicata, Potenza, Italy, in geomorpho-ecohydrology. Summer 2004.

Research-related Knowledge Transfer, Education and Diversity Activities

Foufoula-Georgiou: Participated as an executive committee member of CUAHSI in several community-related activities related to Hydrologic Observatories and the science that can be performed in understanding the coupled geomorphologic-hydrologic-ecologic-biologic system via observations, analysis and modeling at all scales.

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Research Focus Area 2: Channel and Floodplain Dynamics

Lead PIs W. Dietrich, G. Parker, P. Wilcock, G. Wilkerson

Mission: to understand the flux and morphodynamic laws governing channel and floodplain evolution in order to:

1. Develop mechanistic, predictive models of the morphodynamic evolution of channels and floodplains;
2. Link these with each other as well as to larger morphodynamics entities such as drainage basins and submarine fans; and
3. Support restoration, forecasting, and hazard assessment in terrestrial and submarine channel systems.

Strategy and synthesis

Channels 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 Network Dynamics and Scaling group's focus on network-scale behavior and properties. Focus Area leaders Dietrich and Parker have organized the Channels and Floodplains group's research around eight complementary themes (note that much of this work is externally funded) that provide critical insight to NCED's three Integrated Projects (IPs):

Major research themes:

1. **Steep Landscapes and Mountain Rivers.** Steep landscapes define the source for sediment as it enters the river system. Distinctive attributes of these headwaters channel systems include the strong influence of hillslope processes; control of channel evolution by bedrock erosion, boulder trains, and topographic steps; sediment supply and erosion by debris flows; and strong influence of woody debris. The main integrator of NCED's mountain-river research is the Desktop Watersheds IP.
2. **Channel-Floodplain Interaction.** The co-evolution of channels and floodplains is critical to Stream Restoration (primarily through influencing flooding, channel migration, and habitat) and to Subsurface Architecture (floodplain sediments are typically much poorer conductors of fluid flow than channel deposits). In addition, through the link between floodplains and riparian habitat, this activity connects our work with that of the Ecogeomorphology group.
3. **Bank stabilization and vegetation.** Bank erosion is a major cause of channel instability and failure of restoration projects and is intimately tied to floodplain development. NCED's efforts here center on vegetation and fine sediments as a means of improving stream-bank stability and primarily contribute to the Stream Restoration IP.
4. **Dam removal.** There are roughly 75,000 large and two million small dams in the U.S. alone, and many are either considered environmentally undesirable and/or are at the end of their useful life. Developing environmentally benign methods for removing them is a high priority in stream restoration. In addition, there is a strong analogical connection between morphodynamic evolution following removal of a dam and evolution of an incised valley during sea-level fall, linking this theme with the Subsurface Architecture IP.
5. **Stream Restoration Toolbox.** A consistent theme in work with our Stream Restoration Partners Group has been that restoration practitioners often use extremely outdated science (fifty years is a common figure). To address this, we have begun an ambitious project to cast the latest research into the form of tools that can be used by practitioners. These tools are being developed as PowerPoint presentations, augmented by embedded Excel spreadsheets.
6. **Submarine Channels and Fans.** As discussed in the Context section, submarine channel systems show

many analogies with subaerial channel systems (e.g., erosional tributary networks, distributary fans, meandering, channel levees). Our work exploiting these analogies is crucial to the Subsurface Architecture IP and specifically has a strong connection to David Mohrig's program.

7. **Meandering.** The process of meandering is common in fluvial and submarine channels and represents one desired end state in restoration projects. Nonetheless, the conditions under which meandering is stable are still not fully understood and current models do not yet allow complete prediction of meander evolution. Work on meandering dynamics is fundamental to the Stream Restoration and Subsurface Architecture IPs.

8. **Sediment transport.** Quantifying sediment flux remains a basic issue in predicting channel evolution. Current focus topics include washload-suspended load interaction, cohesive sediment behavior, mixed-size transport, relating local and/or short-term flux to reach averaged and/or long-term flux, and novel methods of estimating sediment flux including sonar, tagged particles, and tracers. This work contributes to all three IPs.

Research Accomplishments

Steep Landscapes and Mountain Rivers

Steep landscapes define the source for sediment as it enters the river system and begins its journey to the sea. The main contributors to this topic within Focus Area 2 have been Dietrich and Parker; the main contributor outside Focus Area 2 has been Perg.

Rivers are intricately tied to the landscapes in which they are embedded. As hillslopes erode, their sediment is transferred to channels. Measurements of cosmogenic nuclide concentration in fluvial sediments have provided a reliable means of estimating denudation at a landscape scale. Parker and Perg have developed a conservation equation for cosmogenic nuclides that can be used to estimate the response time for nuclide concentrations in a river to equilibrate to a step change in the denudation rate.

In a mountainous setting, rivers in their uppermost reaches give way to channels incised by debris flows. If a landscape is to be in a statistical steady-state balance between uplift and denudation, headwater incision by debris flows must occur at the same average rate as the fluvial incision just below it. Yet almost nothing was known about debris flow incision into bedrock before the start of NCED. Dietrich and graduate student Hsu have performed drum experiments to determine the laws governing incision by debris flows. Parker is helping with the experimental design. The experiments are for the first time clarifying the laws governing incision into bedrock by debris flows.

Debris flow channels give way downstream to bedrock channels. Parker, graduate student Chatanantavet and Dietrich are developing a generalized model of bedrock incision that incorporates a) an earlier model due to Sklar (SFSU) and Dietrich for abrasion due to wear and b) a form of a model proposed by Whipple (MIT) and others including abrasion due to plucking and macroabrasion. Experiments have been used to determine the relation between alluvial cover of a bedrock bed and gravel supply (Figure 1). Numerical studies have revealed conditions under which autogenic knickpoints can form in bedrock streams. The main contributor outside Area 2 is Voller, who has helped with the formulation of a moving-boundary treatment for the bedrock-alluvial transition.

Alluvial streams with slopes between 2% and 10% may have little or no exposed bedrock, and yet have a bed composed of an obstacle course of large rarely mobile boulders which gravel and all finer particles must traverse annually. Dietrich and graduate student Elowyn Yager have developed a theory for predicting sediment transport rates based on estimating boundary shear stress partitioning

Figure 1: Experimental bedrock stream: note that the bed is only partially covered with alluvium

between the boulders and finer sediment, and on accounting for the proportion of the bed area occupied by mobile sediment. This theory is supported with flume experimental results, and field studies in Switzerland. This research has contributed to the efforts of Parker, Wilcock and Wilkerson.

Wilkerson, Wilcock and Parker have initiated coordinated studies aimed at improving understanding of the transport of sand-gravel mixtures and its relation to streambed armoring. One of the principal objectives of this study is identifying the conditions under which non-layered gravel streambeds form. That is, although the bed surface of most gravel rivers is considerably coarser than the sub-surface, it has been observed that coarse bed surfaces do not develop under conditions of extremely high sediment transport. Understanding the conditions that yield non-layered streambeds is important because bed surface composition affects river dynamics, morphology, and ecology.

Wilcock and graduate student Paul Grams initiated a series of experiments at St. Anthony Falls Laboratory to understand the transport of fine sand in suspension over a bed of coarse, immobile grains. The motivation for the work is to develop a model of sand entrainment for use in a reach-averaged transport model to predict sand transport and deposition in the Colorado River in the Grand Canyon. They installed 5,600 six-inch concrete hemispheres over a 40-m length in the main channel and then fed sand at different rates into a half-meter deep flow. They produced non-uniform transport conditions in order to examine the migration of sand pulses through the channel. They are now using these data within a morphodynamic model to evaluate different sand entrainment functions. Once developed, the entrainment model will be used in the field scale routing model to predict the response of sand transport and sand bars to tributary inputs and operation of Glen Canyon Dam. The research is closely tied to the efforts of the other members of Area 2, i.e., Dietrich, Parker and Wilkerson.

During this past year, Dietrich's group completed its externally funded mapping study of the 1000 km^2 Napa River watershed ; the simplest tools of their Desktop Watershed model were applied to the results. They found that the Napa River network is undergoing systematic disruption, with roughly 20 new reservoirs being built every year since 1950. Over 400 dams now block channels, and there are over 4000 road crossings that are or can become barriers to fish migration. The digital topographic data are now available on the website (http://calm.geo.berkeley.edu/ncalm/index.html).

Dietrich and postdoctoral researcher Christine May have led a US Forest Service supported study of the Salmon River (tributary of the Klamath River) in Northern California to identify linkages between landuse and channel characteristics. Despite the intensive use in this area, they have concluded that it is the intrinsic geomorphology, in which the major tributaries are very steep, that places severe constraints on habitat availability. This has led May to pursue comparison studies on the topography of other landscapes to explore the mapping of geomorphic constraints on salmon diversity and productivity.

Channel-Floodplain Interaction

Dietrich and Parker are collaborating on a study of channel-floodplain co-evolution in large lowland streams. The main study area is the Strickland River, the major tributary of the Fly River in Papua New Guinea. Field and remote sensing data now indicate that about 8 Mt/a are deposited on the floodplain (about 10% of the annual load) but that the lateral migration rate causes 24 Mt/a to exchange with the floodplain. These initial results spotlight the need to document the long-term vertical accretion rates, as the possibility exists that much of the overbank deposits are swept back into the channel.

Parker and student J. Wesley Lauer have developed a set of numerical models to describe the co-evolution of a river channel and its floodplain when subject to e.g., sea level rise. The models have been used to characterize the evolution of the Fly-Strickland River system in response to 120 m of sea level rise since the last glacial maximum. The model uses a moving boundary formulation which was developed with the aid of input from two other NCED

researchers outside of Area 2, Paola and Voller. In addition, Mohrig has also contributed to the effort.

Figure 2: Tie channel in Papua New Guinea

On lowland floodplains with meander loop cutoffs, channels may form where the sediment-laden flow enters the oxbow lake. Theses channels, referred to as tie channels (Figure 2), are similar to delta channels. Dietrich and graduate student Joel Rowland, collaborating with Parker and Mohrig, are conducting physical modeling experiments on tie channel formation. The experiments suggest that tie channel formation is highly sensitive to turbulence intensity and relative grain density.

Bank stabilization and vegetation

Vegetation plays a major role in many stream restoration projects. Wilkerson continued research on an analytical model for predicting depth-averaged velocities in straight trapezoidal channels with rigid vegetation. The original model was for predicting velocities in channels with unsubmerged vegetation. The model was modified in 2004 to facilitate evaluating flow in channels with both submerged and unsubmerged vegetation. This model was originally developed to facilitate the evaluation of bioengineering strategies that use planted willow posts (*Salix nigra*) along streambanks. Four papers document the model in its present state. The model is being generalized to facilitate evaluating the effect of rigid vegetation on depth-averaged velocities in compound channels, on floodplains, and around bends.

Dam removal

CalFed collaborator Yantao Cui (Stillwater Sciences) has completed a 1-dimensional model for predicting the reservoir erosion and downstream sediment transport after dam removal. Among other things, this model suggests that the single most important thing controlling response magnitude and timing is the reservoir grain size. A reservoir composed chiefly of gravel may have a fairly limited downstream influence due to dispersion and particle breakdown. This research is being conducted in cooperation with the efforts of Wilcock and Parker.

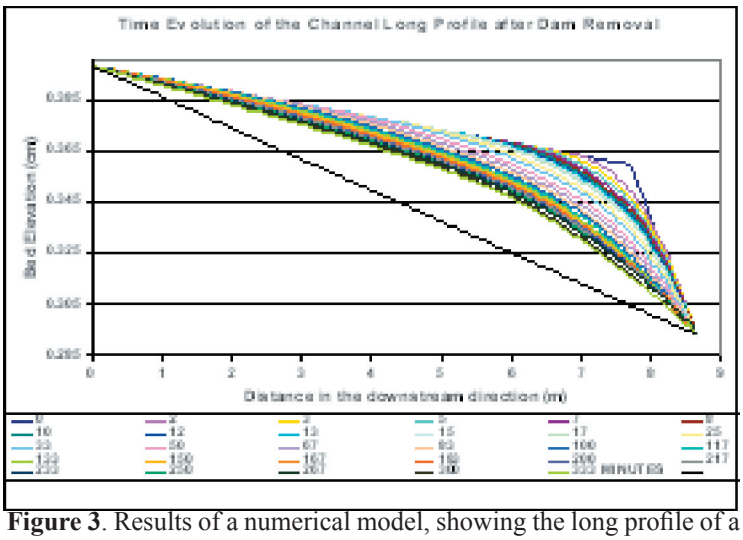


Figure 3. Results of a numerical model, showing the long profile of a channel incising into a reservoir deposit after sudden dam removal.

Research on the morphodynamics of dam removal was performed by postdoctoral research associate Alessandro Cantelli working under the supervision of Parker. Other NCED collaborators include PI's Paola, Wilcock, Dietrich and Voller, and graduate student Miguel Wong. A numerical model describing channel incision after sudden dam removal has been developed and applied to experiments. A diagram illustrating the time evolution of the long profile of a channel as it incises into a reservoir deposit is shown in Figure 3 (next page). Collaboration on the morphodynamics of dam removal also continues between Parker and an NCED partner, Stillwater Sciences.

Stream Restoration Toolbox

NCED believes that it is not enough to perform basic research on topics related to stream restoration. In addition, it is necessary to cast the latest research into the form of tools that can be used by practitioners. These tools are being developed as PowerPoint presentations, augmented by embedded Excel spreadsheets. The following tools were fully or substantially developed during the past year:

Tool title: The gravel river bankfull channel estimator

Tool purpose: Estimation of the bankfull geometry that would result from a bankfull discharge changed by e.g., flow diversion.

Primary tool author: Gary Parker

Status: Ready

Tool title: The gravel river bankfull discharge estimator (Figure 4)

Tool purpose: Allows estimation of bankfull discharge from measured channel characteristics at ungauged sites.

Primary tool author: Gary Parker

Status: Ready

Tool title: The spawning gravel refresher

Tool purpose: Allows design of controlled flood releases from dams combined with gravel feeding to restore over-coarsened and immobile former gravel spawning grounds.

Figure 4. Brown's Gulch, a gravel-bed stream at bankfull flow.

Primary tool author: Gary Parker

Status: Preliminary version is ready.

Tool title: Bank stabilization diagnosis

Tool purpose: Determination as to whether or not bank stabilization should be a part of a river restoration scheme

Primary tool author: J. Wesley Lauer

Status: Preliminary version is ready.

Tool title: The threshold channel calculator

Tool purpose: Design of a threshold channel in an e.g., urban setting, for which the sediment supply has been cut off.

Primary tool author: Peter Wilcock

Status: Preliminary version is ready.

Submarine Channels and Fans

Submarine fans show many analogies with subaerial fans. For example, many fans in both the submarine and subaerial setting are covered with well-defined channels bounded by levees. Recently researchers in Parker's group, including Alessandro Cantelli, have found a way to reproduce intense self-channelization on a subaqueous fan in the laboratory (Figure 5). The research allows detailed study of the processes that lead to self-channelization. An image obtained from the experiments is shown to the right. The research is being closely coordinated with that of Mohrig.

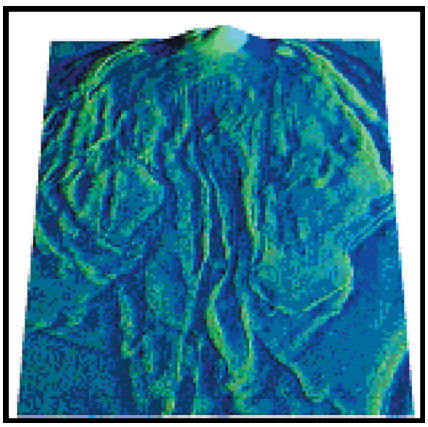


Figure 5. Channelized submarine fan produced in the laboratory.

Research on the response of channelized turbidity currents to slope breaks has been spearheaded by Svetlana Kostic, a postdoctoral researcher working under the supervision of Parker. In the first stage of the research, it was found that channelized turbidity currents undergoing a hydraulic jump at a slope break could leave a depositional

signature in the form of a backward-facing step. Such a slope break is shown in Figure 6 (next page). In the second stage of the research, it was found that sufficiently net-depositional turbidity currents could pass through even a sharp slope break without undergoing a hydraulic jump. This research is being conducted in cooperation with Mohrig and co-workers.

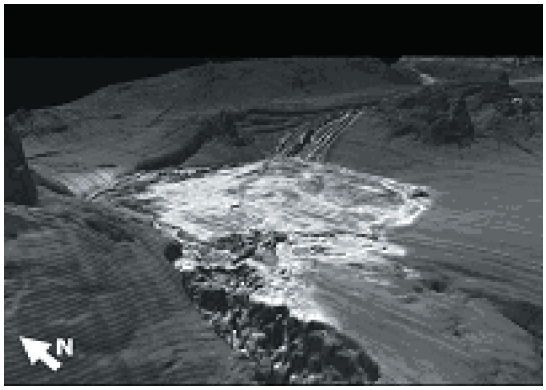


Figure 6. Slope break in a submarine canyon-fan system offshore of the Niger Delta, Africa.

The predominant bedform in rivers is the dune. In the submarine setting, however, the most common bedforms are trains of upstream-migrating sediment waves that have been interpreted as antidunes (Figure 7). Research spearheaded by postdoctoral researcher Svetlana Kostic, working under the supervision of Parker, has revealed that these ubiquitous bedforms are not antidunes, but rather cyclic steps. Cyclic steps are upstream-migrating trains of bedforms that are locked in place by a hydraulic jump upstream and downstream of each step. The research has been applied to the sediment waves and scour holes on a levee of the Sheperd meander of the Monterey Submarine Channel.

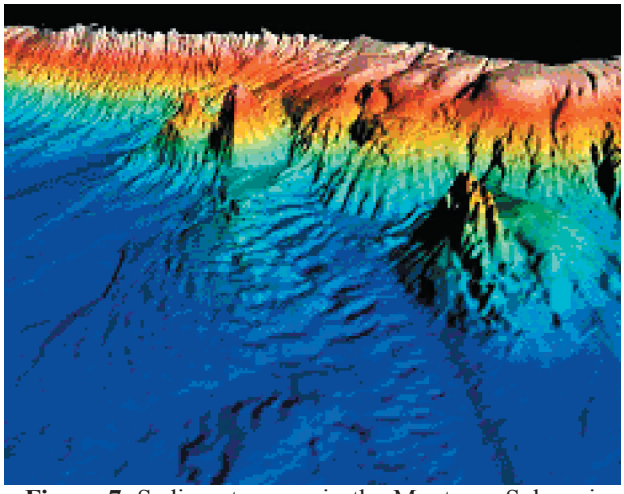


Figure 7. Sediment waves in the Monteray Submarine Channel

Meandering

The process of meandering is widespread in fluvial and submarine channels and has been a long-time research interest of Parker and of Dietrich. This year, Wilkerson took the lead in NCED meandering research. In April 2004, graduate student Robert Hood, working under the supervision of Wilkerson, completed a Master of Science thesis titled "Development of Meandering Channels in a Laboratory Flume: Initial Experience". Compiled in the thesis are a series of test results performed to gain experience with developing stable meandering channels in a laboratory flume. Wilkerson is preparing a manuscript for publication in a peer reviewed journal based on the research.

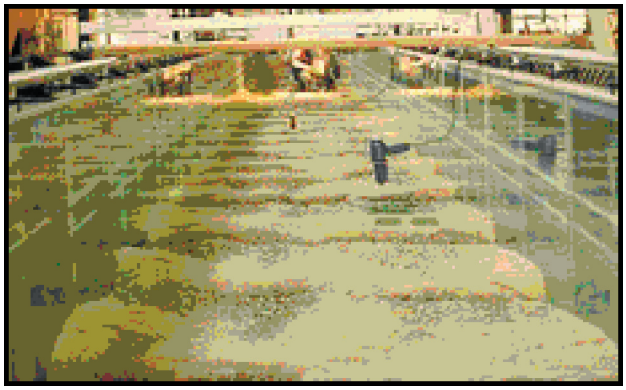


Figure 8. Vertical sediment sorting driven by dunes.

Sediment transport.

Quantifying sediment flux remains a basic issue in predicting channel evolution. In the past year Dietrich's group completely refurbished a building and a 90-ft long flume to conduct experiments on gravel augmentation and dam removal (work supported by CalFed). Parker worked with S. Francalanci, a visitor from the University of Florence, Italy to conduct experiments on the effect of seepage on sediment transport. Upward seepage enhances sediment transport, and downward seepage suppresses it. The results of the experiments are being quantified into a theoretical and numerical framework.

Parker and Astrid Blom, a postdoctoral researcher at University of Twente, the Netherlands, who is supported 25% by NCED, have studied sediment sorting by migrating dunes in rivers (Figure 8). The most recent research focuses on sediment sorting associated with dune migration in a river undergoing aggradation and/or degradation. This process is illustrated in the image above. NCED collaborators are Mohrig and his student, Douglas Jerolmack.

Ph.D. candidate Miguel Wong, working under the supervision of Parker, has developed a theoretical framework relating the dispersion of tracers in mountain streams to gravel bedload transport. The framework has been tested and developed with experiments. The major collaborators in Area 2 are Wilcock, Dietrich; Perg also provides input. A comprehensive set of experiments on the streamwise and vertical dispersion of tracers in gravel-bed streams is now nearing completion (Figure 9, next page). The experiments include both constant flows of varying duration and triangular hydrographs. The research has motivated a re-examination of the famous bedload transport equation of Meyer-Peter and Müller (1948). The research has also demonstrated that the so-called "active layer" thickness varies with the intensity of the flow.

Figure 9: Image from an experiment on tracer dispersion.

A linking question: the topographic signature of life

Dietrich has posed the question, "Is there a topographic signature to life on Earth", as a way to explore how biotic processes matter to landscapes form and evolution. This led to externally funded field work in the Atacama desert (one of most lifeless places on the planet), to several invited talks, and to a manuscript, currently under revision on the topic. The short answer seems to be "no", but life, nonetheless, matters greatly to landscape processes and topography. Related to this work, Dietrich is collaborating with three different groups on soil formation, solute losses, soil transport and deposition. Important findings on these collaborations include the first evidence that the flux of loose soil on moderately steep hillslope depends on the soil thickness, that solute losses can contribute significantly to mass loss during soil transit downslope (affecting the relationships among soil thickness, transport, and surface topography), and that soil deposition in hollows can lead to a significant sink for soil organic carbon.

Research Plans

The new year offers significant possibilities for expansion of both the research effort in Area 2 and collaborations within and without Area 2 in NCED. Dietrich looks forward to the completion of a) a ferris-wheel apparatus which will allow for near-field scale testing of incision due to debris flows, and b) a new set of flumes that will allow for study of dam removal and gravel augmentation as river restoration schemes. Both Parker and Wilkerson move to the University of Illinois, where their physical proximity and the Ven Te Chow Hydrosystems Laboratory will allow for expanded research opportunities. One flume there is being readied for experimental studies by Wilkerson and Parker on issues related to stream restoration. Another flume for the study of channelized turbidity currents in the ocean is presently being built on site. Finally, Wilcock is planning a set of field-scale experiments on gravel transport in rivers using the Main Channel at St. Anthony Falls Laboratory, University of Minnesota.

Steep Landscapes and Mountain Rivers

Dietrich and Parker will continue their collaboration to understand the morphodynamics of steep landscapes, with emphasis on bedrock incision by debris flows and fluvial action. The completion of the ferris-wheel experimental facility will allow for unique experiments on bedrock incision due to debris flows. A comprehensive numerical model of fluvial incision due to wear, plucking and macroabrasion will be completed. The results of the study on bedrock incision by debris flows will provide the upstream boundary condition for the study of fluvial bedrock incision. Parker and Perg will extend their model for cosmogenic nuclides to encompass the case of landsliding and bioturbation.

Dietrich, Parker, Wilcock and Wilkerson will work together to further understand the following issues: a) sand and gravel transport in streams with many bounders; b) transport of sand in suspension over a coarse gravel bed; c) the role of particle clusters in controlling gravel transport; d) the dynamics of tracers in gravel-bed streams and

e) developing source and sink functions for sand and gravels stored in coarse-bedded rivers. A combination of field, experimental and numerical techniques will be used to further this.

Channel-Floodplain Interaction

Dietrich and Parker will continue collaboration with Mohrig, Paola and Voller within NCED to develop models of the exchange of sediment between channels and floodplains at both small and large scale. In the absence of another field trip to Papua, New Guinea, channel-floodplain exchange will be studied on other, smaller streams such as the Minnesota river, and tie channels will be studied in e.g., the lower Mississippi River. The goal is a framework for a) predicting coarse- and fine-grained sediment sequestration in the floodplain, b) predicting channel-floodplain co-evolution as a river aggrades or degrades and c) providing sediment delivery functions to the ocean.

Stream Restoration (replaces Dam Removal and Bank Stabilization themes)

Dietrich, Parker, Wilcock and Wilkerson will team together to address the following issues: a) morphodynamics of dam removal; b) feasibility of gravel augmentation, c) bankfull geometry of self-formed gravel-bed and sand-bed streams, d) use of vegetation as an agent of stream restoration, e) implementation of the Desktop Watersheds concept, f) integrated evaluation of stream restoration projects and g) restoration of sand bars in the Grand Canyon.

Stream Restoration Toolbox

The following new tools should be finished in at least preliminary form during the next reporting year:

Tool title: SHALSTAB
Tool purpose: The tool provides a simple mechanistic model for delineating the relative potential for shallow land-sliding across the landscape
Primary tool author: William Dietrich
Status: Working version is ready, but must be made platform-independent by December, 2005.

Tool title: Estimating sediment budgets in ungauged mountain catchments from displacement tracking of tracer stones
Tool purpose: Means for estimating gravel budgets in mountain rivers for stream restoration programs.
Primary tool author: Miguel Wong
Status: to be completed by the end of summer, 2005

Tool title: Willow post placement analyzer
Tool purpose: Computes altered distribution of depth-averaged velocities that results from a prescribed installation of willows along a river bank.
Primary tool author: Gregory Wilkerson
Status: To be completed by the end of June, 2005.

Tool title: The role of flooding on the encroachment of riparian vegetation
Tool purpose: To help in determining whether or not the restoration of controlled floods on a dammed river can help control or reverse unwanted vegetal encroachment into the channel
Primary tool author: Michal Tal
Status: to be completed by August, 2005

Tool title: The Monte Carlo calculator
Tool purpose: This tool uses a simple and easily understood Monte Carlo algorithm to demonstrate uncertainty in calculations commonly used in stream restoration work.

Primary tool author: Peter Wilcock
Status: To be completed by end of summer, 2005.

Tool title: The bankfull channel mensurator
Tool purpose: This tool will provide a step-by-step explanation of how to a) determine if a channel has a definable bankfull geometry, and b) if so, how it can be accurately measured.
Primary tool author: J. Wesley Lauer
Status: To be completed by end of summer, 2005

Tool title: The sand-bed resistance calculator
Tool purpose: This tool will help in calculating flood flow in sand-bed streams with dunes
Primary tool author: David Mohrig
Status: To be completed by December, 2005.

Tool title: The meander-braid discriminator
Tool purpose: This tool will help in determining whether or not a restored stream should be meandering, wandering or braided
Primary tool author: Gary Parker
Status: To be completed by December, 2005.

These tools will be beta-tested by NCED partners, and then made available at the NCED Stream Restoration Website: http://www.nced.umn.edu/streamrestoration.html.

Submarine Channels and Fans

Parker and postdoctoral researcher Cantelli will continue experimental research on channelized subaqueous fans. This research will be augmented with a theoretical/numerical component to explain self-channelization. Parker and postdoctoral researcher Kostic will perform experiments on cyclic steps created by turbidity currents, and test a numerical model against the experiments. The experiments will be performed at St. Anthony Falls Laboratory in cooperation with Lincoln Pratson and his graduate student Tommy Gerber. Parker and a new graduate student will begin a new set of experiments and numerical models on the morphodynamics of turbidity currents passing over stepped profiles. Finally, a new effort on net-erosional turbidity currents will be started at the University of Illinois. The research on submarine channels and fans will be conducted in close cooperation with Mohrig.

Sediment transport

Parker and Wong intend to complete their current tracer study. New PI Peter Wilcock will be working on mixed-size sediment transport and applications to Stream Restoration.

Collaborations Outside NCED

Dietrich**:** Simon Apte (CSIRO, Sydney, Australia) is collaborating on the floodplain sedimentation project in Papua New Guinea. He has provided use of his laboratory for analyses and his offered his considerable expertise and understanding in analyzing the data.

Dietrich: Brian McArdell (Swiss Federal Institute for Forest, Snow and Landscape) is collaborating on field studies of sediment transport in steep, boulder bed channels. He is provided monitoring data and support staff to graduate student Elowyn Yager.

Dietrich: David Furbish (Vanderbuilt) and Arjun Heimsath (Dartmouth) are collaborating on modeling soil formation and transport.

Dietrich: Ron Amunson (UC Berkeley) and his graduate students are collaborating on soil formation and landscape evolution.

Dietrich: Alan Howard (U. Virginia) is collaborating on various landscape evolution processes studies on Earth and Mars.

Dietrich: Mike Malin (Malin Space Sciences) is leading a lander mission to Mars and Dietrich is a collaborator on this mission.

Dietrich: Leonard Sklar (San Francisco State) and Stillwater Sciences (including Frank Ligon and Yantao Cui) are collaborating on a CalFed funded project to do physical modeling relevant to stream restoration.

Parker: Research on bedrock incision is being done in cooperation with K. Whipple of MIT.

Parker: Research on sediment sorting by dunes is being done in cooperation with S. Hulscher of the University of Twente, the Netherlands.

Parker: Research on the effect of seepage on sediment transport in rivers is being done in cooperation with L. Solari and E. Paris of the University of Florence, Italy.

Parker: Research on the effect of sea level rise on the evolution of large river systems is being done in cooperation with T. Muto of the University of Nagasaki, Japan, and Y. Akamatsu of the Tokyo Institute of Technology, Japan.

Parker: Research on turbidity current morphodynamics in the deep sea is being done in cooperation with ExxonMobil and Shell Oil.

Parker: Research on clinoforms is being done in cooperation with C. Nittrouer of the University of Washington and R. Slingerland of Pennsylvania State University.

Wilcock: Yantao Cui (Stillwater Sciences): development of sediment transport manual

Wilcock: G. Mathias Kondolf (Berkeley): co-teach stream restoration course

Wilcock: Margaret Palmer (U. Maryland): develop and co-teach short course; collaborating on developing a team for in-depth stream restoration project evaluation.

Wilcock: John Pitlick (U. Colorado): development of sediment transport manual.

Wilcock: Jack Schmidt (Utah State University): co-teach stream restoration course; investigate sediment transport and hyporheic flow in a restored stream; develop sediment routing model to support restoration of sand bars in Grand Canyon

Wilcock: Sean Smith (Maryland DNR): Development of sediment budgets for first order Piedmont watersheds.

Wilcock: Fu-Chun Wu (National Taiwan University), Visiting Scholar at JHU, June-September 2005, Fluvial habitat geomorphology and restoration.

Wilcock: Steve Wiele, Scott Wright, Ted Melis (USGS): Sand transport in coarse-bedded canyon rivers: laboratory experiments at NCED, numerical modeling.

Research-related Knowledge Transfer, Education and Diversity Activities

Dietrich: Made presentation to the Napa County Watershed Information Center and Conservancy Board on LIDAR analysis of the Napa Watershed (8/04).

Parker has recruited two new minority graduate students to join the NCED research program. Robert Haydel is an African-American who will be advised by Parker. Javier Ancalle is a Puerto Rican Hispanic who will be co-advised by Parker and Marcelo Garcia of the University of Illinois (where Parker will move in August, 2005). Both will begin as M.S. students in August, 2005.

Parker served as supervisor for the summer internship of Robert Haydel, an African-American undergraduate who will become his graduate student in August of 2005 (see above).

Parker spent much of the last year organizing the 4th River, Coastal and Estuarine Morphodynamics Conference, which will be held from October 4 – 7, 2005 in Urbana, Illinois. Over 170 abstracts have been submitted to the conference. NCED will help fund travel for our Latin American partners to attend the conference.

Parker and Wong organized a Tracers Workshop with 12 attendees at the University of Minnesota, May 2-4, 2004.

Parker attended and presented at an NCED workshop on new computational methods applied to earth surface research organized by V. Voller, held at MIT, May 23 – 25, 2004.

Kostic and Parker gave a presentation at the RiverFlow 2004 Conference, Napoli, Italy, June 24 – 25, 2004.

Parker, Lauer, Wong and Cantelli gave presentations at the ASCE EWRI Conference, Salt Lake City, June 27–July 2, 2004.

Parker gave an invited presentation at the 3rd International Conference on Civil and Environmental Engineering (ICCEE-2004), Hiroshima University July 28-29, 2005.

Parker and Lauer presented at an NSF Source-to-Sink workshop held at Stony Brook, New York, August 14 – 15, 2004.

Parker gave an invited presentation at the 2004 International Conference on Slopeland Disaster Prediction and Mitigation, Taipei, Taiwan, October 5 – 6, 2004.

Parker gave an invited seminar on reservoir sedimentation at the University of Michigan, November 5, 2004.

Parker gave an invited talk at the Desert Research Institute, Las Vegas, Nevada, November 19, 2004.

Parker, Cantelli and Wong gave presentations at the AGU Fall Meeting between December 15 and 19, 2004.

Parker attended and contributed to the NCED Stream Restoration Partners' Meeting, February 24 – 25, 2005.

Parker gave an invited presentation on drainage basin formation at the Hydrology Days Symposium, Colorado State University, March 7 – 9, 2005.

Parker, Cantelli and Kostic all gave presentations at the workshop entitled Modeling of Turbidity Currents and Related Gravity Flows held at Santa Barbara, California, March 13 – 15, 2005.

Parker and Lauer presented at an NSF Source-to-Sink workshop held in Houston, Texas, March 20 – 21, 2005.

Parker organized the NCED Dam Removal Workshop, Torrey, Utah, March 25 – 27, 2005; Cantelli and Lauer attended.

Wilcock: One-week short course in stream restoration: "*Principles and Practice of Stream Restoration*" (co-teach with G. Mathias Kondolf): October 2003, 2004, 2005.

Wilcock: Two-week short course on stream restoration, (i) "*Principles and Practice of Stream Restoration*", (ii) "*Geomorphology and Sediment Transport in Channel Design*", (co-teach with Jack Schmidt): August 2004, May 2005.

Wilcock: One-week short course in stream restoration: "*Ecologic and Geomorphic Foundations of Stream Restoration*" (develop and co-teach with Margaret Palmer): July, 2005.

Wilcock: Presentations and interviews with stream restoration practitioners:
Biohabitats, Baltimore, MD (Jan. 2005),
multiple companies, Louisville KY (April 2005)
Allred Restoration, Provo UT (August 2004)

Wilcock: Public Lecture, "*Sediment transport in stream restoration design*", Baltimore Ecosystem Study, Symposium on Stream Restoration (January 2005)

Wilcock: Public Lecture, "*Sediment transport in stream restoration design*", Maryland Dept. of Natural Resources (February 2005)

Wilcock: Public Lecture, "*Sediment transport in stream restoration design*", Maryland Stream Symposium (August 2005)

Wilcock: American Society of Civil Engineers, Environment and Water Resources Institute Annual Congress, Salt Lake City, "*Sediment Transport in the Restoration of Gravel-bed Rivers*" (June 2004).

Wilcock: Development of guidance manual for estimating sediment transport (with John Pitlick, Yantao Cui), to accompany calculation software developed for the U.S. Forest Service Stream Systems Technology Center, Fort Collins, CO.

Wilkerson: Served as research advisor for two female undergraduate students (K. Puckett and D. Tripp) in the 2004 NCEDUndergrad Summer Internship Program (May – August 2004). Funding for the students was provided jointly by the University Minnesota and University of Wyoming. In addition to a stipend, the students were provided with funding for research supplies, participation in an undergraduate research symposium at the University of Minnesota, and attendance at a professional conference organized by the American Society of Civil Engineers.

Wilkerson: Invited presentation, University of Illinois, Urbana-Champaign (January 2005), "Flow through trapezoidal channel with rigid cylinders.

Research Focus Area 3: Advanced Mathematical and Observational Methods

Lead PIs : V. R. Voller and F. Porté-Agel

Mission: to identify and develop effective mathematical and observational techniques for analysis of channel systems, including localization, scaling, instability, and the coupling of physical and biological dynamics, in order to:

1. Improve the sophistication, accuracy and capabilities of channel and channel system models;
2. Obtain relevant physical data from both field and experimental domains;
3. Contribute to the model components being developed by other Focus Areas; and
4. Support similar modeling efforts being undertaken by our Partners.

Strategy and synthesis

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. Rapid progress and transformation of surface process science requires infusion of advanced techniques in quantitative analysis and observation capable of addressing these complexities. In addition, analytical methods aimed at general problems also provide a natural integrator across the focus areas. Focus group leaders Voller and Porté-Agel have organized the Advanced Methods Focus Area's research around two major themes that provide critical insight to NCED's three Integrated Projects:

Major research themes:

1. **Moving Boundaries** Channels and channel networks represent the most spatially significant instance of spontaneous pattern formation and self-organization on Earth. In many cases, the evolution of these patterns can be well described by moving boundary problems—problems that require the tracking of an evolving surface as part of the solution. These surfaces include critical interfaces like the shoreline, gravel fronts, and ecologic boundaries. Research in this theme contributes to all three IPs.
2. **Turbulence and River Networks** Turbulence in channel systems presents unique problems including effects of moving sediment and the influence of complex boundary geometries and variable roughness. One aim of research in this theme is to make sure that advanced turbulence methods are brought to bear on flow problems in all three NCED IPs. In addition, there are a number of modeling problems that recur in Earth-surface dynamics, including subgrid phenomena and localization, for which the turbulence research community has already developed effective solution methods. Research in this theme focuses on adapting tools from turbulence research to study river networks, with primary applications in the Desktop Watershed and Subsurface Architecture IPs.

Research Accomplishments:

Moving Boundaries

Channels and channel networks represent the most spatially significant instance of spontaneous pattern formation and self-organization on Earth. In many cases, the evolution of these patterns can be well described by moving boundary problems—problems that require the tracking of an evolving surface as part of the solution. In this light, the development of numerical techniques for tracking moving boundaries remains a central theme of the Advanced Methods Focus Area. State-of-the-art moving boundary models provide a vehicle which can be used to

test hypothesis related to the nature of key fluvial processes, e.g., distinguishing between autogenic and allogenic phenomena, and analyzing the effects of channel avulsions. Moving boundary techniques can also be applied to shorter time scale problems, e.g., modeling the evolution of the sediment delta in a reservoir following a dam removal or drawdown. Further, more general moving techniques related to pattern formation, e.g., reaction-diffusion equations, can be used to model vegetation and species distributions in riverine environments.

In the past year moving boundary research accomplishments fall into three applications areas:

1. Modeling of Sedimentary Basins: In sedimentary ocean basins, sediment is generated by erosion of the uplands and transported over the land surface by fluvial processes, i.e., by water flowing through a network of surface channels. In the typical time scales of problems of sedimentary geology these channels are not fixed but can migrate (braid and meander) over the land surface and expand (flood) and contract with time. The sediment arriving at the shoreline fills the near shore region or is carried off-shore by ocean currents and wave motions. An excess of sediment arriving at the shoreline will result in an ocean-ward advance of the shoreline; the moving boundary of interest. Note that in the general case the basement can subside and have a variable topography. In the past year a major area of work has focused on developing models for tracking the movement of sedimentary basin shorelines. Not only does this work provide a description of the development of long time scale stratigraphy, it also provides critical information on shorter time scale fluvial and channel processes (e.g., the control of the frequency of avulsion events). Research accomplishments in this area include:

- Validation of the shoreline balance equation using physical modeling data. This year a detailed interpretation of data obtained from the eXperimental EarthScape facility (XES) has been used to validate our shoreline tracking models; in particular, the critical geomorphic phenomena that control the shoreline movement have been identified. This study underpins the physical validity of our shoreline tracking model.
- A limit case closed-form analytical solution that tracks a shoreline advancing into a constant sloping ocean has been obtained (see Figure 1 for results from this solution). This solution is extremely useful because it provides a means by which the operation of numerical models, designed to track the shoreline in more complex problems, can be verified.
- Building on the advances in the tracking of one-dimensional shorelines in two-dimensional cross-sections, a numerical model based on a fixed grid front-tracking scheme has been developed to analyze shoreline movements in 3D geometries. This model can include the effects of subsidence, ocean level change and variable ocean floor topography. The model is build around the validated shoreline sediment balance and results from the model have been verified by comparing predictions for shoreline advance into a constant sloping ocean with the analytical solution, see Figure 1 (next page). The model has also been used to predict shoreline movements under a number of different conditions. Figure 2 (next page), shows a time snap shot of the fluvial surface when the shoreline is driven by a single sediment point source into an ocean with a subsiding trench on the ocean floor. This trench results in the formation of a ‘cove’ like feature in the shoreline.

2. Moving Boundaries in Landscape Sustainability: It is important to note that many of the long-term sediment transport processes that play out in the movement of an ocean shoreline are also applicable at shorter time scales. This behavior explains how short-time-scale physical experiments (e.g., the XES) can predict long term morpho-dynamic events. This observation has allowed for the successful extension of the fixed-grid shoreline tracking algorithm to the problem of short-time-scale sediment transport. A particular example is the tracking of the sediment delta in a reservoir subjected to draw down (e.g., Lake Powell). Figure 3 (second page following) shows a cross section of a reservoir. At time $t = 0$ a sediment delta is positioned upstream of a dam. As time increases the water level in the dam is lowered at a fixed rate. This drawdown causes the sediment delta to transport downstream. The

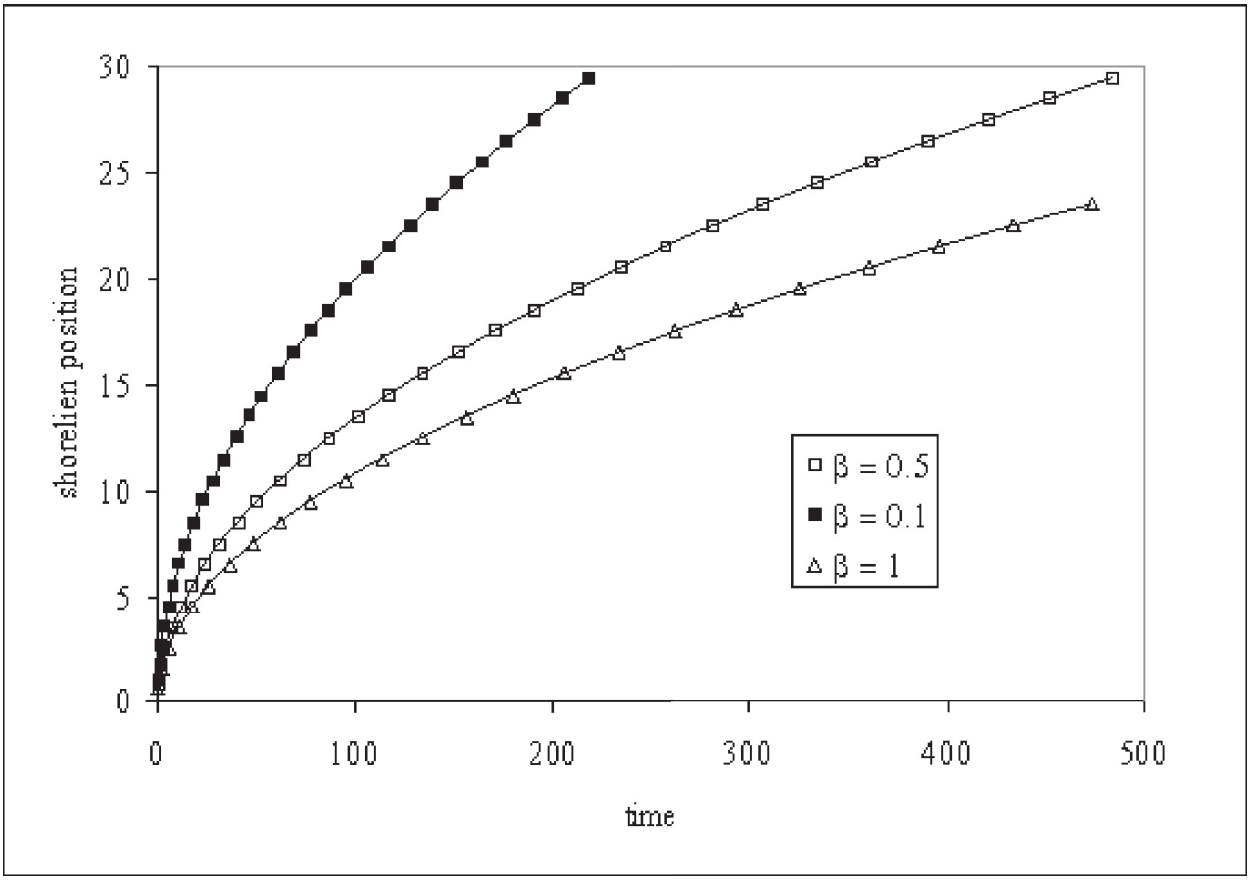


Figure 1: Shoreline positions with time for a shoreline growing into a constant sloping ocean (slope β). The symbols are numerical predictions the lines analytical values.

tracking of the front of the sediment fan in Figure 3 (next page is achieved by using the same fixed grid scheme used for the results in Figure 2. The results are in qualitative agreement with physical experiments conducted at SAFL.

3. Moving Boundaries in Eco-Geomorphology: New cooperative research with the Scaling and Eco-geomorphology Focus Areas has been initiated in the development of techniques to simulate pattern formation and track moving boundaries in riverine ecological systems. Areas of collaborative research include:

- The development of cellular-style methods for tracking pattern interfaces. A preliminary result is the development of a lattice Boltzman method that can be used to track interfaces. This

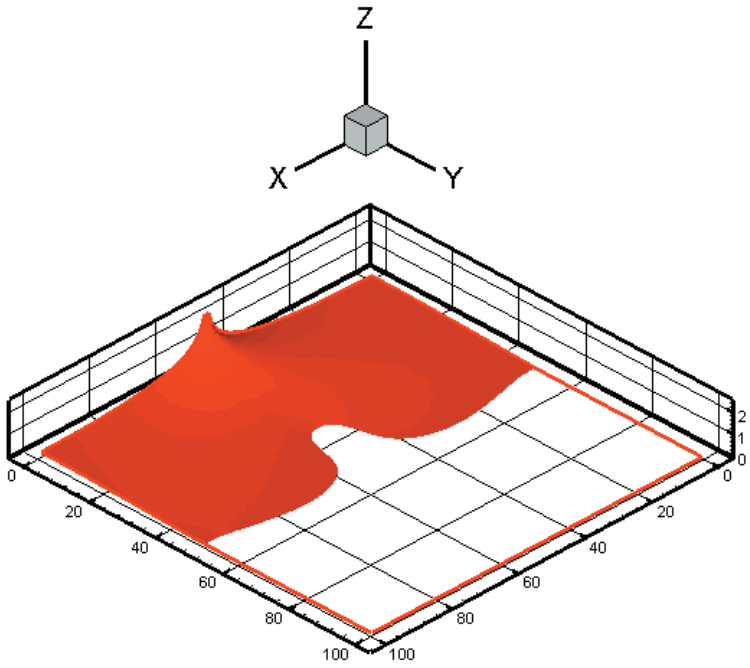


Figure 2: Snapshot of fluvial surface and shoreline for an advance into an ocean with a subsiding slot trench.

discrete approach is seen as fruitful because it can act as a bridge between the continuous processes of geomorphology and naturally discrete eco- bio processes

- Reaction Diffusion models of pattern formation: Dating back to Turing in the 1950's, these models have long been used to understand pattern formations in nature. One well-used reaction diffusion model, derived from thermodynamics, is the phase field model. This year a discrete analog solution of the phase field model has been developed for tracking growth processes controlled by surface curvature. One specific application area is understanding the patterns formed by biological communities in response to their environmental conditions, e.g., bacteria on a Petri dish. The goal is to expand on this method to predict patterns relevant to the ecology of channels and channel systems.
- A third developing research area is the development of tools for describing the transport of solutes into stream beds. This work is related to previous efforts on modeling unsaturated flow in porous media. The current effort is a numerical tool for determining the effective dispersion of the solutes, under varying wave and bed form conditions. The aim is to develop a tool that can make a calculation of physical dispersion which is insensitive to numerical dispersion.

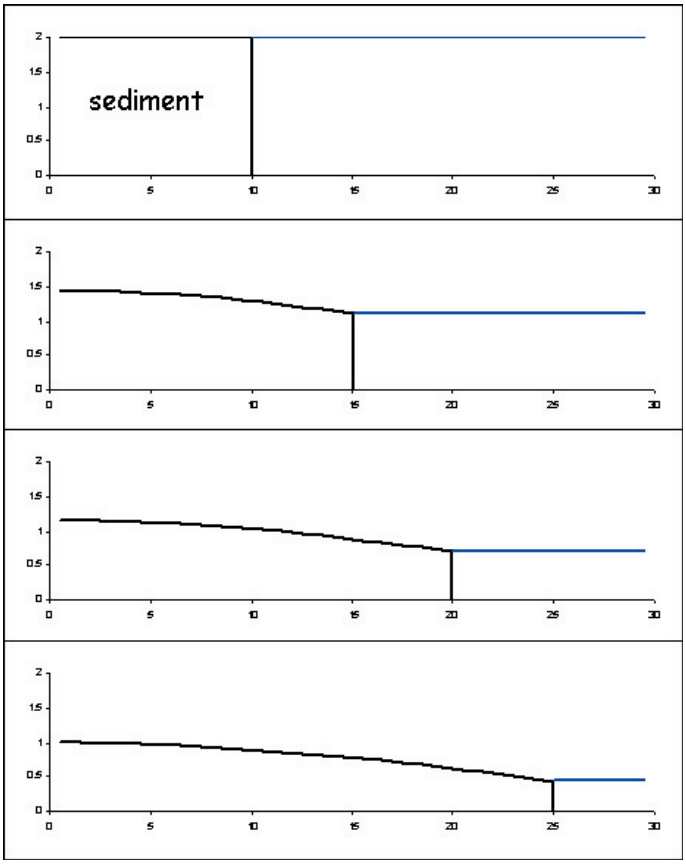


Figure 3. Movement of sediment fan in a dam reservoir subjected to a drawdown

Turbulence and River Networks

The other central research area in the Advanced Methods group is focused on exploiting the similarities between river networks and turbulence with the goal of improving our understanding and ability to model landscape and river network dynamics.

More specific objectives of this research are:

1. Studying the scale (grid-resolution) dependence of numerically-simulated river networks obtained solving the 'standard' prognostic evolution equations.
2. Development of simulation techniques analogous to Large-Eddy Simulations (LES) of turbulence to solve the spatially-filtered prognostic equations for landscape evolution.
3. Development of improved subgrid-scale parameterizations for Large-Eddy Simulations based on scale similarity.

In the past year our main accomplishment in this area was the justification and development of a conceptual modeling framework analogous to Large-Eddy Simulation of turbulence to solve the spatially filtered prognostic landscape evolution equations. In the context of river networks, this approach consists of explicitly resolving landscape features larger than the grid/filter scale, while parameterizing the effect of the non-resolved scales

(subgrid-scale fluxes of sediments or nutrients associated with lower-order basins) with a subgrid-scale model. In particular, during this year we have addressed the following issues:

1. The Large-Eddy Simulation technique has been applied to simulations of the noisy *Burgers Equation*, a one-dimensional equation which has characteristics similar to the equations used to model landscape evolution. This equation is also considered a low-dimensional analogue of the Navier-Stokes equation and has received substantial attention in the physics and turbulence communities. Different subgrid-scale models have been explored and the results compared with direct numerical simulations (that explicitly resolve all the spatial and temporal scales of the dynamics) of the Burgers equation. A manuscript describing these results is currently under preparation to be submitted to the journal *Physics of Fluids*.
2. Simulations of landscape evolution have been performed using a standard set of governing equations: a Langevin equation for the erosion of the landscape coupled to a conservation law for the surface water flow. By using different grid resolutions, we have shown that the simulation results have strong resolution dependence. This is explained by the fact that subgrid-scale processes, not accounted for in the simulations, have a substantial impact on the simulated landscapes. This highlights the need for using a subgrid-scale model to represent the effect of the subgrid scales.
3. A new subgrid-scale model is currently been developed that takes advantage of the scale-invariant, multi-affine characteristic of the system. This type of model has been successfully applied in Large-Eddy Simulations of

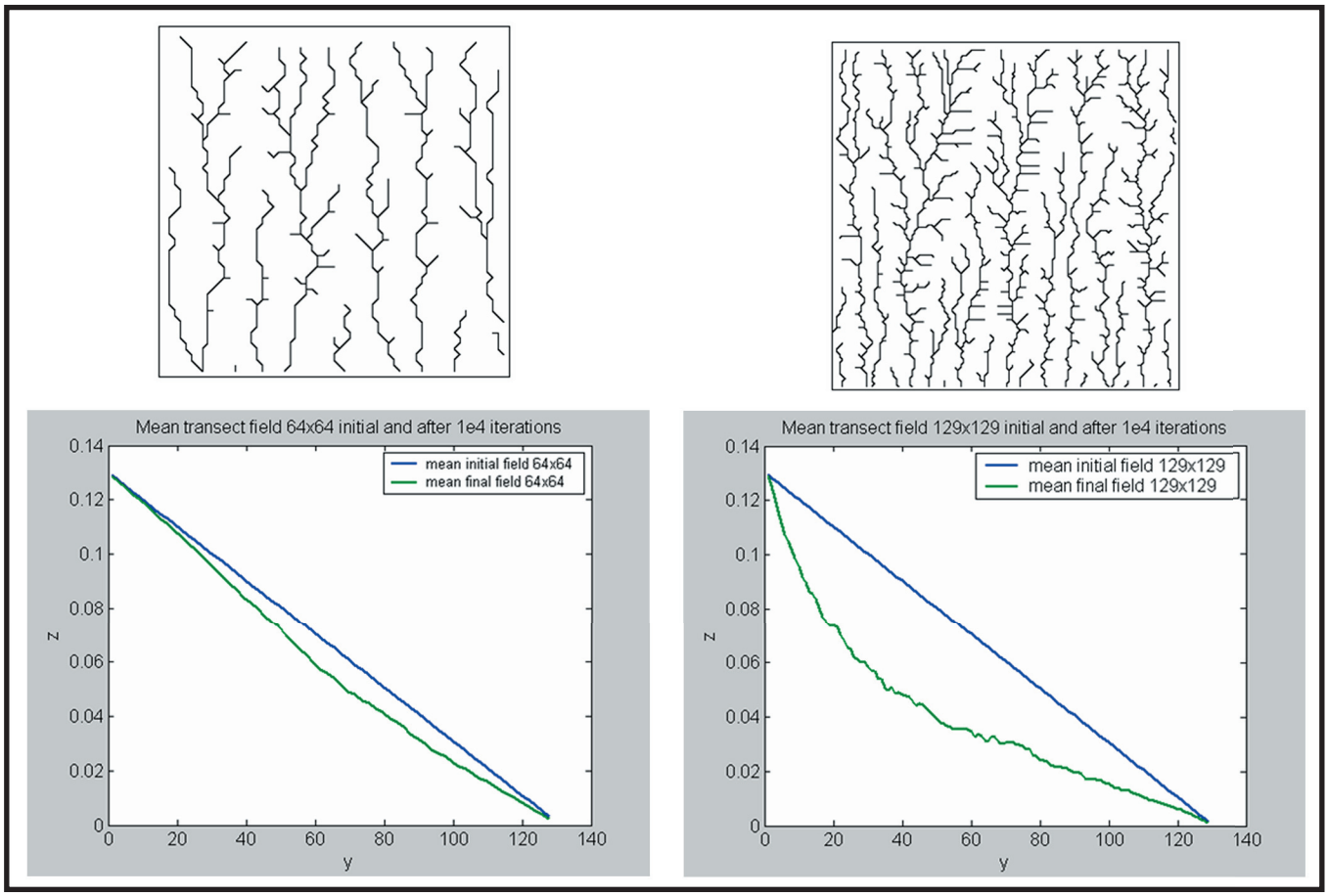


Figure 4: Simulated river networks (top) and mean transects of elevation (bottom) obtained solving a common landscape evolution numerical model. The two networks are obtained using different numerical resolutions (left panels: 64x64 grid points; right panels: 129x129 grid points).

the 1-D Burgers equation as well as 3-D turbulent boundary layer flow, and it is currently been tested in landscape simulations (Figure 4).

Research Plans

Moving Boundaries

In the moving boundary work a major push this next research year will be to directed at

- Incorporating more detailed (smaller) space and time scales of channel behavior into the shoreline-tracking model. This effort will be focused on developing a mechanistic understanding of fluctuations observed in the experimental system, and will be based on coupling deterministic and cellular/lattice type models and utilize statistical surface transport equations, e.g., KPZ.
- Improving the generality of the shoreline model, in particular accounting for a more complete description of the offshore sediment transport processes and shorter time scale sediment transport problems related to stream restoration.
- Developing and implementing physical models of moving sediment fronts that can be used to validate other models, in particular the limit-analytical solution and dam-removal models.
- Developing models and solutions for multi-scale processes related to the coupling of geomorphic and ecological processes. Code for appropriate reaction diffusion models will also be developed with a view of predicting patterns in eco-geomorphic systems.
- Continuing work on transport properties in channel beds. A numerical approach will be developed for calculating appropriated dispersion coefficients to track pollutant transport into stream beds.

Turbulence and River Networks

In the coming years, we plan to improve the LES approach for the simulation of landscapes and river networks. Special emphasis will be placed on the development of the spatially filtered governing equations and subgrid-scale parameterizations required to account for subgrid-scale dynamics. In particular, the following activities will be carried out:

- Further development and testing of subgrid-scale models for closure of the filtered governing landscape evolution equations. In particular, scale-similarity and fractal subgrid models will be tested. In order to avoid ad-hoc parameter tuning, dynamic procedures will be developed to compute the value of the model coefficient(s) based on the dynamics of the resolved scales. Similar procedures have been successfully developed by Porté-Agel in the context of subgrid parameterizations of turbulence.
- An *a priori* study of the subgrid-scale physics, fluxes and transfers of energy (measured as the variance of the fluctuations in elevation) between resolved and subgrid scales. This will be accomplished by calculating these quantities from high-resolution digital elevation maps available for the Angelo common field site. These studies will provide information on the relation between resolved variables (e.g., spatially filtered elevation) and subgrid-scale fluxes (e.g., subgrid-scale fluxes that need to be parameterized). Understanding of this relation between resolved and subgrid scales is essential to development of physically realistic parameterizations.

In another line of research, the LES technique will continue to be developed for simulations of turbulent transport in channel flow. Particular emphasis will be placed on the following activities:

- Simulation of flows over complex topography. Accurate simulation of these flows is essential to improve the parameterization of the effects of complex bed forms (such as dunes and ripples) on the turbulent transport of momentum, sediment and chemicals in channel flows.
- Simulation of stratified turbulent flows. LES of stratified flows remains a challenge due to the increased flow anisotropy and reduction of the characteristic turbulent scales associated with stratification. Our research group is actively involved in developing improved subgrid parameterizations that can capture the effects of flow stratification. These models will be tested and used in simulations of stratified channel flows as well as submarine turbidity currents.
- Simulation of sediment-laden turbulent channel flows. We plan to develop subgrid-scale parameterizations for the transport of sediments in turbulent boundary layers. Emphasis will be placed on (a) the new-generation of tuning-free dynamic subgrid-scale models for sediment fluxes, and on (b) the surface boundary condition used to parameterize the surface fluxes of sediments (erosion/deposition) as a function of the fluctuating (instantaneous) velocity field. Once the LES code (including the new subgrid parameterizations) has been tested, it will be used to (a) study the effects of channel flow geometry on erosion/deposition rates and (b) understand and quantify the mechanisms that govern the formation, dynamics and collapse of turbidity currents.

Collaborations Outside NCED

Voller is collaborating with Bojan Guzina on "Patterns and crack spacing," see research summary.
Voller is collaborating with Heniz Stefan on "Transport in stream beds," see research summary.

Research-related Knowledge Transfer and Education Activities

Voller was Working Group Leader—Surface Evolution, MIT, May 2004.
Voller was a participant and a presenter at NCED's Stream Restoration Partners meeting, Uof M, February, 2005.
Porté-Agel advised NCED Undergraduate Summer Internship Program participant Angel Santiago, University of Puerto Rico, Mayaguez, who plans to return to the UofM in summer 2005 to continue his research on "A Wind Tunnel Study of Turbulent Boundary Layer Over Heterogeneous Surface Conditions".

Research Focus Area 4: Ecogeomorphology

Lead PIs: M. Power, J. Banfield, J. Finlay, M. Hondzo, A. Wold

Mission: to investigate interactions of physical, biologic and biogeochemical processes in channels and floodplains, including effects of channel and floodplain morphology and channel network organization on ecosystem structure and function, and the influences of biota on landscape evolution, in order to:

1. Develop the capability of predicting the effects of restoration and management practices on all components of channelized landscapes;
2. Provide the theoretical and empirical components describing ecogeomorphic processes and interactions for NCED ecogeodynamic models; and
3. Demonstrate both the need and the desirability of a multidisciplinary approach to landscape management and restoration to our Partners and the restoration community at large.

Strategy and synthesis

The strong interplay of biological and physical processes is a central NCED theme, and there are strong connections in both directions. The physical structure of the landscape provides an organizing template for life, influences habitat quality and diversity, and controls sources and flows of critical nutrients. In turn, organisms shape the landscape through microbial weathering, the stirring and diffusion of soil, flow baffling, and the stabilization of bars, banks, and floodplains. Our group's recent focus has been on interactions of physical and biologic processes that structure ecosystems and food webs in upland channels and watersheds. Focus group leaders Power and Hondzo have broken this research down into four complementary themes. Within these, we initially focused our work on ecogeomorphic input to the Desktop Watersheds Integrated Project (IP). Starting next year we will place more emphasis on supporing the Stream Restoration and Subsurface Architecture IPs, focusing first on organism-floodplain interactions such as those described in Theme 4 below and under Focus Area 2.

Major research themes:

1. **Landscape controls on nutrient and carbon flux** to streams, and on their cycling and fate in channel networks. Critical linkages with the physical landscape include turbulence, light and shading, water temperature, and sediment dynamics. Our approach involves a combination of laboratory measurements and field work at the NCED ACRR field site and will provide information on nutrient fluxes for the Desktop Watersheds IP.
2. **Landscape controls on ecosystem processes** (community respiration and photosynthesis) and food web processes (species interactions influencing energy flow to predators (e.g., salmonids) and predator impacts on lower trophic levels). The physical controls listed above also act on ecosystems and food webs. Together, ecosystem process and metabolic data sets, combined with scaling analyses and threshold detections, will give us insights into how watershed morphology affects energy and nutrient dynamics supporting channel food webs, and provide an empirical test bed for Desktop Watershed models.
3. **Landscape geomicrobiology** This work investigates the diversity of microorganisms involved in nitrogen cycling, looking initially at gradients with distance on the Eel River at ACRR. This effort is just beginning but the overall idea is to understand the biogeography of microbial populations and use this spatial framework as a common element linking microbial ecology to the larger ecosystem. The spatial framework will plug this work into the Desktop Watersheds IP.
4. **Vegetation controls on stream pattern** The goal here is to investigate experimentally the role of vegetation in controlling stream pattern. Vegetation controls flow pattern by increasing flow resistance above

the surface and binding the sediment below it. The effect on channel distribution and migration can be quite dramatic, and provides a natural connection to the Stream Restoration and Subsurface Architecture IPs.

Research Accomplishments

Our group's focus over the past year has been the interactions of physical and biologic processes that structure ecosystems and food webs in upland channels and watersheds. This work is central to the Desktop Watersheds and Stream Restoration Integrated Projects. Our work supports the Subsurface Architecture Integrated Project primarily through biotic controls on floodplain dynamics and bank stability that are still being developed. This year we concentrated on landscape controls on 1) nutrient and carbon flux to streams, and on their cycling and fate in channel networks and 2) ecosystem processes (community respiration and photosynthesis) and food web processes (species interactions influencing energy flow to predators (e.g., salmonids) and predator impacts on lower trophic levels).

Laboratory results (SAFL)

PI Hondzo and students, in collaboration with PI Power's group, have investigated mediation of oxygen and nitrate fluxes across the sediment-water interface by turbulent coherent motions occurring near the sediment-water interface (Figures 1, 2, and 3 (next page)). These experiments will facilitate field investigations by allowing us to (1) relate the depth of the sediment oxic zone to mass transfer expressions and determine the effect on denitrification, and (2) formulate mass transfer coefficient expressions for oxygen and nitrate under varying fluid-flow conditions by comparing thin-film and surface renewal theories.

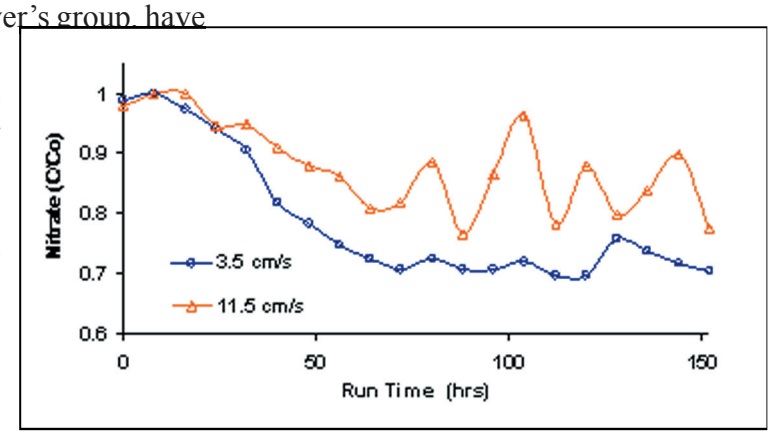


Figure 1: Bulk nitrate concentrations in the water column above sediments. Nitrate concentrations are normalized to the initial nitrate concentration of 2 mg/L as N and the velocities represent mean flow velocities.

Angelo Desktop Watershed investigations

Over the reporting period, we completed detailed measurements of river nutrient cycling and metabolism that will provide primary data for several graduate student and postdoc projects, and will serve as a basis for further work in 2005. We now have river metabolism data across a size gradient of 9 sites (from 1 to 300 km^2 drainage area) in the river network on at least 3 dates, providing to our knowledge a far more detailed dataset than previously available anywhere. In addition, we have measured other environmental and ecological variables at these sites. We have established a routine measurement program for a wide suite of nutrient species in stream water. In addition, we have initiated measurements of other key fluxes (e.g., organic matter from the forest to stream and through the channel (Figure 4, second page following), insect immersion and emergence from streams to forest) and interactions (e.g., plant-herbivore dynamics). These are critical components of the spatially referenced ecological data

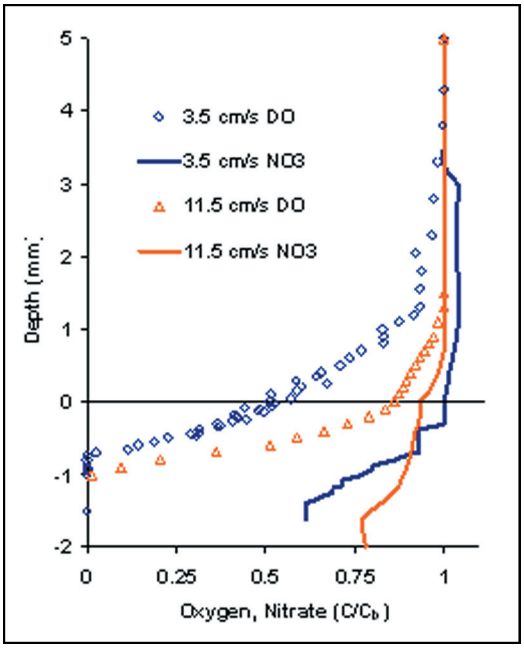


Figure 2: Micro-scale concentration profiles of oxygen (data points) and nitrate (lines) across the sediment-water interface. Concentrations are normalized to bulk water concentrations, C_b, of (~7 mg/L oxygen, and ~1.5 mg/L as N nitrate).

required for the Desktop Watershed.

Whole stream metabolism, environmental variables (nutrient concentrations, temperatures, insolation, cross sectional morphology, bed texture) and ecological variables (insect and terrestrial leaf fluxes (Figure 5, Limm, unpublished data), grazer limitation of algal accrual, algal-bacterial interactions and response to nutrient and carbon enrichment) have also been measured at many or all of these sites.

For predictive purposes, it is important to identify thresholds – points along environmental gradients where dominating processes change. We then can test models that predict similar thresholds in different landscapes, or that predict shifts in the position of such thresholds if environmental factors change in the original landscape. Field measurements led by PI Miki Hondzo and his students have documented 'hot spots and hot moments' of denitrification and algal metabolism and biomass accrual, associated with microenvironments under complex geomorphic and hydraulic control. We have also carried out experiments examining interactions of species and functional groups at different watershed positions. For example, Camille McNeely found that grazers (caddisflies) increased in density as one moves from dark unproductive headwaters to larger, sunnier channels downstream (Figures 6, 7), but that they do not suppress algae until drainage areas exceed

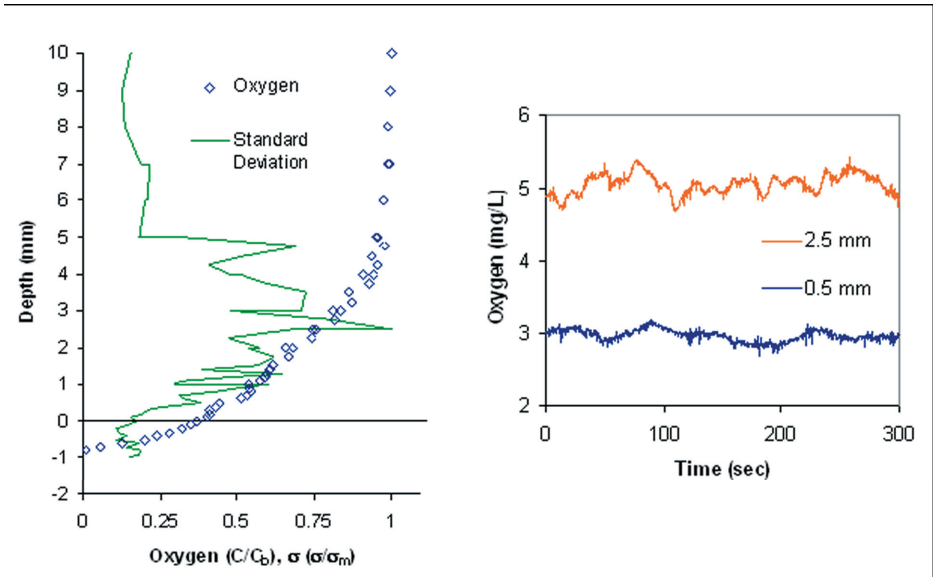


Figure 3: (Left) Micro-scale oxygen profile (data points) and time series standard deviation, σ (line), shown for mean flow velocity of 3.5 cm/s. The oxygen concentration is normalized to the bulk water oxygen concentration, C_b, and the standard deviation is normalized by the maximum standard deviation, σ_m. **(Right)** Time series of oxygen concentration (mg/L) taken at a depth of 2.5 mm and 0.5 mm above the sediment-water interface.

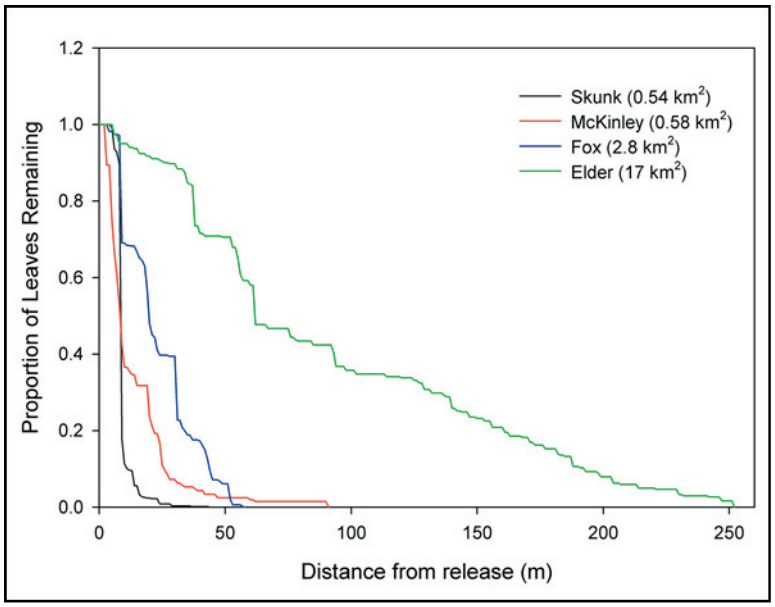
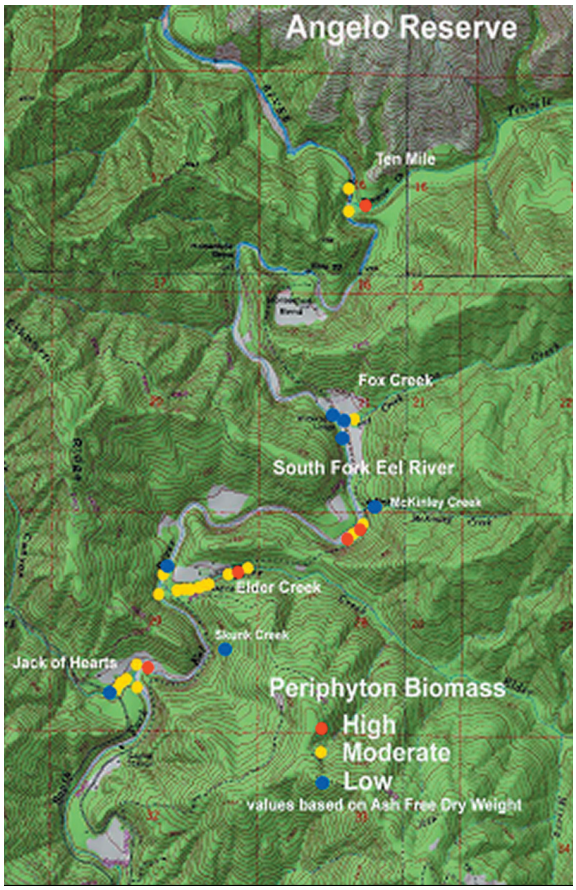
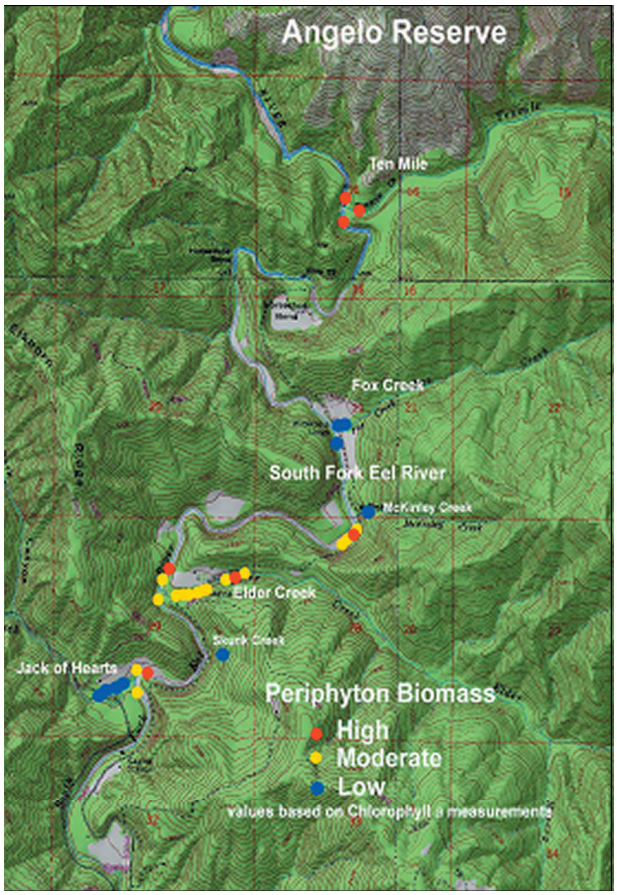


Figure. 5. Proportion of leaves remaining after 2.5 hours during an April spring base flow discharge from point releases made in tributaries of the South Fork Eel River of different drainage areas. Discharge in Skunk, McKinley, Fox, and Elder was 0.03 m3s-1, 0.05 m3s-1, 0.19 m3s-1, 0.85 m3s-1, respectively. Discharge in the South Fork Eel River during this period was ca. 3.5 m3s-1. Non-native gingko leaves similar to native deciduous leaves were used as tracers. These results show that larger tributaries are less retentive of coarse organic matter than smaller tributaries under these flow conditions. These data contribute to our larger study of retention versus 'spiraling' (downstream transport with periodic biotic cycling) of particulate matter and nutrient molecules. We will calibrate spiraling parameters (uptake rates and uptake lengths) for organic matter and nutrients at different river network positions under different flow and seasonal regimes. We will also combine releases with manipulations of channel physical environments and biota (algal or consumer biomass) for mechanistic insight into the relative importance of hydraulic versus ecological controls on retention versus export of particles and solutes from the basin.





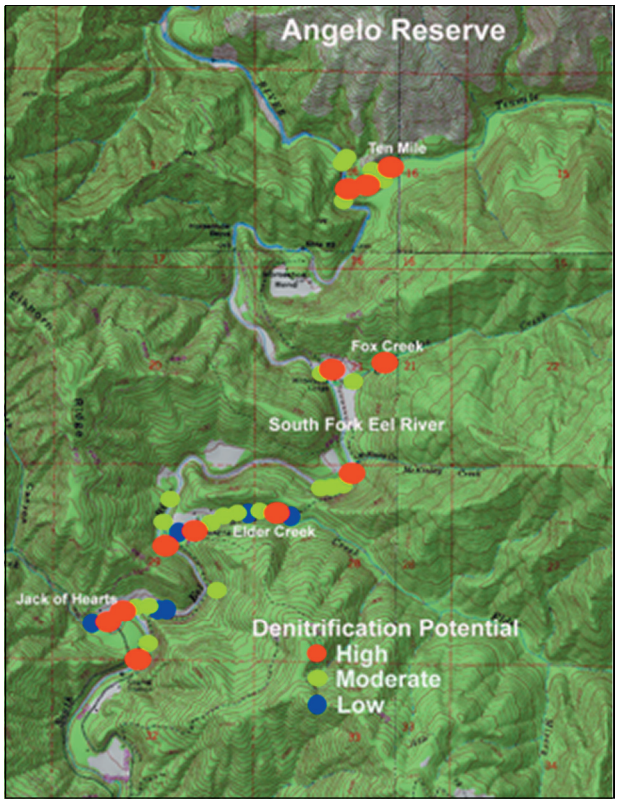


Figure 4: Map of the Angelo Reserve with algal biomass measured as Ash Free Dry Weight and Chlorophyll-a concentration (above left and right, respectively) and denitrification potentials shown for the unlimiting nitrate concentration conditions (right) . The South Fork Eel River is the major river within this system and flows north (to top of page) in this figure. The locations of high denitrification potential have acetylene inhibition rates of > 157 ng-N g^{-1} d^{-1}, moderate potentials are between 7 and 156 ng-N g^{-1} d^{-1}, and low potentials are < 6 ng-N g^{-1} d^{-1}.

2 km^2 (Figure 8). This threshold would move with changes in forest cover and altered insolation. Isotopic surveys carried out by Jacques Finlay had revealed that these armored caddisflies consume algal carbon as far up into the drainage network as they can be collected (Finlay, 2001), while mayfly nymphs, which consume algae in sunny mainstem channels, shift to diets of terrestrial detritus in headwaters < 10 km^2 in drainage area. McNeely's experimental removal of caddisflies from a small (2.8 km^2.) channel at Angelo caused resident mayflies to aquire a more algal isotopic signature (Figure 9, next page). This result, corroborated by a higher proportion of algae in mayfly gut contents (Figure 10, next page), suggests that if armored, predator resistant grazers were removed from the ecosystem (as occurs in some streams due to insect disease epidemics), the landscape position at which predators prey on vulnerable grazers like mayflies would shift upstream in the drainage network. With this change, salmonids and salamanders could derive more of their energy from higher quality, higher productivity algal sources over more of the watershed. Other landscape controls on species interactions are under investigation. Maria Goodrich (Ph.D. student, U.C. Berkeley) has examined algal-bacterial interactions down channel gradients of changing nutrient and carbon availabilities by deploying nutrient and carbon diffusing ceramic substrates (and controls) at the 8 watershed positions. Figure 11 (next page) shows her data on distributions of algae along a gradient of increasing drainage area, from McKinley Creek (0.6 km^2) to the South Fork Eel River at Jane's Riffle (ca. 130 km^2). Figure 12 (second page following) shows corresponding abundance of algal chlorophyll and ash free dry mass (AFDM) on experimental substrates along this same gradient. Bacteria will be counted to estimate their contribution to the AFDM. Based on ecological stoichiometry theory (*Elser and Sterner,* 2002), Goodrich predicts that algal-bacterial interactions will shift qualitatively along this gradient, depending on shifts from carbon to nutrient limitation. These shifts may occur at different landscape positions for bacteria and algae, shifting their interactions from commensal (in headwaters, where light rather than nutrients limit algae) to competitive (for nitrogen) to parasitic (bacteria grow on algal exudates, which increase as bacteria immobilize nitrogen) in sunlit mainstem reaches. Goodrich will test this

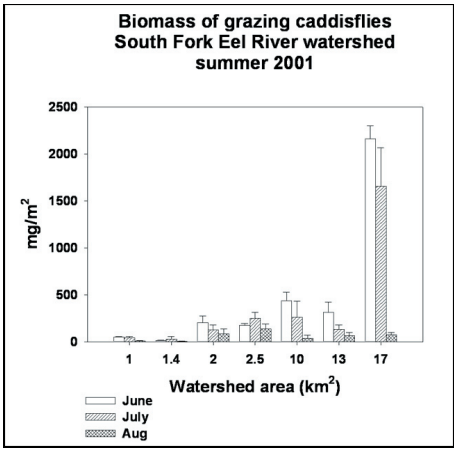


Figure 6. Biomass of grazing caddisflies in seven streams in the South Fork Eel River watershed. Caddisfly biomass increased with drainage area in early summer, but declined in many streams as univoltine species completed their development and pupated. Bars are means with 1 s.e. Biomass was estimated using case-length weight regressions. The stream sites are shown in order of increasing drainage area (0.56 km2: Skunk Creek, 0.59 km2: McKinley Creek, 2.0 km2: Barnwell Creek, 2.7 km2: Fox Creek, 9.9 km2: Jack of Hearts Creek, 13.5 km2: Elder Creek site 1, 16.9 km2: Elder Creek site 2).

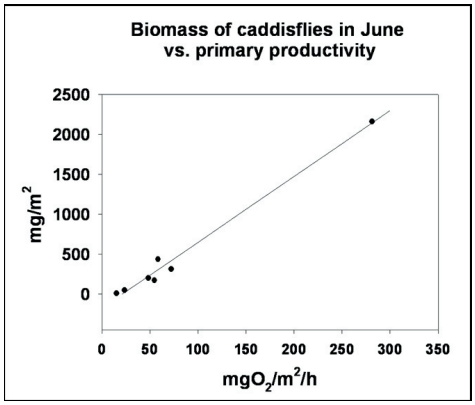


Figure 7. Regressions of June caddisfly biomass against estimates of primary productivity for seven stream sites in the South Fork Eel River watershed. There was a significant relationship between algal productivity and biomass (caddisfly biomass = -183.64 + 8.268 primary productivity, r2 = 0.987, P < 0.001). With the high productivity site removed, the relationship remained significant (r2 = 0.700, P = 0.0378). Error bars are one s.e.

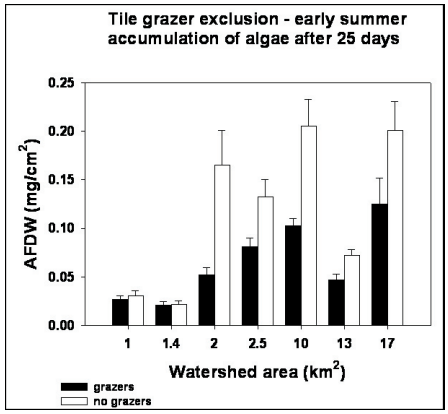


Figure 8. Mean (with 1 s.e.) biomass of biofilms collected from exclusion tiles (no grazers) and control tiles (grazers) from 7 streams in the South Fork Eel River watershed, July 2001 (25 days after deployment). * Denotes pairs where grazer and exclusion tiles are significantly different. The stream sites are in shown in order of increasing drainage area (0.56 km2: Skunk Creek, 0.59 km2: McKinley Creek, 2.0 km2: Barnwell Creek, 2.7 km2: Fox Creek, 9.9 km2: Jack of Hearts Creek, 13.5 km2: Elder Creek site 1, 16.9 km2: Elder Creek site 2).

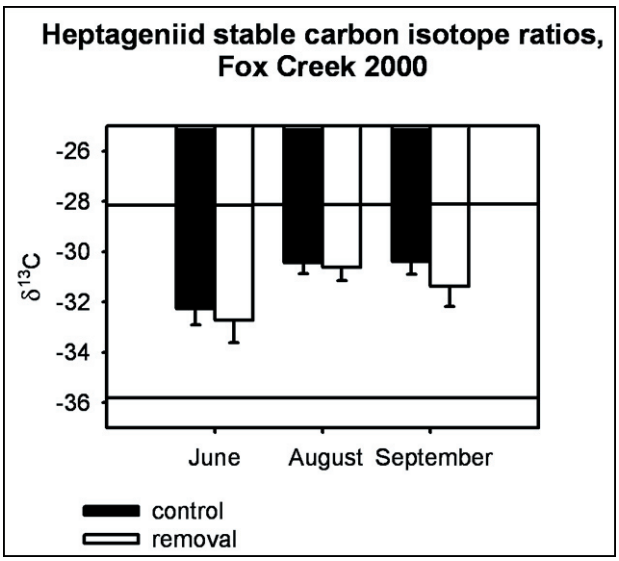


Figure 9. Stable carbon isotope ratios of heptageniid mayfly nymphs. Bars represent means of 5 plots, error bars are 1 standard error. Solid line indicates □ 13C of terrestrial detritus; dotted line indicates □ 13C of algivorous Glossosoma larvae. Mayfly nymph tissue had significantly more negative stable isotope ratios in removal than control plots in September, suggesting greater incorporation of algal carbon.

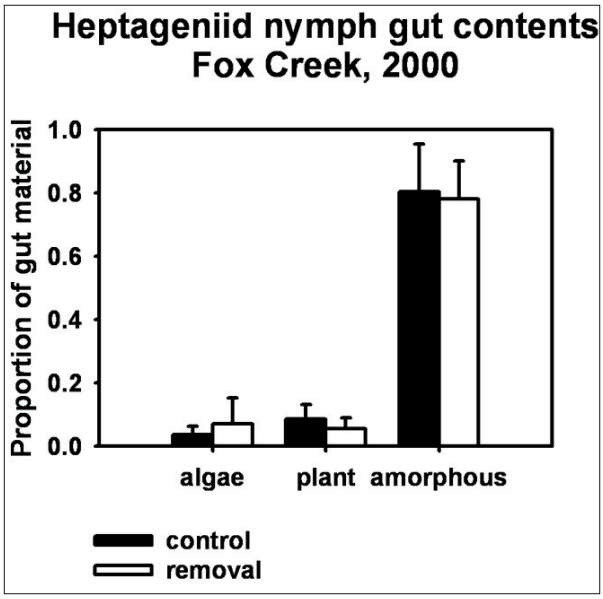


Figure 10. Gut contents of heptageniid mayfly nymphs from experimental plots, September. Data are means with standard error. Guts of heptageniids from Glossosoma removal plots contained twice as much algae as those from control plots (paired 1-tailed t-test on transformed (arcsin(√)) proportions, N = 4, t = -3.029, P = 0.028).

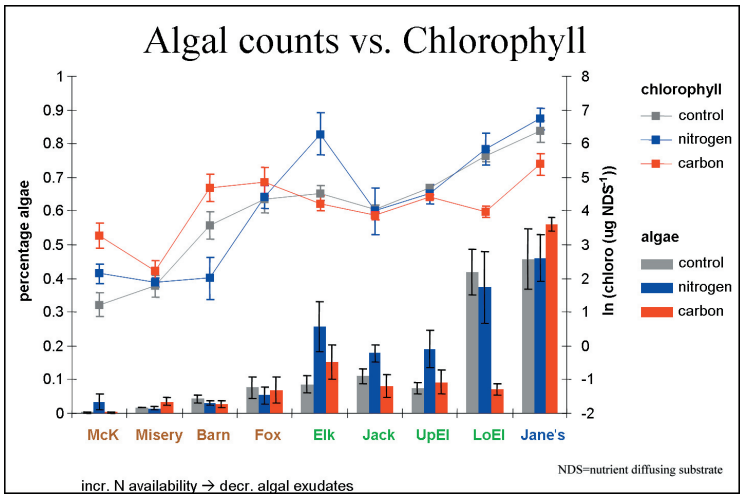


Figure 11. Chlorophyll concentrations and percentage algae from nutrient diffusing substrate (NDS) biofilms. Values are the mean +1 standard error for five replicate NDS. Treatments are nitrogen addition (nitrate), carbon addition (sucrose), and unsupplemented control. Sites are ordered by ascending drainage area. Goodrich, unpublished

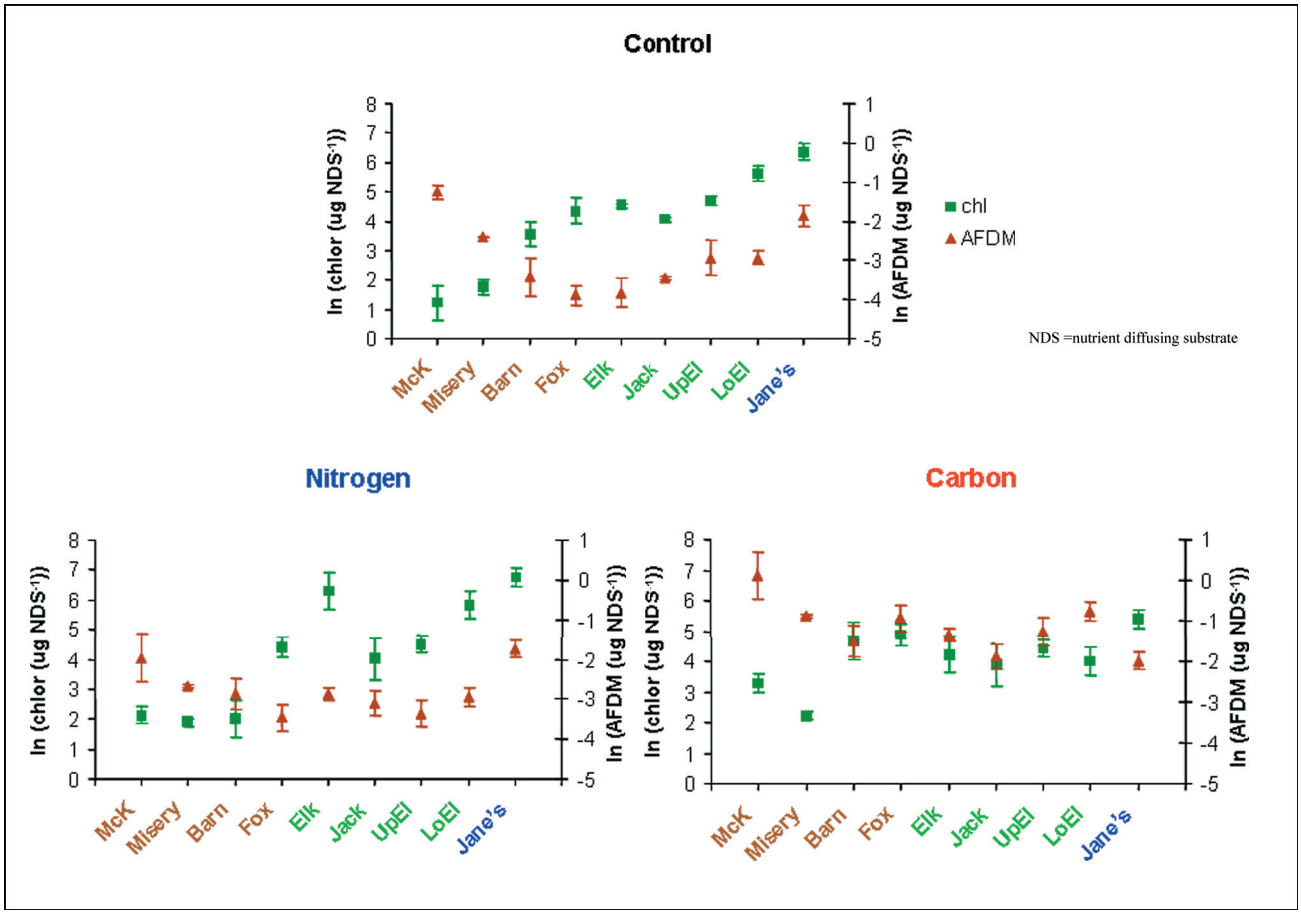


Figure 12. Chlorophyll and ash-free dry mass (AFDM) concentrations from NDS biofilms. Values are the mean +1 standard error for five replicate NDS. Treatments are: A) control, B) nitrogen addition (nitrate), and C) carbon addition (sucrose). Sites are ordered by ascending drainage area. Goodrich, unpublished

hypothesis in 2005 by crossing algicides and antibiotic treatments with her carbon and nutrient supplemental treatments along the river network gradient.

Together, these environmental and ecological data sets, combined with scaling analyses and threshold detections, will give us insights into how watershed morphology affects energy and nutrient dynamics supporting channel food webs, and provide an empirical test bed for Desktop Watershed models.

Geomicrobiology

PI Banfield and students, working closely with Dietrich's group, have continued their studies of the diversity of microorganisms involved in nitrogen cycling, looking initially at gradients with distance from the Eel River at Angelo. Graduate student Karelyn Cruz evaluated the microbiology of several samples and presented some of this work at a team meeting. This work was refocused in mid-2004 towards a more tractable system that makes use of 10-m experimental plots in which rainfall has been experimentally manipulated for the past five years by Blake Suttle, a Ph.D. student of M. Power, who investigated impacts on meadow soils, plant guilds, and food webs of rainfall changes predicted by two leading climate change models . Nitrogen fixing bacteria in plots have been sampled on several occasions, and significant preliminary characterization work has been accomplished. Dr. Anna Rosling, a postdoctoral investigator in the Banfield lab from Sweden, has initiated a study of mineral weathering by fungi in these same plots, and was awarded a fellowship to begin work on this topic in early 2005.

Experimental study of vegetation-braiding interactions

PI Paola and his group, though part of the Long-term Dynamics Focus Area, continued experimental work on how the interplay of vegetation growth and flooding influences stream pattern. The project is a series of experiments in which the following cycle is repeated: a short high-discharge event (flood), reduction in discharge to a fixed low value, seeding of the exposed surface with alfalfa, alfalfa growth for a fixed period, then another flood. The experimental sediment is a well sorted quartz sand, so without vegetation the system is braided. The alfalfa "corrals" the flow by eliminating small, opportunistic channels and leads to development of a better organized channel pattern with greatly reduced rates of lateral migration. This year we began a new long-term (several months) experiment in which the flood frequency was doubled relative to the one we did last year, in which there was a full week for vegetation growth between floods. The result so far has been to create a channel pattern that is intermediate between full braiding and the single channel produced in last year's experiment (Figure 13). In addition, we have expanded our collaboration with the US Forest Service by developing a set of sub-experiments that will be used to optimize tactics for removing vegetation in overgrown braided rivers like the Platte (central Nebraska). This work contributes primarily to Stream Restoration but we intend to start work this summer to use the ACRR site to investigate the extent to which the same ideas apply to this upland watershed. We are also working with the Ecogeomorphology group to see how we can improve on the realism of these experiments.

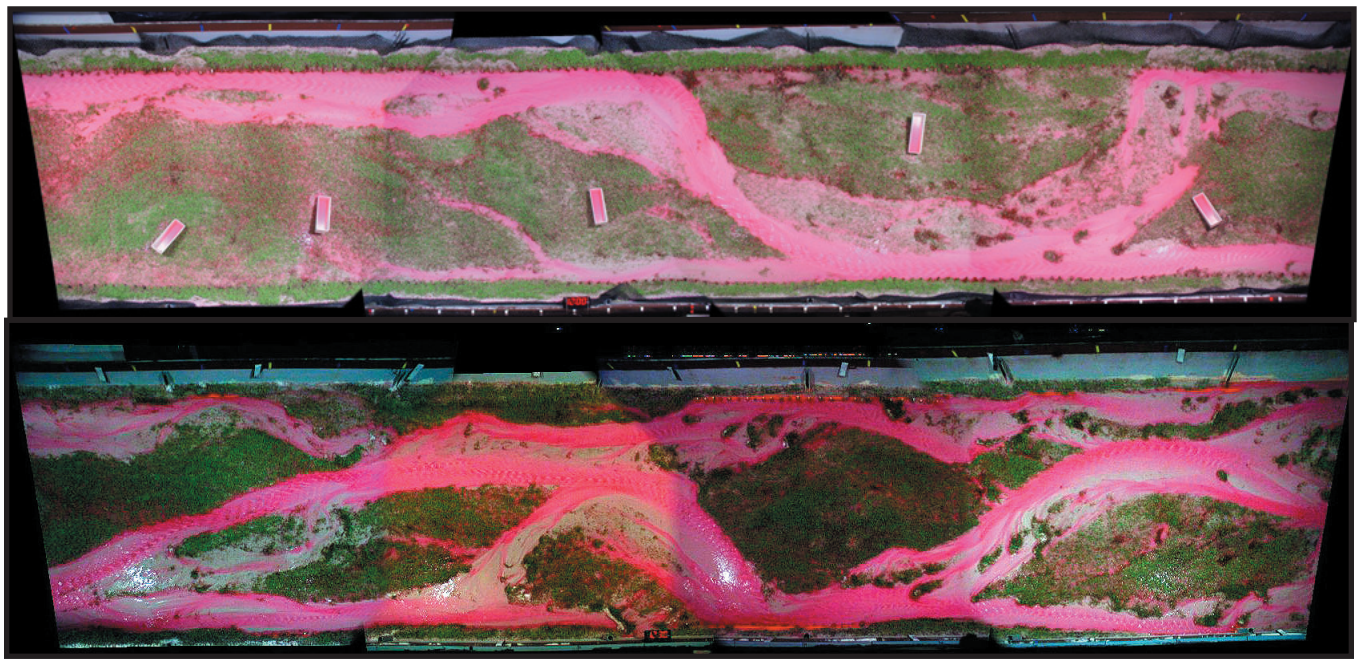


Figure 13. Comparison of channel pattern from two experiments with different time intervals for vegetation growth between floods. Upper: 7 day growth interval, Lower: 4 day growth interval. Note how the shorter growth interval leads to a stable multi-channel pattern after the same total growth time.

Northern Minnesota Rivers and Wild Rice Lakes

NCED research in northern Minnesota is closely coordinated with Fond du Lac Tribal and Community College, and attempts to transfer research tools and ideas from the ACRR site to locations near FDLTCC and important to the Ojibwe tribe. PI Wold sampled three rivers with students from the Native American Math and Science Camps (NAMS Camps). Students analyzed these samples to determine differences in water quality, macroinvertebrate abundance, and stream health among these streams and shared results with students and councilors with the Gidakiimanaaniwigamig Camps at Fond du Lac Tribal and Community College. In collaboration with PI Finlay,

PI Wold and students took water samples from the St. Louis River, Nemadji River, and Knife River, all gauged by the USGS and draining into western Lake Superior, for nitrogen analysis. These samples will be used as part of baseline data on nitrogen inputs to Lake Superior from surrounding watersheds. Wold's lab also continued collection of vegetation, nutrient, and sediment data from two wild rice lakes on the Fond du Lac Reservation to determine spatial and temporal variability and the state of recovery by wild rice in these lakes.

Research Plans

Desktop Watershed, Angelo Reserve

We will build a wireless infrastructure for which Collin Bode (U.C. Berkeley) has provided the design, based on a viewshed analysis of the Angelo Reserve that makes use of canopy and bare earth LIDAR data from Dietrich (Figure 14) and begin deploying automated environmental sensors (of light, temperature, soil moisture, and for biotic variables: bat acoustic detection, repeat photography to document algal blooms).

New sensors (e.g., a novel nitrate probe based on genetically engineered bacterial technology) will be developed and tested at SAFL, then field tested at the ACRR site.

Metabolism studies (PIs Hondzo, Finlay, and Power) will expand to cover 12 positions from 1 to 310 km^2 in the drainage network at Angelo, coupling these with field surveys, mapping, and photographic quantification of patch growth and contraction of algal hotspots through these drainages. We will continue with tracer studies (leaves, stable isotope enrichments, traceable carbon particles) to measure watershed specific flux rates for coarse and fine particulate carbon at different drainage network positions. We will continue and expand studies of species

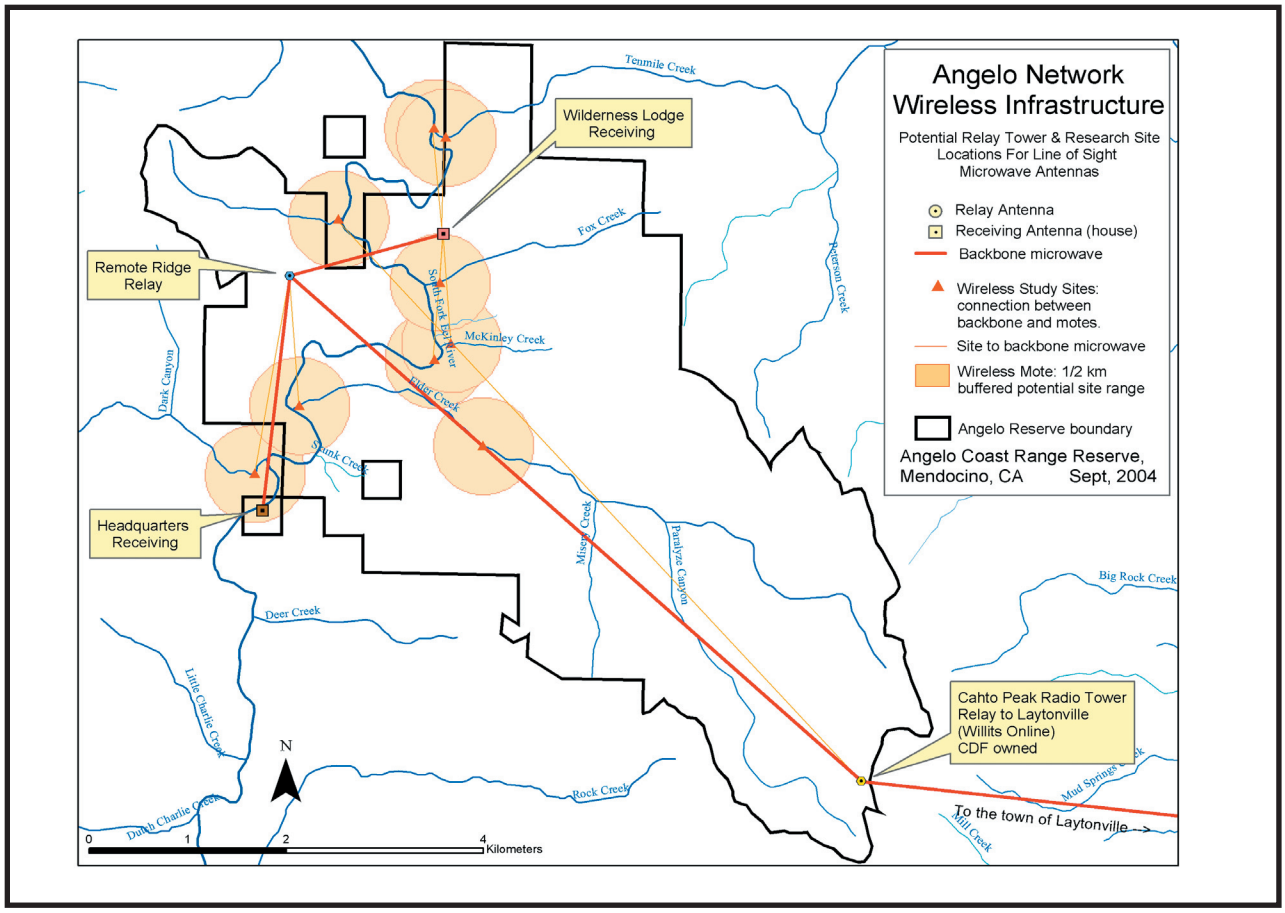


Figure 14. Plan for the Angelo Coast Range Reserve field site wireless infrastructure, scheduled for installation Summer, 2005

interactions down drainage networks and environmental gradients (fungi and soil bacteria along moisture gradients (Banfield group and Power group), and between algae and bacteria, alder and aphids, Nostoc and Cricotopus, lampreys and mussels, grazing insects and algae, and bats and emergent insects as mediated by downstream changing habitat structure, light:nutrient ratios, and local hydraulics (Limm, McNeely, Goodrich, Finlay, Welter, Schade, Power). We will analyze and write up alder population structure, growth rates, and feedbacks to channel cross-section as a function of drainage network position (DiVittorio, Bode and Power). We also hope to initiate experimental studies of nutrient and light manipulations on food web assembly, organismal stoichiometry, and spiraling in the mainstem South Fork Eel (Limm, Schade, Power, in collaboration with Thomas and Flecker, river ecologists from Cornell University, and D. Furbish of Vanderbilt University). Finally, we intend to work closely with PI Rodriguez-Iturbe's group to relate these ground-based studies to their inferences about how relations between vegetation and drainage-basin structure derived from analysis of the ACRR LIDAR data.

Northern Minnesota Rivers and Wild Rice Lakes

PI Wold's lab will continue to monitor the recovery of wild rice lakes on the Fond du Lac Reservation near Cloquet, MN, and investigate microbial communities and their impact on wild rice, especially nutrient dynamics. Preliminary samples will be taken in 2005 in order to develop some effective microbial community sampling techniques and protocols. We will continue to collaborate with Jacques Finlay in investigations of the nitrogen loading into Lake Superior.

Geomicrobiology

The Banfield lab's NCED focus will remain on the study of microbial communities that colonize soil habitats at the Angelo Reserve. Microorganisms play key roles in ecosystem dynamics, most obviously by affecting biological productivity. Central to this impact is their ability to convert gaseous nitrogen to bioavailable nitrogen, the limiting nutrient in the Angelo system. The extent of nitrogen fixation is anticipated to impact vegetation cover, thus hydrology and geomorphology of the Angelo reserve system. Our research focuses on understanding the diversity and distribution of organisms responsible for fixation of nitrogen on a river terrace (an abandoned floodplain in close proximity to the current channel). The approach we will take is to use the tools of molecular biology to assay diversity of organisms involved in nitrogen fixation. This requires amplification, sequencing, and phylogenetic analysis of genes involved in the nitrogen fixation pathway. This work will be combined with other assays of nitrogen form and distribution in the soil. A key question relates to how ecosystem structure and function vary with hydrology. One aspect of this is the question of how these vary with rainfall. In order to address this question, we are conducting the above-mentioned analyses on plots that have experienced rainfall manipulation over 5 years. The plots, established by Blake Suttle in the Power group, have received additional water inputs at two different times of year in order to simulate likely climate change scenarios. Samples will be collected throughout 2005 to examine microbial dynamics as a function of soil conditions. Results from different treatments and controls will be compared to determine how water availability and pattern of supply impacts diversity and, ultimately, productivity. Another question that will be pursued in 2005 relates to the connection between hydrology and total microbial diversity. We will tackle this question by taking a census of microbial populations via high-throughput analysis of 16S rRNA gene sequences amplified from organisms present in the above-mentioned treatments. Given that microbial processes are central to cycling of carbon, nitrogen, and other elements in soils, the question of their community structure is long overdue for analysis. The final topic to be pursued in 2005 relates to fungal activity in soil. It is well known that fungi can dramatically impact soil chemistry and properties, and play key roles in nutrient cycling. We will investigate the form and distribution of fungi in soils at the Angelo reserve and conduct laboratory experiments that study their impact on mineral weathering.

Integrative Activities

Postdoctoral fellows Jill Welter and John Schade (in the Power and Finlay lab, respectively) will work with members of the Banfield lab to relate their studies of microbial functional diversity to *in situ* ecosystem processes, including terrestrial and channel nitrogen fixation, denitrification, and nitrogen loading from meadows to channels. During 2005 PI Wold plans to take a research group from Fond du Lac Tribal College to the Angelo field site to work on the river metabolism studies. This research group will then return to Minnesota and participate in similar research on six north shore tributaries to Lake Superior. These studies will include metabolism measurements, food web determinations using stable isotopes, and elucidation of nutrient limitation using bioassays. Power is particularly interested in seeing if there are differences in these parameters across a gradient of groundwater influence in these streams. Finally, Power and Finlay will begin work with Parker, Paola, Wilkerson, and Wilcock on the theme of organisms and floodplains (including stream banks and effects on channel pattern) to strengthen the Ecogeomorphology group's connections to Stream restoration and Subsurface architecture.

Collaborations Outside NCED

Banfield: Work with the high-throughput sequencing of 16S rRNA genes will involve Dr. Gary Andersen, LBNL.

Banfield: Work on fungal processes in soil at Angelo is being developed in conjunction with Tom Bruns (UCB).

Finlay: Dr. Peter Weber (Lawrence Livermore National Lab). Project investigates control of otolith carbon stable isotope ratios in salmonids. Research uses gradient of stream carbon biogeochemistry and environmental conditions to test a model of controls of otolith chemistry. Data so far suggest that such measurements can be used to determine origin of juvenile salmonids in rivers, including anadromous salmonid species. Awaiting final analyses, beginning manuscript preparation.

Finlay: Upper Mississippi Environmental Science Center (UMESC). So far, this has involved meetings and participation in a workshop on large river food web dynamics. However, relationship with UMESC may lead to collaborations this summer (2005) on river metabolism and food webs, and, potentially, a review paper. There may be many future opportunities for broader NCED involvement for interested PI's.

Finlay: Drs. John Sabo and David Post. We are collaborating on a NSF-funded project on regulation of river food chain structure. We are increasingly interested in understanding the strong effects of geomorphic parameters and physical habitat structure in controlling trophic structure in river food webs.

Power: Collaborated with economists Nick Brozovic (U. Illinois) and David Zilberman (Berkeley) to write this paper:

Power, M.E., Brozovic, N., Bode, C. and Zilberman, D. 2005. Spatially explicit tools for understanding and sustaining inland water ecosystems. Frontiers in Ecology and the Environment 3: 47-55. www.frontiersinecology.org/specialissue.html.

Power: Collaborated with Gary Huxel and the late Gary Polis to edit a book: Food Webs and Landscapes (see publications below).

Power: Collaborating with Drs. Bill Rainey, Jim Quinn and Jeff Mount in a CALFED sponsored research project at the Nature Conservancy floodplain restoration site of the Cosumnes River.

Research-related Knowledge Transfer and Education Activities

Banfield participates in a collaboration with the Lawrence Hall of Science to develop K-12 teaching materials with a geomicrobiology theme.

Finlay: Bell Museum's JASON project science expert for K-12 outreach

Finlay: Guest lecturer on Watershed Ecology in Landscape Ecology (UMN, LA5204)

Finlay: UMN WRS admissions committee member

Finlay: IGERT Graduate Training Proposal

Finlay: Dissertation committee member for Ben O'Connor

Miki Hondzo, with Diana Dalbotten, Fernando Hernandez, and Angel Satiago Perez, presented "Welcome to National Center for Earth-surface Dynamics," at the "Hispanics in Engineering National Conference", October 26-29, San Juan, Puerto Rico, 2004

Miki Hondzo: Summer work on wireless temperature measurements in streams. Undergraduate student (Fernando Hernandez) mentoring and visit to the *gidakiimanaaniwigamig* camp site in Northern Minnesota.

Power: As a member of the Recovery Science Review Panel for NOAA-Fisheries, I review National Marine Fisheries scientists work related to management and recovery of west coast salmonid populations, and publish with our group three reports a year (citation below gives web site). We are confronting the difficult current controversies over equating hatchery with wild fish for listing, and suggestions that anadromous components of salmonid populations with both resident and migrating forms be dropped from consideration for protection.

Power: As a member of The Nature Conservancy-California Board, I give advice to TNC staff about projects and attempt to enhance communication between TNC and university students and researchers.

Wold: Our lab has been involved in providing support for *gidakiimanaaniwigamig* summer camps and *ando-gikendaasowin* summer camps as well as fall, winter, and spring *gidakiimanaananiwigamig* camps for American Indian students from FDL and surrounding communities.

Research Focus Area 5: Long-term Dynamics

Lead PIs: C. Paola, D. Mohrig, L. Perg

Mission: to understand and model the behavior of channels and channel systems on planetary (geologic) time scales, in order to:

- Understand and predict the geometry and characteristics of subsurface sediment bodies;
- Constrain pre-anthropogenic conditions in modern systems; and
- Provide information on long-term trends and variability in surface systems in support of environmental management and forecasting.

Strategy and synthesis

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. Focus group leaders Mohrig and Paola have organized the Long-term group's research around five complementary themes that support the Subsurface Architecture and Desktop Watershed Integrated Projects (IPs). A longer-term goal is to develop linkages to the Stream Restoration IP through our work on natural variability and sediment supply.

Major research themes:

1. **Characterization and averaging of short-term fluctuations.** Long records of stochastic channel processes generally cannot be obtained by direct observation but must be inferred from stratigraphy. These records can provide information on natural variability and rare events if we can learn to account for the effects of stratigraphic filtering. Experimental and theoretical research in this area allows us to create records that reflect numerous events whose statistics can be compared quantitatively with those of the deposits. In addition, fluctuations in erosion rate influence landscape evolution. Our research in this area contributes information on natural variability to all three IPs.

2. **Long-term sediment production and flux: mean and variability.** Long-term sediment supply rates, set mainly by tectonics, lithology, and climate, exert a major influence on many aspects of landscape morphology and evolution. Because of the extent of human influence on landscapes, long-term methods, such as the use of cosmogenic radionuclides (CRNs), may provide the only way of estimating pre-anthropogenic sediment fluxes. This work provides an important part of the framework of Desktop Watershed modeling. Natural variability in sediment supply (along with associated variability in delivery processes such as landsliding) also strongly influences uncertainty and predictabilty in these models.

3. **Fluvial response to changes in sea level, sediment supply, and tectonics.** These three variables are sometimes described as the "stratigraphic trinity" for their dominant role in influencing stratigraphic architecture. We emphasize experimental studies of how fluvial channel systems respond to imposed changes in these variables in order to develop a model incorporating all three elements of the stratigraphic process: quantitatively documented changes in boundary conditions; the resultant topographic and channel-pattern evolution; and the final depositional product. Our work in this area is a key component of the Subsurface Architecture IP and provides data on valley evolution that support dam-removal research in the Stream Restoration IP.

4. **Comparative morphology and dynamics of submarine and subaerial channel networks.** This is a systematic attempt to understand and exploit the powerful morphologic analogies between fluvial and submarine channel systems. As discussed in the Context section, submarine channel deposits are targets of intensive, and very expensive, exploration for hydrocarbons. This work supports the Subsurface

Architecture IP.

5. **Statistical structure of deltaic channel networks** The goal here is to apply statistical and scaling techniques that have revolutionized the study of erosional landscapes to deltaic channel networks. This work, described in Focus Area 1, is listed here because of Paola's involvement and because of its strong contribution to the Subsurface Architecture IP: deltas are major depositional sites.

Research Accomplishments

Most of the Long-term Dynamics Focus Area's work is directed toward the application of NCED channel-system science to understanding and predicting channel deposits in the subsurface, and is the main body of research supporting the Subsurface Architecture Integrated Project. This year, several projects were started that will more fully integrate the Long-term Dynamics group's efforts into the rest of NCED. PI Chris Paola has begun working with PIs Porté-Agel and Foufoula on applying results from the Advanced Methods Focus Area to the problem of averaging spontaneous (autogenic) fluctuations in landscapes, with grad student Paola Passalaqua. This work, which began this year and will support the Desktop Watershed Integrated Project, is reported more fully in Focus Area 3. It will continue in the coming year and should lead to new methods for averaging fluctuations in depositional systems as well. This is a new subproject under theme (1) above.

Two new initiatives attempt to exploit connections between key components of channelized depositional systems and more intensively studied erosional landscapes. Mohrig and Parker are both working on analogies between submarine and subaerial erosional channel systems; Mohrig's work is discussed below and Parker's under Focus Area 2. Paola is working on a new collaboration on comparing channel network structure on deltas (distributary, depositional systems) with Rodríguez-Iturbe, student Alessandra Feola, and postdoc Kelly Caylor. This is Theme 5 above and is discussed in Focus Area 1's group report. These efforts will contribute to both the Desktop Watershed and Stream Restoration Integrated Projects

Characterizing and averaging short-term fluctuations

Graduate student Doug Jerolmack and PI Mohrig have continued research on the evolution of sandy river bottoms dominated by trains of dunes and bars. Bedforms represent a basic linking component between the subsurface project and stream restoration: dunes and bars represent key recorders of sediment flux, so understanding them is critical to using their deposits as "flux meters". But bedform and bar dynamics is also an important element of stream restoration because they represent primary resistance and morphologic elements in sandy rivers. Mohrig and graduate student Doug Jerolmack successfully applied a simple interface model for bedform evolution to the problem of stratigraphy generation by time and space varying bottom topography (see publication list). Model results can be used to quantitatively reconstruct local rates of sediment deposition on sandy river bottoms using the thickness distribution of beds produced by dunes that migrated over the aggrading surface. Mohrig and Jerolmack are also continuing to investigate the role that interactions between dunes have in setting patterns of river-bottom sedimentation and erosion and in determining stage/discharge relationships. They have developed a nonlinear stochastic surface evolution equation for the topography of bedload-dominated sand-bedded rivers in which instantaneous sediment flux explicitly depends on local elevation and slope. This model, which benefited from Mohrig and Jerolmack's participation in the Advanced Methods mathematics working group last May, quantitatively reproduces laboratory observations of initial growth and saturation of bedforms from a flat surface, and also generates long-term dynamical behavior characteristics of natural systems (see Figure 1, next page). The results suggest that the variability in geometry and kinematics of bedforms in steady flow, and the existence of roughness at all wavelengths below the largest dunes, are a consequence of the nonlinear relationship between sediment flux and topography, subject to noise.

Perg and PI Gary Parker have continued their work estimating long-term mean erosion rates, and erosion

rate variability, from landscape morphology. This work is intended to provide important information on mean and variability of sediment supply for Desktop Watersheds models. The initial theoretical framework, which ties the timescale to reset cosmogenic isotope erosion rates to probabilistic erosion rate variability, is in review at Earth Surface Processes and Landforms (*Probabilistic Formulation of Conservation of Cosmogenic Nuclides: Effect of Surface Elevation Fluctuations on Approach to Steady State*). The main results of this work are: The new model focuses on the effects of long-term changes in erosion rate and incorporates the more realistic case of spatial fluctuations in erosion rate around a mean. The results show that when perturbing the erosion rate, the cosmogenic radionuclide (CRN) concentrations used to estimate erosion rate require two to three times the time span previously assumed to fully reflect the new erosion rate. The main implication is that many samples previously assumed to reflect purely Holocene erosion rates also convolve Pleistocene erosion rates into their signal.

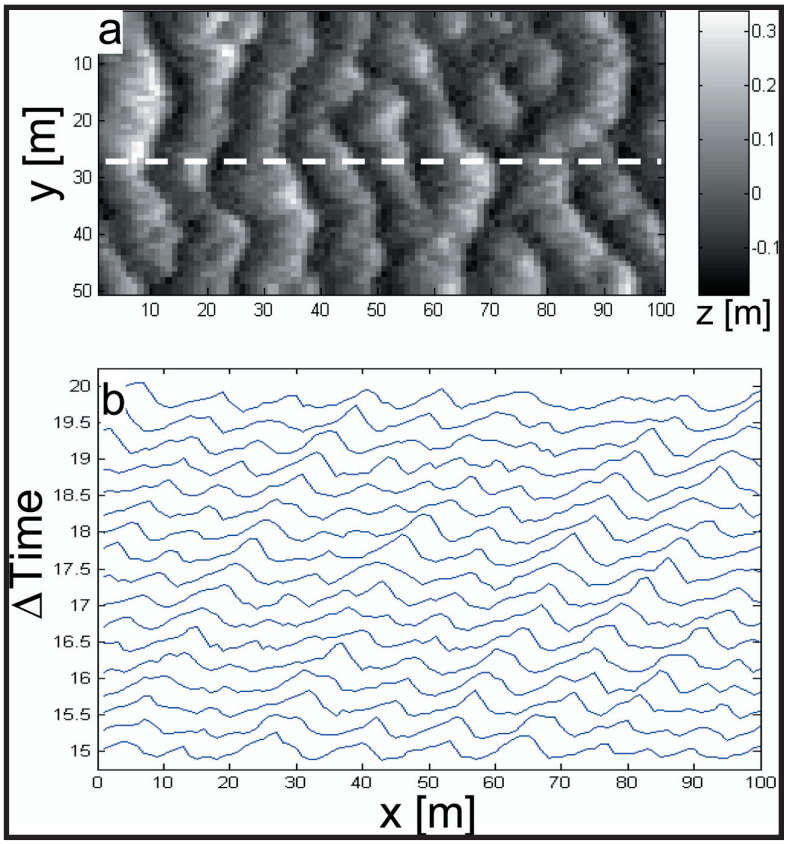


Figure 1. Topography produced by nonlinear stochastic surface evolution equation. Roughness shown is in statistical steady state. (a) Plan view snapshot. (b) Sequential profiles shown every 1500 time steps.

To provide information on spontaneous fluctuations to the Desktop Watershed project, Perg is examining to what extent interpretation of large geomorphologic features, such as stream terraces, can be treated as an inverse problem. Is each feature the result of a distinct external climate or tectonic forcing event, or can such terraces form through natural (autogenic) variability? Answering this question is important in constraining the information that can be extracted from morphology alone. The current project to answer this question is being performed on the ACRR stream terraces with Ted Fuller, a first-year NCED graduate student. Currently the project has mostly been office work, collecting geologic maps, landslide maps, and aerial photographs of the area. Field mapping is planned for early May, and sample collection for cosmogenic isotope dating in mid-July. A poster, *Strath terrace formation as a function of internal stochastic processes versus external forcing*, on the fieldwork portion of the project will be presented at North-central GSA in late May. The field effort to examine the formation of subaerial stream terraces builds on experimental work performed by Chris Paola and Nikki Strong in the XES basin, and examination of subaequeous terraces by David Mohrig.

Finally, Paola and grad student Ben Sheets completed an analysis of how short-term channel evolution is recorded stratigraphically. Using data from an experimental fan-delta with uniform steady aggradation and high-frequency topographic measurement, we identified a characteristic 3-stage sequence that produces fluvial channel complexes in the stratigraphic record: (1) initial incision by an upstream-migrating scour, (2) repeated abandonment and reoccupation of the scour, which persists as a topographic low, and (3) final filling of the channel by a short-lived flow-expansion event that leaves a lobate deposit with a broad convex surface and turns the former channel from an attractor of flow to a repeller (Figure 2, next page).

To provide statistical context for this characteristic sequence, we developed a new method for studying the

effect of repeated channel abandonment and reoccupation on channel stacking and connectivity in the subsurface. Using data from the above experiment, we visualized the space-time distribution of short-term erosion and deposition using, in effect, a high-frequency version of the classic Wheeler diagram (Figure 3). This indicated, among other things, that channel persistence within a given sector of the delta had a characteristic time scale after which the active zone migrated a fairly long distance away. This led us to look for clustering of channel deposits in the subsurface. The method we used to identify clustering was taken from astronomy, where star clusters have been identified using a method known as the minimal spanning tree (MST): the set of lines connecting a field of points scattered on a plane that minimizes the sum of segment lengths without any closed loops (Figure 4). Once the MST has been found, the probability density function of segment lengths indicates the presence of clustering (many short segments and a few very long ones) or anticlustering (a tendency toward avoidance indicated by a uniform distribution of segment lengths). These measurements are made relative to segment-length distributions obtained from randomly placing points.

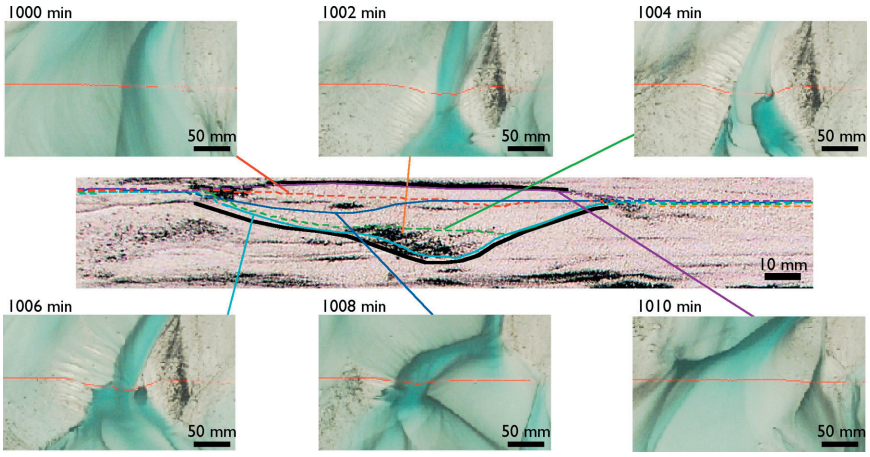


Figure 2. Image of preserved channel stratigraphy (center) with measured topography through time (colored lines) and surface images showing associated changes in channel pattern through time. Note repeated occupation and abandoment of channel and development of convex capping surface.

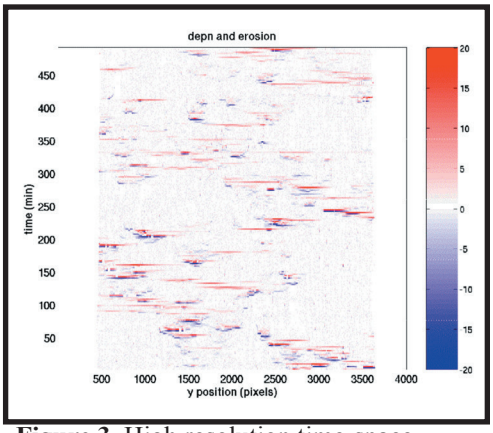


Figure 3. High resolution time-space (Wheeler) diagram, showing localization of erosion and deposition by scour and lobe events. Note also long-term tendency for the locus of maximum activity to shift broadly across the depositional surface.

In the case of channel clusters, the points represent identifiable channel bases in the deposits: either the bases of all channels, many of which represent reoccupations, or the bases of scours into non-channelized deposits, which represent intial scours in the above sequence. We conjectured that the former should show clustering associated with the tendency of existing channels to attract flow, but that the latter should

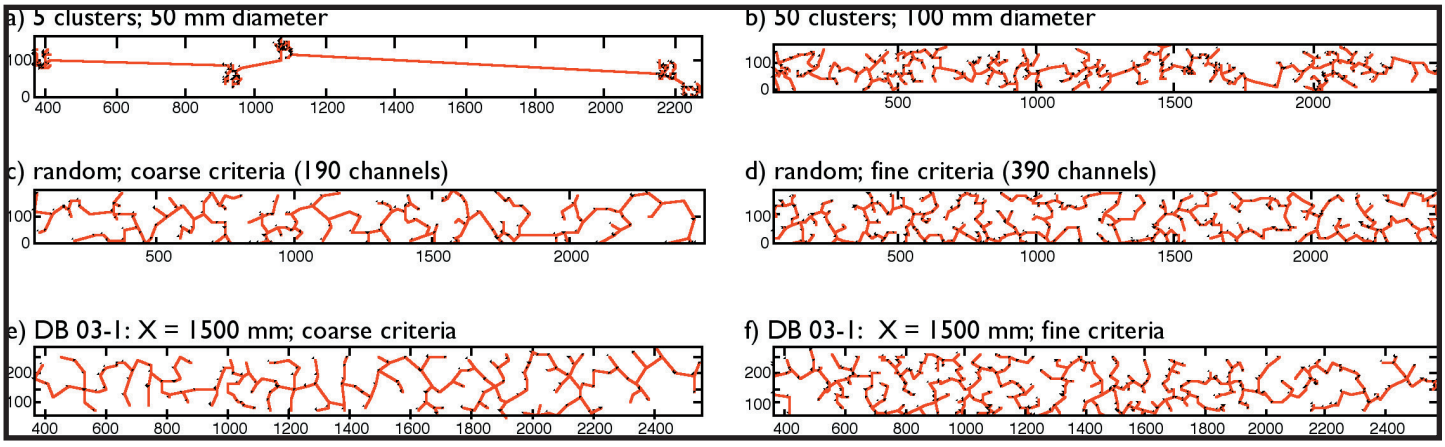


Figure 4. Minimal Spanning Tree (MST) constructed for a series of more or less clustered artificial point clouds and for two measures of experimental channel base locations: 'coarse' refers to sampling only channel bases cutting sheet deposits, and 'fine' to all detectable channel bases.

show anticlustering as flow is steered around convex channel-filling surfaces. The data from our experiment suggest that this is indeed the case (Figure 5).

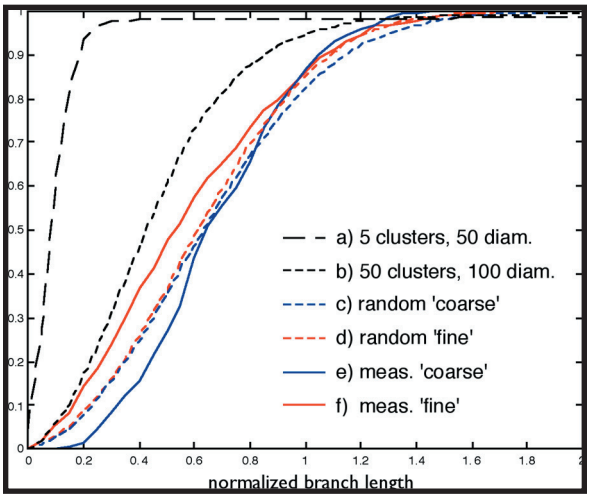


Figure 5. PDFs of MST connection lengths for the cluster scenarios shown in the previous Figure. Note that for the experimental data, the coarse sampling shows a deficit of short connections relative to random data, implying anticlustering, while the fine sampling shows an excess of short connections, implying clustering. Channel complexes develop by repeated abandonment and reoccupation of channelized zones (clustering) which are then capped by a convex sheet deposit that forces water elsewhere (anticlustering).

Long-term sediment flux: mean and variability

The main progress here has been on the part of PI Perg, who has continued working to get her cosmogenic radionuclide (CRN) lab set up and running. There have been significant logistical delays to this, but the first test samples have been run this year. Sampling at ACRR will take place this summer and we expect to have results from the CRN work there next year. The ACRR site provides an excellent opportunity to investigate reported differences between short-term and long-term erosion rates. The high erosion rates at Angelo should put the effective sediment age in the Holocene, and climate fluctuations along these coastal regions are small. The planned ACRR research on monitoring sediment and chemical fluxes, along with work to quantify biogeochemical erosion rates, will provide a more complete short-term history to compare with long-term denudation. Any mismatch between the short and long-term fluxes should then provide a good estimate of the importance of stochastic effects on the system, giving an important field constraint for the NCED work in this area.

Fluvial response to changes in sea level, sediment supply, and tectonics

Paola and NCED grad student Wonsuck Kim completed an analysis of the response of the fluvial system and shoreline to imposed base-level cycles. The work was the first detailed test of the moving-boundary method we have developed with PI Voller to model dynamic boundary migration in the surface environment. The analysis showed that the method could predict shoreline migration accurately under controlled experimental conditions (Figure 6). It also allowed us to investigate, by stepwise degradation of the experimental data set, the effect on shoreline prediction of having only partial information, as would typically be the case in the field. We also continued our work on autogenic shoreline variations, investigating their use as an indicator of long term sediment storage and release in the fluvial system.

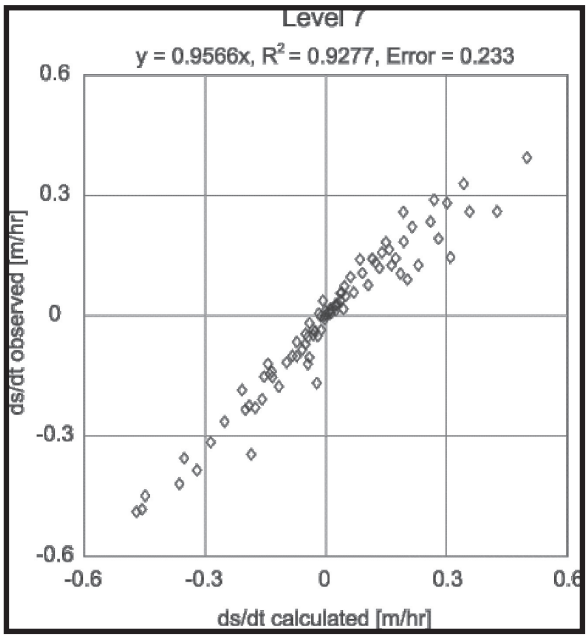


Figure 6. Predicted versus observed shoreline migration rate under variable base level, based on our moving-boundary fluvial-shoreline equation.

NCED grad students John Martin and Wonsuck Kim completed loading the results from our major 2002 experiment on the effect of base-level cycles on deltaic sedimentation into newly acquired 3D seismic analysis software. This was a major effort because of the data volume and the fact that the image data has to be manipulated to make it look like seismic-reflection data to the software. However, in addition to providing us with new analysis capabilities, this step greatly improves compatibility with our industrial partners. Our first step has been to analyze streamwise shifts in depositional center of mass during the experiment. Coupling this

information with our previously measured shoreline variation will allow us to measure for the first time the efficiency of sediment pumping from the fluvial system due to base-level variability. The software will also allow us to efficiently measure the statistics of preserved channels for comparison with topographic records.

Paola, NCED grad student John Martin, and NCED postdoc Alessandro Cantelli, began work on generalizing a theory we developed with PI Parker on the evolution of incised valleys under base level fall. The theory has so far been applied to the case of incision due to dam removal, a major issue in stream restoration, but it is equally applicable to development of incised valleys on continental margins, a critical issue in hydrocarbon exploration. The theory emphasizes the central role of rate of downcutting and sedimentation in controlling valley width through time. This work will provide a major link between one of our major efforts in stream restoration (dam removal) and one in long-term dynamics (incised valley creation and filling).

Collaborative work on these and other subsurface architecture research (Parker's is reported under the Unit Process focus area) has been done with our Stratigraphic Partners through an annual meeting and report, two short courses per year, visits to company offices by NCED personnel, and occasional research visits by company researchers (three this year). NCED participants in these activities include Paola, Kim, Martin, Sheets, Fedele, Parker, Mohrig, and Cantelli. This year NCED grad student Sheets took a position at ExxonMobil's research lab, and grad student Martin will be doing a summer internship at ChevronTexaco.

New Initiative: comparative morphology and dynamics of submarine and subaerial channel networks

Mohrig and graduate student Kyle Straub have begun a new effort to study the evolution of submarine channels on the continental slope. This work, based on data obtained from the northern seaboard of Borneo, is intended to complement that of Parker (reported under Focus Area 2) on channel evolution on submarine fans. Mohrig and Straub's work documents spatial change in channel width, depth, cross-sectional shape and plan form with distance from the shelf edge. This data is collected for the present day seafloor, as well as for two older and now buried seafloor surfaces, and is directly analogous to much better known results on spatial evolution in the geometry of subaerial channels. However, because in this case we have subsurface data as well, the digital maps define both the spatial and temporal evolution of the submarine landscape (see Figure 7). Important results to date include:

1) Definition of an unchannelized surface at the upslope end of the system. Channels do not connect to the shelf/slope break, but emerge a number of kilometers downslope from the head of the system. This transition is being investigated as a submarine analog to the better studied terrestrial

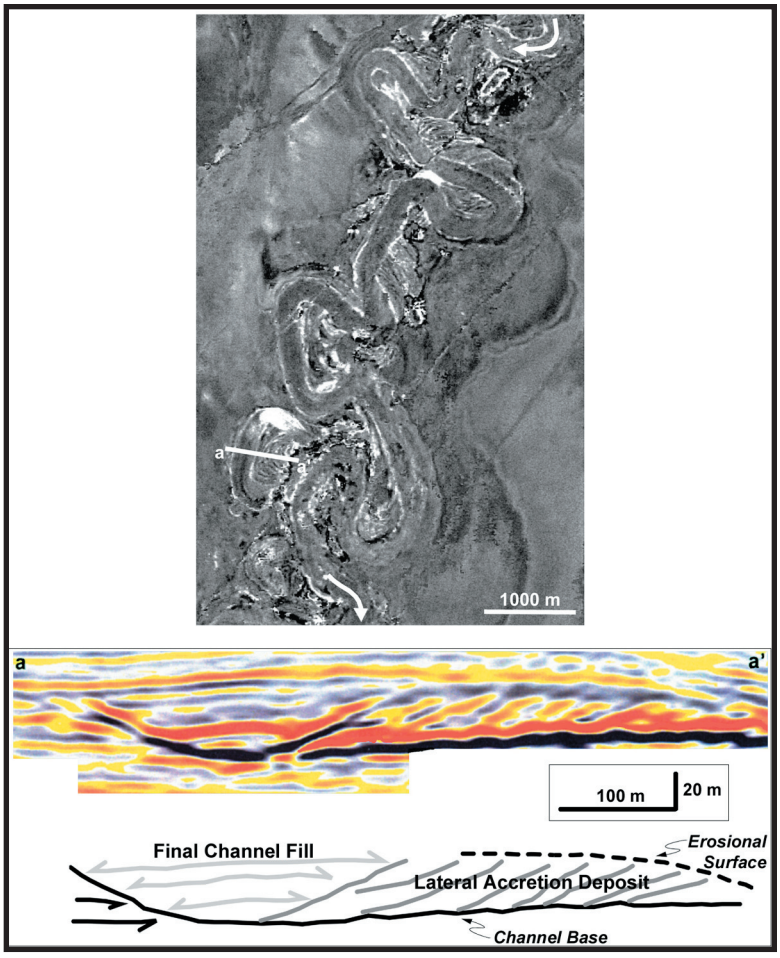


Figure 7. Map and cross section of seismically imaged submarine meandering channel. These data are being used to unravel processes associated with submarine channel evolution. The figure is modified from Das, Imran, Pirmez and Mohrig (2004).

hillslope/channel transition.

2) Persistence of channels and channel networks through time. The continental slope is net-depositional, with overbank surfaces aggrading at about the same rate as channels themselves. The end result is channel forms and patterns that are roughly locked in space and climb, nearly vertically through the preserved sedimentary deposits recording past states of the submarine landscape. This migration differs from the more common fluvial case in which horizontal migration, often abrupt, dominates over vertical migration, so the next step is to understand what this difference in kinematics is telling us about submarine versus subaerial channel dynamics.

New Initiative: statistical structure of deltaic channel networks

This a new project involving PIs Rodriguez-Iturbe and Paola. This project is equally relevant to Long-term dynamics, however, because of the central role of deltas as primary sites of terrestrial deposition. The basic idea is a form of technology transfer: there is an extensive body of techniques for spatial statistical analysis that have provided an array of new insights into the spatial structure of erosional (tributary) systems; we are applying the same set of techniques to depositional (distributary) systems, which in some respects are the topological inverse of tributary systems. (And in some interesting respects, they are not.) The new dimension that deltas add is the possibility of adding time evolution via the subsurface record they contain. The initial results from this work are reported under Focus Area 1.

Research Plans

Characterization and averaging of short-term fluctuations Mohrig will continue work on understanding bed evolution in sand-bed rivers. The main effort will be further work on the nonlinear stochastic surface-evolution equation he has developed with Jerolmack. Work this year will focus on laboratory experiments collecting the necessary topographic and flow data to rigorously test the nonlinear model. One aim for this year will be to develop the connections between Mohrig's approach and the application of turbulence-based methods to surface evolution being carried out by Porte-Agel, Foufoula, Voller, and Paola. The mathematics working group held last May provided a start on this, and we intend to continue working on this connection this year including the second meeting of this working group this spring. In addition, Mohrig plans to begin work on the effects of changing river width on bed composition and morphology. This work is important because of a growing realization of the dominant role of width changes in controlling erosion and deposition. It will be coordinated with developing efforts by Paola's group to examine this connection through focused work on flow expansion and continuing analysis of the roles of channelized versus sheet-like (lobe) depostional elements in building alluvial stratigraphy. This year this work will be expanded to include study of the relation between statistics of surface topography and statistics of preserved topography, to understand quantitatively the filtering and biasing properties of stratigraphic recording.

Long-term sediment production and flux: mean and variability. Perg will focus on combining cosmogenic radionuclides with field observation to estimate long-term sediment flux and statistical variability. Next steps include addition of regolith mixing and stochastic landslides to the theoretical model, and field testing the model in the ACRR joint field site using cosmogenic isotopes. The fieldwork will be performed with Jane Willenbring Staiger, an NCED postdoc starting in September. The model provides a natural link between long-term sediment flux and stochastic erosion events, and the ACRR field project will aim to develop this link by constraining the magnitude and timing of stochastic events. Better constraints on landslide magnitude and frequency will contribute to hazard analysis and set the boundary conditions for mass transfer of sediment from hillslopes to stream systems. One of the long-term aims of the ACRR field work will be to compare field mapping and cosmogenic isotope estimates of stochastic landslides with wavelet analysis of the airborne LIDAR topography. The wavelet analysis will require identifying the best wavelet wavelengths for analysis and testing for internal consistency of results. This work would be performed with Efi Foufoula and Bill Dietrich.

The CRN work on long-term mean and variability of sediment flux also has implications for stream restoration that we intend to develop in the next two years. Any attempt at stream restoration or basin management brings up the question: What are we trying to restore *to*? Modern stream records are problematic, since even the best records are short, and start after significant anthropogenic modification of the natural system. Cosmogenic isotopes provide a long-term integrated record of near-surface residence time. Depending on the situation and sampling strategy, cosmogenic nuclides can be used to quantify long-term mean erosion rates, stochastic variability in erosion rate (and sediment delivery to channels), and the magnitude of recent gullying. The goal is to work with the NCED Partners to develop a white paper on the use of cosmogenic isotopes in stream restoration this summer, developing the best sampling strategy while incorporating practical cost and time constraints. Field applications and development of cosmogenic isotope tools for the stream restoration toolbox will be developed in the following year in collaboration with Jane Willenbring Staiger, the NCED postdoc mentioned previously.

Fluvial response to changes in sea level and tectonics Paola will continue work with Voller on nonlinear modeling of channelized systems, especially application of moving-boundary methods to river-shoreline interactions. The work this year will focus on modeling channel shifting in deltaic systems, with the aim of developing a connection with the new project on deltaic channel spatial structure being led by Rodriguez-Iturbe.

Paola will also continue working on developing and applying the generalized dynamic width equation to channel evolution under varying base level in order to understand the evolution and filling of incised valleys. This work will be done collaboratively with Parker and Mohrig and will exploit the analogy between dam removal and eustatic base-level fall to shed light on the core physics of channel evolution with dynamic width variation. Paola's group will also carry out the first two in a series of experiments planned with our industrial stratigraphic partners group on the effect of linked cycles in sediment supply, water supply, and base level on valley evolution and stratigraphic architecture.

Paola's group will run an experiment in the Experimental EarthScape (XES) facility on how lateral subsidence variation affects channel migration and stacking. Based on previous work, our hypothesis is that on long time scales the effect of lateral subsidence variation on river migration is controlled by the ratio of two time scales, one reflecting channel mobility and the other the tectonic rate. The experiment is designed to test this idea. If successful, it will also provide us with insight on how channel migration might be influenced by active faulting in the modern environment. In addition, we are launching a series of experiments in collaboration with our industrial stratigraphic partners on how coupling between sea-level cycles and changes in water and sediment supply influence valley evolution and filling. In addtion to its relavance to stratigraphic architecture, this work will also provide a valuable data set for valley modeling for dam removal and so will support the Stream restoration IP and strengthen our connection with the Channels and Floodplains group.

Comparative morphology and dynamics of submarine and subaerial channel networks Mohrig's submarine channel work will focus on connecting patterns of overbank sedimentation with in channel sedimentation. Geometric and statistical data from submarine networks will be compared to better studied terrestrial networks, with the goal of extracting information on submarine versus subaerial channel dynamics from the similarities and differences in spatial and migration patterns. A major aim for next year is to connect patterns of sedimentation and erosion to the spatial distribution of uplift and subsidence. A second goal is to begin work with Parker on systematic comparison of subaerial and submarine meandering.

Statistical structure of braided and deltaic channel networks Paola also intends to continue his active collaboration with PIs Foufoula, Voller, and Rodriguez-Iturbe. The work with Foufoula is on stream braiding and vegetation-braiding interactions. Results of this work are described in Focus Areas 1 and 4. This year we intend to begin a new line of related work on how stochastic geometric properties of braided channel networks are preserved stratigraphically, i.e. how do the statistics of preserved topography (e.g. slope, curvature) compare with those of the active topographic surfaces? We expect this research to lead to new techniques for inferring natural

variability from preserved records, including corrections for preservation bias.

Finally, Paola will co-lead two new NCED working groups related to Long-term dynamics: one starting in June on the role of floodplain storage in depositional basins in the carbon cycle; and the other one in September on stratigraphic perspectives and applications to environmental management.

Collaborations Outside NCED

Paola works with postdoc Juan Fedele, John Swenson, University of Minnesota Duluth, Lincoln Pratson, Duke University, James Syvitski of INSTAAR/University of Colorado, and Mike Steckler, Lamont-Doherty Earth Observatory, on long-term modeling of fluvial systems, especially the coupling between the fluvial and offshore systems on continental margins. Our main effort has been to develop a time-averaged model of alluvial channel stacking density by coupling simplified models of avulsion frequency, floodplain deposition, and downstream fining with conventional diffusion-based models for long-term evolution of the fluvial surface. This work is mainly funded by ONR.

Perg is collaborating with S. Mukhopadhyay, School of Earth and Space Science, Harvard University, on ^{3}He measurements in olivine to examine the statistical distribution of residence times in sediment as part of her work in determining the chronology of fan lobes using fan roughness and cosmogenic radionuclide-derived surface ages to examine the timing of lobe switching processes in alluvial fans.

Mohrig is working with Paul Heller of the University of Wyoming on interpreting sandy river deposits in the Western Interior and with a group of researchers from Royal Dutch Shell.

Research-related Knowledge Transfer and Education, and Diversity Activities

Mohrig: Co-organized with V. Voller the first NCED working group - Novel methods for modeling the surface evolution of geomorphic interfaces – at MIT in May of 2004.

Mohrig: Co-led (with Paola) the Future Directions in Sedimentary Geology workshop, sponsored by Society for Sedimentary Geology (SEPM) and the National Center for Earth-surface Dynamics, April 2004, and delivered a presentation on *Environmental Stratigraphy.*

Mohrig: Technical session chair, 2004 AAPG/SEPM Annual Meeting, *Measuring and Modeling Sedimentary Bedforms.*

Mohrig: Invited Speaker, Feb. 2005, Departmental Lecture Series, Department of Earth and Environmental Sciences, Tulane University.

Mohrig: Boyd Distinguished Lectureship in Geological Sciences, Nov. 2004, Jackson School of Geosciences, University of Texas, Austin.

Paola: Led oil industry consortium meeting, August 2004.

Paola: Led industry short course, ExxonMobil Corp, 15 participants, April 2004.

Paola: Participated in ChevronTexaco technology conference and lectured at ExxonMobil research and exploration offices, October 2004.

Paola: Taught freshman seminar “The Skin of the Earth”, NCED based seminar on natural and human influences on surface dynamics, Spring 2005.

Paola: Revamped graduate seminar on Depositional mechanics to incorporate NCED related content.

Paola: Co-led NSF Future Directions in Sedimentary Geology workshop, sponsored by Society for Sedimentary Geology (SEPM) and the National Center for Earth-surface Dynamics, April 2004.

Paola: Mentored USIP student Edith Moreno on her research project “The Role of Vegetation on River Bank Erosion”.

Research Focus Area 6: Human Dynamics

Lead PIs: Nick Flores and Ben Hobbs

Mission: to develop decision-making and economic valuation methods appropriate to stream restoration in order to:

1. Provide a practical framework for decision-making in stream restoration projects;
2. Develop case studies to facilitate adoption of the framework by stream restoration practitioners; and
3. Add the dimension of human dynamics to NCED's stream restoration models.

Strategy and synthesis

This new Focus Area will integrate multicriteria decision analysis methods and economic valuation methods to develop a more comprehensive decision-making framework for landscape management. Initially, research in this Focus Area will focus on stream restoration issues to support the Stream Restoration Integrated Project. In the future, it will apply its research to the Desktop Watershed Integrated Project in support of decision-making in landuse and watershed management.

PIs Flores and Hobbs have organized their research around two major themes**:**

Multicriteria analysis helps those involved directly or indirectly in the decision making process weigh choices between alternative restoration projects. This analysis emphasizes a systematic consideration of tradeoffs, improving consistency and the transparency of decision processes, and ensuring that all project goals are given appropriate consideration.

Economic valuation analysis emphasizes measuring public preferences over alterative projects, potentially in terms of project services and monetary values.

The premise of our research is that more efficient restoration is obtainable through the use of multicriteria decision analysis and economic methods to compare alternatives and quantify benefits. Efficiency can be improved in several ways:

- *By allocating resources to projects that best achieve the public's objectives.*
- *By prioritizing restoration objectives when resource limitations prevent all of them from being achieved and tradeoffs must be made*.
- *By providing quantitative justification for restoration programs and budgets*.

The economic valuation analysis will draw on results from the multicriteria analysis and similarly the multicriteria analysis will draw on the results of a completed economic valuation analysis. Both analyses explicitly consider restoration project uncertainty, an aspect of stream restoration projects that is largely absent from current stream restoration project management.

Research in this Focus Area will focus first on developing a general decision-making framework, and then will apply this framework to a specific case study. The effectiveness of this approach will be gauged through collaboration with other NCED Principal Investigators, NCED's Stream Restoration Partners, and other parties involved in stream restoration decision making.

Research Accomplishments:

Focus Area is new – the major effort to the end of the reporting period has been to develop plans for the coming year.

Research Plans

The research will consist initially of three projects. The first sets the stage for the others, and is an analysis of stream restoration problems to identify particular problem contexts in which the use of economic or multicriteria valuation methods might most usefully inform the process and potentially change decisions. The second and third projects involve demonstrations of the potential usefulness of multicritera valuations under undertainty (theme 1) and economic valuations under uncertainty (theme 2) in a realistic case study.

Project 1: Classification and Assessment of Restoration Management Problems

Stream restoration projects are extremely varied in nature. Project decision-making can involve a wide range of local, state, and federal agencies, the public at large, and watershed partnerships, all with degrees of responsibility and authority that vary from project to project. Projects may be focused on specific stream locations, or may involve the coordination of multiple projects for entire watersheds or regions. Restoration goals vary from project to project as well; many are concerned with water quality (USEPA, 2005), while others focus on stream morphology as it affects ecological functionality, aesthetics, or hydraulic characteristics such as floodwater management.

Because there is no single stream restoration problem, the potential for economic and decision analysis to improve the efficiency of resource allocation in stream restoration may depend on the type of restoration being addressed. The purpose of this task is to create a classification of stream restoration problems and a general assessment of the potential for such analyses for each. These analyses are more likely to be useful when:

- Important environmental values are at stake;
- There are a number of competing restoration alternatives, and the potential resource expenditures are high;
- There is scientific uncertainty and several significant ecological impacts and goals, and there are interactions among the effects of multiple projects so that their cumulative effects need to be considered; and
- The agencies responsible have resources available to devote to analysis.

This project will generate a paper that classifies stream restoration problems along these and other decision-relevant dimensions, and identifies types of problems for which economic and/or decision analysis could make a significant difference in decisions and outcomes. A preliminary assessment will be made of the types of benefits and costs that are good candidates for quantification using economic valuation methods, and those that might be more appropriately quantified in their own terms and considered in a multicriteria framework. This paper would also identify candidate problems for the case studies in the subsequent two tasks outlined below. These problems would be ones that not only might be helped by analysis, but also represent a significant proportion of annual restoration expenditures in the U.S.

Project 2: Application of Multicriteria Valuation Under Uncertainty to Stream Restoration Case Study

Multicriteria decision analysis and stated preference methods in economic valuation are sometimes viewed as distinct approaches to quantifying non-market environmental benefits and costs. However, they are actually alternatives on a spectrum. State-of-the-art stated preference methods that are used in economic analysis involve decomposition of the alternatives to be compared into individual attributes (or criteria) of interest; each person who is being surveyed then is asked to choose from among discrete simplified alternatives to determine the value of each attribute in willingness-to-pay terms. This is similar to the philosophy of multicriteria analysis; it also adopts a “divide and conquer” approach to valuation by considering individual criteria first and then tradeoffs among those criteria.

But there are still some important differences between the two approaches, mainly concerning their role. On one hand, the intent of economic valuation methods is to provide an estimate of societal benefits by adding up individual willingness-to-pay from samples of the public. Such estimates are valuable inputs, among many, to agency and stakeholder decision processes. Multicriteria methods, in contrast, communicate tradeoffs among project goals or criteria, and provide a process by which participants in decision processes can learn about those tradeoffs and develop their own recommendations.

The purpose of this project is to demonstrate the potential of multicriteria methods to improve restoration decision making by applying them to a realistic and important problem. The problem will be selected from one of the problem categories that were identified in Project 1 as being important and potentially benefiting from such a decision process. For instance, multicriteria analysis could be used as a framework to consider the cumulative impacts of alternative sets of projects upon a watershed's restoration goals. The selection of the problem would be done in consultation with other NCED investigators and members of the Stream Restoration Partners Group.

There would be two deliverables from this project. One would be a publishable paper describing the case study and results of the evaluation of the method. The other would be a more extensive report for use by practitioners detailing the steps of the methods, example calculations, and guidelines for use of the methods for the type of problem considered in the case study, as well as other problem categories identified in Task I. The goal is to provide a clear set of multicriteria procedures that will contribute to more systematic consideration of multiple objectives and uncertainties by stakeholders and managers in stream restoration.

Project 3: Application of Economic Valuation Under Uncertainty to Stream Restoration Case Study

The multicriterion analysis outlined above in Project 2 helps individuals who are directly involved in the decision making process consider and weigh the relative importance of different restoration goals in assessing the desirability of restoration alternatives. In contrast, the economic analysis that would be provided in this task focuses on measuring public preferences over alternative projects with an emphasis on estimating economic values for these projects. The basic information regarding alternative project services and associated uncertainties developed in Task II would feed directly into the economic analysis.

This economic valuation project would develop and implement a survey to measure public preferences over alternative projects. Consistent with what has become accepted as "best practice" in economic valuation of environmental goods, the basic outline for this process would be as follows:

- Develop a draft choice survey using information from Task II. The choice scenario first must communicate alternative projects (using written descriptions, maps, diagrams), the types of services projects will provide, and the uncertainties associated with these services. Second, the choice scenario must offer a meaningful choice format, including project cost, through which individuals can express their most preferred alternative.
- Test and refine the choice survey using focus groups and survey pretest. Ten to twelve subjects would be recruited into a focus group. Subjects would be presented with the draft choice scenario and researchers would gauge effectiveness of the survey. The survey would be refined based on the discussion from the focus group. A follow-up focus group would be conducted if deemed necessary. Upon identification of the relevant population, the survey would be administered to a small random sample of households. Survey pretesting helps identify unanticipated problems with the survey and administration.
- Administer the survey to a random sample of households (500 minimum), record data, and analyze data. Statistical methods will be used to estimate the economic benefits of alternative restoration projects as well as identify which project services are most important to the public.

III. Education

Mission

The mission of NCED's Education program is the education of future leaders in NCED's key mission areas (landscape restoration, resource development and environmental forecasting) by effectively engaging them in NCED's research results and methods, in order to:

1. Ensure that students at NCED's institutions benefit from the unique educational opportunities presented by participating in a Science and Technology Center;
2. Improve the teaching of NCED science to K-12 students; and
3. Create unique and stimulating educational experiences, based on NCED science, for the general public, and communicate these via the national science museum community.

As described in the Center Overview, the only significant refinement to our Education program from the current Strategic Plan has been the introduction of a method for linking concepts and technologies between NCED research and Integrated Project areas with Education programs. Specific examples are included in the Center Overview..

[Note: Activity tables are in Appendix 6]

Internal Education Programs – Accomplishments and Plans

Graduate Student Education

Year 3 outcomes: In Year 3, NCED graduate students, across institutions, have taken growing advantage of the wider collaborations a Center makes possible. In particular, they have assumed a collective identity by forming a Graduate Student Council and been active participants in NCED's growing Stream Restoration Project.

Graduate Student Museum Assistantships:

NCED's Graduate Museum Assistantships (GMAs) are designed to enrich the graduate experience by complementing the standard assistantships in teaching and research. Early in Year 3, NCED geology Ph.D. candidates Nikki Strong and Michal Tal completed NCED's first GMAs, working with SMM staff to develop interpretive materials and activities for use in the Big Back Yard. Strong and Tal met regularly with SMM staff and youth, conducting field trips, experiments and activities in the park and in the natural world, to fully immerse the staff and youth in NCED science. This work resulted in well-informed volunteer and youth docents who were able to regularly engage museum visitors in the science behind the mini-golf holes and other interactive experiences in the BBY. In addition, Tal served as an adjunct instructor in Introductory Geology at the University of St. Thomas in summer 2005. Her intimate knowledge of the BBY helped Tal to design an undergraduate laboratory exercise for the BBY. The success of this experience is one of several that have sparked additional planning within NCED aimed at discovering ways to create undergraduate research and learning opportunities at the museum.

In Spring 2005, NCED MS candidate Lisa Tillman is working on a slightly reduced GMA project, supervised by Patrick Hamilton. Lisa will assist Hamilton and NCED Partner Jay Michels in bringing a training program in non-point source pollution mitigation for municipal officials to the museum.

Graduate Student Council

The NCED Graduate Student Council (GSC) was formed at the October 2004 PI retreat. That meeting resulted in an organizational structure for the GSC that includes a representative from each NCED-affiliated university. Representatives have been selected at each of the three largest NCED affiliated Universities. The representative from the UC, Berkeley is Leslie Hsu, the representative from MIT is Doug Jerolmack, and the representative from

the University of Minnesota is Wes Lauer. Development of more formal governing documents for the organization is an ongoing task for the representatives. Approval of the governance structure by the NCED students will be one goal of student activities at the 2005 PI Retreat.

In addition, the GSC drafted an action agenda at the 2004 PI retreat. Selected accomplishments to date include:

1. Travel funding. The GSC has successfully lobbied NCED to implement a travel program for students who wish to attend NCED related activities or workshops or visit associated NCED institutions. Students are currently allowed up to $500 for one trip per year for this purpose.
2. Equipment inventory. Due to GSC lobbying, NCED has developed an online inventory system for equipment purchased using NCED funding or for equipment available for NCED use. The goal of the inventory is to provide students and researchers a comprehensive list of resources already available to them, along with contact information.
3. Clarification of NCED student status. This issue was raised with the Executive Committee which has since defined any graduate student advisee of an NCED PI working on NCED research as being eligible to participate in all NCED graduate student activities, regardless of the source of the student's funding.
4. Student communication with NCED PIs. The GSC developed two suggestions, both of which have been implemented. First, the GSC recommended that time be scheduled at all PI retreats and annual site visits for direct student-PI interaction. This was accomplished at a poster session at the 2004 PI retreat. Second, students volunteered to give presentations during the NCED seminar series so that PIs could provide direct feedback to the student presenters. Several students volunteered for the spring seminar series.

Graduate Program in Applied River Restoration

During Year 3, NCED PI Vaughan Voller, assisted by University of Minnesota undergraduate Christina Omdahl, reviewed the feasibility of implementing a graduate degree program in Stream Restoration at the University of Minnesota. The program would serve three NCED objectives:

1. Graduate education: The program would cover distinctive NCED content.
2. Knowledge transfer: The program would serve as a focal point for combined research and training efforts between NCED researchers and partners and produce graduates prepared to take leading roles in practical applications of landscape sustainability.
3. Diversity in the graduate student body: The natural relevance of landscape sustainability through stream restoration to students from Native American communities (where restoration projects are often conducted) would attract more diverse students to NCED.

Through web-based research, discussion with NCED Partners, and investigation of program implementation options at the University of Minnesota, it became clear that the program should first be offered as a one-year certificate. After successful implementation at the University of Minnesota, the program would be extended to other NCED academic sites and possibly developed into a full master's degree program. It would include a "capstone" practicum involving significant hands-on experience in a stream restoration environment.

A more complete description of the program design is available in Appendix 9.

IGERT award

The University of Minnesota proposed an NSF IGERT (Integrative Graduate Education and Research Traineeship, proposed budget: $3,197,812.00) grant in Year 3. This program will provide training across the disciplines of ecology, civil engineering, and the earth sciences, organized around a theme of non-equilibrium interactions between landscape changes and ecosystem processes across a wide range of spatial and temporal scales, emphasizing non-equilibrium dynamics and nonlinearities inherent to physical processes and materials transport and their effects on ecosystem dynamics. Two NCED PIs, Hondzo and Paola, are co-PIs on the IGERT, several NCED PIs will serve as IGERT faculty. The goal of the IGERT program is to take a major step toward realizing NCED's vision (enabling landscape and ecosystem sustainability through education, research, and knowledge transfer) by using the linked cross-disciplinary themes of nonequilibrium and nonlinear dynamics across space and time to develop an integrated graduate research and education program that brings together civil engineering, ecology, and earth sciences.

The program will produce leaders in the study of physical, geomorphological, biological, and chemical processes that determine the composition, stability, and dissipation of landscapes and ecosystems through time, in support of environmental forecasting, restoration, and resource development. Doctoral students will develop a framework for both empirical and theoretical studies to understand the physical and biological consequences of non-equilibrium dynamics across space and time in a nonlinear world. Students will receive a strong quantitative foundation, from data collection, data analysis and interpretation, to modeling, and a strong empirical foundation through exposure to state-of-the-art instrumentation. The training will emphasize interdisciplinary and collaborative work and will provide in-depth training in the students' core areas, broad exposure to the other two participating disciplines, and training to understand social, ethical, and policy issues relevant to the interdisciplinary theme. Participation in the IGERT will provide graduates the foundation to address many of our pressing environmental problems, including water and air pollution, habitat restoration, hazardous waste management.

Other Graduate Student Activities

Other NCED specific graduate student activities included participation in weekly research-oriented video-conferences, interdisciplinary field and laboratory work, participation in PI retreats, site visits, research meetings with NCED Partners and Workshops and Partner meetings. Graduate students are also active members of NCED's Angelo and Stream Restoration Projects. Some notable examples of inter-NCED collaborative graduate research include collaborations between Foufoula, Paola, students Tillman and Tal in Focus Area One. In Focus Area Two, graduate students have been instrumental in the design and construction of Dietrich's new experimental facility to study gravel bed augmentation and dam removal. This effort includes NCED Partner Stillwater Sciences and PIs Wilcock and Parker, along with their students. In Focus Area 4, Honzo's and Powers' students are increasingly collaborating in river nutrient cycling and metabolism in the ACRR. In Focus Area 5, work on stream terraces in ACRR by Perg and student Fuller connects to experimental work of Paola and Strong in NCED's XES facility, as well as work by Mohrig and students.

"Preparing for an Academic Career", a workshop sponsored by NAGT and NSF, was held at the U of M from July 30 to August 1. An "add-on" workshop, entitled "Using Physical Models in Sedimentology, Stratigraphy, and Geomorphology Courses" was co-led and sponsored by NCED/SAFL. NCED graduate student Nikki Strong and post-doc Juan Jose Fedele participated in the workshop. Karen Campbell collaborated with University of St. Thomas geology faculty member Tom Hickson in planning and conducting examples of surface-process inquiry-based exercises using SAFL experimental facilities. Finally, a new graduate seminar was designed and taught by Voller, involving six NCED students in theoretical and applied NCED research on moving boundary problems.

Undergraduate Student Education

As is true each year, NCED hosted summer undergraduate interns, who participated directly in NCED research,

through its USIP program (see Diversity section of this report). Chris Paola designed and delivered a University of Minnesota Freshman Seminar entitled "Skin of the Earth". In addition to lectures by Paola and NCED graduate students, participants in the seminar spent several class sessions working the Glines Canyon Dam removal experimental flume designed for the SMM School Contact Program, in cooperation with NCED visitor Chris Bromley. Efi Foufoula incorporated NCED research topics and methods into the undergraduate course "Hydrology and Hydrologic Design" in the Civil Engineering Department at the University of Minnesota, Spring 2004. Ignacio Rodríguez-Iturbe teaches a full semester undergraduate course in Ecohydrology at Princeton University which exposes students to a great deal of NCED research.

Greg Wilkerson supervised two female undergraduate students (K. Puckett and D. Tripp) in summer research at the University of Wyoming. Their capstone projects were papers submitted to Wilkerson on topics related to stream restoration. Both students joined NCED's USIP interns (see Diversity section) for an undergraduate research symposium and attended an ASCE professional conference. At the ACRR, members of Mary Powers' lab worked with UCB undergraduate field assistants A. Dombrowski and C. DiVittorio and two Humboldt State students: J. DeWolf and S. Workman.

Two NCED Geology Ph.D candidates, Nikki Strong and Michal Tal, served as undergraduate instructors in Geology at external institutions: the University of St. Thomas, Gustavus Adolphus College and Metropolitan State University. In each case, they developed course materials related to NCED concepts that will be captured, with the assistance of NCED's Graduate Assistants in Teacher Education, Jill Baumtrog and Ben Friesen, for inclusion on NCED's website.

Campbell and Morin continued to collaborate with Dr. Kent Kirkby, University of Minnesota, Geology and Geophysics, and Dr. Anthony Murphy, the College of St. Catherine, to study the effectiveness of 3D visualizations (projected visualizations and paper maps) in K-12 and undergraduate education laboratories. The team conducted a study in K-12 classrooms in spring 2004, held two follow-up workshops for participating teachers in summer 2004, presented numerous papers and posters at regional and national scientific and educational conferences on preliminary study results, and submitted proposals for additional study of the effectiveness of the maps in K-12 education. All of these efforts were coordinated with ongoing study of the effectiveness of the maps at the undergraduate level.

A visualization of surface processes in the Great Lakes region, developed by Paul Morin to promote the May 2005 Annual Meeting of the North-Central Section of the Geological Society of America, was featured at the November 2004 Annual Meeting of the Geological Society of America in Denver. This image, in both 2D paper and 3D digital versions, was widely distributed to and requested by undergraduate instructors in Earth Science nationally.

In Year 3, NCED Director of Higher Education and Knowledge Transfer Campbell was an active participant in a new initiative at the College of St. Catherine (CSC), a women's college in St. Paul, Minnesota. CSC has obtained external funding to develop a "STEM" (Science, Technology, Education and Mathematics) minor at the undergraduate level. The multi-year initiative aims to develop a program of integrated coursework with associated laboratory and field investigations and a final "capstone" project, around an environmental science theme. In this experience, pre-service K-12 teachers, as well as undergraduate students majoring in anything from management to a traditional science, will have the opportunity to experience inquiry-based environmental science, infused with NCED methods and case studies. EAB member Tony Murphy leads this effort; and NCED visualization specialist Morin provides materials.

Internal Education Programs: Plans for Year 4:

1. Continue high level of participation by Graduate students in all center-wide activities

2. Explore the possibility of creating a unified surface process curriculum for all NCED graduate students;
3. Continue to evaluate uses of 3D maps and images in the classroom and informal education; develop more interactive visualizations.

Participation of center students in professional development activities.

In addition to the activities described above, NCED current (or recently-graduated) graduate students and post-docs participated in 8 Conference Proceedings, 11 in-press papers and 12 published papers in Year 3.

External Education Programs – Accomplishments and Plans

ESTREAM: (Earth Science Teachers/Researchers Engaged in Active Modeling)

In Year 3, ESTREAM moved from a pilot experience to a full-fledged program, with two main components and a great deal of interaction with other NCED research and educational activities. Three teachers from the Fond du Lac Ojibwe School, Rachel Breckenridge (math), Pat Kohlen (chemistry) and Leslie Hoffman (biology), participated in NCED's summer ESTREAM internship as a team. Together, they interviewed various NCED PIs and worked with staff members Campbell, Dalbotten and Marr, to develop a "build-it-yourself" re-circulating stream table and a suite of activities for the stream table which interpret various NCED research themes, such as meandering and braiding rivers. They demonstrated the stream tables at the inaugural Earthscapes Teacher Institute, and tested them with *gidakiimanaanawigamig* campers. The table set up and activities are available on the NCED website and are being further tested by NCED's pre-service teachers and other staff at outreach activities.

During the summer of 2004, two pre-service Earth Science teachers, Jill Baumtrog and Benjamin Friesen, joined NCED as part-time Graduate Assistants, shared, as a team, with the University of Minnesota Geology and Geophysics Department. In this role, they have developed visualizations, edited existing ESTREAM activities and developed new ones based on NCED research, produced 3D maps and associated activities for NCED's website and educational programs, tested these activities in their student teaching classrooms, assisted in the Earthscapes Teacher Institute and fully participated in ongoing collaborative research (Campbell, Kirkby, Morin, Murphy—see Undergraduate Education section above) of the effectiveness of 3D visualizations in K-12 and undergraduate education. In addition, Baumtrog and Friesen have both presented NCED educational research at state and national science and education conferences. Finally, they participated as active members of the NCED Graduate Student Council, attending the October 2004 PI retreat and working with NCED graduate students to develop K-12 teaching materials related to the science graduate students' research.

Plans for Year 4

1. Continue posting activities on the NCED website; develop means for tracking their use nationally;
2. Work with DLESE to include activities in DLESE site;
3. Develop opportunities for ESTREAM teacher research to be conducted at NCED-related field sites; and
4. Investigate including undergraduate instructors as ESTREAM teachers.

Science Museum of Minnesota: Earthscapes

The Big Back Yard

Construction of the Museum's 1.75-acre outdoor science park, the Big Back Yard, resumed in March 2004. When the park opened to the public, June 26, 2004, the nine hole regulation Earthscapes mini-golf course was supplemented by a large braided stream table, a 3D topographic and bathymetric map of the world, a 'source-to-sink' and a dam removal model, as well as abundant signage explaining the NCED concepts behind the golf

holes and interactive exhibits. Fabrication of a landscape evolution model and a turbidity current model were not finished in time for the 2004 Big Back Yard season. These components were completed in winter 2004/5 and will be installed for the 2005 Park season.

The Museum hired Mary McEathron, who has been conducting evaluation on NCED programs at the University of Minnesota, to perform a summative evaluation of the Big Back Yard in August 2004. She and her associates tracked 323 visitors as these people explored the park and conducted 92 interviews with a total of 271 participants. The full report is included as Appendix 10 to this report.

Overall, the visitor response to the Big Back Yard was very positive. 83 of the 92 groups knew of the exhibit prior to visiting the museum on the day they were interviewed. In 63 of the group interviews, visitors noted that they enjoyed and appreciated the combination of the educational content with the fun and recreation of miniature golf. Interview findings indicate that the addition of miniature golf did not overwhelm the educational content of the exhibit. Visitors were able to relate some aspect of the educational content in all but eight of the group interviews conducted. Many visitors reported that rather than overwhelm, the addition of mini-golf actually helped them grasp some of the concepts presented.

Over 53,000 people explored the Big Back Yard before it closed for the season on October 3, 2004. Significantly more visitors are expected in 2005 because the park will open on May 7 and close on October 2, resulting in a season seven weeks longer than 2004.

Plans for Year 4

1. The landscape evolution and turbidity current interactive exhibits will be installed for summer 2005.
2. We will experiment with installing 3D maps on the sidewalks and pathways in and around the EarthScapes mini-golf. These maps, on a durable outdoor laminate, will allow park visitors to explore in greater depth various aspects of Earth-process science.
3. NCED has prepared a set of geo-referenced maps of the Mississippi River, showing how its course and width have changed enormously over the past 130 years. These maps will be reproduced with annotation and installed on a wall in the Big Back Yard's Science House building.
4. SMM will be collecting slabs of fossiliferous shale from a quarry in southern Minnesota this spring for installation in the Big Back Yard. SMM will use this shale to highlight the fact that the contemporary processes of sediment erosion, transport, and deposition have been in operation throughout Earth's history.
6. The success of the Big Back Yard has led to ongoing planning between Hamilton, Campbell, Kirkby, Morin, Murphy and other member of NCED/SMM and NCED/SAFL to find ways to incorporate opportunities for undergraduate education and research in SMM's indoor exhibits. These ideas will be further developed in Year 4, pending additional grant funding.

Earthscapes Teacher Institute

In summer 2004, NCED conducted its inaugural Earthscapes Teacher Institute (ETI). During the two-week institute, eleven teachers (ten from Minnesota and one from New Hampshire) spent two days at the Maltby Nature Preserve & Natural Sciences Center on the Cannon River in southeastern Minnesota and two days near the Fond du Lac Tribal and Community College on the Otter Creek in northeastern Minnesota. They actively observed, developing questions, and conducting team investigations related to river dynamics and ecosystems. Institute staff from NCED/SAFL (including a USIP student), NCED/SMM and Maltby supported this field research and integrated scientific and pedagogical content. In Week Two the institute moved to Science House in the BBY,

taking field trips to St. Anthony Falls Laboratory and the Mississippi River, and exploring the BBY. Participants spent one day learning about NCED's visualization resources, were introduced to the "build it yourself" stream table by Rachel Breckenridge, an ESTREAM teacher, and provided feedback on plans for the School Contact Assembly and Residency (see below). By the end of Week Two, teachers had developed "action plans" for bringing similar field and/or classroom experiences to their classrooms.

In February, a subset of the teachers again met with Earthscapes staff in Science House to review progress. They viewed the fully developed School Contact Residency materials, learned more about the social and cultural history of the Mississippi River in the Twin Cities, served as a focus group for NCED's investigation of possible use of 3D technology to produce an NCED movie, and presented any materials and experiences they had been able to implement in the fall term in their classes.

A full evaluation of the ETI has been prepared by UofM graduate students in Educational Policy Stacy Grimes and Mary McEathron. The evaluation is attached as Appendix 10.

Plans for Year 4:

1. Continue the successful ETI, this year as a one-week experience.
2. Investigate possible collaboration with another SMM teacher institute specifically serving teachers of Ojibwe students
3. Involve ETI Institute alums in ESTREAM and NCED presentations at professional meetings
4. Review materials prepared by ETI teachers for inclusion on NCED website where appropriate

NCED/SMM School Contact Program

In Year 3, NCED/SMM discussions with NCED/SAFL staff and students led to the decision to focus the School Contact Program's Earthscapes School Residency (ESR) on the Elwha River dam removal study being conducted by NCED Visitor Chris Bromley and NCED Partners in the Bureau of Reclamation and U.S. Forest Service. Pilot ESTREAM activities had already focused on Bromley's model study and this, combined with media interest in this story of a real river restoration project with significant social impact involving Native Americans made it clear this was a good candidate for additional educational interpretation.

Working with NCED ESTREAM pre-service teacher Ben Friesen, visitor Chris Bromley, and NCED Engineer Jeff Marr, School Outreach staff developed a scaled-down version of Bromley's model of the Lake Mills Reservoir and the Glines Canyon Dam. Nine copies of the resulting portable dam-removal stream table were constructed, eight for use in the outreach program and one for use at NCED/SAFL in K-12 and undergraduate education. The original mold was built with layers of styrofoam building insulation and sculpted with sheetrock mud. A commercial fabrication company created a cast of the basin and sprayed on a fiberglass resin to created the basin models. Each model is contained in a plastic tray with a re-circulating water supply. The cost of materials and fabrication for the Elwha river models was approximately $7,000. Materials include pumps, valves, trays, modeling materials, tubing, trays, buckets, plastic sand, screens, along with the model casts. Working with Paul Morin and Ben Friesen, classroom activities using the models, 3D maps of the Elwha River area, and PowerPoint slide shows have been developed and piloted with teachers and children.

School Outreach will present the ESR in the Spring of 2005 at the schools of the 10 Minnesota teachers who participated in the ETI. SMM staff will spend multiple days at each school and will present an estimated 125 hours of student instruction. In addition, School Outreach will present the Earthscapes residency programs to tribal schools associated with NCED.

Plans for Year 4:

SMM school outreach staff will continue presentation and program delivery of the ESR to participating ETI schools as well as Native-serving schools, beginning in spring 2005 and throughout the 05/06 school year. The program will be modified throughout the year based on the presenter's experiences and participant evaluations. Working with NCED/SAFL, SMM school outreach staff will continue to develop an assembly program based on NCED content and will complete development of the assembly for preview by teachers participating in the summer 05 ETI.

NCED/SMM Youth Science Center (YSC)

At the Science Museum of Minnesota's Youth Science Center (YSC), students in NCED's Earthscapes Park Crew were mentored by NCED Graduate Museum Assistants Nikki Strong and Michal Tal. The 12 high school-aged Park Crew students then assisted visitors in the Big Back Yard (BBY) during summer 2004. The team collectively worked 24 shifts per week, interpreting exhibits and mini-golf holes, providing programming in the Science House, and helping with general visitor needs. They met biweekly to continue content learning and to reflect on the effectiveness of the training to their on-the-job experience. A particular visitor need the youth were able to fill was involving visitors in the interactive exhibit models in such a way that visitors were able to experiment with different processes. This was especially true in the braided and meandering river models. On several occasions park crew teens kept groups of visitors at the exhibits for up to an hour running impromptu experiments and challenging the visitors to make the models behave in certain ways. Once the BBY closed for the season, the Crew designed programming to bring stream tables and related NCED activities to youth in local community centers. They visited 8 sites 3 times each, reaching over 160 youth participants over 4 months. The Park Crew youth also participated in college-readiness programming to help them plan for post-high school education.

The NCED Park Crew model was so successful in its first year that other YSC content teams have adopted it and grant proposals are being written to follow this model. The team began work 3 months before the BBY opening. This time and the involvement of the GMAs allowed the high school students to be immersed in NCED content. Through GMA leadership, the Crew was able to go on field trips and in-lab one-day internships, experience passion and excitement surrounding Earthscapes content, and to internalize the science behind the BBY. As the team transitioned from learners to teachers they were confident and knowledgeable. This helped them assume leadership of the community stream table project. YSC managers believe the ease with which the team met museum and community goals in the summer and fall of 2004 was because of the confidence with the content that resulted from the initial content immersion.

Youth Science Center staff are also active participants in NCED's *gidakiimanaanawigamig* environmental camps, involved in both planning and teaching activities in the year round camps (see Diversity section for further details).

Plans for Year 4

In Year 4, Park Crew youth will:

- again serve as docents in the BBY summer 2005 (many of the graduating Park Crew are eligible and are applying for jobs as supervisors in the BBY for summer 2005);
- 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; and
- continue bringing NCED-related stream table and other activities to community centers in the Minneapolis/St. Paul metropolitan area.

YSC staff will:

- seek another GMA to expand the very successful interaction between NCED graduate students and Park Crew students begun in 2004;
- facilitate internship days to get more of the youth exposed in-depth to SAFL and its NCED research; and
- continue to be full partners in planning and conducting year-round *gidakiimanaaniwigamig* camps.

Additional External Education Activities

Water Planet

The collective effort by the Science Museum and its fellow NCED partners to create the Big Back Yard (BBY) was an excellent example of collaboration at its best. Each entity contributed its respective skills to the project, producing an outcome that no single partner could have accomplished on its own. Building on this success, SMM in Year 3 submitted a proposal to Informal Science Education (ISE) at NSF to develop a 5,000-square-foot national traveling exhibition that uses the role of water in large-scale planetary processes as the medium for communicating the new and evolving field of Earth-system science to large public audiences. ISE has informed the Science Museum of its intention to fund Water Planet. Water Planet will expand on our successful model of collaboration, will involve new partners introduced to SMM through NCED, and will carry significant NCED content. The BBY is a marvelous educational resource for regional audiences, but Water Planet will reach millions of people during its multi-year tour to museums throughout the U.S.

Water Planet will include several innovations in technology and pedagogy:

Development of New Story-Telling Technologies: The project collaborators will prototype ways to utilize new visualization technologies that will make the compelling visual images of Earth processes comprehensible and interactive. By incorporating into the exhibition computer models/visualizations that benefit from periodic updating, the project collaborators will develop protocols and trainings for museums hosting Water Planet that will help them to upgrade their in-house capacities to acquire, process, display, and interpret output generated from large Earth-system datasets. The project will produce program content for these new visualization tools specifically designed for informal science education settings. This content will be digital in format and thus easy to distribute. This model of content development will advance understanding of how digital technology can ameliorate the upfront costs of content production through wide and rapid distribution while also shortening the time needed to produce new science content.

Research Collaborations: Water Planet will involve three NSF Science and Technology Centers: National Center for Earth-surface Dynamics, Center for Advanced Materials for Purification of Water with Systems, and Sustainability of semi-Arid Hydrology and Riparian Areas. NCED will support Water Planet with a shared PI, Hamilton, NCED staff, and Water Planet co-PI Morin, and Water Planet Advisory Board members, Foufoula and Paola.

Innovative Pedagogy and Evaluation: Two NCED experiences, SMM Youth Science Center collaboration with the Fond du Lac Native American community and NCED's development of diagrams to study and promote collaborations based on the work of Diana Rhoten, will be incorporated into Water Planet's efforts to increase participation in the environmental sciences by underrepresented minorities and develop truly effective and innovative research-museum collaborations.

Other activities

In Year 3, NCED engaged in preliminary work for two public education activities that will bring NCED research to very broad national audiences.

- In late summer, 2004, NCED collaborated with Mentorn TV, a London-based television production firm, on modeling work for a one-hour show for to be broadcast in the U.S. as part of Public Television's Nova series (and also to be available for world-wide distribution). The program investigates cataclysmic floods; the Earth-surface processes they involve and the clues ancient floods leave in the geologic record. NCED PI Chris Paola and post-doc Juan Jose Fedele collaborated with Vic Baker, University of Arizona to produce lab-based models of floods that form channeled scablands for filming by a Mentorn crew (see Appendix 4 for media coverage).
- In March, 2005, NCED began design work for a suite of interactive exhibits illustrating river processes and stream restoration research for the Smithsonian Folklife Festival to be held on the Mall in Washington, DC, June-July 2005. One of the focus areas of the festival in 2005 will be the role of NCED Environmental Partner the U.S. Forest Service in American culture. From a nation-wide internal search, the USFS selected employee Gordon Grant's proposal to showcase the agency's research on rivers. Plans include an experimental flume illustrating the role of vegetation in determining channel morphology and two smaller interactive models on dam removal and basic river processes. This exciting collaboration offers NCED the opportunity to bring PI/graduate student research (Paola and Tal), Partner/Visitor research (Grant/Bromley/USFS) and educational products designed for our Earthscapes SMM program to the up to 1 million visitors expected at this highly visible national event.

Evalutation and Performance Indicators

Evaluation

In Year 3, NCED Evaluator, Mary McEathron, assisted by NCED staff and students from the University of Minnesota's Graduate Program in Educational Policy, developed instruments and conducted formal evaluations of several NCED Education Programs. A list of instruments developed and reports completed, as well as summary selected finding follows. Full completed reports are included as Appendix 10.

Education Instruments Developed:

1. Earthscapes Teacher Institute Pre- and Post-Surveys
2. BBY Exit Interview Guide
3. BBY Observational Tracking Form
4. Graduate Student Survey (instrument developed but not yet put into use)

Education Reports Completed (two formal and two informal):

1. Earthscapes Big Back Yard Exhibit (see Appendix 10 for table of contents and executive summary)
2. Earthscapes Teacher Institute
   - Report 1: Focused on the content delivery of the Institute (see Appendix 10 for table of contents and executive summary)
   - Report 2 (informal): Focused on results of the follow-up meeting (participants reported on their curriculum or classroom projects)
3. Earthscapes Youth Science Center Park Crew (informal)

Selected Findings

Big Back Yard

The evaluation included observations or interviews with 323 visitors and 92 group exit interviews with 271 participants. Note: Visitors interviewed were not necessarily the same visitors observed in the tracking portion of the study.

1. Overall, the visitor response to the Big Back Yard was very positive. In the exit interviews, visitors commented frequently about the creativity of the exhibit and how much they appreciated the mixture of fun and learning (63 groups).
2. Visitors were able to relate some aspect of the educational content in all but eight of the group interviews conducted.
3. In 55 interviews at least one member of the group expressed some aspect of the processes that shape the Earth's surface:
   - Source to Sink. Nine of the groups (6 adult and 3 child comments) gave indicating an awareness of the overall idea of source to sink,
   - Erosion. Erosion came up frequently in the interviews with 27 groups mentioning something about erosion (36 adult, 6 teenage, and 2 child comments).
   - Transport and Deposition. Mention of the transport or deposition of sediment occurred less frequently than erosion. Sixteen groups spoke about sediment transport or deposition (14 adult, 1 teenage, and 5 child comments).

Earthscapes Teacher Institute

Surveys and interviews with the 11 participating teachers during the Institute and in the February 2005 follow-up workshop included these findings:

1. Participants' knowledge of Earth-surface process science, use of scientific methods and tool inquiry-based methods for teaching increased;
2. Participants indicated an increase in the frequency with which they planned to use various scientific methods in the classroom;
3. All of the participants who had conducted projects with their classes as of February 2005 indicated that these projects were significantly different than those they had conducted prior to attending Earthscapes Teacher Institute.

Evaluation Plans for Year 4:

The Earthscapes Teacher Institute pre-and post-surveys will be used with the 2005 Institute and results analyzed. A Graduate Student survey will be conducted in early Year 4.

Performance Indicators

See table on next page.

		Goals	Measurement #1		Measurement #2	
			Description	Value	Description	Value
1	**NCED students:**					
	a.	Graduate student participation in NCED Center-wide activities	Number	31		
	b.	Graduate student application and graduation rates, and job placement	Number graduated	11	Number placed	9
			Academic positions	5	Government/ industry	4
	c.	New seminars and course materials developed for undergraduate education	Number of courses impacted	3	Number of institutions	3
2	**Earth Science teachers and students:**					
	a.	Participation in NCED programs	Number of teachers	21	Number of students	1640
	b.	Classroom tools developed and utilized	Number	50	Number web hits	2008
					Data downloaded	32750Kb
3	**Public:**					
	a.	Attendance statistics and feedback from the Big Back Yard	Attendance	53,000	Feedback	See Appendix 10

IV. Knowledge Transfer

Mission

The mission of NCED's Knowledge Transfer program is to inform NCED's research choices with the needs of its Partners, and to accomplish the rapid dissemination of its research results to both its Partners and its scientific community, in order to:

1. Ensure NCED research is informed by Partner needs;
2. Ensure that NCED research results and models are rapidly and effectively made available to both Partners and the broader scientific community;
3. Become a significant force in bringing together the River Restoration community in strengthening the scientific basis for River Restoration; and
4. Maximize the societal impact of NCED research through effective communication of NCED science to policy makers.

Our Knowledge Transfer mission and goals are unchanged from NCED's current strategic plan. In this program area, linkages to Research, and particularly to all three IPs, are rapidly emerging. A particularly exciting development has been the growing involvement of Center graduate students in Partner events and research, with examples in both our Environmental and Stratigraphic Partner areas.

[Note: Activity tables are in Appendix 6]

Environmental Partners – Accomplishments

Environmental Partners Meeting

NCED's 2005 Partners Meeting convened at St. Anthony Falls Laboratory, February 24. The one-and-a-half-day meeting focused on aspects of stream restoration: the current state of the art, basic research, methods and tools for restoration, and training models. In attendance were 29 researchers and practitioners from outside NCED, representing ten Federal agencies, two private consulting firms and five universities. The meeting was led by Peter Wilcock and Karen Campbell; seven additional NCED and SAFL staff and three graduate students attended. The meeting attendees constitute the NCED Stream Restoration Partners Group (NCED SRPG). See Appendix 5 for a detailed meeting report.

Meeting Goals:

- examine the current state of the art and identify persistent knowledge gaps;
- present ongoing research efforts and discuss future research;
- present useful methods and tools; discuss tools needed;
- discuss current training and the need for improvement and coordination; and
- examine objectives and decision making;

in order to:

- Identify the pressing needs in stream restoration research, practice and training;
- Determine what the Stream Restoration Partners Group wants to do to meet these needs; and
- Identify what NCED can do to help.

Meeting Results:

Several major needs facing the stream restoration community have been synthesized from meeting discussion. The community needs:

1. A better understanding of the effect of vegetation on channel "stability" ;
2. More well defined linkages between geomorphic design and ecological outcomes;
3. A means to address institutional/social barriers to scientifically-based restoration practice that are seen to be as important as knowledge barriers;
4. More, and more effective, project evaluation;
5. A means to get the latest science and methods to practitioners; and
6. A means to gather in one place information on monitoring and outcomes of past, present and future projects monitoring data.

The community felt NCED could address all of these needs in some measure, through experiments, field work, workshops and working groups, training for students and professionals, the NCED stream restoration toolbox, and various web-based resources.

Environmental Partners – Plans

Partner interactions in Year 3 made clear the ways in which NCED can provide leadership in the stream restoration community and the importance of this issue to NCED's Environmental Partners. A major Knowledge Transfer focus for Year 4 will be ensuring continued active Partner involvement in NCED's Stream Restoration Project. In particular, NCED plans to:

1. Develop its Stream Restoration portal to include a comprehensive listing of currently available training opportunities and resources;
2.. Launch a print-and-web-based stream restoration newsletter;
3. Coordinate with the National River Restoration Science Synthesis (NRRSS) in developing a data base of projects and outcomes;
4. Initiate Working Groups focused on research needs defined at the Partners' meeting;
5. Focus its emerging Social Science research on the societal dimensions of these needs; and
6. Develop a coordinated set of physical experiments in SAFL's Main Channel (see the Visitor Program section below for more detail on this effort).

Stratigraphic Partners – Accomplishments

Stratigraphic Partners Annual Meeting

At the August 2004 Annual Meeting of the Stratigraphic Partners, several NCED graduate students again made research presentations, giving them opportunities to discuss applied implications of their research and interact with future internship supervisors or employers. Discussions of future plans focused on two joint NCED/Partner efforts. The first was continued planning for a new XES Basin experiment: a relay-ramp scenario to assess the effect of syndepositional extension on alluvial architecture. The second was an effort to increase the intensity of Partner/NCED interaction by embarking on joint research. Data from the 2002 run in the XES Basin is being distributed to the Partners with the goal that joint Partner/NCED interpretation of this data and related declassified Partner field data will lead to joint theme sessions at professional meetings and in publications. Finally, one NCED/SAFL geology PhD candidate, Ben Sheets, was hired by a Partner organization, ExxonMobil, upon graduation in December 2004 and current PhD candidate John Martin will complete an internship with ChevronTexaco in Summer 2005.

Joint Research from previous Partner meetings

At the 2003 Stratigraphic Partners meeting, NCED proposed an experiment to investigate the effect of coupled variation of base-level water and sediment supply on valley evolution and stratal fill. The group agreed to pursue this line of joint NCED-Partner research. NCED graduate student John Martin worked with NCED Partner Martin Perlmutter to design and conduct this experiment at SAFL in March, 2005. Analysis of the data is ongoing and will be presented at the 2005 Partner meeting.

Stratigraphic Partners Short Courses

NCED's series of shortcourses for Stratigraphic Partners continues into 2005, with a deep-water course held in April 2005, and a shallow-water/stratigraphy course planned for May 2005. NCED faculty, staff and post docs plan and conduct these courses for Partner scientists. The courses offer Partner scientists an opportunity to participate in and interpret results of physical experiments; an experience which enhances their understanding of exploration field environments.

Stratigraphic Partners – Plans

1. Conduct one deep and one shallow water short course at NCED/SAFL for NCED's Stratigraphic Partner, ExxonMobil;
2. Continue joint research effort with Stratigraphic Partners;
3. Identify opportunities for Stratigraphic Partner participation in Working Groups; and
4. Continue to improve and enhance both instrumentation and visualization of the physical stratigraphic models used by our Stratigraphic Partners.

Visitors Program – Accomplishments

In year 3 of the Visitors Program, all visitor research took place at NCED's St. Anthony Falls Laboratory facility. The number of awards was reduced in order to strengthen the experience for a smaller number of visitors. All visitors participated in NCED seminars and video conferences and had continuous interaction with NCED faculty and graduate students. One visitor, Chris Bromley, became particularly integrated into NCED, presenting both live and videoconferenced seminars, twice assisting in design and delivery of a four-day high-school math camp dam removal lab experience, supervising two ESTREAM teachers, and assisting in design of models and experiments for the SMM ESR program (see Education section).

Visitors Program – Plans

Plans for year 4 of the visitor program reflect a commitment to this program and further refinement of its structure. NCED will seek proposals focused on specific research topics selected by NCED as critical to NCED's mission and to the community. In year 4, the Visitor Program will mainly focus on research pertaining to gravel-transport in rivers. The Main Channel at NCED's SAFL facility will be configured into a large, re-circulating gravel-bed river in which various experiments can be performed. NCED will request proposals from potential visitors to use this facility in addressing fundamental questions of gravel and mixed-load transport as well as sediment transport monitoring technology. In addition to focusing the topics of visitor research at SAFL, NCED is making efforts to expand the visitor program to other NCED facilities, in particular the ACRR. While the majority of funds will be allocated to the main channel experiments, a portion of year 4 VP funds will be for visitors to other NCED facilities.

Specific plans:

1. Solicit and award Visitor grants that include a field and/or modeling component that support two of NCED's Integrative Activities: The Desktop Watershed Project and Stream Restoration. In particular, solicit proposals for coordinated gravel transport in rivers research in SAFL's main channel.

2. Strongly encourage visitors to match their NCED award with other funds and to meet regularly with NCED research groups and present local and videoconference seminars during their visits.

Visualizations – Accomplishments

Our Digital Visualization focus in Year 3 has been two-fold.

1. Particular emphasis has been placed on acquiring and visualizing both legacy and new data related to the Angelo Coast Range Reserve, continuing to explore the ways in which NCED researchers wish to utilize this data, and finding effective ways to both display this data and utilize emerging technologies to "instrument" the Angelo field site to provide online, real-time access to this "observatory" data. To this end, Morin has joined the Technology Committee of CUAHSI and participated in many meetings, sessions and talks related to observatories and technology across the Environmental Sciences. In addition, Colin Bode, UC Berkeley, has joined NCED as a full time technology specialist for the ACRR project. Finally, increasing collaboration between Morin and Bode and staff of the NCALM (NSF Center for Airborne Laser Mapping, operated jointly by the Department of Civil & Coastal Engineering, College of Engineering , University of Florida (UF) and the Department of Earth and Planetary Science, University of California-Berkeley (UCB)) ensures that NCALM-acquired LIDAR data for ACRR is accessible for NCED visualization in effective and timely ways.
2. At the same time, NCED's concerted initiative to develop and evaluate three-dimensional maps, images and related activities for use in formal and informal educational and Knowledge Transfer settings grew in Year 3. It has become increasingly clear that the best way to communicate NCED's integrated interdisciplinary understanding to students and the public is through visualization. When people can view a 2- or 3-dimensional interpretation of a landscape in which surficial features are clearly presented in familiar relationships, explaining the processes involved in shaping these landscapes becomes much easier. Initial discussions with NCED's new social science PIs and Environmental Partners make clear that visualization can help a great deal in communicating science to stakeholders in stream restoration projects.

   Maps and other visualizations developed this year were presented at local and national conferences, installed in the Big Back Yard and Science House, used at both ANAMS and *gidakiimanaanawigamig* camps, and incorporated into the work of NCED's undergraduate teacher interns and SMM graduate interns. The maps were a focal point of SMM School Residency and Teacher Institute programs. A summer 2005 ESTREAM teacher will focus on the maps and various plans are underway to incorporate them further in the SMM.

   Finally, Karen Campbell, Paul Morin, Kent Kirkby (University of Minnesota), David Rapp (University of Minnesota Educational Psychology) and Anthony Murphy (College of St. Catherine, member EAB) and ESTREAM teachers Ben Friesen and Jill Baumtrog continued to work with K-16 instructors and students to test and evaluate the use and effectiveness of these visualizations in the K-16 classroom and laboratory. Summer workshops were held for local K-12 teachers participating in the study, data collection continued at the undergraduate level, and a proposal for additional funding was submitted to NSF by Campbell, Morin and Murphy.

Visualizations – Plans

1. Continue to develop the use of visualization to combine remotely-acquired topographic data about NCED's field area, ACCR, with ecological data to yield new insights in the ecogeomorphological realm.
2. Expand NCED study of the effectiveness of 3D paper visualizations in K-16 settings, through ongoing collaboration with Kent Kirkby and Tony Murphy:
   a. Develop web-based materials to accompany maps; distribute through NCED and Geowall websites
   b. Develop, print and distribute to undergraduate classrooms in the Upper Midwest, 3D visualization of this area for laboratory use

c. Publish Research findings

3. Expand and study the use of stereo-spatial material at the museum-to-museum level:
   a. Temporarily install a GeoWall2 at SMM, summer 2005, and fund a visualization graduate student to develop images, along with Morin and SMM staff, for use in museum settings.
   b. Morin will speak at ASTC 2005 (Association of Science and Technology Centers)
   c. Install large (~ 12x12 foot) NCED images at science and technology centers around the country
      i. Sci-Tech, Aurora, Illinois
      ii. Utah Museum of Natural History, Salt Lake City, Utah (new museum building)

Website – Accomplishments

1. Entered into maintenance agreement with web site vendor to provide for quick response to routine maintenance requests, and for the creation and maintenance of a parallel "test" site to prove out new capabilities and layouts before implementing them on production system.
2. Web log analysis system implemented to report on web site usage
3. Significantly improved website/archive capabilities, especially
   a. Users can browse/download from archive by folder instead of by file
   b. New, web-based archival of data and metadata implemented
      i. System automatically maintains metadata database for future links to external search engines
      ii. System automatically creates data access pages complete with metadata
4. Used new web-based archive system to archive and make accessible nearly 900 megabytes of research data
5. Launched Stream Restoration portal
6. Added user registration system:
   a. Users can request email notification when items of interest are added to archive
   b. System will track who downloads what data

Website – Plans

1. Build out the public Stream Restoration Network portal(s) to include:
   a. Interactive forums to facilitate communications between NCED and stream restoration practitioners (including Partners);
   b. Timely intra-group communications: contact information, meeting plans and results, links
   c. More downloadable data, tools, visualizations (especially from Partners)
2. Improve Education portal that makes publicly available:
   a. Materials and visualizations prepared by ESTREAM teachers, once tested and evaluated
   b. Materials developed in cooperation with SMM education programs
3. Develop portal for public access to Angelo Coast Range Reserve and Digital Watershed research
   a. Post three-dimensional, interactive and remotely updated visualizations and images to form an image gallery of ecogeodynamic processes on the Earth's surface.
   b. Expand the Data Vault (archive), with particular attention paid to presenting data and visualizations related to research and educational field sites in Minnesota.

Working Groups and Workshops – Accomplishments

NCED working group: Novel methods for modeling the surface evolution of geomorphic interfaces, Massachusetts Institute of Technology, May 22-May 25, 2004

The working group's charge was to explore state-of-the-art methodologies for modeling the surface evolution of geomorphic interfaces. Eighteen researchers, from diverse backgrounds covering mathematical and numerical methods, experimental techniques and field observations, were involved. After three days of talks and intensive working sessions three areas (questions) were identified for further work. See Appendix 7 for more on this Working Group meeting.

NCED workshop: National Workshop on Sediment Remobilization and Channel Morphodynamics in Active and Abandoned Reservoirs, March 25-27, 2005, Torrey, Utah.

The goal of the workshop was to exchange ideas and expertise, in preparation for a position paper on research needs regarding sediment remobilization and channel morphodynamics associated with dam removal to be posted on the NCED Stream Restoration Website. The workshop included overview presentations and discussion on sediment–related dam removal issues and research needs in the areas of field, experimental, and numerical modeling studies, as well as a day-long field trip to Lake Powell . The workshop was planned and led by Gary Parker and Peter Wilcock; twenty-six people participated in the workshop, of which eight were NCED PIs (see Appendix 8 for more information on this workshop).

External Workshops

Future Directions in Sedimentary Geology workshop

The second Future Directions in Sedimentary Geology workshop, cosponsored by NCED, NSF and SEPM, was held April 16, 2004 in Dallas Texas. The purpose of the meeting was to develop a "science plan" for sedimentary geology that includes scientific motivation and overall driving questions for study of sedimentary sequences; societal applications, education, and knowledge transfer; infrastructure needs; and linkages to other parts of Earth sciences, programs and initiatives. Paola co-organized the workshop and Mohrig presented.

Specific next steps determined during the meeting include: holding a series of sedimentary geology forums at national (AAPG/SEPM, GSA, AGU) and international meetings (EUG, IAS) to develop the plan with ongoing community input. A third workshop was held preceding the Geological Society of America Annual Meeting, November 6, 2004, in Denver, Colorado. Another outcome of this effort will be an NCED working group on Environmental Stratigraphy to begin work in fall 2004.

Community Surface Dynamics Modeling System

NCED hosted a CSDMS workshop in May 2004. The purpose of this meeting, the second of two NSF-sponsored workshops, was to develop and Implementation Plan for a community-built, freely available suite of integrated, ever-improving software modules aimed at predicting the erosion, transport, and accumulation of sediment and solutes in landscapes and sedimentary basins over a broad range of time and space scales. The CSDMS shares an overall vision with NCED but is focused on large-scale computer modeling. Two publications, available at http://instaar.colorado.edu/deltaforce/workshop/csdms.html and linked from the NCED website, resulted from this workshop: *A Science Plan of the Community Surface Dynamics Modeling System* and *Implementation Plan of the Community Surface Dynamics Modeling System*. NCED PIs Paola and Dietrich participated in the workshop.

Salt Marsh Geomorphology: Physical and Ecological Effects on Landforms

In October, 2004, NCED cosponsored the five day AGU Chapman Conference on Salt Marsh Geomorphology: Physical and Ecological Effects on Landforms, Halifax, Nova Scotia, Canada. The workshop was convened

by Raymond Torres, University of South Carolina; Danika van Proosdij, Saint Mary's University; Sergio Fagherazzi, Florida State University; and Charles Hopkinson, Marine Biological Laboratory. Grace Brush, a member of NCED's External Advisory Board, was a member of the planning committee and presented at the conference.

The conference objective was the integration of physical and ecological sciences to enhance understanding of the interactions between salt marsh channel networks, intertidal sedimentary processes, and ecology. Salt marsh and mudflat productivity is attributable to many physical and biological factors, and their areal extent and quality vary in response to the dynamic balance between sedimentary processes and intertidal topography. Hence, the intertidal landscape is the template upon which highly productive ecosystems thrive, and feedback between the scientific disciplines of ecology-sediment transport-geomorphology ultimately controls marsh sustainability. The conference was structured to promote exchanges between physical and biological scientists through plenary presentations, panel discussions, and small groups break out sessions, and field trips. The conference goal is publication of contributions in a special issue of JGR-Earth Surface.

Working Groups – Plans

1. Assess needs of Environmental and Stratigraphic Partners in relation to topics of planned and emerging Working Groups; determine appropriate mechanisms (e.g., direct involvement, timely reporting, inclusion of Partner problems/data in Working Group) for Partner involvement;
2. Plan and carry out second meeting of Numerical Methods Working Group

   The next meeting is planed for the summer of 2005. The theme will be Moving Boundaries related to shoreline in sedimentary basins. Questions:

   - Where and how can existing models be updated including both (i) the addition of new features into the existing diffusion model and (ii) the development of new and alternative models (phase field/cellular)?
   - What field data and lab data can be used to support model development?
   - What are the appropriate computational techniques (fixed grid, front tracking, deforming grid) and how should they be modified/adapted to handle the models in (1)?

   The expected outcome is a review paper(s) that summarizes the state of the art and points the way forward to more sophisticated landscape surface models.
3. Plan and carry out the first meeting of Carbon Storage Working Group, and any Working Groups that result from the March 2005 Dam Removal Workshop;
4. Ensure that Working Group data analyses, reports or tools (algorithms, models) are made available to Partners through Partner web portals; and
5. Assess additional direct methods to involve Partners in Working Groups and Working Group formation, such as videoconference- or web-based discussions.

Knowledge Transfer Challenges

NCED's partnership with its Stratigraphic Partners is a rich and productive one. Stratigraphic Partner organizations offer opportunities for graduate student internships and job placement; NCED research offers educational experiences otherwise unavailable to Partner scientists. Increasing opportunities for joint research are emerging. However, due to the traditionally competitive nature of the oil exploration business, very few specifics of this work and its impact on the industry can be made public. Finding ways to remedy this situation remains a challenge for NCED.

While NCED has had two very successful Environmental Partners meetings, regular sustained contact with these Partners has yet to be fully established. Unlike the 2004 Partners' Meeting, however, the 2005 Partners' meeting produced a very specific agenda of educational and research goals shared by NCED and its Environmental Partners. Such shared agendas have been very effective in improving the intensity of Knowledge Transfer contact between NCED and its Stratigraphic Partners; we are confident this will be the case with our Environmental Partners as well.

The functionality of NCED's website and data archive greatly improved in Year 3. Many of the functionality improvements were central to both the archiving and retrieval of research data, however, and the site's content is still light as a result. We will catch up in year 4, and the improvements will leave us well-positioned to integrate our archives with those of the broader scientific community in the future.

While most of NCED's Environmental Partners intersect most closely with NCED on the pressing needs in stream restoration, a few of those Partners, such as the Office of Naval Research and NASA, are not involved in this area of practice. NCED will need to decide, during Year 4, whether there are appropriate ways to continue those partnerships.

Evaluation and Performance Indicators

Evaluation

In Year 3, NCED Evaluator, Mary McEathron, assisted by NCED staff and students from the University of Minnesota's Graduate Program in Educational Policy, developed instruments and conducted formal evaluations of several NCED Knowledge Transfer Programs. A list of instruments developed follows.

Evaluation Instruments Developed

- Working Group Pre- and Post-Surveys
- Short Course/Workshop Pre- and Post-Surveys
- Partners Meeting Pre- and Post-Survey (Focused on stream restoration)
- Visitor Survey

Evaluation Plans for Year 4

In Year 4, instruments will be fully used and reports completed for:

- Partners meeting February 2005
- Carbon Storage Working Group 2005
- Numerical Modeling Working Group II
- Additional Partner meetings, Workshop and Working Groups, as scheduled
- All NCED visitors to date.

Performance Indicators

See table on next page.

Goal			Measurement #1		Measurement #2	
			Description	Value	Description	Value
1	All stakeholders					
	a.	Web site visits and downloads, both within and without NCED* *we were not able at this time to determine internal versus external	total visits to NCED homepage in year ending March 31, 2004:	3758		
			total visits in year ending March 31, 2005:	13, 333		
	b.	Timely archival of NCED data and documents with appropriate metadata	visits to NCED's data archive in year ending March 31, 2004:	440	Amount of research data archived and made available	900 mb
			visits in year ending March 31, 2005:	1647	metadata	system designed and implemented
	c.	Use of NCED-developed visualizations and visualization methods	downloads of visualizations from website in year ending March 31, 2005: (site did not exist in 2004)	1459		
	d.	Number and inter-disciplinary character of Special Sessions and Journal Issues	Special session planned for May 2005	Not yet held		
2	NCED PIs (metrics shared with Research):					
	a.	PI participation in Working Groups and Workshops	Number (total PIs, not total attendance)	9	Percent	50%

Goal			Measurement #1		Measurement #2	
			Description	Value	Description	Value
	b.	PI and student involvement with visiting scientists		2 PI research groups spent time with all Yr 3 visitors		
	c.	PI involvement with community initiatives	Number of initiatives	2	Percent PIs	10%
	d.	Joint publications with partners	Number (in press)	2		
	e.	PI involvement in partner meetings and other joint activities	Percent	50%		
	f.	PI contributions to web site and other KT dissemination venues	Number contributors	7	Number data sets or papers	9
3	**NCED Partners:**					
	a.	Partner participation in NCED activities and events	Partner representatives who attended NCED meetings and workshops	90		
	b.	Partner adoption of NCED tools, methods or training opportunities	Not applicable yet			
4	**Wider Community**					
	a.	Participation of external researchers in NCED workshops, working groups and other research activities	Workshops and working groups	27	Visitors conducting research with NCED	6
	b.	Impact of NCED research or tools on policy and practice in river restoration and landscape management	Not applicable yet			

V. External Partnerships

External partners 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.

1. Knowledge Transfer Partnerships

Environmental Partners	
Description	**Governmental and Corporate organizations involved with environmental remediation and forecasting**
Current Partners:	

Name	**Type**
NASA/Goddard Space Flight Center	Government Agency
Office of Naval Research	Government Agency
R2 Resource Consultants	Environmental consulting firm
Stillwater Sciences	Environmental consulting firm
US Army Corps of Engineers	Government Agency
US Bureau of Reclamation: Sedimentation and Hydraulics Group	Government Agency
US Department of Agriculture: National Sedimentation Laboratory	Government Agency
US Department of Agriculture: US Forest Service	Government Agency
US Department of Commerce: National Oceanic and Atmospheric Administration: Office of Global Programs: GAPP Program	Government Agency
US Department of the Interior: Bureau of Reclamation	Government Agency
US Department of the Interior: Geological Survey	Government Agency

Types of interaction	**Frequency**
Strategy meeting	Annual
Participation in Working Groups	1-3 times per year per group - varies by group needs

Stratigraphic Partners		
Description	Oil companies interested in the long-term dynamics of channel systems	
Companies		Type
1	Anadarko Petroleum Corporation	oil exploration company
2	ChevronTexaco	oil exploration company
3	ConocoPhillips	oil exploration company
4	ExxonMobil	oil exploration company
5	Japan National Oil Company	oil exploration company
6	Shell International Exploration and Production Company	oil exploration company

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

Other Knowledge Transfer Partners		
Partner		**Type**
1	Advanced Materials for Water Purification	NSF STC
Purpose: Joint development of traveling Water Exhibit (in proposal phase) with SMM.		
2	Association for Women Geoscientists, Minnesota chapter	Professional association
Purpose: connections to local professionals, career development for students, networking evenst, K-12 activities for children, events at regional conferences; Karen Campbell, past president, Lesley Perg, president-elect,		
3	CHRONOS	NSF funded center
Share information about cyberinfrastructure issues; host joint sessions at national conferences		
4	Geowall Consortium http://www.geowall.org/	Consortium
Purpose: exchange visualizations, tools and methods with 3-D developers worldwide; Paul Morin, organizer—NCED is a member		
5	SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas) http://www.sahra.arizona.edu/	NSF STC
Purpose: Joint minority recruiting, regular consultation between Education Directors and Knowledge Transfer Directors at both Centers, service between Centers, joint development of traveling Water Exhibit (in proposal phase) with SMM.		
6	SciTech Hands On http://scitech.mus.il.us/	Museum
Purpose: develop joint proposals, share exhibit and 3-D visualization expertise		
7	Utah Museum of Natural History	Museum
Purpose: pilot use of Earth-surface visualizations in museums nationally.		

Environmental Partnerships in development	
Name	**Type**
CALFED Bay-Delta Program	State Government
Collaboration on river restoration issues	
US Environmental Protection Agency	Federal Government
Collaboration on river restoration issues	

Minnesota Geological Survey	University
Joint development of mapping, modeling and visualization of channelized flows; distribution of NCED visualizations for educational and knowledge transfer purposes.	

2. Research Partnerships

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		
Description	**Non-NCED organizations which partner with NCED to perform joint research**	
Current Partners:		
Name		**Type**
1	National Academy of Science	Government Agency
Ongoing coordination of river restoration study		
2	National River Restoration Science Synthesis	Project
Ongoing coordination of river restoration study		
3	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		
4	University of Colorado/INSTAAR	University
Coordinated development of Community Surface Dynamics Modeling System		
5	Universidad Nacional del Litoral	University
Joint studies of large river systems and river engineering		
6	Universidad Central de Venezuela	University
Joint research on rivers and debris flows		

3. Education and Diversity Partnerships (all are Partners in both efforts)

Education and Diversity Partnerships		
Partner		Type
Description of Activities		
1	AISES: American Indian Science and Engineering Society	Minority Professional Organization
NCED has sent ANAMS students 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		
2	AIHEC: American Indian Higher Education Consortium	Consortium of tribal colleges.

NCED participates in their conferences, recruiting students at their career fairs		
3	Center for Embedded Network Sensing	NSF Center
Collaborates on joint recruiting of underrepresented undergraduate and graduate students		
4	Center of Research Excellence in Science and Technology, Texas A&M Kingsville	University
Collaborates on joint recruiting of underrepresented undergraduate and graduate students. We are also exploring possibility of formal partnership.		
5	Division of Indian Work	Non-Profit
Collaborates with NCED on middle-school diversity programming		
6	Dragonfly TV	Educational television producers
Partner on science programming for middle-school age children, based on BBY		
7	Fond du Lac Ojibwe School	Public School
Partners with NCED on *gidakiimanaaniwigamig* Native American youth science immersion program		
8	Get Ready! Minnesota Higher Education Services Office	Government
Collaborates with NCED on middle-school diversity programming		
9	Graduate School Outreach Office, University of Minnesota	University
Partners with NCED on recruiting and hosting underrepresented undergraduate students for our Undergraduate Summer Internship Program		
10	Laurentian Center, Britt, Minnesota	Environmental Learning Center
Hosts NCED's gidakiimanaanawigamig camps		
11	Nova/Mentorn TV	Educational Television producers
Partner on educational science programming for all ages		
12	QEM	NSF funded program
Partners with STCs in recruiting underrepresented groups for graduate and post-doc positions		
13	SAHRA	NSF Center
Collaborates on joint recruiting of underrepresented undergraduate and graduate students		
14	The Science Center at the Maltby Nature Preserve	Non-profit
Partners with NCED on delivering Earthscapes Teacher Institutes		
15	The University of Minnesota Materials Research Science and Engineering Center (MRSEC)	University
Collaborates on joint recruiting of underrepresented undergraduate and graduate students.		

VI. Diversity

Mission

The mission of NCED's Diversity program is to increase participation by underrepresented groups in NCED's scientific disciplines. The Diversity mission has a dual focus: a short-term improvement in participation by under-represented groups within NCED, and a long-term improvement in the representation of Native Americans in Earth science disciplines.

This mission has not changed from our current Strategic Plan. Diversity shares with Education a commitment to find explicit linking technologies and concept with Research, especially with our IPs. We have found that the interdisciplinary nature of our Environmental IPs and the timely appeal of wireless technologies are especially helpful in increasing the size of the pool of students from which we recruit.

[Note: Activity tables are in Appendix 6.]

Native American Programs – Accomplishments

In Year 3, NCED's *gidakiimanaaniwigamig* (Our Earth Lodge) and *ando-giikendasowin* (Seek To Know) Programs have brought over 100 middle- and high-school students to Native American Math and Science Camps for hands-on science activities related to NCED research. Content in the camps included activities on topics in the Hydrologic Cycle, Groundwater, Continental Divides and Drainage Networks, Food Webs, and Rivers and Lakes. Students in our programs have shown increases in their math and science grades and test scores since the inception of the program.

K-12 level: gidakiimanaaniwigamig (Our Earth Lodge)

NCED held four seasonal *gidakiimanaaniwigamig* camps in Year 3. Eighty-seven youths have participated in *gidakiimanaaniwigamig* activities (53% have attended two or more *gidakiimanaaniwigamig* activities). Participants in *gidakiimanaaniwigamig* have shown increases in Math and Science grades and test scores since the inception of the camps in 2003. Staff from the SMM Youth Science Center are active participants in planning and staffing the *gidakiimanaaniwigamig* camps and activities. In Year 3 we initiated an annual NCED/Fond du Lac Tribal and Community College (FDLTCC) sponsored American Indian Regional Science Fair for Native American K-12 students. 12 students were chosen to represent NCED and FDLTCC at the AISES National American Indian Science and Engineering Fair in Albuquerque, NM, where *gidakiimanaaniwigamig* participants made a huge splash, competing against over 300 students and taking home 7 medals (1st, 2nd or 3rd in their category) and earning three of the eight coveted spots on the team that will represent NAISEF at the Intel International Science Fair in Phoenix, NM this year. NCED has also launched an urban *gidakiimanaaniwigamig* program with the Division of Indian Works Youth Program. NCED undergraduate student Perla Ruiz will be leading their weekly Many Rivers program this summer, leading hands-on science activities and field trips for grade-school youths in their program.

K-12 level: ando-giikendaasowin (Seek to Know)

Ando-giikendaasowin, Ojibwe for "seek to know," is a ten-day residential camp for Native American high school students from across the country. In 2004, we had about 35 students representing five different states participating in one of the three sessions offered. They represented five different bands of Ojibwe, four different bands of Dakota, Pueblo, Navajo, Aztec, Onieda, Carrier, and HoChunk nations.

ANAMS held its third annual summer programs for Native American high-school students since NCED's partnership (15 continuous years all together). There were 12 first-year students who participated in the Introduction to Indigenous Science section. 10 out of the 15 students in the Earth, Water and Wildlife section were returning students. And all 9 students in the Heart, Health and Technology camp were returning students.

In the Earth, Water and Wildlife (the NCED-related section of the camp): NCED PI Andrew Wold led the camp, supported by personnel from NCED, the Ojibwe schools, and staff from the St. Louis Riverwatch program. Students surveyed several stream sites throughout northern Minnesota including the Dark River north of Virginia, MN, the Nemadji River south of Cloquet, MN, and the Deer Creek south of Cloquet, MN. Students were given background information on the streams and formulated hypotheses relating to potential differences between streams in these watersheds. In order to ascertain differences, students measured water temperature, discharge, and habitat diversity in these streams. Students also collected several biotic samples in the Dark River, Nemadji River, and Deer Creek. Biological components sampled included stream periphyton, fine particulate organic matter (FPOM), Coarse Particulate Organic Matter (CPOM), and aquatic macroinvertebrates. Students were required to present their hypotheses, data, and conclusions in a PowerPoint presentation to the other groups, faculty and staff, and the middle-school (*gidakiimanaaniwigamig*) summer camp students.

Finally, as a result of NCED's support, we have been able to leverage several smaller funding opportunities like a $3,500 grant from the State Street Foundation in New York, an $11,500 grant from the University of Minnesota Office of Multicultural and Academic Affairs and are in the final pool for a $13,000 grant from the Xcel Energy Foundation.

Outreach to Undergraduates at Fond du Lac Tribal and Community Collge

Further progress on increasing the pool of Native American students who choose STEM careers was created when NCED participating institution Fond du Lac Tribal and Community College initiated the first steps in the creation of a new Associate in Science Degree in Civil Engineering. NCED diversity staff arranged for the visit of Dr. Fred Norwood from Southwestern Indian Polytechnic Institute, which is collaborating with Fond du Lac on this initiative. The University of Minnesota's Institute of Technology and Department of Civil Engineering have agreed to support and advise as needed.

Native American Programs – Challenges

Native American K-12 students: NCED's *gidakiimanaaniwigamig* program has shown some progress in increasing the grades and test scores of students in the program. However, our data indicates that students in *gidakiimanaaniwigamig* are still struggling to pass the 8th grade math proficiency exam. In Year 4, NCED faculty and camp staff will incorporate more intensive math exercises into the camp's science exploration activities.

Native American Undergraduates: As reported in Year 2, our major challenge in working with undergraduates from Fond du Lac Tribal and Community College has been in addressing the gap between tribal college and graduate school. In supporting Fond du Lac Tribal and Community College's development of an Associate of Science Degree in Civil Engineering, NCED can institute supporting research experiences at SAFL and in the Department of Civil Engineering that create a bridge to graduate school.

Native American Programs – Plans

1. Develop new opportunities for students from Fond du Lac Tribal and Community College to interact with researchers from NCED. As FDLTCC develops their new Associate Science Degree in Civil Engineering, which will increase the number of undergraduates who would have an interest in the research done at NCED, we will collaborate with FDLTCC faculty to provide those students with research experiences, University tours, and support if they choose to transfer to the University of Minnesota.
2. Increased emphasis on applied mathematics in the gidakiimanaaniwigamig camps.

Diversity Recruiting Programs – Accomplishments

Diversity among researchers at NCED was increased this year with the addition of a new PI, Nicholas Flores, and graduate student, Karelyn Cruz, both Hispanic. The addition of these two members to our research program has increased the percent of researchers from underrepresented groups from 7% to 10% of our total research group.

The NCED Undergraduate Summer Intern Program provided funding for six undergraduate students to participate in research at SAFL and University of Wyoming in summer 2004. Two of these students have plans to pursue graduate studies at NCED (Robert Haydel has been accepted to begin research in Fall 2005 with Gary Parker. He has received the prestigious SURGE fellowship from the University of Illinois at Urbana-Champaign. Angel Santiago is finishing his junior year at University of Puerto Rico, Mayaguez and will return to NCED this summer to do another research project with his advisor, Fernando Porte-Agel. He plans to apply for graduate school at University of Minnesota for entrance in Fall 2006). Of our 4 other supported undergraduates from Summer 2004, 2 plan to attend graduate school, but have not finished their undergraduate degrees. (Edith Moreno intends to finish her degree in Biology and then pursue graduate work; Fernando Hernandez has decided to become a K-12 teacher based on his work with the *gidakiimanaaniwigamig* program). NCED supported 5 of our summer interns in presenting their work at professional conferences in 2004/05. Robert Haydel's project on Gravel Bed Stream Evolution won a 2nd place medal in engineering at the 2005 Louisiana Alliance for Minority Participation conference. Angel Santiago and Fernando Hernandez presented their research at the Hispanic National Engineering Conference in San Juan, Puerto Rico in October 2004. Angel Santiago also presented his research at the SACNAS conference in Austin Texas in November 2004. Danielle Tripp and Kerri Puckett presented their research at an ASCE conference in August 2004.

Faculty-to-Faculty

In order to initiate new contacts with Minority Serving Institutions (MSIs), NCED piloted its Faculty-to Faculty program in Year 3. The goal of Faculty-to-Faculty is to form research collaborations with faculty from institutes that serve a large percentage of students from groups underrepresented in STEM fields. In Year 3, the following faculty have visited NCED to participate in research workshops or discuss collaboration on research:

- Jianhong-Jennifer Ren, Assistant Professor, Texas A&M University at Kingsville
- Jennifer Cherrier, Assistant Professor, Florida A&M University

In order to identify potential Faculty-to-Faculty partners, NCED has completed a survey of U.S. MSIs that have two- and four-year programs in Civil Engineering and Geology. Faculty at these MSIs who are pursuing compatible research will receive invitations to visit and learn more about NCED research projects. Schools with large numbers of underrepresented students in Civil Engineering, Geology, or Ecology but that do not have faculty doing research in areas compatible with NCED will be targeted for recruiting visits. Faculty from MSIs who choose to do visiting research at NCED will be encouraged to come with a research team that includes students from their institutions.

2b. Impacts on Enhancing Diversity at the Center

In Year 3, diversity at NCED was enhanced through adding PI Nicholas Flores (Hispanic), graduate student Karelyn Cruz (Hispanic). Program activities also increased the number of K-12, undergraduate, and graduate students who were interacting with the Center. Significant milestones include:

1. Undergraduate Summer Internship Program. In summer 2004, six students participated in our intership program. Five were members of underrepresented minorities and three were women. One student from this group, Robert Haydel, will begin graduate studies with NCED in Fall 2005. Another, Angel Santiago, will return to the University of Minnesota this summer to continue his research with NCED. He plans to apply to

graduate school at the University of Minnesota upon completion of his undergraduate degree at the University of Puerto Rico, Mayaguez.

2. A Hispanic student, Javier Ancalle, has been recruited to the University of Illinois, where he will begin graduate work in fall 2005, co-advised by Parker and Marcelo Garcia.
3. A Hispanic undergraduate freshman, Perla Ruiz, was recruited by graduate student Nikki Strong from her class at Metro State College (which Perla was attending as a high-school senior) to work for NCED as she begins her freshman year at University of Minnesota. Perla is working jointly for the NCED education program as an advisor to the Urban *gidakiimanaaniwigamig* program with the Division of Indian Works youths and for the NCED research program in the capacity of junior scientist (advised by Jeff Marr). Nikki Strong will continue to act as her mentor.
4. In Year 3 we initiated an annual NCED/FDLTCC sponsored American Indian Regional Science Fair for Native American K-12 students. Twelve students were chosen to represent NCED and FDLTCC at the AISES National American Indian Science and Engineering Fair in Albuquerque, NM, earning 3 of the 8 coveted spots on the team that will represent NAISEF at the Intel International Science Fair in Phoenix, NM this year. FDLTCC has initiated a scholarship program for any student who participates in this science fair who chooses to attend FDLTCC in the future.

Diversity Recruiting Programs – Challenges

Traditional, broad-brush approaches to recruiting students at the graduate level from underrepresented groups met with limited success because it has been proven hard to identify students from underrepresented groups who have the science background and interest that would make them good candidates for graduate study at NCED. On recruiting trips to MSIs, at booths and presentations at professional conferences, and attending minority professional conferences such as AISES or SHPE, we have consistently found only a small fraction of attendees are interested in the geosciences. In addition, many of the schools that attract large numbers of minority students do not have programs that would prepare students for graduate studies in NCED. Those schools that do are often inundated with recruiters attempting to compete over the small numbers of students with compatible interests. Based on a review of our Diversity programs in Year 2, NCED piloted a new program in Year 3, *Faculty-to-Faculty*, which will systematically introduce NCED research to faculty from Minority Serving Institutions (MSIs) that have Civil Engineering, Geology, Ecology, and Biology programs that are compatible to NCED research themes. Through research workshops and visiting research positions, MSI faculty and their students will have an opportunity to visit NCED research facilities and form collaborations with NCED researchers. These faculty have the power to reach out to their undergraduate students and stimulate their interest in pursuing research careers in the geosciences. We believe that the benefits of this approach include:

1. Faculty at MSI's will gain a new level of excitement and interest in the research being done at NCED;
2. MSI faculty will also be able to inject some of this excitement into their courses, potentially recruiting an untapped potential for future research scientists;
3. These faculty will provide a link to students at MSI's, increasing the natural flow of students from MSI's into NCED research groups;
4. Research partnerships will help to build the research infrastructure of the faculty members' home institutions; and
5. Junior faculty at MSI's will be greatly assisted in their professional development.

Diversity Recruiting Programs – Plans

NCED recognizes that although we have made progress in increasing the number of researchers from underrepresented groups who engage in NCED-funded research, that this progress has been slow. NCED will address this through a strategy that includes the following:

Attract a PI/Postdoc from an underrepresented group:

1. Wide advertisement of open positions at NCED through minority professional organizations such as QEM, GEM, AGEP, SACNAS, AISES, NSBE, HACU, SHPE, AWG.
2. Inclusion of individuals from underrepresented groups on NCED search committees.
3. Utilize visitor's program, workshops, and seminar series to bring scholars from underrepresented groups into NCED.

Faculty-to-Faculty Program

1. Form research ties to faculty from schools with large minority enrollments, and particularly with faculty from Minority Serving Institutes such as HBCU's, HIS's and Tribal Colleges.
2. Identify potential research partners from faculty at MSI's who work in NCED research areas.
3. Bring faculty with their students to NCED as visiting researchers, to participate in conferences and workshops, and to speak at seminar series.
4. Recruit researchers from MSI's to be PIs in NCED research program.

Graduate Recruiting

1. Involvement of all NCED PIs in graduate recruiting through incentives and recognition
2. Work with the graduate schools of participating institutions to recruit and fund students from underrepresented groups. Also collaborate with other research centers and education and diversity specialists within participating institutions to help meet diversity goals.
3. Creation of new Graduate Degree in Stream Restoration
4. Wide advertisement of graduate research opportunities through MSI's, minority professional organizations, and student groups.
5. Collaboration in STC-GEM partnership for graduate recruiting
6. Research partnerships with MSI faculty and faculty from other schools with high minority enrollment
7. Highlight opportunities such as the University of Minnesota's Community of Scholars Program to graduate student recruits from underrepresented groups. This program assists under-represented students to more fully participate in the University, develop supportive relationships with advisors and mentors; build a sense of community through academic seminars and professional development workshops; and connect students to the Twin Cities community through research and civic engagement opportunities

Evaluation and Performance Indicators

Evaluation

NCED has been conducting a formal evaluation of our diversity programs. To date we have set up evaluation plans for the Undergraduate Summer Internship Program, for diversity recruiting, and for *gidakiimanaaniwigamig*. The *ando-giikendaasowin* program is currently reviewing their evaluation plan, which will be updated before the summer 2005 programming.

Evaluation Plans for Year 4

Evaluation plans will be implemented for USIP, our recruiting, and for *gidakiimanaaniwigamig* and *ando-giikendaasowin.*

Performance Indicators

See tables on following pages.

		Goal	Measurement #1		Measurement #2	
			Description	Value	Description	Value
1	**NCED community**					
	a.	Increasing the size of the pool from which underrepresented participants are recruited	Number of applicants for USIP: this year/ last year	94		
	b.	Increasing the representation of underrepresented groups within NCED	Percent of researchers: this year/last year	9.80%/7.2%	Percent of participants/ affiliates: this year/last year	P-05: 18% A-05: 5%
	c.	Enhancing educational and career outcomes for NCED participants from underrepresented groups	List of outcomes	See table below		
2	**Native American students**					
	a.	Number of Native students participating in NCED programs	Number of students	87	Attendance and grades	See table below.
	b.	Repeat contacts with students	Number of repeat contacts	1 camp: 41; 2 camps: 19 (22%); 3 camps: 19 (22%); 4 camps: 6 (7%); 5 camps: 2 (2%)		
3	**Youth Science Center**					
	a.	Number of kids enrolled/ demographics	Numbers and demographics	12 students participated. 6 male, 6 female, 7 from underrepresented groups (58%).		
	b.	Number of visitor kids/ demographics	Numbers and demographics	160 youth participants, 110 (69%) from underrepresented groups		
	c.	Number of activities conducted outside SMM by YSC programs/hours	events/hours	27 activities; 54 program hours		

Educational Outcomes						
Name	**Category**	**Gender**	**Disability**	**Ethnicity**	**Race**	**Citizenship**
Cruz, Karelyn	Grad	Female	None	H/L	White	US/PR
Outcome	Currently doing graduate work with Jill Banfield					
Bassatt, Brandon	Education	Male	None	non H/L	Black	US/PR
Outcome	Park Crew member, Currently a senior; will be attending Dakota County Technical School this fall.					
Beaufeaux, Jillian	Student	Female	None	non H/L	White	non US
Outcome	Chosen to represent AISES at Intel Science Fair; senior currently applying to colleges including Harvard, Dartmouth and St. Thomas; already accepted to St. Thomas					
Conley, Taurean	Education	Female	None	non H/L	Black	US/PR
Outcome	Park Crew member					
Cortes-Ruiz, Perla	Staff	Female	None	H/L	White	US/PR
Outcome	Has applied to IT at U of MN and is working for NCED					
DeNasha, Arelia		Female	None	non H/L	White	non US
Outcome	Chosen to represent AISES at Intel Science Fair					
Gbolo, Simeon	Education	Male	None	non H/L	Black	US/PR
Outcome	Park Crew member. Currently a senior, will be attending St. Paul Technical School in the fall and then plans to transfer to a 4-year program after 1 year.					
Greensky, Amber	Education	Female	None	non H/L	White	US/PR
Outcome	Studying to become a teacher					
Haydel, Robert	Undergrad	Male	None	non H/L	Black	US/PR
Outcome	USIP Intern who has been accepted as NCED graduate student, advisor Gary Parker					
Hernandez, Fernando	Undergrad	Male	None	H/L	White	US/PR
Outcome	Decided based on his undergraduate internship at NCED to become a science teacher					
Lott, Terry	Education	Female	None	non H/L	Black	US/PR
Outcome	Park Crew member					
Moreno, Edith	Undergrad	Female	None	H/L	White	US/PR
Outcome	Has declared an undergraduate major in biology with an ecology focus, combined with a major in Hispanic studies					
Northrop, Clint	Student	Male	None	non H/L	White	non US
Outcome	Won a NAISEF Math Competition and represented *gidakiimanaaniwigamig* at AISES National Conference					

Educational Outcomes (continued)						
Name	**Category**	**Gender**	**Disability**	**Ethnicity**	**Race**	**Citizenship**
Nunley, Tarrell	Education	Male	None	non H/L	Black	US/PR
Outcome	Park Crew member. Currently a senior, will be attending St. Paul Technical School in the fall and then plans to transfer to a 4-year program after 1 year.					
Olerode, Santita	Education	Female	None	non H/L	Black	US/PR
Outcome	Park Crew member					
Powell, Brittany	Education	Female	None	non H/L	Native American/ Black	US/PR
Outcome	Park Crew member					
Santiago, Angel	Undergrad	Male	None	H/L	Hispanic	US/PR
Outcome	Will continue his research as an undergraduate summer intern at SAFL for a second summer and plans to apply to U of MN for graduate study					
Tripp, Danielle	Undergrad	Female	None	H/L	White	US/PR
Outcome	Currently working for a consultant firm, but plans to pursue graduate work in the future					

Attendance and grades for Native K-12 students										
Attendance	2003/Benchmark year					2004/Year end				
	Ave. score	Proficient rate		% Proficient		Ave. score	Proficient rate		% Proficient	
	82	90%	48%	95.96	90%	62%			90%	
Grades	2003/Benchmark year					2004/Year end				
	Ave. score	Proficient rate		% Proficient		Ave. score	Proficient rate		% Proficient	
GPA / Math	2.33	2.0		85%		2.80	2.0		88%	
GPA / Science	2.67	2		88%		3.28	2		92%	

VII. Management

1a. Overall Organizational Strategy

NCED's Management component provides personnel, infrastructure, systems and activities to ensure synergistic connections between and among NCED members and our external stakeholders. Our Management goals and strategy are unchanged from our current Strategic Plan.

1b. Performance and Management Indicators

(see Table at end of this section)

1c. Challenges and Plans

The ongoing challenge in managing any interdisciplinary endeavor is ensuring effective integration across disciplines and institutions to ensure maximum synthesis and impact. In each of its three years in operation, NCED has refined its focus, developing increasingly integrated methods of operation. A major achievement in Year 3 has been to focus our work into three Integrated Projects, Desktop Watershed, Stream Restoration, and Subsurface Architecture. Recasting the research into projects will allow for managing the research in terms of deliverables and timelines. In early Year 4, at NSF's request, we will conduct a final, pre-renewal tune-up of our Strategic Plan, in consultation with management consultant John Latta.

2. Management and Communications Systems

a. Biannual retreats for NCED PIs, Directors, administrative staff and graduate students;
b. Weekly videoconference: Although mainly devoted to disseminating research projects and results, these meetings are also used to discuss administrative issues;
c. Weekly staff meeting: The NCED Directors and administrative staff meet weekly to promote internal communication and bring up and resolve issues;
d. Website: We continue to increase the use of our website as a way of communicating among the various NCED sites.

3. Internal and External Advisors

Internal advisors: NCED is advised internally by its Executive Committee, which consists of the Director (Chris Paola), co-Director (Efi Foufoula-Georgiou), Higher Education and Knowledge Transfer Director (Karen Campbell), Diversity and K-12 Education Director (Diana Dalbotten), Deputy Director of Administration (Rochelle Storfer), and two at-large PIs (currently Mary Power and David Mohrig).
External advisors: NCED is advised by an External Advisory Board. Appendix 3 has a list of current members and the report from the Year 3 EAB meeting, October 2003. EAB Chair Rip Sparks attended the 2004 Site Visit.

4. Changes to Strategic Plan

We submitted a revised Strategic Plan to NSF during Year 3. As discussed above, we plan meetings early in Year 4 between NCED's Executive Committee and PIs and management consultant John Latta.

5. Ethics Training

In Year 3, we provided all new NCED students and staff with digital access to NCED's Ethics training. In addition, all NCED/SAFL PIs, students and staff again received mandatory Safety and Ethics training in September.

	Goal		Measurement #1	
			Description	Value
1	**NCED people**			
	a.	Written objectives for each employee	Frequency	Annual
	b.	Written performance evaluations for each employee	Frequency	Annual
	c.	Employee feedback	Type/Frequency	Feedback at annual review
2	**Center Culture**			
	a.	Hold Center-wide activities	Type/Frequency	Retreat – 2x/year Research Videoconference – weekly during school year (20 held or scheduled for academic year 2004/5)
	b.	Have active participation in Center-wide activities	Number participating retreats	PIs 24 (total over 2 retreats) Students (31 over 2 retreats)
			Number participating in videoconferences	PIs 10 (average) Students 20 (average)
3	**Fiduciary Responsibilities**			
	a.	All transactions reviewed for accuracy	Frequency	Daily
	b.	Review of headquarters and sub-award accounts	Frequency	Monthly
	c.	Broad review of overall Center finances	Frequency	Quarterly
	d.	Timely response to NSF requests and requirements	Compliance	Yes
4	**Problem detection and resolution**			
	a.	Responsiveness to External Advisory Board	Type/Turnaround	Written response to report/ within two weeks
	b.	Regular formal review of metrics; prompt action where indicated	Who/Frequency	Executive Committee / Quarterly

Center-wide Outputs

1. Publications

Conference Proceedings - Published

Basu, S., F. Porté-Agel, and E. Foufoula-Georgiou, Large-eddy simulations of very stable atmospheric boundary layers: a scale-dependent dynamic modeling approach, European Geosciences Union General Assembly, April 25-30, Nice, France

Carper, M.A., and F. Porté-Agel, Coherent structures and subfilter-scale energy transfer in LES: A field study, 16th Symposium on Boundary Layers and Turbulence of the American Meteorological Society, August 9-13, Portland, Maine, 2004

Caylor, K.K. and I. Rodríguez-Iturbe, Coupling ecohydrological patterns and processes in semi-arid landscapes, Proceedings of the British Hydrological Society's International Conference on Hydrology: Science & Practice for the 21st Century

Lauer, J.W. and G. Parker, Net transfer of sediment from floodplain to channel on three southern US rivers, Proceedings of the ASCE World Water and Environmental Resources Congress, Anchorage, Alaska, May 15-19, 10 p.

Parker, G., The uses of sediment transport and morphodynamic modeling in stream restoration, ASCE World Water and Environmental Resources 2004 Congress, Salt Lake City, June 27-July 1, 10 p.

Stoll, R., and F. Porté-Agel, Scale-dependent dynamic models for LES: Surface heterogeneity effects, 16th Symposium on Boundary Layers and Turbulence of the American Meteorological Society, August 9-13, Portland, Maine, 2004

Voller,V. R., J.B. Swenson, W. Kim and C. Paola, A fixed grid method for moving boundary problems on the Earth's surface, European Congress on Computational Methods in Applied Sciences and Engineering, ECCOMAS 2004 (eds. P. Neittaanmäki, T. Rossi, S. Korot)

Wong, M., A. Cantelli, C. Paola, and G. Parker, Erosional narrowing after dam removal: theory and numerical model, Proceedings, ASCE World Water and Environmental Resources 2004 Congress, Salt Lake City, June 27-July 1, 10 p.

Papers - In Press

**Pasternack, G.B., C. Ellis, K. A. Leier, B. L. Valle, and J. D. Marr, Convergent hydraulics at horseshoe steps in bedrock rivers, Geomorphology

Cantelli, A., C. Paola, and G. Parker, Experiments on upstream-migrating erosional narrowing and widening of an incisional channel caused by dam removal, Water Resources Research, 40 (in press), 2005

Cui, Y., G. Parker, C. Braudrick, W. E. Dietrich, and B. Cluer, Dam Removal Express Assessment Models (DREAM). Part 2: Sample runs/sensitivity tests, Journal of Hydraulic Research

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Dodov, B. and E. Foufoula-Georgiou, Incorporating the spatio-temporal distribution of rainfall and basin geomorphology into nonlinear analyses of streamflow dynamics: Methodology development and a predictability study, Advances in Water Resources, 2005

Dodov, B., and E. Foufoula-Georgiou, Fluvial processes and streamflow variability: interplay in the scale-

frequency continuum and implications for scaling, Water Resources Research, 2005

Gupta, R., V. Venugopal and E. Foufoula-Georgiou, A methodology for merging multisensor precipitation estimates based on expectation-maximization and scale recursive estimation, Journal of Geophysical Research, 2005

Haider, Z., M. Hondzo, and F. Porté-Agel, Advective velocity and energy dissipation rate in an oscillatory flow, Water Research

Hondzo, M., T. Feyaerts, R. Donovan, and B. O'Connor, Universal scaling of dissolved oxygen distribution at the sediment-water interface: A power law, Limnology and Oceanography,

Jerolmack, D., and D. Mohrig, Interactions between bedforms and their roles in determining stream-bed profiles, Journal of Geophysical Research

Parker, G. and L. Perg, Probabilistic formulation of conservation of cosmogenic nuclides: Effect of surface elevation fluctuations on approach to steady state, Earth Surface Processes and Landforms

Puma, M. J., M. A. Celia, I. Rodríguez-Iturbe, and A. J. Guswa, Functional relationship to describe temporal statistics of soil moisture averaged over different depths, Advances in Water Resources

Roering, J. J., J. Kirchner, and W. E. Dietrich, Characterizing structural and lithologic controls on deep-seated landsliding: Implications for topographic relief and landscape evolution in the Oregon Coast Range, USA, Geological Society of America Bulletin

Stock, J. D., D. R. Montgomery, B. R. Collins, L. Sklar, and W. E. Dietrich, Field measurements of incision rates following bedrock exposure: implications for process controls on the long-profiles of valleys cut by rivers and debris flows, Geological Society of America

Stoll, R. and F. Porté-Agel, Effect of roughness on surface boundary conditions for large-eddy simulation, Bound.-Layer Meteorology

Strong, N., B. A. Sheets, T. A. Hickson, and C. Paola, A mass-balance framework for quantifying downstream changes in fluvial architecture, Sedimentology in press, 2005

Venugopal, V., S. Basu, and E. Foufoula-Georgiou, A new metric for comparing precipitation patterns with application to ensemble forecasts, Journal of Geophysical Research, 2005

Yoo, K., R. Amunson, A. M. Heimsath, and W. E. Dietrich, Erosion of upland hillslope soil organic carbon: coupling field measurement with a sediment transport model, Global Biogeochemical Cycles

Yoo, K., R. Amunson, A. M. Heimsath, and W. E. Dietrich, Spatial patterns of soil organic carbon on hillslopes: Integrating geomorphic processes and the biological C Cycle, Geoderma

Papers - Published

Basu, S., E. Foufoula-Georgiou, and F. Porté-Agel, Synthetic turbulence, fractal interpolation and large-eddy simulation, Journal of Geophysical Research, 2004

Blom, A. and G. Parker, 2004, Vertical sorting and the morphodynamics of bedform-dominated rivers: a modeling framework, Journal of Geophysical Research Earth Surface, 109, F02007, doi:10.1029/2003JF000069, 15 p.

Carper, M. and F. Porté-Agel, Coherent structures and subfilter-scale dissipation rates of turbulence measured in the atmospheric surface layer, J. of Turbulence, doi:10.1088/1468-5248/5/1/040.

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Caylor, K.K. T.M. Scanlon, and I. Rodríguez-Iturbe, Feasible optimality of vegetation patterns in river basins, Geophysical Research Letters, 31(13):L13502.

D'Odorico, P., A. Porporato, F. Laio, L. Ridolfi, and I. Rodriguez-Iturbe, Probabilistic modeling of nitrogen and carbon dynamics in water-limited ecosystems, Ecological Modeling, 179, 205-219, 2004.

Daly, E., A. Porporato, and I. Rodríguez-Iturbe, Coupled dynamics of photosynthesis, transpiration and soil water balance: I. Upscaling from hourly to daily level, Journal of Hydrometeorology, Vol. 5. No. 3, 546-558, 2004.

Daly, E., A. Porporato, and I. Rodríguez-Iturbe, Coupled dynamics of photosynthesis, transpiration and soil water balance: II. Stochastic analysis and ecohydrological significance, Journal of Hydrometeorology, Vol 5 No. 3, 559-566, 2004.

Das, H.S., J. Imran, C. Pirmez, and D. Mohrig, Numerical modeling of flow and bed evolution in meandering submarine channels, Journal of Geophysical Research, v. 109, C10009, doi:10.1029/2002JC001518.

Dodov, B., and E. Foufoula-Georgiou, Generalized hydraulic geometry: Insights based on fluvial instability analysis and a physical model, Water Resources Research, 40(12), W12201, 10.1029/2004 WR003196, 2004.

Fernandez-Illescas, C. and I. Rodríguez-Iturbe, The impact of interannual rainfall variability in the spatial and temporal patterns of vegetation in a water-limited ecosystem, Advances in Water Resources, 27 (1), 83-96, 2004.

Finlay, J.C., Patterns and controls of lotic algal stable isotope ratios, Limnology and Oceanography. 49: 850-861.

Guswa, A. J., M. A. Celia, and I. Rodríguez-Iturbe, Effect of vertical resolution on prediction of transpiration in water-limited ecosystems, Advances in Water Resources, Vol. 27, No. 5, 467-480, 2004.

Guzina, B. B., V. R. Voller, and D. H. Timm, Crack spacing in strained films, Journal de Physique IV, 120, 201-208, 2004.

Hickson, T. A., B. A. Sheets, C. Paola, and M. Kelberer, Experimental test of tectonic controls on three-dimensional alluvial facies architecture, Journal of Sedimentary Research, in press, 2005.

Jerolmack, D.J., and D. Mohrig, Frozen dynamics of migrating bedforms, Geology, v.33, p. 57-60.

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Lauer, J.W. and G. Parker, 2004, Modeling channel-floodplain co-evolution in sand-bed streams, ASCE World Water and Environmental Resources Congress, Salt Lake City, June 28- July 1, 10 p.

Lima-Vivancos, V., and V. R. Voller, Numerical methods for modeling variably saturated flow in layered media, Vadose Zone Journal 3, 1003-1037, 2004

Paola, C., Improving public understanding of scientific research: A view from the research side, in Creating Connections: Museums and the Public Understanding of Current Research, edited by D. Chittenden, G. Farmelo, and B.V. Lewenstein, pp. 145-152, Altami

Porporato, A., Daly, E., and I. Rodríguez-Iturbe, Soil water balance and ecosystem response to climate change, American Naturalist, Vol. 164, No. 5, 625-632, 2004.

Porté-Agel, F., A scale-dependent dynamic model for scalar transport in large-eddy simulations of the atmospheric boundary layer, Bound.-Layer Meteorol., 112(1), 81-105.

Scanlon, T.M., K. K. Caylor, S. Manfreda, S. Levin, and I. Rodríguez-Iturbe, Dynamic response of grass cover to rainfall variability: Implications for the function and persistence of savanna ecosystems, Advances in Water Resources, 28(3):291-301.

Sklar, L. and W. E. Dietrich, A mechanistic model for river incision into bedrock by saltating bedload, Water Resources Research, 2004, Vol. 40, W06301, doi:10.1029/2003WR002496.

Suttle, K. B., M. E. Power, J. A. Levine and F. C. McNeely, How fine sediment in river beds impairs growth and survival of juvenile salmonids, Ecological Applications 14: 969-974.

Venugopal, V., F. Porté-Agel, E. Foufoula-Georgiou, and M. Carper, Multiscale interactions between surface shear stress and velocity in turbulent boundary layers, Journal of Geophysical Research, 108(D19): 10.1029/2002JD003025.

Vinuesa, J.-F. and F. Porté-Agel, A dynamic similarity subgrid model for chemical transformations in LES of the convective atmospheric boundary layer, Geophys. Res. Letters., 32 (3): Art. No. L03814.

Voller, V. R, J. B. Swenson, and C. Paola, An analytical solution for a Stefan problem with variable latent heat, International Journal of Heat and Mass Transfer, 47, 5387–5390, 2004.

Voller, V. R., A Monte Carlo scheme for tracking filling fronts, J. Comp. Phys., 200, 399-411, 2004.

2. Awards and Honors

Ben O'Connor	Student	Frank and Julie Tsai Travel Award
Ben Sheets	Student	Frank and Julie Tsai Travel Award
Blake Suttle	Student	Distinguished Graduate Student Instructor award from the Department of Integrative Biology, U.C. Berkeley
Boyko Dodov	Postdoc	NCED Postdoc Research Scholarship, 2004-2006
Camille McNeely	Student	Distinguished Graduate Student Instructor award from the Department of Integrative Biology, U.C. Berkeley
Camille McNeely	Student	Presidents Award, North American Benthological Society, 2004
Chris Paola	Faculty	Elected vice-chair, GSA Sedimentary Geology Division
Chris Paola	Faculty	Selected to the SEPM Pettijohn Medal committee and GSA Sloss medal committee
Chris Paola	Faculty	Nominated to University of Minnesota Academy of Distinguished Teachers
Damien Kawakami	Student	Frank and Julie Tsai Travel Award
Efi Foufoula-Georgiou	Faculty	Elected Fellow of the American Meteorological Society
Efi Foufoula-Georgiou	Faculty	Elected Member, Executive Committee of CUAHSI
Fernando Porté-Agel	Faculty	McKnight Land-Grant Professorship
Gary Parker	Faculty	Names W. H. Johnson Professor of Geology, University of Illinois, Urbana
James R. Stoll	Student	NASA graduate student fellowship 2004-2007
Kelly Caylor	Student	Invited speaker at the Spring 2005 AGU Meeting for a session on Integrative Hydrological Processes convened by Kevin McGuire and Markus Weiler
Kyle Straub	Student	American Geophysical Union (2004 Spring Meeting) – Outstanding Student Paper Award – Seismology Section
Lisa Tilman	Student	Frank and Julie Tsai Travel Award
Maria Goodrich	Student	Mathias Award, University of California Natural Reserve System 2004-2005; NSF Graduate Research Fellowship Honorable Mention 2004
Mary Power	Faculty	John and Margaret Gompertz Chair in Integrative Biology, 2002-2007
Mary Power	Faculty	Kempe Award for Distinguished Ecologists 2004 from Umea University and the Swedish University of Agricultural Science
Mary Power	Faculty	G. Evelyn Hutchinson Medal, American Society of Limnology and Oceanography, summer 2005
Mary Power	Faculty	G. Evelyn Hutchinson Medal, American Society of Limnology and Oceanography, summer 2005
Matthew Carper	Student	SAFL Anderson Award 2004
Michal Tal	Student	Outstanding Student Paper award, 2004 AGU Meeting

Miguel Wong	Student	Received Silberman Award from SAFL
Mike Limm	Postdoc	Distinguished Graduate Student Instructor award from the Department of Integrative Biology, U.C. Berkeley
Wesley Lauer	Student	Received Anderson Award from SAFL
William Dietrich	Faculty	Elected member of the National Academy of Sciences
William Dietrich	Faculty	Elected member of the American Academy of Arts and Sciences
Wonsuck Kim	Student	Awarded the Richard Clarence Dennis Graduate Fellowship
Wonsuck Kim	Student	Outstanding Student Paper award, 2004 AGU meeting
Wonsuck Kim	Student	Frank and Julie Tsai Travel Award

3. Graduated Students

Student	Advisor	Degree/Year	Years in program	Placement
Lisa Tilman	Foufoula-Georgiou	MS, 2005	2	Consulting
Sukanta Basu	Foufoula-Georgiou – Porté-Agel	PhD, 2005	4	Faculty, Texas State University
Rohit Gupta	Foufoula-Georgiou	MS, 2004	2	PhD candidate in Computer Sciences Dept. U of Minnesota
William Lyons	Mohrig	Ph.D., 2004	6	Shell Exploration Co.
Christina Kaba	Mohrig	MS, 2004	2	Working at MIT
Elowyn Yager	Dietrich	Ph.D. 2005	6	Post-doc Arizona
Benjamin O'Connor	Hondzo	Ph.D. / 2005	3.5	USGS/Post-doc
Tanya Warnaars	Hondzo	Ph.D./ 2005	3.5	
Blake Suttle	Power	Ph.D./ May 05	5	
Camille McNeely	Power	Ph.D./Dec. 04	6	Postdoc, U. Minn. (Jacques Finlay
Ben Sheets	Paola	Ph.D./Dec. 04	6	ExxonMobil

4. General Outputs of Knowledge Transfer

Not applicable.

5. Participants (131)

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6. Affiliates (216)

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7. Summary listing of Partners

	Organization Name	Type of org.	Address	Contact Name	Type of Partner	160 hours
1	Advanced Materials for Water Purification	NSF - STC	University of Illinois 3253 Digital Computer Lab 205 N. Mathews Ave. MC-250 Urbana, IL 61801	Susan Herricks	Education & Diversity Know-ledge Transfer	N
2	AIHEC: American Indian Higher Education Consortium	NGO	121 Oronoco Street Alexandria, Virginia 22314	N/A	Education & Diversity	N
3	AISES: American Indian Science and Engineering Society	NGO	AISES P.O. Box 9828 Albuquerque, NM 87119-9828	N/A	Education & Diversity	N
4	Anadarko Petroleum Corporation	Corporation	1201 Lake Robbins Drive The Woodlands, Texas 77380	Todd Green/ James Parr	Know-ledge Transfer	N
5	Association for Women Geoscientists, Minnesota chapter	professional	NA	Karen Camp-bell, past president Lesley Perg, president elect	Know-ledge Transfer	N
6	CALFED – Bay-Delta Program	State Government	THE CALFED BAY-DELTA PROGRAM 650 Capitol Mall, 5th Floor Sacramento, CA 95814	Bill Dietrich		N

7	Center for Embedded Network Sensing	NSF STC	UCLA, Hilgard Ave., 3731 Boelter Hall, Los Angeles, CA 90095	Deborah Estrin, Director		N
8	Center of Research Excellence in Science and Technology, Texas A&M Kingsville	University	Department of Environmental Engineering MSC 213 Texas A&M University - Kingsville Kingsville, Texas 78363	Dr. Lee Clapp	Education & Diversity	N
9	ChevronTexaco	Corporation	4800 Fournace Place Bellaire, TX 77401	Martin Perl-mutter	Know-ledge Transfer	N
10	CHRONOS	NSF funded research center	Iowa State University Department of Geological and Atmospheric Sciences 275 Science I Ames, Iowa 50011-3212 USA	Cinzia Cervato	Know-ledge Transfer	N
11	ConocoPhillips	Corporation	P.O. Box 2197 Houston, TX 77252-2197	Al Shultz	Know-ledge Transfer	N
12	(CUAHSI Consortium for the Advancement of Hydrologic Sciences, Inc.) http://www.cuahsi.org/	consortium	Consortium for the Advancement of Hydrologic Sciences, Inc. (CUAHSI) 2000 Florida Avenue, NW Washington, DC 20009	Efi Foufoula Foufoula is board member Morin is on technical	Know-ledge Transfer	N

13	DragonFly TV	Educational Television Producers	Twin Cities Public Television, Inc. 172 East 4th Street St. Paul, MN 55101	Richard C. Hudson	Education & Diversity	N
14	ExxonMobil Upstream Research Co.	Corporation	P.O. Box 2189 Houston, TX 77252-2189	Penny Patter-son	Know-ledge Transfer	N
15	Fond du Lac Ojibwe Schools	NGO	1720 Big Lake Rd. Cloquet, MN 55720	Leslie Hoffman	Education & Diversity	Y
16	Geowall Consortium	Consortium	http://www.geowall.org/	Paul Morin	Know-ledge Transfer	N
17	Get Ready! Minnesota Higher Education Services Office	Government	Energy Park Plaza 1400 Energy Park Drive, Suite 24 St. Paul, MN 55108	Holly Pellerin	Education & Diversity	N
18	Graduate School Outreach Office, University of Minnesota	University	101 Pleasant Street SE 322 Johnston Hall Minneapolis, MN 55455	Kather-ine Johnson	Education & Diversity	N
19	Japan National Oil Company	Corporation	Fukoku Seimei Bldg., 2-2-2 Uchisaiwai-cho, Chiyoda-ku Tokyo 100-8511, Japan	Osamu Takano	Know-ledge Transfer	N
20	Laurentian Center		Laurentian Environmental Center -- 8950 Peppard Road -- Britt, MN 55710	Sue Hankner	Education & Diversity	N

21	Minnesota Geological Survey	University	Minnesota Geological Survey 2642 University Ave. W. St. Paul, MN USA 55114-1057	Harvey	Know-ledge Transfer	N
22	NASA/Goddard Space Flight Center	Government Agency	Code 974, Hydrological Sciences NASA/Goddard Space Flight Center Greenbelt, MD 20771	David Toll	Know-ledge Transfer	N
23	National Academy of Sciences	Government Agency	National Research Council 2101 Constitution Avenue, NW Washington, D.C. 20418	William Logan	Research	N
24	National River Restoration Science Synthesis (NRRSS)	Project	Plant Sciences BLDG 4112 University of Maryland College Park, MD 20742-4415	Margaret Palmer	Research	N
25	Nova/Mentorn TV	Educational Television Producer	Mentorn 43 Whitfield St. London, WIT 4HA	Ben Fox	Education & Diversity	N
26	NSF Center for Airborne Laser Mapping (NCALM)	NSF Center	365 Weil Hall, PO Box 116580 University of Florida, Gainesville, FL 32611	Bill Dietrich	Research	N

27	Office of Naval Research	Government Agency	800 N. Quincy Street Arlington, VA 22217	Tom Drake	Know-ledge Transfer	N
28	QEM	Federal Government	1818 N Street, NW, Suite 350 Washington, DC 20036	Dr. Shirley McBay	Education & Diversity	N
29	R2 Resource Consultants	Corporation	15250 NE 95th Street Redmond, WA 98052	Paul DeVries	Know-ledge Transfer	N
30	SACNAS: Society for the Advancement of Chicanos and Native Americans in Science	NGO	PO Box 8526 Santa Cruz, CA 95061	N/A	Education & Diversity	N
31	SAHRA (Sustainability of Semi-Arid Hydrology and Riparian Areas) http://www.sahra.arizona.edu/	NSF STC	Univ. of Arizona, Hydrology & Water Resources, College of Engineering and Mines, Tucson, AZ 85721	Jim Wash-burne	Education & Diversity	N
32	SciTech Hands On http://scitech.mus.il.us/	Museum	18 W. Benton Street Aurora IL 60506	Ronen Mir, Execu-tive Director	Know-ledge Transfer	N
33	Shell International Exploration and Production Company	Corporation	3737 Belaire Blvd., Houston, Texas 77025	Carlos Pirmez	Know-ledge Transfer	N
34	The Science Center at the Maltby Nature Reserve	Non-profit	Maltby Nature Preserve 789 Sciota Trail East Randolph, MN 55065	Seliesa (Sil)	Education & Diversity	N
35	Stillwater Sciences	Corporation	2855 Telegraph Ave., Suite 400 Berkeley, CA 94705	Yantao Cui	Know-ledge Transfer	N

36	US Army Corps of Engineers	Government Agency	US Army Corps of Engineers 2422 Viridian Drive, Suite, 101 South Bend, IN 46628 574-299-0214	Meg Jonas	Know-ledge Transfer	N
37	US Department of Agriculture: Forest Service	Government Agency	316 E. Myrtle Street Rocky Mountain Research Station Boise, ID 83702	Jim McKean	Know-ledge Transfer	N
38	US Department of Agriculture: National Sedimentation Laboratory	Government Agency	United States Department of Agriculture, Agricultural Research Service, National Sedimentation Laboratory PO Box 1157 Oxford, MS 38655	Doug Shields	Know-ledge Transfer	N
39	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	Know-ledge Transfer	N

40	US Department of the Interior: Bureau of Reclamation	Government Agency	Sedimentation and River Hydraulics Group (D-8540) U.S. Bureau of Reclamation Technical Service Center PO Box 25007 Denver, CO 80225-0007	Tim Randle	Know-ledge Transfer	N
	US Department of the Interior: Geological Survey, CERC	Government Agency	4200 New Haven Road Columbia, MO 65201	Robert Jacobson	Know-ledge Transfer	N
41	US Environmental Protection Agency	Government Agency	WW-16J US Environmental Protection Agency 77 West Jackson Boulevard Chicago, IL 60604-3507	Tom Daven-port	Know-ledge Transfer	N
42	Universidad Central de Venezuela	University	Instituto de Mecánica de Fluidos Facultad de Ingeniería Universidad Central de Venezuela	Prof. Jose L. Lopez	Reearch	N
43	Universidad Nacional del Litoral	University	Department of Eng. and Water Sciences Universidad Nacional del Litoral Santa Fe - Argentina	Mario Luis Amsler	Research	N

44	University of Colorado/INSTAAR	University	Institute of Arctic and Alpine Research (INSTAAR) University of Colorado at Boulder 1560 30th Street, Campus Box 450 Boulder, Colorado 80309-0450	James P.M. Syvitski	Research	N
45	The University of Minnesota Materials Research Science and Engineering Center (MRSEC)	University	489 Amundson Hall, 421 Washington Ave. SE Minneapolis, MN 55455	Dr. Frank Snow-den	Education & Diversity	N
46	Utah Museum of Natural History	Museum	Univeristy of Utah 1330 E. President's Circle Salt Lake City, UT 84112	Rebecca Menlove	Education	N

8. Summary funding table

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Section IX. Indirect/Other Outputs

Not applicable to this Center.

X. Budget

Budget information deleted from public version.

Section XI. Appendicies

Appendix 1. New Faculty Biographies

Biographies included for:
Nicholas Flores
Benjamin Hobbs
Peter Wilcock

January 27, 2005

CURRICULUM VITAE

Nicholas E. Flores

Addresses:
Office: Department of Economics
University of Colorado, Boulder
Boulder, Colorado 80309-0256
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(303) 492-8960 FAX
floresn@stripe.colorado.edu

Home: 1285 Linden Avenue
Boulder, Colorado 80304
(303) 417-9854

Place of Birth: Augsburg, Germany

Citizenship: U.S.A.

Marital Status: Married

Children: Two

Education:
University of California, San Diego, Ph.D., 1995, Economics
University of California, San Diego, M.S., 1994, Mathematical Statistics
University of California, San Diego, M.A., 1993, Economics
University of Texas at Austin, B.A., 1989, Economics, Mathematics Minor

Academic Employment History:
Associate Professor of Economics, University of Colorado, Boulder (2002-present)
Faculty Associate, Institute of Behavioral Science, University of Colorado, Boulder (2003-present)
Assistant Professor of Economics, University of Colorado, Boulder (1995-2002)
Research Assistant (economics), University of California, San Diego (Spring 1995), La Jolla, California
Teaching Assistant (economics), University of California, San Diego (1993-1994), La Jolla, California
Teaching Assistant (mathematics), Austin Community College (1988-1989), Austin, Texas

Other Professional Activities:
Research Associate, Natural Resource Damage Assessment, Inc. (1991-1995), La Jolla, California
Associate Editor, The Journal of Environment and Development (1992-1994), La Jolla, California

Awards/Honors:
Phi Beta Kappa (1989)
National Science Foundation Graduate Fellow (1990-1994)
National Science Foundation Fellow, Enabling the Next Generation of Hazards Researchers (1996-1997)
Stanford Calderwood Faculty Teaching Award, Department of Economics, University of Colorado (2001)
Plenary Speaker, "Preferences for the Environment," World Congress for Environmental Economists, Monterrey, California (June 2002)

Courses Taught:
Economics 3535, Resource Economics for non-majors
Economics 3818, Introductory to Statistics with Computer Application
Economics 4309, Economics Honors Seminar I
Economics 4545, Environmental Economics for majors
Economics 7808, Quantitative Economics for Ph.D.
Economics 8209, Research Economics Workshop I for Ph.D.
Economics 8219, Research Economics Workshop II for Ph.D.
Economics 8535, Natural Resource Economics Seminar for Ph.D.

Research and Creative Works:
Published and Forthcoming Work :

Boland, John, Nicholas E. Flores, and Charles Howe, "Economics' Contributions to Water System Planning and Management," in *Water Resources Development: Recent Trends in the Decision Making Process, U.S. ACE-UCOWR*, *forthcoming*, 2005.

Evans, Mary F. and Nicholas E. Flores, "Multiple Bounded Uncertainty Choice Data as Probabilistic Intentions." *Land Economics*, 2003 **(79)** 4: pp. 549-560.

Flores, Nicholas E., "Conceptual Framework for Non-Market Valuation," in *A Primer on Non-Market Valuation*, P. Champ and K. Boyle Editors, Kluwer Academic Press, 2003.

Heath, Fred, Martha Kyrillidou, Duane Webster, Sayeed Choudhury, Ben Hobbs, Mark Lorie, and Nicholas E. Flores, "Emerging Tools for Evaluating Digital Library Services: Conceptual Adaptations of LibQUAL+ and CAPM," *Journal of Digital Information,* 2003 (4) 2: Article No. 170, 2003-06-09

Chivers, James and Nicholas E. Flores, "Market Failure in Information: The National Flood Insurance Program." *Land Economics*, 2002 **(78)** 4: pp. 515-521.

Champ, Patricia, Nicholas E. Flores, Thomas Brown, and James Chivers, "Contingent Valuation and Incentives." *Land Economics*, 2002 **(78)** 4: pp. 573-591.

Flores, Nicholas E., and Jennifer Thacher, "Money, who needs it? Natural Resource Damage Assessment." *Journal of Contemporary Economic Policy*, 2002. **(20)** 2: pp. 171-178.

Flores, Nicholas E., "Non-Paternalistic Altruism and Welfare Economics." *Journal of Public Economics*, 2002. (32) 2, pp. 293-304.

Choudhury, Sayeed, Ben Hobbs, Mark Lorie, and Nicholas E. Flores, "A Framework for Evaluating Library Digital Services." *D-Lib Magazine*, 2002. (8) 7/8: http://www.dlib.org/dlib/july02/choudhury/07choudhury.html.

Carson, Richard T., Nicholas E. Flores, and Robert C. Mitchell, "The Theory and Measurement of Passive Use Value," in *Valuing Environmental Preferences: Theory and Practice of the Contingent Valuation Method in the US, EC, and Developing Countries*, I.J. Bateman and K.G. Willis, Editors. 2001, Oxford University Press: Oxford.

Carson, Richard T., Nicholas E. Flores, and Norman F. Meade, "Contingent Valuation: Recent Controversies and Evidence." *Journal of Environmental and Resource Economics*, 2001. **19**: pp. 173-210.

Carson, Richard T., Nicholas E. Flores, and W. Michael Hanemann, "Sequencing and Valuing Public Goods." *Journal of Environmental Economics and Management*, 1998. **36**(3): pp. 314-323.

Flores, Nicholas E. and Richard T. Carson, "The Relationship Between the Income Elasticities of Demand and Willingness to Pay." *Journal of Environmental Economics and Management*, 1997. **33**(3): pp. 287-295.

Flores, Nicholas E., "Reconsidering the Use of Hicks Neutrality to Recover Total Value." *Journal of Environmental Economics and Management*, 1996. **31**(1): pp. 49-64.

Carson, Richard T., Nicholas E. Flores, Kerry M. Martin, and Jennifer L. Wright, "Contingent Valuation and Revealed Preference Methodologies: Comparing the Estimates for Quasi-Public Goods." *Land Economics*, 1996. **72**(1): pp. 80-99.

Unpublished Manuscripts:

Flores, Nicholas E. and Aaron Strong, "Stated Preference Analysis of Public Goods: Are we asking the right question?" University of Colorado Department of Economics Discussion Paper no. 04-2, January, 2004.

Flores, Nicholas E., "*Conservation Reconsidered, The Economics of Natural Environments*, and Our Understanding of Environmental Preferences." World Congress for Environmental Economists, Monterrey, California, June 2002.

Lucier, John, Nicholas E. Flores and Philip E. Graves, "Price Dispersion, Spatial Competition, and Product Bundling in Gasoline Retailing."

Evans, Mary and Nicholas E. Flores, "Relative Economic Efficiency and the Provision of Rationed Goods." University of Colorado Department of Economics Discussion Paper no. 01-3, March, 2001.

Flores, Nicholas E. and Philip E. Graves, "On the Valuation of Public Goods: Why Do We Work?" University of Colorado Department of Economics Discussion Paper no. 01-5, May, 2001, 2001.

Flores, Nicholas E., "Environmental Values and National Economic Accounts: A Theoretical Inquiry." University of Colorado Department of Economics Discussion Paper no. 99-14, October, 1999.

Flores, Nicholas E., "The Importance of Agenda and Willingness to Pay." University of Colorado Department of Economics Discussion Paper no. 99-30, October, 1999 .

Technical Reports:
"Comprehensive Access to Print Materials User Benefit Study," with Donald Waldman, report prepared for the Andrew Mellon Foundation (2001).

"Economic Analysis for Hydropower Project Relicensing: Guidance and Alternative Methods," with Robert Black, Bruce McKenney, and Robert Unsworth, report prepared for Division of Economics, U.S. Fish and Wildlife Service (1998).

External Funding:
Research Grants:
"Collaborative Research: Neighborhood Choice, Environmental Justice, and Policy Analysis," Principal Investigator, National Science Foundation, 2003-2006 ($206,967).

"Institutions and Incentives for Mitigating Wildfire Risks," Principal Investigator, U.S. Forest Service, 2003-2005 ($95,500).

"A Decision-Making Framework for Stream Restoration from Acid Mine Drainage," Principal Investigator, National Science Foundation, 2001-2003 ($110,000).

"CAPM User Benefits Study," Principal Investigator, Johns Hopkins University and the Andrew Mellon Foundation, 1999-2000 ($58,373).

"The Economics of Fee Programs," Principal Investigator, U.S. Forest Service, 1998-2001 ($24,153).

"Contingent Valuation and Incentives," Principal Investigator, U.S. Forest Service, 1996-1998 ($39,700).

"Environmental Values and National Economic Accounts: A Theoretical Inquiry," Principal Investigator, Environmental Protection Agency (NSF-EPA Environmental Partnership Program), 1996-1997 ($43,395).

Teaching Related Grants:
"Carbon, Climate and Society," Co-principal Investigator, National Science Foundation, 2000-2005 ($2,638,000).
Teaching and Service Related Grants:
"CU Environmental and Resource Economics Workshop," Principal Investigator, U.S. Environmental Protection Agency, ($57,800).

Students Advised:
Undergraduate Students:
Brent Berc (Economics Honors Advisor)
Charles Sandona-Bieler (Environmental Studies Honors Advisor)
Thomas Bowen (McNair Faculty Mentor & Economics Honors Advisor)
Chendra Conklin (McNair Faculty Mentor)
Joanne Derwin (Principal ENVS Honors Advisor)
Caitlan Dull (International Affairs Honors Advisor)
John Gardener (Undergraduate Research Opportunities Program Advisor)
Christine Hurley (Economics Honors Advisor)
Christopher Jensen (Environmental Studies Honors Advisor)
Trevor Nordeen (Economics Honors Advisor)
Chad Salvador (Economics Honors Advisor)
Drew Soderburg (Economics Honors Advisor)
Jesse Walker (Economics Honors Advisor)

Master's Students:
James Chivers (Economics Advisor)
Rian Melnick (Economics Advisor)
Charlotte Oliver (Economics Advisor)
Robert Stubbs (Economics Advisor)
Josh Wimpey (Economics Advisor)

Ph.D. Students:
Mary Evans (Economics Advisor)
David Kritzberg (Economics Advisor)
Aric Shafran (Economics Advisor)
Josh Sidon (Economics Advisor)
Aaron Strong (Economics Advisor)

Service Activities:

Service to the Economics Department:

Department Chair, Summer 2003 and Summer 2001.
Recruitment Committee Chair for departmental search in any field, associate/full professor, Fall 2002 - Spring 2003
Executive Committee Member, Fall 1998 - Spring 2002
Diversity Officer, Fall 1998 - present
Faculty Teaching Excellence Program Departmental Liaison, Fall 1999 - present
Recruitment Committee Member for departmental search in environmental and natural resource economics, Fall 2000 - Spring 2001
Recruitment Committee Member for departmental search in environmental and natural resource economics, Fall 1999 - Spring 2000
Recruitment Committee Member for departmental search in econometrics, Fall 1997 - Spring 1998
Department Representative for the National Research Council project on Faculty Stresses at Research Universities, 1996
Research Committee Member, Fall 1995 - Spring 1998

Service to the University Outside of the Economics Department:

Graduate College Executive Committee Member, Fall 2003 - present.
Recruitment Committee Member for Institute for Behavioral Science search for Environment and Behavior Program Director, Fall 2001 - Spring 2002
Advisory Committee Member for the Natural Hazards Research and Applications Information Center, 1996 - present
Worked to design and gain approval for the University of Colorado's Actuary Certificate Program, 1997
Advisory Committee Member for the Environmental Studies Undergraduate Program, Fall 1997 - Fall 1998
Faculty Mentor, Ronald McNair Post Baccalaureate Achievement Program, 1995 - 1997
Contacted prospective students through the CU Foundation's Calling Program, 1997

Professional Service:

Organized and hosted the annual CU Environmental and Resource Economics Workshop, Summer 1999 - 2003
Panel Member, STAR Fellowship Selection, U.S. Environmental Protection Agency, 1997 - 1998
Conference Participant (speaker/discussant): Allied Social Sciences Meetings, National Bureau of Economic Research Summer Workshop, National Science Foundation Econometrics Lab Workshop (UC Berkeley), Association of Environmental and Resource Economics Summer Workshop, Camp Resources, CU Environmental and Resource Economics Workshop, American Agricultural Economics Meetings, Natural Hazards Summer Workshop
Referee for *American Economic Review*
Referee for *Journal of Environmental Economics and Management*
Referee for *Journal of Public Economics*
Referee for *International Economic Review*

Referee for *Journal of Regulatory Economics*
Referee for *Land Economics*
Referee for *American Journal of Agricultural Economics*
Referee for the *Journal of Developing Areas*
Referee for *Resource and Energy Economics*
Invited speaker: GAMS/MPSGE General Equilibrium Modeling Workshop, Boulder, CO, Fall, 1995

Community Service:
Invited Speaker: "Partnerships with Business and Industry," sponsored by the University of Colorado Graduate School, 1999
Public Lecture: "The Economics of Recycling," for the seniors of Colorado Springs School (high school)
Invited speaker: "The Future of Nuclear Electricity," sponsored by the University of Colorado Graduate School, 1997
Invited speaker: National Coalition for Endangered Species Forum, San Diego, CA, Fall 1995.
Invited speaker: Uncertainty in Science & Implications for Society, A Public Interest Science Conference, Boulder, CO, Fall 1995.

Projects Consulted:
"Economic Analysis for Hydropower Project Relicensing Process: Guidance and Alternative Methods," U.S. Fish and Wildlife Service, through Industrial Economics, Inc., 1998.

"Economic Benefit Evaluation of Everglades Restoration and Preservation," South Florida Water Management District, through Natural Resource Damage Assessment, Inc., 1992.

"Prospective Interim Lost Use Value Due to DDT and PCB Contamination in the Southern California Bight," National Oceanic and Atmospheric Administration, through Natural Resource Damage Assessment Inc., 1992-1995.

"A Contingent Valuation Study of Lost Passive Use Values Resulting from the Exxon Valdez Oil Spill," Attorney General of the State of Alaska, through Natural Resource Damage Assessment, Inc., 1991-1992.

BENJAMIN F. HOBBS
Department of Geography and Environmental Engineering
Whiting School of Engineering
The Johns Hopkins University
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Baltimore, MD 21218
(410) 516-4681, bhobbs@jhu.edu

EDUCATION

Cornell University, School of Civil and Environmental Engineering, Ithaca, NY. Ph.D., Environmental Systems Engineering, Jan. 1983. Minors: Operations Research and Resource Economics.

State University of New York, College of Environmental Science and Forestry, Syracuse, NY. M.S., Resources Management and Policy, May 1978.

South Dakota State University, Brookings, SD. B.S. with Highest Honor, May 1976. Major: Non-Major (self-designed program integrating environmental science, mathematics, economics).

Prescott College, Prescott, AZ. Sept. 1972 - May 1974.

EMPLOYMENT

The Johns Hopkins University, Whiting School of Engineering, Baltimore, MD.

- Professor of Geography & Environmental Engineering, 1995 to present
- Chairman of Geography & Environmental Engineering, July 2002-June 2003; Acting Chair July-August 2004
- Professor of Applied Mathemats and Statistics (secondary appointment), 1999 to present.

Teaching, research in optimization, decision analysis, simulation, and economics, and their application to environmental, power, and water systems. Courses taught: environmental systems simulation and decision analysis; energy planning and policy modeling; introductory optimization; engineering microeconomics; advanced environmental engineering applications of optimization. Member of JHU Academic Council, 2000-2005.

Case Western Reserve University, Case School of Engineering, Cleveland, OH. Assistant Professor of Systems Engineering, Jan. 1984 to Feb. 1988. Assistant Professor of Civil Engineering, Sept. 1986 to Feb. 1988. Associate Professor of Systems Engineering and Civil Engineering, Feb. 1988 to June 1994. Professor of Systems, Control, and Industrial and Civil Engineering, July 1994 to July 1995. Adjunct Professor of Electrical Engineering and Computer Science, Aug. 1995 – June 2000. Courses taught: reliability and risk analysis; water and energy systems engineering; decision analysis; mathematical modeling; engineering economics and financial accounting; introduction to systems engineering; legal, economic and social aspects of resources management.

Oak Ridge National Laboratory, Energy Division, Wigner Fellow, Jan. 1982 to Jan. 1984. Research on water supply for electric power, energy planning in developing countries, power markets, spatial market economics. Sponsors: Electric Power Research Institute, US Agency for Intl. Development, Wigner Fellowship program.

Brookhaven National Laboratory, Division of Regional Studies, Upton, NY. Economics Associate III. Sept. 1977 to Aug. 1978, Summer 1979. Research on power plant siting, water supply for power, northeastern coal markets. Sponsors: US Department of Energy, US Nuclear Regulatory Commission.

Summer positions with the **Maryland Power Plant Siting Program**, Annapolis, MD (1977), **Oak Ridge National Laboratory**, Energy Division, Regional & Urban Studies Section, Oak Ridge, TN (1975, 1976), **Northeast Utilities**, Dept. Regional & Environmental Planning, Berlin, CT (1974). Internships with the **Salt River Project**, Phoenix, AZ (March - April, 1974), **The President's Council on Environmental Quality**, Washington, DC (April - May, 1973).

VISITING APPOINTMENTS

Visiting Researcher, Energieonderzoek Centrum Nederland (ECN, Netherlands Energy Research Foundation), Policy Studies Unit, Amsterdam, The Netherlands, Sept. 2001 – July 2002.
Visiting Professor, Systems Analysis Laboratory, Helsinki University of Technology, Espoo, Finland, Aug. 2000.
Visiting Professor, Dept. of Geography & Environmental Engineering, The Johns Hopkins University, Baltimore, MD, Aug. 1995 – June 1996.

Visiting Scientist, Dept. Civil Engineering, University of Washington, Seattle, WA, Sept. 1991 - Nov. 1992.

CONSULTING

Maryland Power Plant Research Program, 2003
Planit Management, Ltd., 2001
Federal Energy Regulatory Commission, 1996-2001
U.S. Dept. of Energy, Energy Information Agency, 2000
Analysis Group/Economics, 1999
Gas Research Institute, Chicago, IL, 1991, 1994, 1997-1999
U.S. Army Corps of Engineers, Institute of Water Resources, Ft. Belvoir, VA, 1984-1998
Commonwealth Energy, 1998
Electric Power Research Institute, 1997
Edison Source and Resource Management Intl., 1996
Northeast Ohio Sewer District, Cleveland, OH, 1995
BC Gas, Ltd., Vancouver, BC, 1994-95
Ontario Hydro, Toronto, ONT, 1995
BC Hydro, Vancouver, BC, 1995-96
Decision Systems International, Atlanta, GA, 1994-95
Oak Ridge National Laboratory, Oak Ridge, TN, 1994
Energy & Environmental Economics, Inc., San Francisco, CA, 1994
IDEA, Inc., Washington, DC, 1992-1994
U.S. Army Corps of Engineers, Detroit District, 1994
National Regulatory Research Institute, Columbus, OH, 1989-1994
Seattle City Light, Resource Planning and Analysis Group, Seattle, WA, 1991-1992
Utility Air Regulatory Group, Washington, DC, 1991

South Florida Water Management District, West Palm Beach, FL, 1989
Hamilton, Rabinovitz, and Szanton, Los Angeles, CA, 1980-1981
New York Department of Law, New York, NY, 1981
Brookhaven National Laboratory, Upton, NY, 1980
Argonne National Laboratory, Argonne, IL, 1980

HONORS

Project Associate, Cambridge-MIT Institute Energy Project
2004 Decision Analysis Publication Award (for the best Decision Analysis publication in 2002), Decision Analysis Society of INFORMS (for Anderson and Hobbs, "Using a Bayesian Approach to Quantify Scale Compatibility Bias," Management Science, 2002)
First Place, INFORMS Energy, Natural Resources, and Environment Section, Student Paper Competition, November 2004 (Second author and advisor to Yihsu Chen)
Invited Plenary Speaker: International Association of Energy Economics European Meeting, Prague, June 2003; International Conference on Complementarity Problems, Cambridge, July 2002.
Second Place, INFORMS Decision Analysis Section, Student Paper Competition, November 2001 (Second author and advisor to R. Anderson)
Institute Associate, National Regulatory Research Institute, 1989-1995.
Mortar Board, 1991 Outstanding Professor Award, Case Western Reserve University, April 1991.
1990 Outstanding Research Oriented Paper, American Society of Civil Engineers (ASCE) Water Resources Planning and Management Division (for "Risk Analysis of Aquifer Contamination by Brine", ASCE JWRPM, 1988)
Ameritech Fellow, Center for Regional Issues, Case Western Reserve University, 1987, 1988, 1989.
Nominated for John S. Diekhoff Award for Outstanding Graduate Teaching, Case Western Reserve University, March 1988 and March 1991.
Presidential Young Investigator Award, National Science Foundation, 1986-1991.
ASCE Energy Division Nominee for the ASCE Walter L. Huber Civil Engineering Research Prize, May 1985.
Wigner Fellow, Oak Ridge National Laboratory, 1982-84.
Sage Fellow (1979-80) and McMullen Fellow (1978-79), Cornell University.
Rhodes Scholarship Nominee from South Dakota State University, 1975.

PROFESSIONAL ACTIVITIES

Member, Market Surveillance Committee, California Independent System Operator, 2002-2004
Scientific Advisor, Policy Studies Unit, Energieonderzoek Centrum Nederlands (ECN), 2003
Member, Public Interest Advisory Committee, Gas Technology Institute, Chicago, 2003
Area Editor, Environment and Natural Resources, Operations Research, 1996-Present
Editorial Board, The Electricity Journal, 1995-Present
Associate Editor, Energy, The International Journal, 1996-Present
Associate Editor, Journal of Infrastructure Systems (ASCE), 2003-present
Deputy Editor, Systems Analysis and Economics, Water Resources Research, 1997-2000.
Associate Editor, Energy Services Journal, The Journal of the Asso. of Energy Services Professionals, 1995-1996
Associate Editor, Water Resources Research 1988-1995
Past Chairman, Executive Committee, Energy Division, American Society of Civil Engineers (ASCE), 1999-Present (Chair, 1998-1999; Vice Chair, 1997-1998; Secretary 1996-1997)

Chairman, Sessions Committee, ASCE Energy Division; Organizer of ASCE sessions for American Power Conference
Contributed Papers Chair, INFORMS National Meeting, Philadelphia, Nov. 1999.
Member, Systems Economics Committee and Working Group, IEEE Power Engineering Society
Member, Emissions Task Force, IEEE Power Engineering Society, 1992-96
Member, Northeast Ohio Areawide Coordination Agency Task Force Hazardous Material Transportation, 1990-95
Member, Northeast Ohio Environmental Priorities Project, Quality of Life Committee, 1994-95.
Chairman and Control Member, Energy Resources Management Committee, ASCE Energy Division, 1985-91
Member, Task Committee on Groundwater Monitoring Network Design, ASCE Hydraulics Division, 1988-90
Member, Task Committee, Risk and Reliability Analysis of Water Distribution Systems, ASCE Hydraulics Div., 1986-88
Member of American Geophysical Union, American Society of Civil Engineers, Association of Energy Services Professionals, Institute of Electrical and Electronics Engineers, Institute for Operations Research and Management Science, International Association of Great Lakes Researchers

SPONSORED RESEARCH

- "Methodology for Assessing the Effects of Technological and Economic Changes on the Location, Timing and Ambient Air Quality Impacts of Power Sector Emissions," USEPA STAR Grant, 2005-2007 (H. Ellis, PI; B. Hobbs, D. Burtraw, K. Palmer, Co-PIs).
- "Analysis of Equilibrium Long-Run Prices in Multidimensional Capacity Markets," PJM, 6/04-12/04.
- "Development Of A Regional-Scale Model For The Management Of Multiple-Stressors In The Lake Erie Ecosystem," USEPA STAR grant, Subcontract to CWRU (J.F. Koonce, PI; B.F. Hobbs, coPI), 2003-2006.
- "Active Load Management Under Retail Access," Maryland Power Plant Research Program, 12/03-11/04.
- "Dynamic Game-Theoretic Models of Electric Power Markets and Their Vulnerability", National Science Foundation (B.F. Hobbs PI; J.-S. Pang, J. Harrington, and T. Friesz, CoPIs), 7/1/02-6/30/05.
- "Analysis of Multipollutant Policies for the Electric Power Sector under Multiple Objectives: The Value of Policy Coordination Under Technological and Economic Uncertainties," USEPA, Office of Atmospheric Programs, 8/02-8/03.
- "Implications of Climate Change for Regional Air Pollution, Health Effects and Energy Consumption Behavior," USEPA STAR Grant, 2/01 – 2/04 (H. Ellis, PI; B. Hobbs, F. Joutz, J. Patz, Co-PIs).
- "Comprehensive Access to Off-Site Library Print Materials," Sponsored by Mellon Foundation, 1/99-12/01 (S. Choudhury, PI; B. Hobbs, Co-PI).
- "Simulating Strategic Behavior in Multiple Power Markets by Complementarity and MPEC Methods; Energy, Capacity, Ancillary Services, Green Power and Emissions Allowance Markets," NSF, 9/00 – 8/02 (J.-S. Pang, Co-PI).
- "An Analysis of Electric Power Capacity Markets," Maryland Power Plant Research Program (MPPRP), 12/99 – 12/01.
- "The 1997 *Pfiesteria Piscicida* Outbreak In Maryland: Possible Economic Impacts," MPPRP, 1/99 – 6/00.
- "Multicriteria Evaluation of Lake Erie Ecosystem Management." USEPA Region V, 9/98-12/00.
- "Distribution Capital Budgeting Evaluation System." Baltimore Gas & Electric Corporation, 2/98-8/98.
- "Assessment of Fishery Resource Values Used for Damage Compensation in Maryland, and Economic Assessment of Acid Mine Drainage Abatement in the North Branch of the Potomac River Watershed: Application." MPPRP, 11/96-6/00.
- "Modeling and Multiobjective Risk Decision Tools for Assessment and Management of Great Lakes

Ecosystems." USEPA, 9/96-10/00 (J.F. Koonce, Co-PI).
- "New Methods for Decision Focussed Integrated Assessment: Multiple Objectives, Risk Evaluation, and Visualization." NSF, 9/96-9/98 (Co-PI; H. Ellis, PI).
- "Economic Assessment of Acid Loading Abatement in the North Branch of the Potomac River Watershed: Procedure and Demonstration." MPPRP, 5/96-8/96.
- "Methods for Integrating Resource and Transmission Planning: Multiarea Production Costing and Resource/T&D Coordination." NSF, 9/95-8/99.
- "The Value of Improved Short-Term Load Forecasts." Electric Power Research Institute (EPRI), 9/95-12/97.
- "Development of a Method for Quantifying Benefits of Projects Addressing Environmental Issues," Gas Research Institute, 1/95-2/96.
- "Multiarea Production Costing Methodology Development" and "Analyzing the Effect of NO_x Constraints on Expected Production Cost," EPRI, 1/94-12/94.
- "Climate Change Information and Great Lakes Management: Modeling, Worth of Flexibility, and Process Evaluation." NSF and US Army Corps of Engineers, 4/93-3/96.
- "Improved Methods for Considering Environmental Externalities in Resource Acquisition: Multiple Criteria, Location-Specific Impacts, and Secondary Effects." US Dept. of Energy Integrated Resource Planning Research Program, Oak Ridge National Laboratory, 9/92-3/94.
- "Enhancement of the `Most Value' Criterion: Multicriteria Analysis." Centerior Energy Corporation, 3/91-11/91.
- "Acid Rain Special Topic Information." Ohio Consumers' Counsel, 8/90 - 6/91.
- "Comprehensive Emission Reduction Model." Ohio Air Quality Development Authority (OAQDA), 5/89-7/90.
- "Integrated Resource Planning Assistance." Centerior Energy Corporation, 8/89 - 6/90.
- Presidential Young Investigator, NSF, 5/86-5/91.
- "Analysis of Risks in Least Cost Planning." National Regulatory Research Institute, 4/88-12/88.
- "Multiobjective Screening of Water Resources Projects Under Risk." U.S. Army Corps of Engineers, 2/88-6/89.
- "Session on Natural Hazards." NSF, 1/88-1/89.
- "Development of a Multiobjective Evaluation System for Water Resources Planning." South Florida Water Management District, 11/88-6/1989.
- "Criteria for Evaluating Integrated Resource Planning Programs." Centerior Energy Corporation, 9/88-2/89.
- "Economic Criteria for Integrated Resource Planning." Centerior Energy Corporation, 9/87-1/88.
- "Regional Economic Impacts of Least Cost Planning and Proposed Acid Rain Legislation." Ameritech Fellowship from the Center for Regional Economic Issues, Case Western Reserve University, 9/87-6/90.
- "Least Emissions Dispatching: Cost and Employment Impact Analysis." OAQDA, 6/87-6/88.
- "Water Resources Issues Management." EPRI, 4/87-12/87.
- "Identification of Least Cost Planning Issues for the Centerior Energy Corporation." Centerior Energy Corporation, 10/87-3/88.
- "Impact of Precipitation Interruption upon Water Supplies." Federal Emergency Management Administration (through Oak Ridge National Lab.), 2/87-10/87.
- "Project Management Assistance, Aircraft Deployment Analysis System Project." U.S. Military Airlift Command (through ORNL), 10/86-8/87.
- "Monte Carlo Simulation of Energy Investments." Standard Oil Company, 10/86-10/87.
- "Risk-Benefit Analysis of Annular Disposal of Oil and Gas Brines." U.S. Geological Survey, Ohio Water Resources Center, 7/85 - 6/87.

PUBLICATIONS

Books

B.F. Hobbs and P. Meier, Energy Decisions & The Environment: A Guide to the Use of Multicriteria Methods, International Series in Operations Research & Management Science, Kluwer Academic Publishers, Boston/ Dordrecht/London, 2000, 257 pp.

B.F. Hobbs, M.H. Rothkopf, R.P. O'Neill, and H.-p. Chao, eds., The Next Generation of Electric Power Unit Commitment Models, International Series in Operations Research & Management Science, Kluwer Academic Publishers, Boston/Dordrecht/ London, 2001, 319 pp.

Edited Proceedings

B.F. Hobbs, ed., Energy in the 90's, Specialty Conference of the Energy Division, American Society of Civil Engineers, New York, NY, April 1991.

Journal Articles

- Y.H. Chen, B.F. Hobbs, T. Munson, and S. Leyffer, "Leader-Follower Equilibria for Electric Power and NO_x Allowances Markets," Computational Management Science, submitted.
- B.F. Hobbs and F.A.M. Rijkers, "The More Cooperation, The More Competition? A Cournot Analysis of the Benefits of Electric Market Coupling in the Benelux Countries," The Energy Journal, submitted.
- K. Neuhoff, J. Barquin, M.G. Boots, A. Ehrenmann, B.F. Hobbs, and F.A.M. Rijkers, "Network-constrained Cournot models of liberalized electricity markets: The devil is in the details," Energy Economics, accepted for publication.
- Y.H. Chen and B.F. Hobbs, "An Oligopolistic Power Market Model with Tradable NO_x Permits," IEEE Transactions on Power Systems, Feb. 2005.
- R.P. O'Neill, P.M. Sotkiewicz, B.F. Hobbs, M.H. Rothkopf, and W.R. Stewart, Jr. "Efficient Market-Clearing Prices in Markets with Nonconvexities," Euro. J. Operational Research, in press.
- M.L. Bell, B.F. Hobbs, and H. Ellis, "Metrics matter: Conflicting air quality rankings from different indices of air pollution," J. Air & Waste Management Association, 55(1), 2005, 97-106.
- J.S.-Pang and B.F. Hobbs, "Spatial Oligopolistic Equilibria with Arbitrage, Shared Resources, and Price Function Conjectures," Mathematical Programming B, 101(1), Sept. 2004, 57-94.
- M. Boots, F.A.M. Rijkers, and B.F. Hobbs. "A Two-Level Oligopoly Analysis of the European Gas Market". The Energy Journal, 25(3), July 2004, 73-102.
- B.F. Hobbs and F.A.M. Rijkers, "Modeling Strategic Generator Behavior with Conjectured Transmission Price Responses in a Mixed Transmission Pricing System I: Formulation," IEEE Trans. Power Systems, 19(2), May 2004, 707-717.
- B.F. Hobbs, F.A.M. Rijkers, and A.F. Wals, "Modeling Strategic Generator Behavior with Conjectured Transmission Price Responses in a Mixed Transmission Pricing System II: Application," IEEE Trans. Power Systems, 19(2), May 2004, 872-879.
- M.L. Bell, B.F. Hobbs, and H. Ellis, "The Use of Multicriteria Decision-making Methods in Integrated Assessment: Implications for IA Practitioners," Socioeconomic Planning Sciences, 37(4), 2003, 289-316.

- J.B. Kim and B.F. Hobbs, "Multicriteria Bayesian Analysis of Lower Trophic Level Uncertainties and Value of Research in Lake Erie," Human & Ecological Risk Assessment, 9(4), June 2003, 1023-1057.
- S.A. McCusker and B.F. Hobbs, "A Nested Benders Decomposition Approach to Locating Distributed Generation in a Multiarea Power System," Networks & Spatial Economics, 3(2), June 2003, 197-224.
- C. Metzler, B.F. Hobbs, and J.-S. Pang, "Nash-Cournot Equilibria in Power Markets on a Linearized DC Network with Arbitrage: Formulations and Properties," Networks & Spatial Economics, 3(2), June 2003, 123-150.
- F. Heath, M. Kyrillidou, D. Webster, S. Choudhury, B. Hobbs, M. Lorie, N. Flores. "Emerging Tools for Evaluating Digital Library Services: Conceptual Adaptations of LibQUAL+™ and CAPM". Journal of Digital Information, 4(2), 2003 (Web-based journal: http://jodi.ecs.soton.ac.uk/Articles/v04/i02/Heath/).
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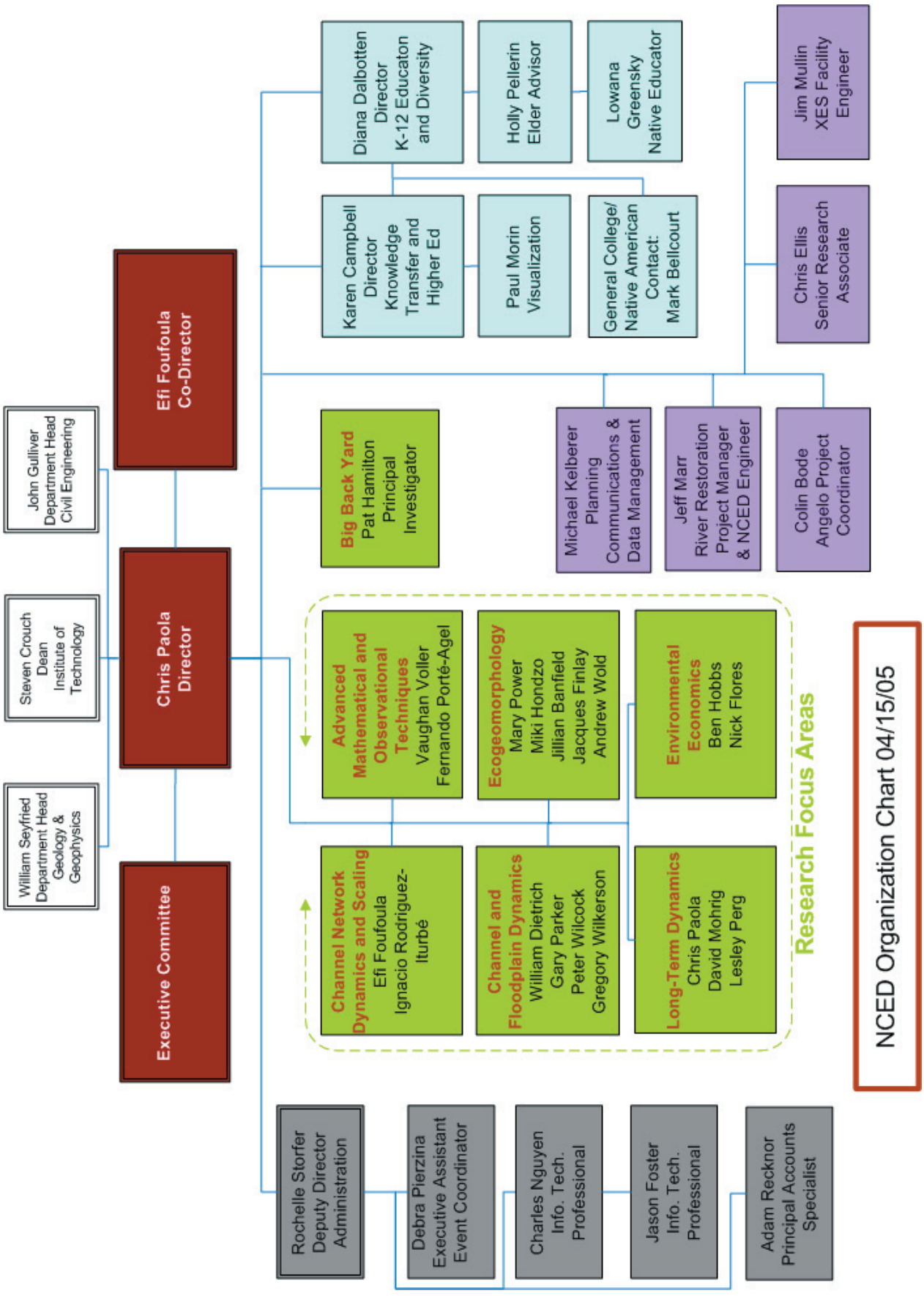
Appendix 2: Organization Chart



Appendix 3: External Advisory Board

External Advisory Board Membership

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Senior Oceanographer, CME

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Sr. Vice President & Regional Manager
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Dr. David Jon Furbish
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External Advisory Board Report

Starts on next page. Note: The Director's response has the full text of the report

Director's response

Third Report of the External Advisory Board of the National Center for Earth-surface Dynamics (NCED)

On behalf of the entire Center, I would like to start by expressing our sincere appreciation of the hard work that the External Advisory Board has put into this report and its verbal comments during the October meeting. We are deeply grateful for their effort in meeting with us at Fond du Lac and for the thoughtful advice and commentary presented here. The Director's responses to specific suggestions and comments are given below *in italics*.

SUMMARY

1. The Angelo Coast Reserve has provided a focus, as the EAB thought it would–a place where both senior investigators and graduate students network together and where collaborative, multi-disciplinary projects are underway.

    1.1. The prospect of using advanced sensors in connected networks on the site is exciting, and if fulfilled, should lead to breakthroughs in measuring and understanding physical and biological processes that occur at fine temporal and spatial scales, or that are event-triggered.

We agree and are working to insure that our Angelo Coast Range Reserve wireless network will have event-triggering capability.

    1.2. The team should expand on the concept that there are "hot spots" and "hot moments" that have important consequences and that go undetected with conventional observation systems.

    This work is very exciting and gains power from NCED's center structure, specifically the apparent influence of location in the network on hot-spot/hot-moment events and their relation to physical controls such as sediment movement. Further advances in this are reported in this year's Annual Report.

    1.3. Although EAB could not provide a specific answer to the question, "How much should NCED invest in these networks?" we do suggest that trials be undertaken to better assess the costs (including staff time) and benefits.

    Our strategy for developing the ACRR network is staged so that we can evaluate total costs including staff time, and benefits, before determining our total investment level. We are also vigorously pursuing additional funding for this work.

2. The Angelo site was intended to represent a place where erosional processes dominate, and progress is being made (as of October 2004) on the selection of a "sister", depositional site.

    2.1. The EAB would welcome a report from David Mohrig's group (the critical "downstream", depositional component of the NCED source to sink vision) at the next EAB meeting in September 2005 on how

they integrate with the larger NCED effort.

This spring's NCED videoconferences included one by Mohrig on a potential site on the Niobrara. We are considering several possibilities but do not expect to develop a second site until the ACRR site is fully functional. I am certain the Mohrig would be glad to present his thoughts on possible sites at the next EAB meeting.

2.2. What are the specific action items for collaborations and linkages between the upstream and downstream components, both now and for the near future?

This is a short and highly relevant question with a long answer, which is summarized in the Context document for this year's Annual Report. A major theme is that, based on conversations with our partners and our own analysis, we see a trend in environmental sciences toward increasing emphasis on system-scale linkages, such as between watersheds and individual reaches, or upstream and downstream parts of a river system. These linkages become increasingly important as we work toward the longer time scales required for true sustainability.

3. The selection of river restoration as a major theme is certainly congruent with NCED expertise in predictive modeling of the physical processes that drive natural and regulated systems.

3.1. The development of a user-friendly "toolbox" of models to support analysis and decision-making could be an important, practical contribution.

Under Parker's enthusiastic leadership, this project is making good progress already, which we expect to accelerate as NCED's Stream Restoration project develops. The toolbox concept was introduced to and welcomed by our Partners at the February Partner meeting; a sample tool on our website is already getting "hits".

3.2. Soil erosion is such a global problem and so critical to sediment flux and channel dynamics, that any river restoration tool kit should include some way to model both the effects and remediation strategies.

We certainly appreciate the importance of soil erosion in channel dynamics in general and restoration in particular. Because of its importance in agriculture, there are large, well supported programs on soil erosion in the federal government, especially the Department of Agriculture. The point raised by the EAB leads to a question we are working on with our agency partners: how best to interface our toolbox effort with their complementary restoration-related efforts. The stream restoration portal of the NCED website may be especially helpful here as an information center.

The EAB review of the NCED Strategic Plan is separate from this report, because of time limitations at the EAB meeting on 4 October. Members were invited to review the Strategic Plan and respond by email. Strategic staffing is an important part of achieving the goals of the strategic plan and if Gary Parker (who was instrumental in the formation of NCED) is phasing out of NCED (or already has phased out) are the skills and perspectives he contributed now being provided by others?

This is an extremely important point of clarification: Gary Parker is moving from the University of Minnesota to the University of Illinois, but he is in no way "phasing out" of NCED. He will continue to be one of our

most energetic and productive PIs in his new location. He will strengthen existing NCED ties to the University of Illinois, expanding NCED in important ways. The University of Illinois will become an NCED institution this summer, bringing NCED some important new experimental facilities, as well as the recruiting resources of another major research institution to aid in our Diversity recruiting goals.

1 DIVERSITY

NCED recognizes that it should try to diversify its group of co-investigators (specifically drawing from Native Americans, African Americans, Hispanics). Each NCED investigator from an under-represented group provides a point of contact to a minority community and a role model for minority undergrads who could more easily see themselves as future scientists and engineers.

The EAB understands that this is not an easy task, given that project groups and universities are competing with each other for a very limited pool of under-represented groups within some of the academic disciplines. There is a very limited supply of post-doctoral researchers from under-represented groups currently emerging from the supply "pipeline" that starts with children who can be attracted to science in kindergarten and elementary schools. We think that NCED is quite rightly addressing the supply side of the "pipeline", as well as competing to recruit scientists from under-represented groups. Following are some suggestions from EAB, most of which address the supply side, in reverse order from post-doctoral researchers back to K-12 education. We also make a specific suggestion that NCED consider adding someone from a Minority Serving Institution (MSI) to the EAB.

We appreciate both the importance of this dimension of NCED and especially the EAB's considerable consideration of it. Beginning with the specific EAB recommendation above, I will address each recommendation in order. We acted quickly to implement the suggestion of adding someone from an MSI to the EAB. We recently submitted a suggestion for a new minority EAB member to the Board, which endorsed our proposal. The individual is not at an MSI but works for an organization of MSIs. He has been invited and is investigating whether his organization will allow him to participate in the EAB. We will update the Board when we have a final decision.

1.1 Researchers

Engage professors at minority-serving institutions (MSIs), by offering direct involvement as visiting scientists. Particularly important are the junior faculty at the MSIs who will have long teaching careers and who would benefit from mentoring by NCED researchers. Note that these professors need not necessarily be minority members themselves, although that would certainly be the most desirable situation.

We agree with this approach and are taking energetic steps to implement it. We are specifically targeting young faculty at MSIs. We have already made arrangements for two young professors (neither minority themselves, but both women) to participate in NCED research activities this summer, and are seeking others.

1.2 Graduate Students

Question: Is NCED working with diversity departments at the NCED institutions; also, with appropriate NSF programs (e.g., the Science & Technology Centers, STC, diversity program) and the USGS, which has its own minority recruitment program?

From its inception, NCED has energetically participated in STC- to- STC and STC- wide Diversity recruiting

efforts. For example, we regularly do joint recruiting with SAHRA and an MSI (Texas A&M University, Kingsville) with a strong program in environmental sciences. We also work with all the STCs, through CENS, to share the recruiting of undergraduate summer interns. We are also working with several University of Minnesota diversity programs and are pushing to develop stronger and more coordinated diversity efforts in our own Institute of Technology. We should and will do more to engage at the institutional level across NCED institutions and with NCED Partners such as the USGS.

NCED graduate students could accompany Diana Dalbotten on some of her recruiting/informational trips. Students identify with others who are not only similar in terms of ethnicity, but also closer in age.

We will do this, and as we gain minority students will attempt to include them in such activities to the extent that it does not compromise their research. We were able to include two underrepresented summer interns in a recruiting trip this year, offering them an opportunity to present their research at a national level conference.

1.3 Undergraduate Students

Consider preparing bright, but unprepared undergraduates for grad school. Look at the University of North Dakota Indians into Medicine program (INMED) and the Johns Hopkins School of Medicine programs, as examples. NCED should commit to the success of these students; e.g., by assigning a mentor, as well as a major advisor.

We do commit to success through mentoring and follow up with our undergraduate minority interns, and this has led to two interns committing to graduate school in NCED programs already. We will look into the two programs mentioned here, and others like them, as examples as well. We hope that our collaboration with FDLTCC to develop a proven pre-engineering program at FDLTCC will also contribute to this goal; we would very much like to build on our already strong ties and geographical proximity to the Fond du Lac community by making it a successful example of the strength of the model you describe.

1.4 K-12 Students

As indicated in the last EAB report, NCED has identified gaps in the pipeline from kindergarten to 12th grade, where students are apt to be lost from the pipeline. NCED programs are specifically focused on these gaps, and EAB commends this strategy. NCED has initiated an assessment of this program that will follow up students who have participated. In the meantime, there was at least one encouraging success brought to our attention: that of a young Native American who has gone on to major in science at the university level.

We remain committed to these programs and have benefited from having brought Holly Pellerin and Lowana Greensky formally into NCED this year. We have also been able to document quantitatively the effect our Native American programs are having on student performance and success. We are especially proud that Pellerin and Greensky were invited to describe NCED's K-12 efforts with the Fond du Lac community at this year's meeting of Education Directors from NSF-funded science and engineering centers.

1.5 General Comments on Engagement of NCED Scientists and on Marketing

The co-investigators should be more involved in recruitment. As mentioned under 1.2 above, graduate students should also be involved. Not every co-investigator needs to be involved, but a scientist should accompany Diana Dalbotten when she visits schools to help answer the question: where would I work after getting a degree? It would be ideal to have someone from a minority community and from the local area explain what

the professional opportunities are. Scientists need not be limited to just the NCED investigators (who represent the academic track), but should include representatives from private industry and government.

We like these ideas. I would like to stress that overall, the PIs have been quite energetic about minority recruiting, without prodding from the Director's office. This year has seen one specific example of team recruiting, with Miki Hondzo joining Dalbotten and two summer interns at a recruiting conference in Puerto Rico. But the PIs have also been busy on their own. We have at least three new minority grad students joining us next year, which we are proud of in light of the overall low participation of minority students in environmental science. We have also earmarked a substantial block of funds to support minority recruiting across the center. The suggestion about including students and/or non-academics in recruiting is very well taken. We will do our best to implement it.

Query NCED investigators to find out what drew them into science. The answers might help guide the recruiting program and would certainly provide some personal stories that scientists could share with students. These kinds of personal accounts may motivate students who are excited by science, but do not understand that science can be a paying career or do not see themselves as scientists.

This is an excellent idea. We will act on it and investigate ways in which we might use the power of the internet to increase our visibility in this way.

Diana should contact Historically Black Colleges and Tribal Colleges (if she has not already done so), to make presentations (with one of the scientists and one of the graduate students).

We appreciate the spirit of this suggestion: it's personal connections that brought most of us into science and we need to find every way we can to extend those connections to underrepresented students. We have compiled information on HBCUs and other MSIs that have NCED-related programs, but we have been warned that simply touring MSIs and giving talks is not an effective recruiting strategy. So, we are focusing instead on building research relations with selected faculty at MSIs who we believe can help us with recruiting. Those connections include inviting the MSI faculty to give videoconferences to NCED institutions and will in the future include visits by NCED PI and graduate students to MSIs to present joint research with MSI faculty.

Marketing of science could be more engaging – use CDs, DVDs, other materials to showcase exciting research and to target particular audiences. Consider partnering with marketing experts at a business school on development of brochures and electronic media.

This suggestion is well taken, and we will act on it. We are working now to make our web site more engaging for marketing the center generally.

2 LINK RESTORATION AND RECRUITMENT

There must be a gateway to jobs, so a market survey of likely employers should be done. What critical skills are needed by the employers? What is the likely demand over the next 5 to 20 years for graduates with those skills? There is no point in gearing up a major program to produce graduates in excess of the likely manpower needs.

We very much appreciate these suggestions. We have done research on critical skills by surveying local

practitioners and discussing the proposed restoration program with our Environmental Partners at the recent Stream Restoration Partners Group meeting. We believe, based on the current size of restoration efforts and the popularity of restoration short courses, that there will be demand for environmental scientists with practical restoration training. The best format may be a certificate rather than a MS degree. We agree about the potential of this program for minority recruiting and intend to use it vigorously for that purpose.

The term "remedial engineering" was used, but might be more diplomatically worded as "an introduction to engineering for ecology and geology students". Shouldn't there also be "an introduction to river ecology for engineers"? The proposed structure (below) seemed to be a good starting point.

3 credits Seminar series
3 credits Case studies/intern course
1-4 credits Basic river restoration engineering
Science content: Transport laws, channel design, relationships between channels and their basins, channel/vegetation interaction.

These points are well taken, and the proposed structure will be considered as we design our graduate program.

3 RIVER RESTORATION

The EAB offers the following suggestions:

3.1 Soil erosion is such a global problem, that any river restoration tool kit should include some way to model both the effects and remediation strategies. Soil erosion plays a critical role in river dynamics and sediment flux.

My response to this well taken point is given above.

3.2 The Restoration Website is a good idea. There should be links to on-going research, databases (including the National River Restoration Science Synthesis, NRRSS, database), restoration experts, educational materials, etc.

We have established a Stream Restoration Portal on our website; the idea of using the web as a community resource for the restoration community was met with a great deal of enthusiasm at our February Partners meeting. We are working to insure that our efforts are coordinated with related programs like NRRSS. In addition, PI Peter Wilcock is working closely with NRRSS leader Margaret Palmer on a possible collaborative extension of the NRRSS effort.

3.3 However, NCED cannot just put models on the web site. Need to develop and market the tool kit. Some market research should be undertaken with the potential user community. Is there a need? How user-friendly does the model need to be? What modules are especially needed and likely to be used?

At this early stage in the toolbox's development, we are relying mainly on guidance from our Stream Restoration Partners Group, who represent a fair cross-section of the user community. Much of the recent Partners Group meeting, in fact, was devoted to identifying such user community needs. In addition, PIs Parker (originator and leader of the toolkit project), Dietrich, Wilkerson, and Wilcock are well integrated into the restoration

community, and can provide additional effective guidance as to key toolbox components and attributes based on their contacts and experience. As the toolkit develops, however, we will investigate undertaking more broadly-based marketing efforts. At some point it may make sense to hand off non-research aspects of toolkit development (e.g. adding more elaborate GUI components) to another operation better suited to such work.

3.4 Document the process of how models are applied/adopted/adapted in a test community. Involve a social scientist. Pick a restoration site that involves a minority community and provides an opportunity to demonstrate the practical application of science to local problems and a recruiting opportunity as well.

This is a very interesting suggestion that we will follow up on. An urban restoration project might be a good target for this. We have added a team of social scientists to our PI group. Each has experience in environmental restoration; they did some preliminary research at our February Partners meeting and are formulating research plans along very similar lines to this suggestion.

3.5 In addition to the organizations mentioned above, contact the American Fisheries Society, North Central Division, Rivers and Streams Technical Committee, which is heavily involved in river restoration and dam removal. The Technical Committee organized a 1999 Symposium, *Dam Removal and Fish Passage: Restoration of Aquatic Ecosystems*, at the 61st Midwest Fish & Wildlife Conference in Chicago, IL.

We will follow up on this.

3.6 Is it possible to develop a desk top watershed model? A technical version might be developed after doing the market research described in 3.2 above. An educational version might also be developed.

We are convinced it is possible to do this, and believe that, under the leadership of Dietrich and Power, we are well along on getting started. Our long-term strategy involves developing ways to use Desktop watersheds to provide the watershed context for restoration, a critical step in improving restoration outcomes. Once the model framework has been developed, we will look into educational applications.

3.7 After careful consideration of the effort and resources involved, consider publishing (on the web or as paper document) a Quarterly Restoration bulletin (newsletter). Audiences: landscape and channel restoration practitioners; educators. Integrate education and science, such as projects for undergraduate classes that use tools from the tool kit.

We are working now to implement this suggestion.

EAB was not able to respond to a specific request from NCED for help with models that incorporate biology. Part of the reason is that plant and animal communities are more region- and site-specific and less generalizable than the physical processes that govern fluxes of water, sediment, and other materials in streams. Once the locales are specified, models could be developed for biological populations and communities that are functionally important, important as indicators, or highly valued by humans.

We appreciate the EAB's effort on this. We believe that melding physical and biological effects in Desktop watershed type models requires a hybrid modeling approach that combines classical methods (e.g. differential equations) for physical processes with more heuristic (e.g. inductive, rule-based) approaches for at least some of the biological processes. Specific implementations of the Desktop watershed approach will be site-specific,

but the overall methodology will be quite general.

4 SHOULD NCED INVEST IN HIGH TECH SENSING?

While EAB was reluctant to provide additional specific recommendations, we can suggest what NCED should be asking itself before committing to substantial investments:

4.1 What are the questions this technology enables you to answer that you cannot answer now?

We realize these are "thought questions" for us to use in planning development of the ACRR site, but for the sake of keeping the EAB informed, here are our current views . We have provided a detailed answer to this question elsewhere (e.g. recent proposal by Power and Hondzo to augment the initial NCED network), but in short, the network we envision would dramatically increase our ability to detect biological and physical events in the environment when and where they happen. Everything we have learned so far about the ACRR site, which in this respect we believe to be quite typical, suggests that important events in nutrient flux, biological productivity, and physical disturbance are quite localized in space and time ("hot spots" and "hot moments"). We will miss many of these if we have to rely exclusively on ground-based measurements.

4.2 Are these questions central to the goal of determining what sustains the Eel River and its watersheds? Miki Hondzo and Mary Power talked about the importance of "hot spots" and "hot moments" – flesh out these ideas. The concept is that short-lived and localized phenomena may have important consequences in the ecosystem and can only be detected and assessed by continuous, in-place measurements.

Without estimates of ongoing fluxes of all the relevant quantities (particulates, nutrients, biota), Desktop watersheds would be static and therefore of limited use for forecasting and evaluating the effects of changing land use, climate, etc. These fluxes cannot at present be predicted but must be measured when and where they occur. Our instrumentation efforts at ACRR, which mix conventional sensing and logging methods with new wireless devices, are intended to accomplish this.

4.3 Do you have the people to support the system and keep it running?

After considerable effort, we believe we do. The support team includes staff at UCB (Collin Bode) and SAFL (Chris Ellis).

5 OTHER COMMENTS & SUGGESTIONS

5.1 The NCED research plan is to include both erosional and depositional processes and to have at least one representative site for each. The erosional site (Eel River in the Angelo Forest Reserve) was selected first, so it is not surprising that activities there were well under way and there was much to report by the time of the 4 October 2004 EAB meeting. David Mohrig's group (long-term dynamics and the "downstream" component of the NCED source to sink vision) is promising, but needs to be better linked to the other focus areas and this part of the program definitely needs more emphasis by the time of the next NSF site visit. The EAB would welcome a report from David's group at the next EAB meeting in September 2005 on how they integrate with the larger NCED effort. What are the specific action items for collaborations and linkages, both now and for the near future?

My response to this is given above.

5.2 The Big Back Yard (BBY) at the Science Museum of Minnesota continues to be an outstanding example of effective collaboration between researchers and exhibit designers. Following are some suggestions for building on what has already been done:

> 5.2.1 Could the BBY become a subject of research? This might be done at relatively modest cost by engaging graduate students (and their advisors) from the College of Natural Resources or College of Education, further linking the University and the Museum. Assess the effectiveness of the exhibits in terms of enhancing understanding of concepts by adults and school children. Does tying culture to science enhance or confuse understanding of the scientific concepts?

These are very intriguing suggestions that we will follow up on with Pat Hamilton of the SMM. We are doing evaluation research there with Mary McEathron, who has worked specifically on the effectiveness of the exhibits in terms of how well our messages were being communicated to the public.

> 5.2.2 The Monterey Bay Aquarium in California effectively reports its submarine canyon investigations using live as well as recorded video from its manned submersibles and fixed underwater cameras. An interpreter addresses a public audience one to several times a day, using the videos. If real time instrumentation is set up in the Angelo Reserve, could something similar to the program at the Monterey Bay Aquarium be done at SMM? Companion exhibits could display the instruments, explain how they work, and why it's important to observe "hot spots" and "hot moments".

This is also a fascinating set of ideas. We will follow up.

5.3 NCED is to be complimented for following up on the suggestion to hold NCEAS-(the NSF-funded National Center for Ecosystem Analysis & Synthesis) type workshops centered around topics, as part of effort to be of service to entire science community. The first such workshop (on modeling) was held in May 2004.

5.4 The NCED graduate students are complimented for having reached "activation energy" and becoming self-organizing. They have an important role to play in the outreach and education efforts (see recommendations under 1.2 and 1.5 in the Diversity topic above).

We are glad that the EAB supports our efforts on working groups and the graduate student council. Both programs are flourishing and will continue in the coming year.

Appendix 4: Media Coverage

1. Big Back Yard Press Coverage
2. New York Times article on NCED Visualization
3. Interview on Minnesota Public Radio of NCED Visitor Chris Bromley
4. Education activities at Maltby Nature Preserve
    a. ESTREAM Teacher Institute – MNP newsletter
    b. ESTREAM Teacher Institute – Newspaper coverage
    b. Participation in Make A Splash K-12 event
5. Nova episode filmed at NCED
6. NPR interview with Bill Dietrich
7. Washington Science Teachers Association
8. Civil Engineering News - coverage of BBY
9. University of Wyoming Alumni Association coverage of NCED Stream Restoration Research
10. Lower Minnesota Watershed District coverage of BBY

Big Back Yard Media Coverage Summary

Dragonfly TV, a nationally-distributed science program for youth produced by Twin Cities Public Television and supported by the National Science Foundation, used the Big Back Yard in July as a location to shoot segments for an episode about rivers and landscape processes (http://pbskids.org/dragonflytv/show/rivers.html). This episode has been produced and distributed to PBS stations across the U.S. for broadcast.

The Big Back Yard secured coverage by all major media outlets in the Twin Cities metropolitan area. The result was about $104,000 in free media:

Media	Date	News Hour	Duration	Est. Ad Equivalency
KARE-TV	Thurs., June 24, 2004	5:30 a.m.	3:18	$3,522
KARE-TV	Thurs., June 24, 2004	6:30 a.m.	3:31	$4,876
KARE-TV	Thurs., June 24, 2004	10:30 a.m.	2:46	$767
WCCO-TV	Fri., June 25, 2004	5 a.m.	3:07	$155
WCCO-TV	Fri., June 25, 2004	5:30 a.m.	3:44	$1,548
WCCO-TV	Fri., June 25, 2004	6 a.m.	2:59	$1,393
WCCO-TV	Fri., June 25, 2004	6:30 a.m.	2:46	$1,703
KSTP-TV	Fri., June 25, 2004	11:30 a.m.	:39	$460
WCCO-TV	Sat., June 26, 2004	8:30 a.m.	:28	$232
KMSP-TV	Tues., June 29, 2004	6 a.m.	2:50	$2,762
KMSP-TV	Tues., June 29, 2004	6:30 a.m.	2:50	$1,393
KMSP-TV	Tues., June 29, 2004	7 a.m.	3:22	$1,806
KMSP-TV	Tues., June 29, 2004	7:30 a.m.	2:13	$1,277
KMSP-TV	Tues., June 25, 2004	8 a.m.	3:25	$1,445
TOTAL	**14 segments**		**37:58**	**$23,339**

Substantial print coverage of the Big Back Yard was also secured:

Media	Date	Title/Headline	Est. Ad Equivalency
Avenues	June 26, 2004	Putt-putt with purpose	$2,595
Villager	July 14, 2004	Putt-putt with purpose	$3,225
WHERE Twin Cities	July 2004	Mini-golf: Art or Science?	$6,200
Pioneer Press	June 22, 2004	Calendar listing	$200
Pioneer Press	June 26, 2004	Links Lessons	$22,152
Star Tribune	June 24, 2004	Science in the Sun	$425
Star Tribune	June 26, 2004	Science lessons at the fore	$15,763
Star Tribune	July 14, 2004	Strokes of Genius	$30,535
TOTAL			**$81,095**

New York Times coverage of NCED Visualization work

GeoWall Project Expands the Window Into Earth Science

Electronic Visualization Laboratory, the University of Illinois, Chicago
Arun Rao, right, and Nicholas Schwarz, graduate students at the university, with a four-panel display of core images and data.

By HENRY FOUNTAIN

Published: March 3, 2005

PAUL MORIN, who helps earth science researchers and teachers visualize information at the University of Minnesota, remembers being frustrated five years ago with the 3-D technology he was using.

"I was working with a cave at the University of Michigan," Mr. Morin said, referring to an elaborate and expensive room-size three-dimensional display system. "And it was cheaper to fly me to the cave from Minneapolis than it was to build one ourselves."

What's more, while the system was good for researchers, it wasn't suitable for teaching. "A cave is really a one-person operation, it's really immersive," said Mr. Morin, who is affiliated with the National Center for Earth-surface Dynamics in Minnesota. But students didn't need to feel as if they were someplace else; they needed to be able to visualize basic things like mountain ranges and the interactions of tectonic plates. "We needed stereoscopic imaging, but we didn't need immersion," he said.

Mr. Morin voiced his concerns to other visualization specialists,

including Jason Leigh at the Electronic Visualization Laboratory at the University of Illinois, Chicago, who had developed cave systems. The result, after several years of tinkering and tweaking and with support from the National Science Foundation, was the GeoWall, an inexpensive system that uses a PC with an advanced graphics card and digital projectors to present the geophysical world to dozens or even hundreds of students at a time.

The success of the GeoWall - there are now more than 400 of the systems in use at schools, colleges and other institutions, loosely linked through a consortium (geowall.org) - has spawned next-generation efforts meant more for researchers than for students. These include the GeoWall2, a system that typically uses 15 flat-panel liquid-crystal display screens stitched together, and a desktop system, the Personal GeoWall2, with four L.C.D.'s.

While these newer systems can be used for 3-D displays, the more immediate goal is to give geoscientists the resolution they need to study things like maps with remote-sensing data or images of rock cores. A 15-panel GeoWall2 system, for example, has a resolution of about 30 million pixels.

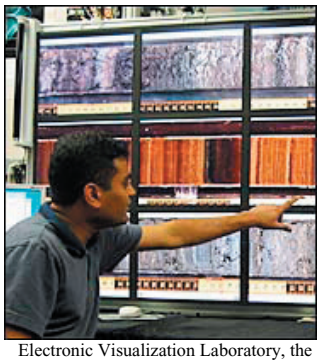
"If you want a lot of resolution, getting the big flat-panel system works well," said Dr. Leigh, an associate professor of computer science at the University of Illinois, Chicago, and a director of the visualization lab. The high resolution eliminates the need to constantly zoom in to study detail, as is necessary with a typical single-screen PC.

The display also allows someone studying a rock core, for example, to "drive" its length to compare the composition at different points. Such comparisons can be a tedious process with the actual core itself.

These newer systems are more expensive: a 15-panel setup, with its cluster of computers, costs about $90,000, although that should drop as the price of L.C.D.'s fall. And their 3-D capabilities are limited.

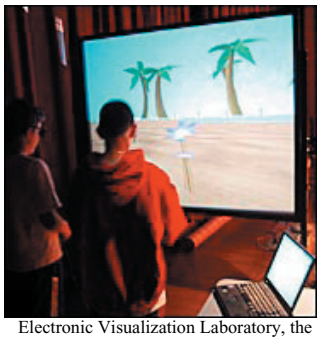
"The holy grail is 3-D without glasses, but at enormous resolution," Dr. Leigh said. The systems are not there yet.

For teaching, the original GeoWall system is generally preferred. It uses off-the-shelf parts ("Anything that a nerdy kid in his basement uses to shoot aliens," Mr. Morin said) and open-source and vendor software for creating 3-D images from data. A PC with a graphics card controls two digital projectors that use polarized light to display slightly offsetting images on a silvered screen. Simple glasses with polarizing filters block one image from each eye, creating the stereoscopic effect.



Electronic Visualization Laboratory, the University of Illinois, Chicago

DEEP IMPACT - At the University of Illinois, Chicago, Naveen Krishnaprasad, a graduate student, examines core images on a 15-panel GeoWall2.



Electronic Visualization Laboratory, the University of Illinois, Chicago

Systems for visualizing geoscience information include a 3-D GeoWall, above, used by elementary students in Oak Park, Ill.

A basic GeoWall, either purchased as a unit or assembled by someone with a basic knowledge of computers, costs less than $10,000. That figure is important, Mr. Morin said. "It's what a department chair or a dean can sign off on without going through an approval process," he said.

Stephen J. Reynolds, a geology professor at Arizona State University who uses the GeoWall for as

many as 220 students at a time in introductory earth science classes, said he takes his students on a tour of the main features of the planet using a presentation developed by Mr. Morin.

"It's a lot easier for them to learn," Dr. Reynolds said. "We spend a good hour or so just exploring the face of the earth."

Later he uses the GeoWall to explain more complex subjects like seismicity - rotating a 3-D plot of earthquake epicenters off Indonesia, for example, so that students can see how one plate slides under another. "They can see the data we've used to come to some of the models we've developed in geology, like plate tectonics," he said.

The GeoWall uses such basic technology that it is unlikely to change much. But Mr. Morin, Dr. Leigh and others in the consortium are keeping an eye out for improvements to the more advanced systems.

"We are always trying to find better display technology so we can make higher resolution, more seamless displays," Dr. Leigh said. One improvement, he said, would be to eliminate the frame around each L.C.D., which gives a multipanel display a segmented look.

But he acknowledged that most geoscientists are much more concerned with improving resolution. When it comes to eliminating the frames, Dr. Leigh said, "the geoscience community couldn't care less."

Minnesota Public Radio Interview with NCED Visitor Chris Bromley (Web Text)

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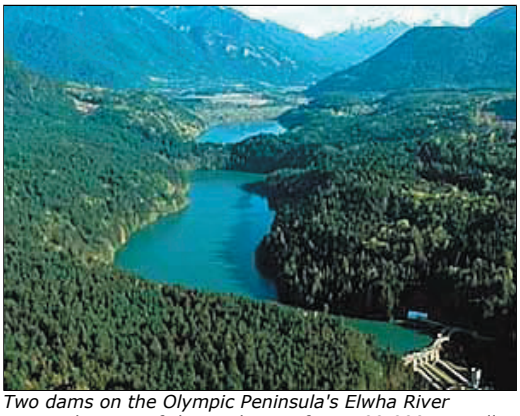
Getting ready to breach the dam

by Dan Olson, Minnesota Public Radio
April 7, 2004



Two dams on the Olympic Peninsula's Elwha River system have cut fish populations from 400,000 annually to less than 4,000. Researchers at the University of Minnesota are helping determine the best ways to remove those dams. (Photo courtesy of Elwha Restoration Project)

Photos
The Elwha River in Washington state
Removing the dam in the lab
Researcher Chris Bromley
View full slideshow (5 images)

Resources
The government's Elwha dam removal plan
Dam removal projects in Wisconsin

Your Voice
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A researcher at the University of Minnesota is part of a salmon rescue mission. The work is helping officials in the state of Washington prepare for the country's largest dam removal project. The goal is restoration of a legendary salmon river to its original condition.

Minneapolis, Minn. — Water runs over Chris Bromley's model dam as he removes sections from the top. One day soon, this may be what happens to the Glines Canyon dam holding back water on the Elwha River in the state of Washington.

"The primary benefit is that it's going to restore fish passage for salmon," Bromley says.

Bromley is a U of M geography graduate student from England. A grant from the National Science Foundation is paying for his research to show the best way to remove the dam. There are two dams on the Elwha. The plan is to remove both. Bromley's research is on the larger structure.

Researcher Chris Bromley

The Glines Canyon dam is 246 feet high. If the structure is taken down too fast, a thick and suffocating layer of sediment would spread across the river bottom.

Bromley's 30-yard-long model of the dam and the lake behind it is at the U's St. Anthony Falls hydraulic laboratory on the banks of the Mississippi River in Minneapolis.

Robert Elofsen is directing the river restoration. Elofsen, a member of the Lower Elwha Klallam tribe, says before the dams were built the tribe's culture and

economy were based on the fish taken from the Elwha.

The Klallam began lobbying the federal government nearly 30 years ago to remove the two dams. Congress gave the go-ahead 12 years ago, because the power produced from the dams was replaced by other sources.

Elofsen says once the dams are removed, it will be be years before millions of tons of sediment are redeposited and the river valley floor is reforested.


The Glines Canyon dam

"You might get some harvestable salmon in 10 or 12 years returning to the river," Elofsen says. "But to actually reach an equilibrium, where natural runs approach where they were before, could take 20 years or more."

The Elwha River starts in the 7,000-foot-high snow-capped peaks of the Olympic peninsula. Most of the area lies within the Olympic National Park.

Before the dams were built, the river coursed through a thickly forested valley. The land was clearcut after construction.

Connie Kelleher, a spokeswoman for the advocacy group American Rivers, says 1(species of fish reproduced and thrived in one of North America's most productive waterways.

"Huge individual chinook salmon sometimes exceeded 100 pounds. There were also sea run cutthroat trout, and native char, and winter and summer runs of steelhead there -- as well as coho, pink, sockeye, and spring and summer and fall chinook salmon. And they numbered approximately 400,000 each year," Kelleher says.

After the dams went in, Kelleher says, fish populations declined to about 4,000 a year, nearly all planted from hatchery stock.


What the river will look like

Grad student Chris Bromley's work predicts the course the water will take once the dam is breached. The release will cause turbid water for a time. He says the salmon returning to the river will tolerate some sediment in the water.

"The sediment to a certain extent will make the fish uncomfortable," Bromley says. "But the removal of the dam has been designed in such a fashion that when the bulk of the sediment is moving ... will be the times when the fish and their eggs -- and their young, when they've hatched -- are least sensitive to that sediment."

The two Elwha River dams on Washington's Olympic Peninsula are owned by the federal government, and federal taxpayers are footing the $180 million dam removal and river restoration cost.

The dam removal effort began when Robert Elofsen was finishing college. Now 51, Elofsen says his Klallam tribe is confident the river and its remarkable fish producing ability will one day be restored.

"I told my daughter, in fact, when we were visiting the dam that if I don't get this done then she'll have to. She was kind of shocked at that thought," Elofsen says.

Elwha River dam removal is scheduled to begin in 2007.

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NCED Earthscapes Teacher Institute at Maltby Nature Preserve - MNP Newsletter

Volume 2, Issue 3 *Fall Edition* *September, 2004*

Beyond Book Learning – Doing Real Science in the Real World

By Sil Pembleton, Education Director

In *place-based education,* students investigate their environment. Asking questions of (and getting answers from) the insects, rocks and streams is exciting! When students find larval Caddis Flies, May Flies and Stone Flies in the stream, the insects confirm the results of chemical tests that indicate good water quality. The discovery of marine fossils in the rock tells students that ancient oceans once covered Minnesota. State maps and stream tables help students visualize how rivers flow and change – and they may recognize why their town grew along the banks. And a study of runoff on the school grounds may raise many new questions about what's happening in their backyard.

Place-based education uses the environment as an integrating concept for classroom study. Students learn vital science concepts by investigating their schoolyard and neighborhood. Science is a way of looking for answers; it's not just a list of facts. As we focus on the places where we live, some of the seemingly simple questions become the basis of the educational program: *Where am I? What is the nature of this place? What sustains this community?* Exploring these broad questions helps connect children to their "place"' and also helps tie the curriculum together. The most basic skills of science – careful observation, critical thinking and problem solving – are crucial in many school subjects. Science, math, history, geography, civics, language and the arts become linked in a way that is meaningful to young learners.

Research begun by the State Education and Environment Roundtable, a collaboration of 12 state education agencies, including Minnesota, shows that place-based education, using the environment as an integrating concept, yields these positive results:

- Better performance on achievement tests
- Reduced discipline problems
- Increased engagement and enthusiasm for learning
- Greater pride and ownership in accomplishments.

At Maltby the natural world is our learning laboratory–a place for students and teachers to observe, explore, experiment, and then communicate their understanding of how the world works, and how they are connected to it. As part of ***Riverworks*** , our science education program, Maltby staff will guide science learning experiences at the Preserve, and will also work with students and teachers in their classrooms and schoolyards. The river and ponds, the woods, the prairie, the playgrounds and the community become the real classroom.

I am excited as the Maltby Nature Preserve and Natural Sciences Center begins collaborating with local teachers to provide student-centered, hands-on, inquiry-based science that supports the state academic standards. Plus, it connects students to their social and natural communities, and fosters involved citizenship and stewardship!

Maltby Hosts Earthscapes Teacher Institute

Teams of middle school science teachers from across the state spent two days studying the geology of the Cannon River watershed, gauging stream flow, collecting macroinvertebrates, and testing water quality before moving on to Duluth for two days of comparison studies in the St. Louis River watershed.

With a full immersion into field and laboratory experiences over the course of two weeks, the teachers experienced the synergy of science professionals and the research being conducted at the National Center for Earth-surface Dynamics. They observed, collected and interpreted data, used stream models and predicted processes that shape Earth's changing surface. In the process they visited Fond du Lac Tribal and Community College and toured St. Anthony Falls Laboratory. They explored resources at the Science Museum of Minnesota, played miniature golf in the Museum's new *Big Back Yard* watershed exhibit, and studied 3-D maps and visualizations as they traveled the Mississippi River shoreline.

Throughout the Institute teachers and scientists pooled their professional expertise to translate current scientific research into developmentally appropriate field and classroom learning experiences for students. Three of the Institute participants from Cannon Falls and Rosemount school districts are planning classroom curricula and field research experiences in partnership with the Education Director at Maltby.

This professional development program for middle and high school science teachers was funded by a grant from the National Science Foundation and conducted in partnership by the National Center for Earth-surface Dynamics and the Science Museum of Minnesota

Nova Episode Filmed with NCED - from Civil Engineering News (Web version presented here)

U of M Civil Engineering

CE Home CE News **'Nova' crew films at St. Anthony Falls Lab**

'Nova' crew films at St. Anthony Falls Lab

A British-led film crew spent two days in September at the St. Anthony Falls Laboratory filming segments for a documentary that will air next year on the PBS science series "Nova."

Prof. Chris Paola discusses waterfall migration and turbulence as a "Nova" crew films a simulation of the Ice Age floods.

The documentary, tentatively titled "The Mystery of the Scablands" explores the scientific controversy over the forces that shaped the unique landscape of the Pacific Northwest.

Researchers from the National Center for Earth-Surface Dynamics (NCED), which is based at the lab, set up a series of experiments on erosion, cavitation and plucking-pressure effects that pull rocks from outcrops-to show how the extreme force of the water could have eroded the landscape.

"Because of the (facility's) head of water, they can do pretty spectacular experiments to suggest a catastrophic flood," said Victor Baker, regents' professor in the Department of Hydrology and Water Resources at the University of Arizona.

NCED staffers spent six weeks preparing for the film crew, and they also found themselves designing experiments on the fly during the intense two-day shoot.

"It's a great way to get the word out about the science we do," said NCED Director Chris Paola. "The features we generated in the lab are very similar to what they're seeing in the field. But things happen so much faster in the lab."

The scablands controversy dates back to the 1920s, when geologist J Harlen Bretz proposed that a single, cataclysmic event caused the distinctive scablands, coulees and boulder fields found scattered across the Northwest.

"The idea that a single catastrophic flood had occurred sounded Biblical," said Baker, a consultant for the project. "Only in the 1970s did we begin to get an idea of how these forces work."

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Baker said research done at experimental facilities including the St. Anthony Falls Lab helped geologists put the pieces together.

Scientists now believe that a series of floods swept the Northwest when ice dams broke next to Glacial Lake Missoula, sending a wall of water hurtling across Idaho, Washington and Oregon at speeds of more than 60 miles an hour. The force of the water pulverized rock and pulled boulders free from rock faces, dramatically reshaping the landscape, Baker said.

"Since then we've found that these processes are not unique-they also occur on Mars," he said.

Work on the "Nova" project has already led to one new collaboration for NCED. Juan Jose Fedele, a research associate who worked on the film shoot, plans to submit a proposal to NASA with Baker to model remnants of horseshoe waterfalls found on Mars.

"It was exciting that the same features have been observed on Mars," Fedele said. "It leads to the idea that on Mars you have huge flooding and the presence of water."

The "Nova" documentary is expected to air in fall 2005 on PBS and the National Geographic Channel.

National Public Radio interview with NCED PI Bill Dietrich regarding his NCED Research

National Public Radio
Morning Edition

December 28, 2004

Analysis: New laser technology reveals Earth's surface as never before

Edition: 11:00 AM-12:00 Noon

Estimated printed pages: 3

Article Text:

RENEE MONTAGNE, host:

Geologists are raving about a new technology that reveals the Earth's surface as never before. The technique is helping scientists solve puzzles about earthquakes, salmon streams and more. NPR's Richard Harris caught wind of this excitement at a recent scientific meeting.

RICHARD HARRIS reporting:

Scientific gatherings are usually an orderly procession of talks in banquet rooms and posters pinned up neatly on display boards in the great hall. So it was a bit odd to encounter a knot of people on the floor at the recent American Geophysical Union meeting in San Francisco. There, right in the middle of a broad hallway, a bespectacled man with a gray moustache knelt down and rolled out some three-foot-wide landscape images.

Mr. BILL DIETRICH: OK.

Unidentified Man: Is that Eldridge Street?

Mr. DIETRICH: Yeah, it's Eldridge, yeah.

Unidentified Man: Yeah, that's an old air photo! there.

Mr. DIETRICH: That's not an aerial photograph. That is a topographic image of the forest taken via laser.

Unidentified Man: It's gorgeous. It's gorgeous.

HARRIS: The kneeling man with the moustache, Bill Dietrich, says the images are not just gorgeous, they're changing his world.

Mr. DIETRICH: This is revolutionizing what we can do in many fields.

HARRIS: These images are gathered by a remarkable new process. A low-flying plane zigzags across a landscape and shines a laser to the ground. Those light waves bounce back up to the plane and are pieced together to create an image that makes the ground below look stark naked. Dietrich, at the University of California at Berkeley, is in raptures about this technique, which is called airborne LIDAR. At the least provocation, he'll unroll his tube full of high-quality images.

Mr. DIETRICH: I brought it for my talk and to show to people, sort of like as a kid does when they! 've discovered something really exciting they want to show everybody.< P>

HARRIS: Some of Dietrich's research with this technique involves a conflict between salmon and Cabernet. He flew LIDAR over California's prime wine country, the Napa Valley. Wineries may be thriving in this valley but salmon are not.

Mr. DIETRICH: And there's a concern that that decline has been associated with the use of the Napa Valley very successfully for the production of wine that we all love to drink.

HARRIS: Dietrich gathered half a billion data points from the LIDAR instrument to reveal the ground through the trees, shrubs and vineyards.

Mr. DIETRICH: In this 1,100-square-kilometer basin, there are over 1,200 reservoirs. Almost 40 percent of the entire watershed is blocked by dams.

HARRIS: These reservoirs are important for grape growers. They provide water for irrigation and water to spray in the winter to ward off frost damage.

Mr. DIETRICH: But the consequence, there's only so much water, and by taking water out! for those purposes, there's less for fish.

HARRIS: Dietrich is hoping to identify key bottlenecks to help the salmon co-exist with the vineyards. This is just one example of using airborne LIDAR. He says the technique measures ground features so accurately, it's being used now to study the ebb and flow of glaciers and to measure bulging lava domes atop volcanoes.

As Dietrich starts to roll up his landscape images, Kevin Furlong from Penn State University comes up to take one last glimpse. Furlong has been trying to track fault quakes through Northern California and he's dying to use the laser technique to help reveal structures in the Earth that are now too hard to see. He says, take for example, Mt. Tamilpais, just north of San Francisco.

Mr. KEVIN FURLONG (Penn State University): It's just a few miles from the Golden Gate, from the Pacific Ocean, and it goes up quite high, 2,500 feet. Now we're thinking it might be actually associated with the f! aults that make up the San Andreas system, so if that's true, there ma y be some new faults that we didn't know about.

HARRIS: Maybe airborne LIDAR will reveal a hidden hazard here.

Richard Harris, NPR News.

MONTAGNE: The time is 21 minutes before the hour.

Record Number: 200412281104

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Event Calendar

November 2004

7	8	9	10	11	12	13
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Today:
NSTA and WSTA Convention, Seattle, WA

Suggest an event

6 November 2004 Earth Science Sites of the Week
Posted on Sunday, November 07 @ 08:31:17 PST by rick

Hello everyone,
This week's 6 November 2004 "Earth Science Sites of the Week" feature
1) shuttle radar topography maps
2) maps in 3-D
3) education map catalog
4) assessment and national science standards
5) planetary maps

For All

Features:
1) Animations: drawing contours
2) Teaching Tip: using field Labs
3) Neat Pictures: phases of the moon
4) Good Read: Do lead bullets continue to be a hazard after they land? and Food shortages threaten Antarctic wildlife
5) Good Quotes: on the value of active learning
6) Trivia: Why doesn't the length of each day change much around the solstices?
7) Humor: This is what happens when you think your computer is asleep.

SITES OF INTEREST

1) SHUTTLE RADAR TOPOGRAPHY MISSION (SRTM), NASA, "The Shuttle Radar Topography Mission (SRTM) obtained elevation data on a near-global scale to generate the most complete high-resolution digital topographic database of Earth." Find a compelling gallery of images as well as animations of river flooding, faults, and mountain chains.
http://www2.jpl.nasa.gov/srtm/

2) NCED National Center for Earth-Surface Dynamics, University of Minnesota, (suggested by Warren Huff, University of Cincinnati), Put on those 3-D glasses and watch the landforms "jump out." The site contains a collection of digital maps, both in a viewable and high-quality download format. Map interpretation

teaching resources are currently being developed.
http://www.nced.umn.edu/Maps.html

3) USGS Education Map Catalog, USGS, (suggested by Joseph Kerski, USGS), The USGS publishes over 76,000 maps on a huge variety of topics. Find a catalog organizing USGS maps in the following topical areas: topography, geology, image, history, national parks and monuments,international and world, water, planetary, environmental, land cover, energy and physics, and earthquakes, volcanoes, and landslides. The catalog allows the user to examine the maps in detail and provides ordering instructions. The education map catalog, developed by Joseph, represents a subset of some of the most useful USGS maps for teaching purposes.
http://rockyweb.cr.usgs.gov/outreach/mapcatalog/

4) PERFORMANCE ASSESSMENT LINKS IN SCIENCE (PALS) SRI International, (suggested by Holly Devaul, DLESE), Find an on-line, standards-based, continually updated resource bank of science performance assessment tasks. The tasks are indexed via the National Science Education Standards (NSES) and various other standards frameworks and are collected from numerous sources. They include student directions and response forms, administration procedures, scoring rubrics, examples of student work, and technical quality data calculated from field testing. On-line rater training packets have also been created for some tasks.
http://pals.sri.com/index.html

5) MAP A PLANET, USGS, (suggested by Mary Power, Farmington, MI), Access global imagery of the planets and satellites from a variety of missions in an easy to use web interface. Customize and download your own image maps of the Moon, Mars, Venus, and other planets and moons [Ganymede, Europa, Io, and Callisto]."
http://pdsmaps.wr.usgs.gov/

FEATURES

1) ANIMATIONS:
Draw Contours, Visual Entities, The Flash based animation allows students to create and edit contours. Clicking on the "Edit" mode will place the contour at 10 foot intervals on a map from 610 to 690 ft. The previous contour disappears so a student can only see the correct contour configuration for one interval.

CIVIL ENGINEERING NEWS

EDUCATION

Park Demonstrates Erosion Processes

When educators with the National Center for Earth-Surface Dynamics (NCED), headquartered at the University of Minnesota, considered how to raise public awareness of sediment erosion, transport, and deposition, they faced a conundrum. How, they wondered, could the complexities of these natural processes be broken into their constituent parts and conveyed in a way that would be both fun and informative?

The answer: combine the message with miniature golf.

The NCED, part of the National Science Foundation's Science and Technology Centers Program, teamed up with the Science Museum of Minnesota, located in St. Paul, to create a park that would enable visitors to learn about geology, geomorphology, hydraulics, and ecology as they putted their way around a nine-hole miniature golf course on the museum grounds. Part of a larger park known as the Big Back Yard, the miniature course also includes several stand-alone, interactive displays.

One of the goals of the university's St. Anthony Falls Laboratory, which is part of the NCED, is to raise public awareness of the earth's changing landscape and the effects of changes in sediment flows on the environment, says Jeff Marr, P.E., the NCED's engineer and one of the designers of the park. "This was a great way for us to broadcast to the public what we're doing," Marr says. The museum, meanwhile, wanted an outdoor learning center that would allow visitors to enjoy Minnesota's short but balmy summer.

Visitors begin at a three-dimensional world map that displays satellite images of the earth's continental plates and ocean floors. Such features as mountains, which, in eroding, yield sediment, are shown in a rough texture, whereas depositional areas are smooth. From there the golfers move to the first hole, which introduces a "source to sink" sediment transport concept. "The source is uplands or mountains from which rock is eroded," Marr says. "The sediment then moves down gradient via rivers and landslides, and the result is depositions in sinks, like deltas or basins."

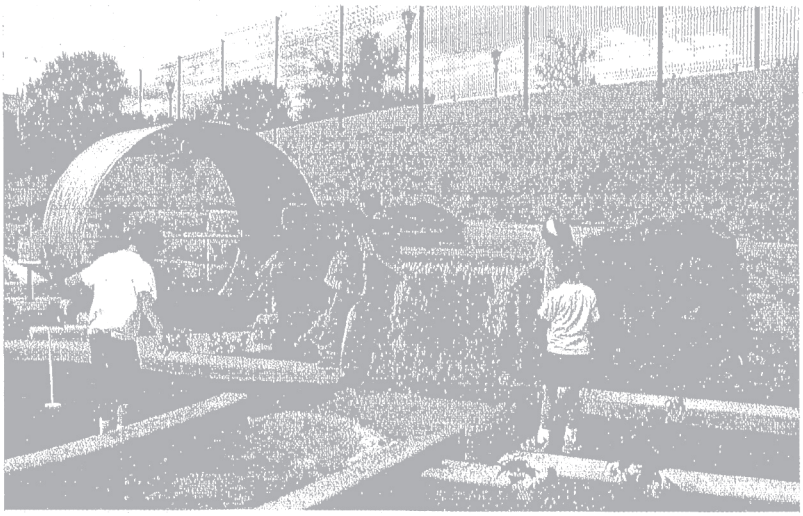
The second hole requires golfers to putt up a slope to send the ball into a model of a drainage basin; the following hole requires them to putt the ball over what is known as a hydraulic jump, a sheet of shallow, fast-moving water that is created when water overtops a natural or man-made dam. Marr says the water at this location moves at a pace of 5 ft/s (1.5 m/s) over a 5 in. (127 mm) tall spillway, and successfully traversing it is by no means assured. "Visitors will get soaked, but it'll be a great time," he says.

Another hole requires players to "tee off" through a storm sewer grate, and subsequent holes require them to traverse a small-scale farm field, an area of wetlands, and a pervious surface, all while learning about the role that natural and built environments play in the process of erosion. The eighth hole, for example, requires players to maneuver through a river that has been drained by a lock and dam, and the last hole replicates the Gulf of Mexico and requires a shot into the delta of the Mississippi River.

The freestanding exhibits placed around the course demonstrate such processes as how water creates erosion networks in sand, how braided rivers are continuously formed and re-formed, and how removing a dam affects the landscape. A transparent model flume enables visitors to create their own erosion by lifting one side of a tank containing black and white sand to see how water and sediment behave at varying slopes.

The Big Back Yard, which opened in June, also includes a 17,000 sq ft (1,579 m²) life-size maze and a science center that uses solar power. In addition to the University of Minnesota and the museum, the NCED includes the University of California at Berkeley, the Massachusetts Institute of Technology, Princeton University, the University of Wyoming, and Fond du Lac Tribal and Community College.

—*Laurie A. Shuster*



University of Minnesota

Children play at a golf course hole intended to show how water behaves at a hydraulic "jump," part of a new park at the Science Museum of Minnesota designed to give the public a better understanding of sediment transport.

A (Little) River Runs Through It

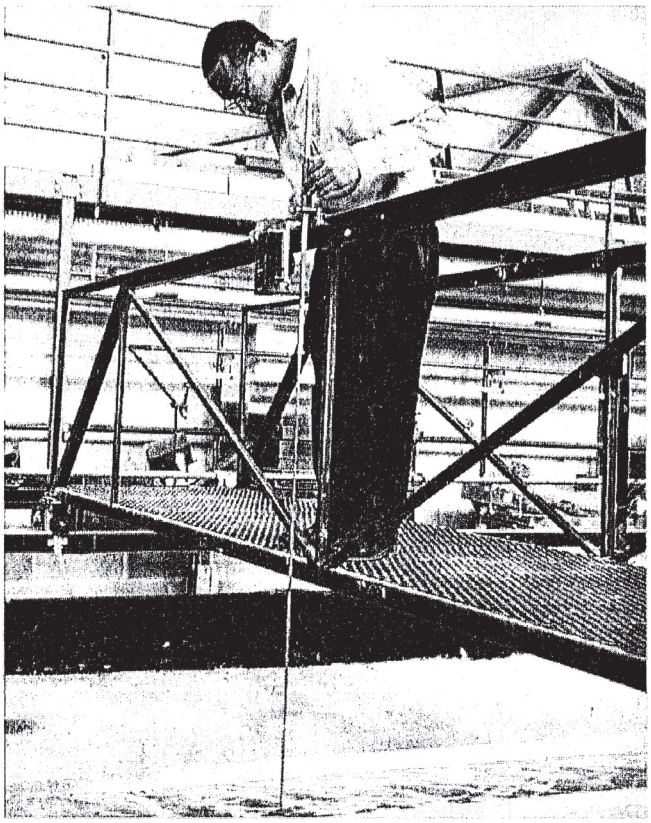
by Suzanne B. Bopp
Alumnews Editor

In the basement of UW's Engineering Building, there is a river. It has a gravel bed, a flood plain and a water table, just like any river. No fish though, and this river is only 18 inches wide.

It is, in large part, a creation of Greg Wilkerson, who teaches engineering at UW. The lab stood empty when Wilkerson first came to Wyoming. "I'd been wanting this before I got here; it would allow me to ask questions that are of great interest to me," he explains. "Why do rivers behave the way they behave? But you have to answer 50 other questions before you can answer that."

To start to answer those questions, he put together the hydraulics lab in 2001. "There are probably not more than a couple dozen facilities in the country that have these capabilities," he says.

The flume in the lab is a model of a real river, Oak Creek in Oregon, "because that's the gold standard," Wilkerson explains. Measurements have been made of Oak Creek that the scientific community has accepted as good measurements. "Whether or not they are is another thing," he says. "But if we model Oak Creek and compare what we get, and if our measurements match, then we know we're good modelers."



Greg Wilkerson measures the depth of the water in his model river.

So what he and his students have built is a gravel bed river on a 10:1 scale of Oak Creek. The slope of the model river is the same as that of the actual river; the gravel is 1/10th the size. The width is not to scale, but Wilkerson explains that width is not important for their purposes. "I'd love to make it 14 feet wide, but where would I get the water?" he says.

"Anyway, with most rivers, the depth of flow is smaller than the width. They're at least 10 times wider than they are deep. So you can ignore what happens at the sides." Of course, it's possible to build a model that is too narrow, which causes "sidewall effects," and there are rules in the scientific community about the dimensions necessary. "I'm pleased with it," Wilkerson says. "It is, in my mind, a good model and a unique model."

> "WHY DO RIVERS BEHAVE THE WAY THEY BEHAVE? BUT YOU HAVE TO ANSWER 50 OTHER QUESTIONS BEFORE YOU CAN ANSWER THAT."
> Greg Wilkerson

The flume is both a teaching lab and an experiment; the experiment has been multifaceted. Because Wilkerson, who earned his master's degree and PhD from Colorado State University in civil engineering, wanted to experiment with clay as a modeling material, the sides, which are the river's flood plains, are made of clay. The clay can be eroded, so it acts like dirt. In one part of the experiment, he added models of trees in order to look at the effects of vegetation density on flood plain flow.

"Now we're backing away from all that complexity," he says. "We found the clay cracked more with the higher density vegetation, less with lower density. So we did learn something, but we don't understand it. I want to get back to that question."

What he's focusing on now is the issue of sediment transport. Rivers, Wilkerson explains, transport both water and sediment and the latter is as much of an issue as the water itself. "Once the sediment gets in the river, it will keep moving," Wilkerson says. On the Mississippi, for example, "the sediment gets in there and then the river wants to move. They have to dredge the river because the barges are trying to transport things up and down the river. The government spends a lot of money to get it out." So sediment transport is a big area of research; it's also a complicated process to study. "It's difficult to get a handle on," Wilkerson says. "There are lots of people with lots of equations."

In his lab, five pumps allow him to deliver water wherever he wants in the system. A reservoir holds water at a constant elevation before it enters the flume; it first enters a stilling box, so that when it leaves there it is calm and flows into the flume at a steady rate. At the side is a sediment feeder. The Oak Creek model uses sediment that is a mix of 70 percent sand and 30 percent gravel. On the sides of the clay flood plains are boxes that hold water to represent the ground water table; Wilkerson has plans for future experiments involving those. "I want to know what happens to sediment transport if I raise or lower the ground water table. Does that affect the channel shape?" Wilkerson asks. "Nobody's ever looked at that because it's so difficult."

When the water reaches the end of the flume, the sediment gets separated, dried and measured. Then Wilkerson can look at the total weight of the sediment and its size distribution.

The lab, funded in its building phase primarily by EPSCOR, is now operating under funding from the NSF Science and Technology Center's National Center of Earth-Surface Dynamics (NCED). The center is headquartered at University of Minnesota. "Some guys in Minnesota found out about the work I was doing," Wilkerson says. "I went to Minnesota to meet with them. I was excited to meet them; I knew about their work. It turned out it was an interview." He was accepted into the program and now goes up for renewal every year. "I have to be productive for NCED. Most of the other P.I.s [primary investigators] are very senior. I'm a junior guy, and I learn from them and have access to them."

The lab is a benefit for Wilkerson's students too. It offers students with a broad range of backgrounds both part- and fulltime jobs. It introduces undergraduates to graduate students. "It shows them what research is and lets them see it being conducted," Wilkerson says. Last summer, he took two undergraduates to the American Society of Civil Engineering Conference in Minnesota, where they presented the results of research projects they had conducted.

Wilkerson hopes his work in the hydraulics lab might eventually bring him closer to answers about why rivers behave the way they do, and why researchers seem to have found different behavior in different rivers. "I'm looking for a unifying principle," he says. "I don't think that rivers are behaving differently. I think we don't understand rivers well enough to know."

The Online Lower Minnesota River Watershed District News, October 2004

Home page

Hole 4: dam and spillway
(Click any photo on this page to enlarge & get more information.)

Hole 7: meandering rivers

Sandstone dam exhibit

Braided rivers exhibit

DISTRICT CONTRIBUTES TO SCIENCE MUSEUM'S BIG BACK YARD

This past June the Science Museum of St. Paul launched a new outdoor fun-and-learning space called the Big Back Yard. Since the new museum on the river opened in December 1999, says Patrick Hamilton, director of environmental and earth system sciences, it very much wanted to "fund an outdoor science park, where visitors can have as much fun and learn as much as they do inside."

In partnership with the National Center for Earth Surface Dynamics, at the U of M, and many contributors, including the District, the museum constructed a science park that includes

- A nine-hole mini-golf course and related exhibits
- A solar-powered building called Science House that's used as a classroom and lab space
- A series of rainwater gardens that receive stormwater runoff
- A maze planted with prairie grasses and flowers, to which next year will be added full interpretive signs

Source-to-sink educational fun & games

From opening day, visitors have been both informed and energized by the Big Back Yard. The theme of the mini-golf course, for example, is "source to sink." "Landscapes erode," says Hamilton , "rivers transport sediment, and the sediment ends up in ocean basins." As players putt their way through the course, they have fun and at the same time learn about human interactions with the landscape.

Visitors are giving positive feedback, reports Hamilton. They're having fun and learning at the same time, in keeping with the mission of the Science Museum and the experience of inside-the-museum visitors over time. "For most people that visit here," he says, "learning *is* fun. Playing is productive, and they learn about real-world processes and their consequences."

The golf course does not feature the "fanciful or fantastic landscape," says Hamilton, that the player may be used to from playing mini-golf. Rather, it's realistic, scientific, heuristic — a landscape true to nature and instructive of how water-forces work on the land.

Hole 3, for example, features a spillway on a dam. As the water rolls down the spillway in a fast, thin layer, it hits slower moving, deeper water at the bottom and forms a "hydraulic jump," a turbulent area that players must putt across. Hole


Rainwater garden


Prairie maze


Flume where visitors can pan for minerals

4, which boasts a large culvert, tells the story of urban stormwater pollution. Hole 6 teaches about pervious and impervious urban landscapes, and dramatizes just how fast urban flash-floods can be, since so much surface has been paved or built over.

On hole 6, as on all holes, the pin, ingeniously, is plumbed to the rainwater gardens down the slope. So, the putter himself or herself plumbs the connection between input, we might say, and output — whether these forces are a golf ball or a volume of water.

Life lessons

How can a player get through the course and just not get it? If he dumps oil down a drain, this pollutant gets into the groundwater, rolls downstream, and affects life along the way. If she tosses fast food refuse out the window of her car, this trash also gets in our waterways, posing a hazard to wildlife and spoiling the natural landscape.

Besides the nine holes of golf, the course is planted with exhibits that dramatize water dynamics.

One exhibit, in a large plexiglass tank, demonstrates how dams trap sediment in their reservoirs. The player/learner cranks up the dam gate, and the sand spills downstream fast, building up a delta. When he lowers the gate, the sediment builds up before our eyes. This is a real-life, hands-on demonstration of the aquatic forces that have prevented fish like salmon from migrating upstream and filled reservoirs with sediment.

Hole 8, a schematic model of St Anthony Falls, continues the hydraulic lesson. Tons of engineering, over the last 150 years, suggests Hamilton, have changed the shape and contour of the river. First, snags and logs were pulled out to make the river more navigable. Then, in the late 19th century, thousands of wing dams, composed of layers of willow mats and stone, were installed, like those on the north side of the falls, to scour the river bottom and constrain flow to one central channel. Then, in the 1930s, lock and dam systems began to be built.

Near the end of the course, there's a fun flume exhibit where players can pan for gemstones and fossils. They buy a bag, empty the contents into a sieve box and shake out sand into the rushing water of the flume. Their winnings may not reach Power Ball magnitude, but they get to keep the mineral or fossil fragment that they find.

Stay tuned for next April

Eager to play and learn? Alas, the mini golf course closed for the season in early October. But it will reopen next April: the plants on the steep slopes and around the golf holes will bloom again; the rainwater gardens will blossom; and the

prairie maze, complete with interpretive signage, will infiltrate all of us with the sense of just how lucky we are to live in such a time and place where the river lies just below, the skies open immensely up above, and we can re-create ourselves like nature.

For more information on the Big Back Yard, go to the Science Museum's web site at http://www.smm.org/bigbackyard/.

Appendix 5: Partners Meeting

February 2005 NCED Stream Restoration Partners Group Meeting - Advance Agenda
St. Anthony Falls Laboratory, Third Avenue SE at Mississippi River, Minneapolis (612-624-4606)

Wd 2/23	7:00 PM	Dinner Sawatdee Restaurant 607 Washington Avenue South
Th 2/24	8:30 - 9:00	Introductions, Overview
		Paola, Campbell, Wilcock
	9 - 10:30	I. Restoration State of the Art
		Downs, Fischenich, Jacobson
		Discussion
		What are the knowledge gaps hindering effective restoration practice? *How can restoration successes and failures be used more effectively to inform research, method development, and training?*
	10:30 - 11	Break
	11 -12:30	II. Restoration Research
		Kondolf , Sklar, Marr
		Discussion
		To what questions would research be most fruitfully directed? *Should restoration research be coordinated?*
	12:30-1:30	Box Lunch
	1:30 - 3:00	III. Restoration Methods & Models
		Randall, Shields, Parker
		Discussion
		What new or revised methods (models, techniques, tools) are most needed? *What knowledge is needed to use methods reliably?* *How are methods and models best disseminated?*
	3 - 3:30	Break
	3:30 - 5:15	IV. Restoration Training
		Rosgen, Voller, Kite, Castro, Fripp, Jonas, Fogg, Schmidt
		Discussion
		What training is needed to design and implement stream restoration? *Do different restoration activities require different levels of training?* *Should restoration training be coordinated?*
	5:15 - 6:30	Lab tour, refreshments, more discussion
		Mohseni: lab overview & introduction of proposed SAFL outdoor bioengineering lab

	7:00 on	Dinner at the hotel, more discussion *Courtyard by Marriott (The Depot)*, 225 3rd Avenue S, Minneapolis
Fr 2/25	8:30 – 9:00	Va. Restoration objectives, values, tradeoffs, decision-making I *Flores, Hobbs: introduction of questionnaire* *What are the social drivers of restoration? The objectives and desired results? How to most effectively evaluate tradeoffs? How to best incorporate science and engineering, including estimates of uncertainty, into restoration decision-making?*
	9:00 – 10:00	VIa. Open Discussion: Prospects for joint efforts *Should research, method development, training be coordinated? Interest in joint monitoring and research. Role & content of web site.*
	10 - 10:30	Break
	10:30-11:30	Vb. Restoration objectives, values, tradeoffs, decision-making II *Flores, Hobbs: Discussion of questionnaire*
	11:30-12:30	VIb.Open Discussion: Partners Group directions. How can NCED help?
	12:30 on	Box Lunch & Departures

Meeting Attendees

Name	Affiliation
Baird, Drew	Sedimentation and River Hydraulics Group, U.S. Bureau of Reclamation Technical Service Center
Bernard, Jerry	USDA-Natural Resources Conservation Service
Buffington, John	USDA Forest Service
Castro, Janine	US Fish and Wildlife Service
Cambell, Karen	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Cluer, Brain	NOAA Fisheries
Dalbotten, Diana	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Davenport, Thomas	US Environmental Protection Agency
Downs, Peter	Stillwater Sciences
Fischenich, Craig	ERDC Environmental Laboratory
Flores, Nicholas H	Institute of Behavioral Science, Economics, University of Colorado, Boulder
Fogg, Jim	Bureau of Land Management
Fotherby, Lisa	Sedimentation and River Hydraulics Group. U.S. Bureau of Reclamation Technical Service Center
Foufoula, Efi	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Fripp, Jon	NRCS - NDCSMC

Gray, John	US Geological Survey, Office of Surface Water
Hobbs, Benjamin	Department of Geography & Environmental Engineering, Whiting School of Engineering, The Johns Hopkins University
Jackson, Bill	Water Resource Division, National Park Service
Jacobson, Robb	US Geological Survey - CERC
Jonas, Meg	US Army Corps of Engineers
Kelberer, Michael	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Kite, Steve	Department of Geology & Geography, West Virginia University
Kondolf, Matt	Department of Landscape Architecture and Environmental Engineering, University of California
Marr, Jeff	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Mohseni, Omid	St. Anthony Falls Laboratory, University of Minnesota
Orr, Bruce	Stillwater Sciences
Paola, Chris	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Parker, Gary	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Potyondy, John	Stream Systems Technology Center, USDA, Forest Service, Rocky Mountain Research Station
Power, Mary	Department of Integrative Biology, University of California, Berkeley
Pranger, Hal	National Park Service, Natural Resources Program Center, Geologic Resources Division
Randle, Tim	Sedimentation and River Hydraulics Group, U.S. Bureau of Reclamation Technical Service Center
Rosgen, Dave	Wildland Hydrology
Schmidt, Jack	Department of Aquatic, Watershed, and Earth Resources, College of Natural Resources, Utah State University
Shields, Doug	National Sedimentation Laboratory, Agricultural Research Service, United States Department of Agriculture
Soileau, Rebecca	St. Paul District, Corps of Engineers
Sklar, Leonard	Department of Geosciences, San Francisco State University
Storfer, Rochelle	National Center for Earth-surface Dynamics, University of Minnesota
Striz, Elise	EPA National Risk Management Research Laboratory Ground Water and Ecosystems Restoration Division
Temple, Alan	USFWS-National Conservation Training Center
Voller, Vaughan	National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota

Appendix 6: Activity Tables

Education Activity Tables

Internal Education Activities

Undergraduate Education			
Intended Audience	Undergraduates and NCED and other institutions		
Date	Location	Led by	Attendees
Nov. 2004	Austin, TX	Mohrig	UT Austin students and faculty
Boyd Distinguished Lectureship in Geological Sciences, Jackson School of Geosciences, University of Texas, Austin			
Feb. 2005	New Orleans, LA	Mohrig	Tulane students and faculty
Invited Speaker, Departmental Lecture Series, Department of Earth and Environmental Sciences, Tulane University			
Winter term 2004/5	Princeton	Rodríguez-Iturbe	Princeton University students
Full course in Ecohydrology, CEE/ENV 505, taught at Princeton University using NCED funded research.			
January 200	Urbana, Illinois	Wilkerson	University of Illinois students
Invited presentation, University of Illinois, Urbana-Champaign, “Flow through trapezoidal channel with rigid cylinders.”			
Spring 2005	U of M	Paola	U of M first year students
Paola developed and taught Freshman Seminar, “The Skin of the Earth”, based on natural and human influences on surface dynamics			
2004/5	U of M	Foufoula	U of M undergraduates
Undergraduate students from the “Hydrology and Hydrologic Design” course were recruited to perform undergraduate research related to NCED: Christina Omdahl working on designing Stream Restoration Masters program with Vaughan Voller and Carl Peterson who will work with Foufoula as an MSI summer intern			
2004/5	UofM	Finlay	U of M students
Guest lecture on Watershed Ecology in Landscape Ecology (UMN, LA5204)			
Spring 2005	Uof M	Foufoula	U of M undergraduates
One lecture in the undergraduate “Hydrology and Hydrologic Design” course to introduce 60 students to the complex problems encountered in observation and modeling of the land-atmosphere, land-water interactions. Introduction to the scope of NCED and its research and practical activities given.			
Summer 2004	Wyoming	Wilkerson	2 undergraduates

Served as research advisor for two female undergraduate students. In addition to writing NCED-related papers, each participated in an undergraduate research symposium sponsored by the University of Minnesota, and attended a professional conference organized by the American Society of Civil Engineers.			
March 7 – 9, 2005	Colorado	Parker	Students at Colorado State University
Gave an invited presentation on drainage basin formation at the Hydrology Days Symposium, Colorado State University.			

Graduate Education			
Intended Audience	NCED Graduate students		
Date	Location	Led by	Attendees
Spring 2004	St. Paul, MN	Patrick Hamliton	Nikki Strong, Michal Tal, SMM youth, staff and volunteers
Tal and Strong server as Graduate Museum Assistants at the SMM, focusing on developing interpretive materials and activities for the BBY.			
July 29, 2004	U of M	Tom Hickson, Karen Campbell, Nikki Strong, Jeff Marr, Juan Jose Fedele	15 graduate students in geology from around the US: Reuben Heine, Nick Lang, Dawn Cardace, Isla Castenada, Eric Roberts, Greta Bjork Krisjansdotter, Ziya Cetiner, Mark Sweeney, Brent Dalzell, Jody Webster, Dorthea Panayoutou
NCED sponsors and hosts "add-on" workshop, "Using Physical Models in Sedimentology, Stratigraphy, and Geomorphology courses" as part of NAGT/NSF sponsored "Preparing for an Academic Career" workshop.			
Summer 2004	Potenza, Italy	Rodríguez-Iturbe	Students at Universita di Basilicata
Short course in Universita di Basilicata-Potenza,Italy- in geomorpho-ecohydrology.			
Summer 2004	Venice, Italy	Rodríguez-Iturbe	
International Workshop in Venice promoted by the Istituto Veneto di Scienze, Letter ed Arti. Lectures to postdocs and graduate students from different countries-including USA- on geomorphohydrology and ecohydrology.			
October 2004	Cloquet, MN	Wes Lauer	NCED graduate students and post-docs
NCED graduate students attend PI retreat, present current research to one another, present a poster session to all PI retreat attendees and youth from *gidakiimanaaniwigamig* Environmental Camp, and form Graduate Student Council			
ongoing	All sites	Wes Lauer, Leslie Hsu, Doug Jerolmack	All NCED graduate students
NCED graduate students agree on agenda for GSC and carry those out: election of officers, request for travel funds, equipment inventory, e-mail list.			

Ongoing	SAFL	Paola and Parker	NCED Stratigraphic Partners
NCED graduate student John Martin, Ben Sheets, and Wonsuck Kim organize portions of Short Courses and Annual Meeting, maintain private website, conduct experiments for NCED Stratigraphic Partners			
ongoing	All sites	Wes Lauer	All NCED weekly videoconference viewers
NCED graduate students Chatanantavet, Jerolmack, Lauer, Tal and Suttle give weekly video-seminar. (additional students volunteered after the slots had filled).			
August 2004	SAFL	Paola	Nova TV viewers
Paola and NCED post-doc Juan Jose Fedele co-lead SAFL Nova/Mentorn TV episode on Cataclysmic Floods, Sept 2004 (with Vic Baker, University of Arizona).			
January 2005	Jackson, Mississippi	Nikki Strong	Small oil exploration companies
Strong invited to teach sequence stratigraphy course, Experimental Stratigraphy; Stratal Geometries Associated with Sequences: Delineating Sequence Boundaries, to members of the not-for-profit Petroleum Technology Transfer Council			
January 2005	Denver	Michal Tal	Employees of Sedimentation and River Hydraulics Group. U.S. Bureau of Reclamation Technical Service Center
Tal invited presentation on vegetation and channel morphology to sedimentation and river hydraulics group			
February 23-5 2005	SAFL	Campbell	Michal Tal, Wes Lauer
NCED graduate students involved in stream restoration actively participate in NCED Stream Restoration Partners Group meeting			
March 2005	Torrey, Utah	Parker	Lauer
Graduate student Lauer uses GSC travel funds to attend NCED National Workshop on Sediment Remobilization in Active and Abandoned Reservoirs in Torrey, Utah			
Ongoing	SAFL, Berkeley	Marr	Tal, Lauer, Hsu, Braudrick
NCED graduate students participate in research video conferences of NCED Stream Restoration Group			
Summer 2004, Fall 2004	St. Paul and St. Peter, Minnesota	Tal	Undergraduate students at the University of St. Thomas and Gustavus Adolphus College
NCED Graduate Student Michal Tal serves as an undergraduate instructor teaching introductory geology and geomorphology. Incorporates NCED concepts and research in curriculum, including developing an undergraduate laboratory experience in the BBY.			
Fall 2004, Spring 2005	St. Paul, MN	Strong	Undergraduate students at Metro State University
Strong teaches geology classes at a community college, incorporating NCED research and concepts.			

Fall 2004	U of M	Paola, Hondzo	Graduate students at the University of Minnesota
University of Minnesota submits NSF Integrative Graduate Education and Research Traineeship (IGERT) grant.			
March 20 – 21, 2005	Houston, Texas	Parker and Lauer	Workshop attendees
presented at an NSF Source-to-Sink workshop			
November 5, 2004	Michigan	Parker	University of Michigan students and faculty
An invited seminar on reservoir sedimentation at the University of Michigan.			
August 14 – 15, 2004	Stony Brook, New York	Parker and Lauer	Workshop attendees
Presented at an NSF Source-to-Sink workshop			
June 27 – July 2, 2004	Salt Lake City, Utah	Parker, Lauer, Wong and Cantelli	Conference attendees
Presentations at the ASCE EWRI Conference			

Weekly Research Seminar		
Intended Audience	U of M NCED graduate students and researchers	
Date	Presenter & Affiliation	Subject
Sept 15, 2004	Victor Koren, Lead Scientist, Office of Hydrology, National Weather Service, Silver Springs, Maryland.	From Lumped to Distributed Modeling in the Hydrological Prediction: Combining Physically-based and Conceches
Sept. 22, 2004	Kelly MacGregor, Professor, Macalester College	A Tale of Two Rivers
Nov. 3, 2004	Blair Greimann, U.S. Dept. of the Interior Bureau of Reclamation	Two-phase Flow Analysis of Suspended Sediment Transport
Dec. 1, 2004	Dr. Tim Demko, Professor, University of Minnesota, Duluth	Identifying Regional-scale Sequence Boundaries in Continental Strata

Dec. 8, 2004	Alessandro Cantelli, NCED Post-doctoral fellow	Erosional Narrowing after Dam Removal: Theory and Numerical Model
Feb 23, 2005	Thanos Papanicolaou, Associate Professor, IIHR - Hydroscience & Engineering	Recent Developments in the Area of Sediment Transport and Aspects of Aggregative Fluidization in Estuarine Environments
March 9, 2005	Janok Bhattacharya, University of Texas at Dallas	Hyperpycnal versus Hypopycnal River Plumes in the Cretaceous and the Origin of Shelf Mud
March 17, 2005	Simona Francalanci, Florence, Italy	Effect of Non-Hydrostatic Pressure Distributions on Sediment Transport
March 23, 2005	Lisa Tilman, Graduate Student, St. Anthony Falls Laboratory, University of Minnesota	Scaling Relationships of Braided River Channels
April 1, 2005	Emily Zedler, Stanford University and Gary Parker, St. Anthony Falls Laboratory	Large Eddy Simulation: Unearths Small-Scale Sediment Transport Patterns? and Cyclic Steps: A Universal Bedform of Froude-Supercritical Flow in Rivers and Turbidity Currents Flowing over Erodible Beds
April 13, 2005	Helene Muller-Landau, Asst. Prof., Dept. of Ecology, Evolution, and Behavior, U of MN	Spatial Dynamics of Plant Species and their Specialized Natural Enemies
April 20, 2005	Chris Paola, St. Anthony Falls Laboratory	The National Center for Earth-surface Dynamics: Earth, Water, Life, and SAFL
April 27, 2005	Gary Parker, St. Anthony Falls Laboratory, U of MN	Sustained Turbidity Current Generated by Slow Failure of a Vertical Subaqueous Face Due to Breaching: Similarity Solution and Prospects for Self-Acceleration

Weekly NCED Videoconference		
Intended Audience	NCED Graduate students and researchers	
Date	Presenter/Affiliation (* indicates student presenter)	Subject
October 12, 2004	Patricia Saco The University of Newcastle	Flow Dynamics in Large River Basins: Self-Similar Network Structure and Scale Effects

October 19, 2004	Gary Parker	The Gravel River Bankfull Channel Estimator
October 26, 2004	Mary Power	Towards Mapping and Forecasting Regime Changes Down Watersheds
November 02, 2004	Blair Greimann, U.S. Bureau of Reclamation Technical Service Center, Sedimentation and River Hydraulics Group, Denver, Colorado	Sediment Movement after Dam Removal
November 16, 2004	Jianhong-Jennifer Ren Department of Environmental and Civil Engineering, Texas A&M University - Kingsville	Transport of Colloids and Sorbing Contaminants between Streams and Streambeds
November 30, 2004	Chris Paola and Vaughan Voller	A Generalized Exner Equation
November 23, 2004	Chris Paola	NCED Renewal Plan
Decmber 7, 2004	Praveen Kumar	Tools for Data-driven Discovery From Very Large Datasets
February 01, 2005	Bill Dietrich	Angelo Story Revisited
February 08, 2005	Vaughan Voller	Geometry and Heat Transfer Models of Shoreline Movements
February 15, 2005	Doug Jerolmack*	A Unified Model for Subaqueous Bedform Dynamics
February 22, 2005	David Mohrig	Niobrara River as a Depositional Site
March 01, 2005	Boyko Dodov	Floodplain Morphology Analysis from 1m Angelo DEM: A Preliminary Result
March 08, 2005	Peter Wilcock	Stream Restoration Partners Meeting Report
March 22, 2005	Diana Dalbotten/Holly Pellerin	NCED's *gidakiimanaaniwigamig* Environmental Camp: Future Planning
March 29, 2005	Phairot Chatanantavet*	Bedrock Incision by Plucking
April 05, 2005	Wes Lauer*	Predicting the Residence Time for Fine Sediment in the Floodplains of Meandering Rivers
April 12, 2005	Blake Suttle*	Community-level Responses to Changing Rainfall Patterns in a Northern California Grassland

April 19, 2005	Michal Tal*	Coupling Sediment Transport and Channel Morphology in Response to Vegetation Forcing in a Laboratory Channel
April 26, 2005	Nick Flores and Ben Hobbs	NCED's Social Science Program

External Education Activities

E-STREAM			
Intended Audience	Middle to High School Earth Science teachers		
Date	Location	Led by	Attendees
Summer 2004	SAFL and Cloquet, MN	Campbell, Dalbotten, Marr	Rachel Breckenridge, Leslie Hoffman, Pat Kohlen
Fond du Lac Ojibwe School teachers serve as ESTREAM interns; developing build it yourself stream tables and NCED related activities for the stream tables, demonstrating these at the Earthscapes Teacher Institute and testing them at *gidakiimanaanawigamig* camps			
September 2004	Randolph, MN	Campbell, Kelberer	160 middle school youth
Campbell and Kelberer test stream tables and activities with school children at Project Wet event at Maltby Nature Preserve.			
Summer 2004-	SAFL, Uof M	Campbell, Morin	Baumtrog, Friesen, Kirkby, Murphy
Baumtrog and Friesen serve as Graduate Assistants, developing and testing ESTREAM activities, 3D maps and supporting materials, assisting in and presenting NCED—U of M—College of St. Catherine collaborative research on the effectiveness of 3D maps and visualizations in K-12 and undergraduate classrooms			
Summer 2004	SAFL	Campbell, Murphy	Baumtrog, Friesen, Kirkby, Morin, Murphy
Workshops in the use and interpretation of 3D paper maps of Earth's surface for K-12 teachers conducted at SAFL/NCED for teachers involved in collaborative study. Materials developed for workshops posted on NCED website.			
November 2004	Denver, CO	Ben Freisen	Geological Society of America annual meeting attendees
Friesen presents poster on NCED 3D maps at Geological Society of America meeting and participates in promotion of North Central section meeting and associated distribution/explanation of Morin visualization poster			
December 2004	San Franscisco, CA	Jill Baumtrog	American Geophysical Union annual meeting attendees
Baumtrog presents poster on NCEDs ESTREAM and Earthscapes programs at AGU annual meeting			
ongoing	SAFL	Campbell, Baumtrog, Friesen	Attendees of local and regional professional education and teachers' association meetings

Baumtrog and/or Friesen prepare and submit abstracts to or staff NCED promotional tables at annual meetings of Minnesota Earth Science Teachers Association, Minnesota Environmental Educators Association, Minnesota Science Teachers Association (joint with North Dakota), and North-Central Section, Geological Society of America
2004 NCED / UMN / CSC map workshop participants

Science Museum of Minnesota Big Backyard			
Date	Location	Led by	Attendees
Intended Audience	General public, teachers and students		
May 2004	St. Paul, MN	Hamilton, Marr, Roe, Campbell, Paola	various
Final exhibit and signage design, construction and installation; Paola Lead research PI in launch of SMM BBY Earthscapes components			
June 2004	St. Paul, MN	Hamilton, Campbell	various
Opening activities: June 19-20: soft opening; June 24 Donor Event, June 26: public opening			
August 2004	St. Paul, MN	Campbell, Halker	K-12 teachers
Week 2 of Earthscapes Teacher Institute held in BBY; teachers meet each day in Science House, explore the Park and the museum			
August 2004	St. Paul, MN	Hamilton, McEathron	Museum visitors
McEathron designs and coordinates summative evaluation of the Park			
Winter 2004/5	St. Paul, MN	Hamilton, Marr	
Design and construction of landscape evolution and turbidity current models completed.			
Winter 2004	St. Paul, MN	Hamilton, Morin, Campbell	various
Discussions of indoor extensions of BBY concepts and use of SMM space for undergraduate education			
Winter 2004	St. Paul, MN	Hamilton, Campbell	
Fossiliferous limestone display and signage planned			
Winter 2004	St. Paul, MN	Hamilton, Morin	
Additional 3D map features (laminates for sidewalks, Mississippi River channel evolution for Science House) designed and produced for summer 2005 installation			

Earthscapes Teacher Institute			
Intended Audience	Middle to High School teachers, primarily Science teachers		
Date	Location	Led by	Attendees
Spring-to summer 2004	SAFL, SMM, Randolph and Cloquet, MN	Campbell	Campbell, Lee Schmidt, Dawn Cameron, Nils Halker, Sil Pembleton, Michael Kelberer, Courtney Kowalzick, Carrie Jennings

Planning meetings and site investigations for institute			
August 2-13, 2004	SAFL, SMM, Randolph and Cloquet, MN	Campbell, Halker, Pembleton	11 ETI teachers See list of participants below
Inaugural ETI conducted			
August 2004	SAFL	Campbell	
Action plans and field books graded for those who wished graduate credit			
September, 2004--	various		
ETI teachers carry out action plans. A particularly ambitious set of classes is conducted in collaboration with the Maltby Preserve.			
February 12, 2005	SMM	Campbell, Halker, McEathron	7 ETI teachers
Follow up workshop: presentation by David Wiggins, National Park Service, on social and cultural history of Mississippi River in Twin Cites area, viewing of Mars 3D movie and focus group on NCED 3D movie possibilities, presentation of action plan results			
Spring 2005	SAF	Campbell, Morin	Mark Ryan
Planning for Mark Ryan, 2004 ETI teacher, to participate in 2005 ESTREAM program, focusing in developing 3D activities			

Earthscapes School Contact Program			
Intended Audience	Middle School Earth-science students		
Date	Location	Led by	Attendees
Summer 2004	SAFL/SMM	Larry Thomas, Sue Meyer, Karen Campbell	Chris Bromley, Jeff Marr, Ben Friesen, Paul Morin
Planning meetings for ESR; development of scale model prototype, maps, activities and slide shows			
August 2-13, 2004	SMM	Sue Meyer, Larry Thomas, Joel Halverson	11 ETI teachers See list of teachers in ETI section
ESR and Assembly prototypes presented to ETI teachers			
Fall-winter 2004/5	St. Paul, MN	Larry Thomas	
Nine copies of the scaled "Bromley flume" fabricated professionally. Travis Sandland, recent Stanford geology Master's level graduate, hired to further develop and deliver ESR.			
February 12, 2005	SMM	Campbell, Halker, Sandland	7 ETI teachers
At ETI followup workshop, Sandland presents fully developed model and activities to 2004 ETI teachers			
March 2005	Minneapolis	Campbell, Friesen, Sandland	Paola, others
SAFL acquires one full "Bromley flume" set-up for use in school visits and undergraduate classes. Paola, Friesen, others, test			

Spring 2005	various	Sandland	ETI teacher's schools, Ojibwe schools
Sandland begins bringing full ESR to shools			

External K-12 and public education activities			
Intended Audience	K-12 students and/or teachers; members of the general public		
Date	Location	Led by	Attendees
2004/5	Berkeley, CA	Banfield	
Banfield participates in a collaboration with the Lawrence Hall of Science to develop K-12 teaching materials with a geomicrobiology theme.			
2005	Minneapolis, MN	Dalbotten	K-12 students nationally
Finlay, Banfield, Foufoula, Parker, Strong, and Voller serve as science experts for Bell Museum's JASON project for K-12 outreach			
March 2005	SAFL	Marr	Marr, Gordon Grant, Karen Campbell, Michal Tal
Design exhibits, interactive including experimental research flume, to used to explain to the public the role of river research in the U.S. Forest Service at the Smithsonian Folk Life Festival in Washington, D.C., summer 2005—up to 1 million visitors expected.			

Knowledge Transfer Activity Tables

NCED Partners Meeting on Stream Restoration	
Led by	Karen Campbell, Peter Wilcock
Location/Date	Minneapolis, February 23-25, 2005
	Attendee Name , Affiliation
1	Drew Baird, Sedimentation and River Hydraulics Group, U.S. Bureau of Reclamation Technical Service Center
2	Jerry Bernard, USDA-Natural Resources Conservation Service
3	John Buffington, USDA Forest Service
4	Alessandro Cantelli, Post-doc, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
5	Janine Castro, US Fish and Wildlife Service
6	Karen Campbell, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota

7	Brian Cluer, NOAA Fisheries
8	Diana Dalbotten, National Center for Earth-surface Dynamics, St. Anthony Falls Labortaory, University of Minnesota
9	Thomas Davenport, US Environmental Protection Agency
10	Peter Downs, Stillwater Sciences
11	Michael Ellis, Center for Earthquake Research and Information, The University of Memphis
12	Craig Fischenich, ERDC Environmental Laboratory
13	Nicholas H Flores, Institute of Behavioral Science, Economics, University of Colorado, Boulder (NCED)
14	Jim Fogg, Bureau of Land Management
15	Lisa Fotherby, Sedimentation and River Hydraulics Group. U.S. Bureau of Reclamation Technical Service Center
16	Efi Foufoula, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
17	Jon Fripp, NRCS - NDCSMC
18	John Gray, US Geological Survey, Office of Surface Water
19	Benjamin Hobbs, Department of Geography & Environmental Engineering, Whiting School of Engineering, The Johns Hopkins University (NCED)
20	Bill Jackson, Water Resource Division, National Park Service
21	Robb Jacobson, US Geological Survey - CERC
22	Meg Jonas, US Army Corps of Engineers
23	Michael Kelberer, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
24	Steve Kite, Department of Geology & Geography, West Virginia University

25	Matt Kondolf, Department of Landscape Architecture and Environmental Engineering, University of California
26	Wes Lauer, Grad Student, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
27	Jeff Marr, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
28	Omid Mohseni, St. Anthony Falls Laboratory, University of Minnesota
29	Bruce Orr, Stillwater Sciences
30	Chris Paola, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
31	Gary Parker, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
32	John Potyondy, Stream Systems Technology Center, USDA, Forest Service, Rocky Mountain Research Station
33	Mary Power, Department of Integrative Biology, University of California, Berkeley (NCED)
34	Hal Pranger, National Park Service, Natural Resources Program Center, Geologic Resources Division
35	Tim Randle, Sedimentation and River Hydraulics Group, U.S. Bureau of Reclamation Technical Service Center
36	Dave Rosgen, Wildland Hydrology
37	Jack Schmidt, Department of Aquatic, Watershed, and Earth Resources, College of Natural Resources, Utah State University
38	Doug Shields, National Sedimentation Laboratory, Agricultural Research Service, United States Department of Agriculture
39	Rebecca Soileau, St. Paul District, Corps of Engineers
40	Leonard Sklar, Department of Geosciences, San Francisco State University
41	Elise Striz, EPA National Risk Management Research Laboratory Ground Water and Ecosystems Restoration Division

42	Michal Tal, Grad Student, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
43	Alan Temple, USFWS-National Conservation Training Center
44	Vaughan Voller, National Center for Earth-surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
45	Peter Wilcock, Department of Geography & Environmental Engineering, Johns Hopkins University (NCED)
46	Greg Wilkerson, Department of Civil & Architectural Engineering, University of Wyoming (NCED)

Stratigraphic Partners Short Courses	
Description	Deep Water
Led by	Alessandro Cantelli, Gary Parker, Jeff Marr, Sara Johnson
Date(s)	April 14-15, 2005
Organizations Involved	
ExxonMobil	

Stratigraphic Partners Shortcourses		
Description	Shallow Water	
Led by	John Martin, Chris Paola	
Date(s)	May 4, 5, 6, 2005	
Organizations Involved		
ExxonMobil		

Annual Stratigraphic Partners Meeting	
Led by	John Martin
Date(s)	August 26-27, 2004
Organizations Involved	
Anadarko Petroleum Company	
ChevronTexaco	
ConocoPhillips	
ExxonMobil Upstream Research Company	
Japan Oil, Gas, and Metals Company	

Stratigraphic Partners Joint Experiment	
Description	Effect of coupled variation of base level water and sediment supply on valley evolution and stratal fill
Led by	John Martin and Martin Perlmutter
Date(s)	March 22-26, 2005
Martin and Perlmutter design and run experiment; Perlmutter gives seminar to NCED geology graduate students and Paola	

Visitors Program		
Intended Audience	Research community outside NCED PIs	
Visitor	Affiliation	Research Topic
**indicates visitors selected in Year 3 whose research will take place primarily in Year 4		
Peter Wilcock, PI Paul Grams, Graduate Student	Department of Geography and Environmental Engineering, The Johns Hopkins University	Research title: Sand routing over a coarse immobile streambed.
T. Tietjen, PI Ted Melis and Scott Wright	Northern Arizona University, Colorado Plateau Cooperative Ecosystem Studies Unit USGS, Grand Canyon Monitoring and Research Center	Research title: Acoustic monitoring of particulate organic carbon transport and suspended sediment transport.
Chris Bromley	Oregon State University	Research title: Laboratory investigation of the variables that control the rate and volume of sediment movement through and out of impoundments during dam removal.
Eugene Rankey, PI** Briggitte Vlaswinkel, Graduate Student	University of Miami	Quantification of spatio-temporal patterns of tidal creek networks.
Emmanuel Gabet, PI**	University of Montana	Sediment supply controls on channel roughness and flushing of sediment pulses
Jennifer Duan, PI**	Desert Research Institute	Experimental study of bed load sediment sorting around spur dikes

Digital Visualization			
Intended Audience	Educators, Researchers, Partners		
Date	Location	Led by	Attendees
May 2004--	SAFL	Morin and Hondzo	
Develop algorithm to derive primary productivity from topographic data and geographic coordinates; develop visualizations to communicate this to researchers at ACRR.			
July 2004	SAFL	Morin, Dalbotten, Friesen	Attendees of *gidakiimanaanawigamig* and ANAMS camps
3D maps prepared for use in *gidakiimanaanawigamig* and ANAMS camps			
July 2004	SAFL	Morin, Campbell, Friesen	Attendees of ETI
3D maps prepared for use in ETI and by teachers in their classrooms subsequently			
July-August 2004	SAFL	Morin, Campbell, Murphy, Friesen, Kirkby	Minnesota K-12 teachers
Workshops held for teachers participating in ongoing study, led by Murphy, of effectiveness of 3D maps in K-12 classroom			
August 2004–March 2005	SAFL/SMM	Morin, Campbell, Bromley, Friesen, Baumtrog, SMM staff Thomas, Meyer and Sandland	Students in ESR program
3D maps and associated activities related to Elwha River Glines Canyon Dam model study developed and produced			
ongoing	SAFL/SMM	Morin, Hamilton	SMM visitors
Continued development of 3D maps for installation in the BBY and sale to the public			
ongoing	SAFL/SMM	Morin, Hamilton, Campbell	SMM visitors
Summer 2005 pilot of use of Geowall in SMM developed			
November 2004	SAFL	Morin, Campbell, Murphy	All NCED education participants
Joint proposal for additional funding of 3D map efficacy study submitted to NSF			
November 2004	Denver, CO	Morin, Campbell, Kirkby, Freisen, Jim Roe	Attendees, Geological Society of America Annual Meeting
Posters and talks presented on use of 3D maps in classrooms, laboratories and the BBY. Morin visualization of Upper Midwest-Great Lakes region, developed to promote 2005 Annual meeting, North Central Section, GSA, presented and distributed to attendees			
November 2004	Biloxi, MI	Murphy	Attendees, National Association of Environmental Educators Annual Meeting
Talks presented on use of 3D maps in K-12 classrooms			

December 2004	San Francisco	Morin, Campbell, Kirkby, Baumtrog, Hamilton	Attendees, Annual meeting of American Geophysical Union
Posters and talks presented on use of 3D maps in classrooms, laboratories and the BBY			
February 2005	SAFL	Morin, Campbell, Kirkby, Baumtrog, Murphy, Sandland	Attendees of North Central Section, Geological Society of America Annual meeting
Abstracts submitted (and accepted, March 2005) for 10 talks/posters related to NCED visualization in research and eduation			
February 2005	Washington, DC	Morin	Readers of the New York Times
Following Morin talk at Annual Meeting, American Association for the Advancement of Science, Morin's visualization work is feature in the Tech Section of the New York Times, March 3, 2005			
April 2005	Finland, MN	Campbell, Murphy	Attendees at Minnesota Association of Environmental Educators annual meeting
Talks presented on use of 3D maps in classrooms			

Working Group: Novel methods for modeling the surface evolution of geomorphic interfaces		
Led by	David Mohrig, Vaughan Voller	
Location, Date(s)	MIT, May 22-May 25, 2004	
	Attendee Name , Affiliation	Talk Title
1.	Jon Pelletier Department of Geosciences, University of Arizona	Examples of Moving Boundary Problems In Earth Science
2.	Chris Paola Department of Geology and Geophysics, National Center for Earth-surface Dynamics, University of Minnesota	Turbulent Landscapes
3.	Hans J. Herrmann Institute for Computational Physics, University of Stuttgart	A Model of Aeolin Barchan Dunes
4.	David Cocks Mathematics Institute, University of Oxford	A Mathematical Analysis of Sand Dune Models
5.	David Mohrig (NCED PI) Department of Earth, Atmospheric and Planetary Sciences, MIT	Approaches for Analysis of Field Data of Sub-Aqueous Bedforms
6.	H S Udaykumar Mechanical Engineering, University of Iowa	Advanced Level Set Methods for the Fixed Grid Tracking of Interfaces

7.	Vaughan Voller (NCED PI) Dept. of Civil Engineering, University of Minnesota	Phase Change and Ocean Fronts
8.	John Swenson University of Minnesota, Duluth, Geological Sciences and Large Lakes Observatory	A Micro-Macro Model of Delta Formation in Shorelines
9.	Gary Parker (NCED PI) Dept. of Civil Engineering, University of Minnesota	Sand-Gravel Transitions and other Moving Boundaries in River Networks
10.	Nikolas Provatas Materials Science and Engineering, McMaster University	Development and Application of Phase Field Models in Materials Science
11.	Efi Foufoula-Georgiou (NCED PI) Dept. of Civil Engineering, University of Minnesota	Scaling of Braided Rivers
12.	Gretar Tryggvason Mechanical Engineering, WPI	Multiphase Flow Simulations
13.	Andrew Fowler Mathematical Institute, University of Oxford	A Mathematical Model for the Formation of River Networks
14.	Colin Stark Lamont-Doherty Earth Observatory, Columbia University	A "Toy" Model to Uncover the True Scaling of Landslides
15.	Nigel Goldenfeld Department of Physics, University of Illinois	Modeling of Geomorphologic Shapes and Structures

Workshop: National Workshop on Sediment Remobilization and Channel Morphodynamics in Active and Abandoned Reservoirs		
Led by	Gary Parker	
Location, Date(s)	Torrey, Utah, March 25-27, 2005	
	Attendee Name , Affiliation	Talk Title
1.	Stuart Beck R2 Resources	Private sector needs
2.	Chris Bromley University of Nottingham, UK	Laboratory experiments
3.	Alessandro Cantelli National Center for Earth-surface Dynamics, University of Minnesota	
4.	Yantao Cui Stillwater Sciences	Numerical modeling

5.	Diana Dalbotten National Center for Earth-surface Dynamics, University of Minnesota	
6.	Bill Dietrich (NCED PI) University of California, Berkeley	
7.	John Dohernwend Southwest Satellite Imaging	Lake Powell; history and overview of field trip
8.	Martin Doyle Univeristy of North Carolina	Field monitoring and field experiments
9.	Jim Evans Utah State University, Logan	
10.	Blair Greimann U.S. Bureau of Reclamation	
11.	Rollin Hotchkiss Washington State University	
12.	Wes Lauer National Center for Earth-surface Dynamics, University of Minnesota	
13.	Tom Lisle USFS Redwood Sciences Laboratory	
14.	Jane Marks Northern Arizona University	
15.	Johnnie Moore University of Montana	Geochemical issues
16.	Gary Parker (NCED PI) Dept. of Civil Engineering, University of Minnesota	
17.	Jim Pizzuto University of Delaware	
18.	Mary Power (NCED PI) University of California, Berkeley	Biological and ecological implications
19.	Lincoln Pratson Duke University	Lake Powell: what's under the water
20.	Tim Randle U.S. Bureau of Reclamation	Government needs
21.	Jack Schmidt Utah State University, Logan	Implications for policy
22.	Leonard Sklar San Francisco State University	
23.	Greg Stewart Oregon State University	

24.	Vaughan Voller (NCED PI) Dept. of Civil Engineering, University of Minnesota	
25.	Peter Wilcock (NCED PI) Johns Hopkins University	
26.	Greg Wilkerson (NCED PI) University of Wyoming	
27.	Ellen Wohl Colorado State University	

Website and Data Archive			
Intended Audience	NCED internal and external community		
Date	Location	Led by	Attendees
2004	UofM	Kelberer	UrbanPlanet, Inc.
Entered into maintenance agreement with web site vendor to provide for quick response to routine maintenance requests, and for the creating and maintenance of a parallel "test" site to prove out new capabilities and layouts before implementing them on production system.			
2005	UofM	Nguyen	Kelberer, Campbell
Web log analysis system implemented to report on web site usage			
	UofM		UrbanPlanet, Inc.
Significantly improved website/archive capabilities			
	UofM	Kelberer	
Used new web-based archive system to archive and make accessible nearly 900 megabytes of research data			
	UofM	Kelberer	Campbell, Marr, Wilcock
Launched Stream Restoration portal			
	UofM	Kelberer	UrbanPlanet, Inc.
Added user registration system			

Individual Knowledge Transfer Activities			
Intended Audience	Practioners in industry, consulting, agencies and non-profits		
Date	Location	Led by	Attendees
April 2004	Dallas, TX	Mohrig	Conference attendees (note AAPG serves primarily the oil industry)
Technical session chair, 2004 AAPG/SEPM Annual Meeting, *Measuring and Modeling Sedimentary Bedforms*			
Ongoing	California	Power	

Member, Recovery Science Review Panel for NOAA-Fisheries: review National Marine Fisheries scientists work related to management and recovery of west coast salmonid populations, and publish with our group three reports a year			
ongoing	California	Power	TNC staff
Member, The Nature Conservancy-California Board: give advice to TNC staff about projects and attempt to enhance communication between TNC and university students and researchers.			
Ongoing	UofM	Foufoula	
A contract with the National Weather Service on implementing a Hydraulic-Geometry-based routing approach over large areas accounting for the channel and floodplain has led to knowledge transfer from academia to the federal agencies responsible for flood prediction over the U.S.			
August 2004	Napa County, CA	Dietrich	Napa County Watershed Information Center and Conservancy Board
Made presentation to the Napa County Watershed Information Center and Conservancy Board on LIDAR analysis of the Napa Watershed			
Ongoing	CA	Dietrich	Cal-Fed
Collaborating with Leonard Sklar (San Francisco State University and Stillwater Sciences) on a Cal-Fed funded project to do physical modeling relevant to stream restoration.			
Ongoing	Baltimore, MD	Wilcock	U.S. Forest Service
Development of guidance manual for estimating sediment transport (with John Pitlick, Yantao Cui), to accompany calculation software developed for the US Forest Service Stream Systems technology Center, Fort Collins, CO.			
October 2004		Wilcock	Agency professionals
One-week short course in stream restoration: "*Principles and Practice of Stream Restoration*" (co-teach with G. Mathias Kondolf):			
Ongoing		Wilcock	Agency professionals
Two-week short course on stream restoration, (i) "*Principles and Practice of Stream Restoration*", (ii) "*Geomorphology and Sediment Transport in Channel Design*", (co-teach with Jack Schmidt): August 2004, May 2005; develop sediment routing model to support restoration of sand bars in Grand Canyon			
ongoing	Baltimore, MD	Wilcock	Agency professionals
Develop one-week short course in stream restoration: "*Ecologic and Geomorphic Foundations of Stream Restoration*" (develop and co-teach with Margaret Palmer): July, 2005.			
June 2004	Baltimore, MD	Wilcock	ASCE attendees
American Society of Civil Engineers, Environment and Water Resources Institute Annual Congress, Salt Lake City, "*Sediment Transport in the Restoration of Gravel-bed Rivers*"			
January 2005	Baltimore, MD	Wilcock	
Public Lecture, "*Sediment transport in stream restoration design*", Baltimore Ecosystem Study, Symposium on Stream Restoration			
February 2005	Baltimore, MD	Wilcock	Maryland Dept. of Natural Resources
Public Lecture, "*Sediment transport in stream restoration design*", Maryland Dept. of Natural Resources			

Ongoing	Baltimore, MD	Wilcock	Maryland Dept. of Natural Resources
With Sean Smith (Maryland DNR): Development of sediment budgets for first order Piedmont watersheds.			
Aug 2004-April 2005	various	Wilcock	stream restoration practitioners:
Presentations and interviews with stream restoration practitioners: Biohabitats, Baltimore, MD (Jan. 2005), multiple companies, Louisville KY (April 2005) Allred Restoration, Provo UT (August 2004)			
ongoing	various	Parker	ExxonMobil and Shell Oil companies
Research on turbidity current morphodynamics in the deep sea is being done in cooperation with ExxonMobil and Shell Oil.			

Diversity Activity Table

Year 3 Activities			
Intended Audience	Underrepresented minorities and women		
Date	Location	Led by	Attendees
Summer 2005	UofM	Hondzo	Fernando Hernandez
Miki Hondzo supervises USIP student, Hernandez and Hondzo attend gidakiimanaaniwigamig summer camp to work with students on “Measuring Lake Temperatures” using sensor they developed.			
Summer 2005	UofM	Paola	Edith Moreno
Paola and Tal supervise USIP student			
Summer 2005	UofM	Porté-Agel	Angel Santiago
Porté-Agel supervises USIP student			
Summer 2005	UofM	Parker and Wong	Robert Haydel
Parker and Wong supervise USIP student			
Summer 2005	U of Wyoming	Wilkerson	Danielle Tripp, Kerri Puckett
Wilkerson supervises 2 USIP students; Tripp and Puckett visit SAFL, August 2004, to present their poster at MSROP poster session and at ASCE conference.			
July 2004	U of M	Dalbotten	Dean Colucci visit to U of MN
Dean Jose Colucci, University of Puerto Rico, Mayaguez, visits U of MN to discuss research collaborations with NCED and Civil Engineering; meets with IT Dean Crouch, CE Dept. Head John Gulliver; NCED Director Chris Paola.			
October 2004	Austin, Texas	Porté-Agel	Angel Santiago, Mark Bellcourt
Angel Santiago (undergrad intern advised by Porté-Agel) attended and presented poseter at SACNAS conference. Santiago staffed U of MN Grad School recruiting booth at conference.			

October 2004	San Juan, Puerto Rico,	Miki Hondzo	Dalbotten, Hondzo, Hernandez, Santiago
Diana Dalbotten, Miki Hondzo, Fernando Hernandez, Angel Santiago Perez, "Welcome to National Center for Earth-surface Dynamics," Presentation at the "Hispanics in Engineering National Conference", October 26-29, San Juan, Puerto Rico, 2004. Hondzo and Dalbotten visit University of Puerto Rico, Mayaguez and meet with heads of Depts. of Civil Engineering and Geology.			
October 2004	New Orleans, Louisiana	Gary Parker	Robert Haydel
Robert Haydel attends Annual LS-LAMP Student Research Conference and wins 2nd place award in Engineering			
November 2004	Anchorage, Alaska	Dalbotten	Bellcourt, Dalbotten, Pellerin, Greensky, Kohlin, Hoffman, Northrop
GC sponsored booth at American Indian Science and Engineering Society National Conference college fair. Holly Pellerin and Lowana Greensky attended and presented workshop with Gary Benenson, professor from CUNY. ESTREAMS teachers Pat Kohlin and Leslie Hoffman attended with AISES high-school math competition finalist Clint Northrop, a student from *gidakiimanaaniwigamig* camps.			
February 2005	Orlando, Florida	Vuruputur	Vuruputur
Venu Vuruputur, NCED Post-doc, represented NCED at booth at college fair at National Association of Black Physicists Conference			
May 2004	Kingsville, TX	Dalbotten	Ray Hozalski
Faculty-to-Faculty: NCED sponsors visit of Prof. Ray Hozalski, Civil Engineering, U of MN to Texas A&M University, Kingsville to meet with students and faculty and discuss NCED research			
November 2004	U of M	Dalbotten	Jianming Ren
Faculty-to-Faculty: NCED sponsors visit and seminar of Jianming Ren, Texas A&M University, Kingsville. Prof. Ren will be at SAFL as an NCED visiting researcher summer 2005.			
2005	U of M	Strong	Perla Cortes-Ruiz
Nikki strong mentors Hispanic undergraduate Perla Cortes-Ruiz, currently working at NCED			
2004/5	UofM	Paola	African American undergraduate
Paola supervises African American undergraduate in Physics in independent research			
2004/5	Berkeley	Power	Research Assistants
Power supervises two Native American high school graduates (both taking time off from community college) and one African American female undergraduate on independent research and technical field work at ACRR			
July 2004	FDLTCC	Wold	Pellerin, Greensky, Dalbotten, Hondzo, Hernandez
gidakiimanaaniwigamig Summer Camp. Theme: Food Webs; attended by 33 middle-school Native American students, 2 faculty mentors from U of MN and FDLTCC, 2 pre-service teachers, 6 teachers, 1 elder, 5 NCED staff, 4 others adult mentors			

October 2004	Laurentian Center	Wold	Pellerin, Greensky, Dalbotten,
gidakiimanaaniwigamig Fall Camp. Theme: Continental Divides, Watersheds, Drainage Networks; attended by 41 middle-school Native American students, 2 faculty mentors from U of MN and FDLTCC, 2 pre-service teachers, 6 teachers, 1 elder, 2 NCED staff, 8 others adult mentors			
October 2004	St. Croix Forestry Center	Pellerin	NCED PI's, Graduate Students, *gidakiimanaaniwigamig* teachers, staff and students
Students from the *gidakiimanaaniwigamig* program present their research posters to NCED PIs and Graduate students at the annual NCED retreat			
December 2004	San Francisco, CA	Dalbotten	Dalbotten, Steiner, Pellerin
Presented talk on *gidakiimanaaniwigamig* Program at American Geophysical Union annual national conference.			
January 2005	FDL Ojibwe School	Wold	Wold, Pellerin, Marr, Dalbotten, *gidakiimanaaniwigamig* students and teachers
Annual science fair at the Ojibwe School, Fond du Lac Reservation. 100 students participated; NCED staff participated as science fair judges			
January 2005	FDLTCC	Wold	Wold, Pellerin, Marr, Dalbotten, *gidakiimanaaniwigamig* students and teachers
First annual AISES regional science fair at Fond du Lac Tribal and Community College. 42 students participated. 12 students were chosen to represent *gidakiimanaaniwigamig* at the National American Indian Science and Engineering Fair in Albuquerque, NM.			
February 2005	Laurentian Center	Wold	Pellerin, Greensky, Dalbotten, Gary Benenson, CUNY
gidakiimanaaniwigamig Winter Camp. Theme: Hydrologic Cycle; attended by 27 middle-school Native American students, 2 pre-service teachers, 7 teachers, 1 elder, 4 NCED staff, 9 others adult mentors			
March 2005	Albuquerque, NM	Pellerin	Pellerin, teachers from Ojibwe school
12 students attended National American Indian Science and Engineering Fair, Albuquerque, NM. 7 students won medals, 3 were chosen to represent AISES at the Intel International Science Fair			
April 2005	SMM	Steiner	Pellerin, Bellcourt,
gidakiimanaaniwigamig students attend Native Americans in Science Day at Science Museum of Minnesota			
April 2005	SMM	Steiner	Pellerin, Dalbotten, Greensky
gidakiimanaaniwigamig Spring Camp. Theme: Technology; hosted by Youth Science Center, Science Museum of Minnesota			
April 2005	Pasadena, CA	Pellerin	Dalbotten, Greensky, Pellerin

Attended 4th Annual NSF Research Center Educator's Network Conference. Greensky and Pellerin gave featured dinner talk on Friday evening.			
February 2005	FDLTCC	Pellerin	Fred Norwood, Southwestern Indian Polytechnic Institute; Dalbotten
Fred Norwood, Southwestern Indian Polytechnic Institute, visits FDLTCC to discuss collaboration between NCED, Ithaca Community College, and FDLTCC to create Associate in Science Degree in Engineering to be established at FDLTCC			
Summer 2004	U of MN	Dalbotten	Youths from Division of Indian Works Youth Program, Minneapolis, MN
NCED collaborates with Division of Indian Works Youth Program to provide summer program, "Many Rivers," for K-6 Native American youths, who tour SAFL, Civil Engineering at U of MN, visit Bell Museum, and SMM.			
Summer 2004	SAFL	Theresa Stets	Dalbotten, Stets, Steiner
Students in SMM MyBest Program (Youth Science Center) tour SAFL			
July 2004	Madison, WI	Dalbotten	Dalbotten
Diana Dalbotten attends DLESE Annual Conference to facilitate NCED research and ESTREAM lessons accessed by DLESE			
April 2005	Washington, DC	Dalbotten	Dalbotten
Diana Dalbotten attends NSF Division of Human Resources Development Joint Annual Meeting 2005 to promote Faculty-to-Faculty program and develop new strategies for promoting diversity at NCED			
Ongoing	SMM	Hamilton	Nikki Strong, Michal Tal, Theresa Stets
NCED graduate students Nikki Strong and Michal Tal, in their role as SMM Museum Graduate Assistants, mentor YSC students in the Park Crew.			
Ongoing	UofM	Campbell and Perg	All Earth scientists – student to professional
Campbell (past president) and Perg (president elect) serve on Board of local chapter of American Association for Women Geoscientists. This activity provides an additional mechanism for NCED to attract diverse participation. AWG highlights coinciding with NCED YR 3 include: • institute monthly networking events to connect students and unemployed professionals with opportunities; one woman placed in industry this year • participate in local events to encourage participation of girls in science, such as environmental science day at the Bell Museum, University of Minnesota • sponsor events at local and national professional conferences promoting Earth science education and careers for all Americans			

Appendix 7: Advanced Methods Working Group Report

Novel methods for modeling the surface evolution of geomorphic interfaces
MIT, May 22-May 25, 2004

The working group charge was an exploration of the state-of-the-art methodologies for modeling the surface evolution of geomorphic interfaces. Eighteen researchers, from diverse backgrounds covering mathematical and numerical methods, experimental techniques and field observations, were involved (see participant and talk list below).

After three days of talks and intensive working sessions three areas (questions) were identified for further work

1. Moving boundaries:

How can state of the art moving boundary techniques be used to better understand landscape evolution?

For example:

a) Coupling between domains

b) Treating localization (a discrete stream on a landscape)

c) Using analogies with phase change systems

- Is there a phase filed model for landscapes?
- Is there an analogy between unstable growth process (dendritic growth and shorelines).
- Can a level set approach be used to track shorelines?

2. Macro – Meso – Micro

What existing techniques for coupling across time and space scales can be used to model land scale process?

Particular focus was placed on methods for networks. Lines of thought included:

a) Using LES = Scaling

b) Two fluid models

c) Multi grid-applications of CA

d) Electrical analog model of river networks-analogy with freeway systems

3. Surface Evolution Equations

a) What and how can Surface Evolution Equations be used?

b) How can equations such as KPZ and BCRE be used to model bed forms?

c) How can sediment fluid coupling be modeled when one is more important than the other?

d) How can data and scaling be use to verify and validate models?

Next steps

The next meeting is planned for the summer of 2005. The theme will be Moving Boundaries in the Environment. Questions to be addressed include:

a) How can current models be updated, including both (i) the addition of new features into the existing models and (ii) the development of new and alternative models (phase field/cellular)?

b) What field data and lab data can be used to support model development?

c) What are the appropriate computational techniques (fixed grid, front tracking, deforming grid) and how should they be modified/adapted to handle the models in (a).

The expected outcome is a review paper(s) that summarizes the state of the art and point the way forward to more sophisticated landscape surface models.

Participants and Talks

Jon Pelletier
Department of Geosciences, University of Arizona
Examples of Moving Boundary Problems In Earth Science

Chris Paola (NCED PI)
Department of Geology and Geophysics, University of Minnesota
Turbulent Landscapes

Hans J. Herrmann
Institute for Computational Physics, University of Stuttgart
A Model of Aeolin Barchan Dunes

David Cocks
Mathematics Institute, University of Oxford
A Mathematical Analysis of Sand Dune Models

David Mohrig (NCED PI)
Department of Earth, Atmospheric and Planetary Sciences, MIT
Approaches for Analysis of Field Data of Sub-Aqueous Bedforms

H S Udaykumar
Mecahnical Engineering, University of Iowa
Advanced Level Set Methods for the Fixed Grid Tracking of Interfaces

Vaughan Voller (NCED PI)
Dept. of Civil Engineering, University of Minnesota
Phase Change and Ocean Fronts

John Swenson
University of Minnesota, Duluth, Geological Sciences and Large Lakes Observatory
A Micro-Macro Model of Delta Formation in Shorelines

Gary Parker (NCED PI)
Dept. of Civil Engineering, University of Minnesota
Sand-Gravel Transitions and other Moving Boundaries in River Networks

Nikolas Provatas
Materials Science and Engineering, McMaster University
Development and Application of Phase Field Models in Materials Science

Efi Foufoula-Georgiou (NCED PI)
Department of Civil Engineering, University of Minnesota
Scaling of Braided Rivers

Gretar Tryggvason
Mechanical Engineering, WPI
Multiphase Flow Simulations

Andrew Fowler
Mathematical Institute, University of Oxford
A Mathematical Model for the Formation of River Network

Colin Stark
Lamont-Doherty Earth Observatory, Columbia University
A “Toy” Model to Uncover the True Scaling of landslides

Nigel Goldenfeld
Department of Physics, University of Illinois
Modeling of Geomorphologic Shapes and Structures

Appendix 8: Dam Removal Workshop

National Center for Earth-surface Dynamics

National Workshop on Sediment Remobilization and Channel Morphodynamics
in Active and Abandoned Reservoirs
March 25-27, 2005
Torrey, Utah

Agenda and Notes

Purpose of workshop
Exchange of ideas and expertise, and preparation of a position paper on research needs regarding sediment remobilization and channel morphodynamics associated with dam removal. The position paper will be posted on the NCED Stream Restoration Website

Workshop Format
Our approach includes a mix of overview presentations and discussion among the full group and smaller break-out groups. The first morning is devoted to prepared comments on sediment–related dam removal issues from eight different perspectives. The afternoon is given to group discussions focusing on research needs in the areas of field, experimental, and numerical modeling studies. We then have the evening and the entire following day to visit Lake Powell while continuing the discussion among ourselves. The morning of the third day begins with a summary of the discussion of research needs, followed by a lengthy breakout session to define the research needs in more detail. During the final afternoon, the full group reconvenes to evaluate the progress and plans for research needs in each area. If you wish, you are welcome to come prepared with (very) short organized comments (preferably on a cd). These would most obviously fit on the afternoon of the first day.

Day 1 (Friday, March 25)
Breakfast is served at 07:30 at the Red Cliff Restaurant in Capitol Reef Resort

Conference Venue	Conference Room of Capitol Reef Resort	
08:30 – 09:00	Welcome, purpose and logistics of workshop	
09:00 – 09:20	Self-introductions	
Motivational presentations	Moderator: Peter Wilcock	
09:20 – 09:40	Field monitoring and field experiments	Martin Doyle
09:40 – 10:00	Laboratory experiments	Chris Bromley
10:00 – 10:20	Numerical modeling	Yantao Cui
10:20 – 10:50	Break	
10:50 – 11:05	Geochemical issues	Johnny Moore
11:05 – 11:20	Government needs	Tim Randle
11:20 – 11:35	Private sector needs	Stuart Beck
11:35 – 11:50	Implications for policy	Jack Schmidt
11:50 – 12:20	Biological and ecological implications	Mary Power
12:20 – 14:30	Break	

Periods for extended discussion
14:30 – 15:40 Field research and monitoring needs
Moderator: Ellen Wohl Reporter: TBA
15:40 – 16:00 Coffee
16:00 – 17:00 Experimental research needs
Moderator: Leonard Sklar Reporter: Greg Wilkerson
17:00 – 17:20 Coffee
17:20 – 18:20 Numerical research and software needs
Moderator: Blair Greimann Reporter: Alessandro Cantelli

Introduction to Glen Canyon Dam
20:00 – 20:45 Lake Powell; history and overview of field trip
John Dohrenwend
20:45 – 21:05: Lake Powell: what's under the water
Lincoln Pratson

Day 2 (Saturday, March 26)

Depart for Lake Powell from Capitol Reef Resort at 07:30.

Day 3 (Sunday, March 27)
Breakfast is served at 09:00 at Red Cliff Restaurant in Capitol Reef Resort

Conference Venue	Conference Room of Capitol Reef Resort
10:00 – 10:30	10 minute summary reports on research needs from each of the reporters; Wilkerson, Cantelli Moderator: Rollin Hotchkiss
10:30 – 10:50	Organization of breakout groups (number and topic to be determined) Moderator: Bill Dietrich
10:50 – 12:20	Discussion in breakout groups: finalization of list of research needs: naming of authors for the NCED position paper: preparation and printing of outline.
14:00 – 16:00	Plenary session with distribution of outlines and open discussion Moderator: Jim Pizzuto
16:00 – 16:10	Closing remarks by Jack Schmidt

Appendix 9: NCED Graduate Program in Applied Stream Restoration - Design

1. Rational

The development of graduate program in stream restoration supports three NCED objectives:

1. Graduate education: The program will provide graduate-level teaching that will have a distinctive NCED brand.
2. Knowledge transfer: The program will act as a focal point for combined efforts between NCED researchers and partners and produce graduates who are able to take leading roles in practical applications of stream restoration.
3. Diversity in the graduate student body: The theme of landscape sustainability through stream restoration is seen as a natural conduit for attracting graduate students from Native American communities where stream restoration projects are a high priority.

2. Program description

The following key components of a graduate program in stream restoration have been identified:

Theme 1: Orientation:

Overview of stream restoration focusing on the main issues and emphasizing the integration of the fields of civil engineering, ecology, geology and social science.

Theme 2: Basic Engineering Tools:

GIS
Surveying
Computer Applications
Statistics

Theme 3: River & Floodplain Ecology:

Quantify and Design Habitat
Freshwater Biota
Ecological Models
Stream Ecology

Theme 4: River Protection & Restoration:

Stream Channel Analysis
Stabilization Techniques
Riparian Re-vegetation
Types of Disturbances & Their Impact

Theme 5: River Hydrology and Geomorphology:

Geomorphologic & Hydrologic Interactions
Hydrologic Modeling
Sediment Dynamics
Channel Stabilization

Theme 6: Water Quality & Groundwater:

Water Chemistry
Groundwater Mechanics
Water Quality Modeling

Theme 7: Water Policy & Management:

Restoration Planning
Social Impediments to Restoration
Monitoring and Evaluation
Existing Policy

Theme 8: Practicum

Extended Field Experience
Participation in Laboratory Experiments
Development of Restoration Tools

In the long term, specific courses will be developed in each of the themes, but in the short term students will be allowed to take existing graduate-level courses that fit a given theme. The exceptions will be Themes 1, 2 and 8: a specific orientation course (theme 1), tools course (theme 2) and practicum (theme 8) will be developed.

The orientation will introduce students to the key ideas and concepts in stream restoration and provide a stream restoration context for subsequent courses in their program of study. It will be presented in a seminar style and will utilize the skills of multiple NCED researchers and Partners. Students will be required to take this course in their first semester.

The tool course will provide a means by which students entering the program from a non-engineering discipline will have an opportunity to "catch up" on basic engineering tools and principles used in stream restoration.

The practicum will act as a cap stone on the student's experience, and serve to integrate their basic science learning with real-life stream restoration practice. An internship program with NCED partners will be implemented which will allow students to have direct, "hands on" experience of an actual stream restoration project.

3. Program Development and Operation

The program will be developed as a certificate program at University of Minnesota. Typically a certificate program spans a calendar year of course work and can be taken as a stand-alone program or as part of a masters or Ph.D. degree program. After "field-testing" and refining this program at the University of Minnesota, it will be transported to other NCED academic institutions.

Participants will include both traditional graduate students and working professionals. Scholarships will be made available for students from underrepresented groups.

A student will be required to take Theme 1. Theme 2 will only be required if the student's background in not sufficient. The students will then be free to choose a minimum of four courses from a range of courses offered by the University of Minnesota that support Themes 3-7. The required practicum will come at the end of the student's studies and, as noted above involve significant hands-on experience in a working stream restoration environment.

The overall program goal will be to produce certificate-holders who will be able to prioritize stream restoration objectives, design and implement stream restoration projects, and perform meaningful post-project evaluations for the benefit of future projects.

Appendix 10: Formal Education Evaluation Reports

Two formal evaluation reports have been produced for NCED's Education program: one on the Big Back Yard, and another on the Earthscapes Teacher Institute. The title page, table of contents and executive summary for each are included here.

Summative Evaluation of the Science Museum of Minnesota's Big Back Yard

Prepared by
Mary McEathron
and
Amy Grack

December 2004TABLE OF CONTENTS

We would like to acknowledge Stacey Grimes, the third member of the evaluation team, who provided invaluable assistance during the planning and interview stages of the evaluation; as well as Shari Couch, Tracey Goodrich, Jennifer Heisey, Angie Goodrich Hong, Verna Monson, and Kara Stucki, for collecting observational tracking data.

EXECUTIVE SUMMARY

I. Principal Findings: Tracking Study

Tracking took place daily from August 13, 2004, to September 2, 2004 during all hours that the Big Back Yard was open. The principal findings for the tracking study are based on the 323 visitors that were tracked during this period.

Visitor Demographics

- There were slightly more male visitors (52.0%) than female visitors (47.1%).
- The largest group of visitors was between 25-44 years of age (38.1%).
- Most visitors were Caucasian (89.8%).
- A majority of visitors were with groups of three or more people (79.6%) and the most frequent type of groups tracked were composed of adults and children (82.7%).

Visitor Experience (Golfers, Non-golfers with golfers, Non-golfers not with golfers)

- The most frequent type of visitor experience in the Big Back Yard was "golfers" (51.7%).

Total Time in Big Back Yard

- The highest median total times in the Big Back Yard based on type of visitor experience were for golfers (42 minutes) and non-golfers, with golfers (43 minutes).
- The groups of visitors with the highest median total time were groups composed of both adults and children (34 minutes).
- Overall, the shortest amount of time a visitor spent in the Big Back Yard was less than a minute and the longest amount of time was 2 hours and 28 minutes.

Tee Times

- Of the 323 visitors tracked in the Big Back Yard, 194 were golfing or with a golfing group. Of these golfing visitors, 23.7% had to wait for tee times.
- Visitors had to wait a median of 9 minutes, 13 seconds for their tee time. The longest period a visitor had to wait for a tee time was 59 minutes, 39 seconds.
- Over half (65.2%) of the 46 visitors waiting for tee times spent all or part of their waiting time visiting exhibit components. The most popular exhibit to visit while waiting for tee times was Panning for Gems.
- There was a significant difference between the total time golfing groups spent in the Big Back Yard based on if tee times were in use or not (median of 53 minutes when tee times used, median of 40 minutes when tee times not being used).

Holes

- The holes where golfing groups had the highest median times were Hole 4 (3 minutes, 39 seconds) and Hole 5 (3 minutes, 8 seconds).

- Hole 4 had the highest percentage of visitors waiting for their group to golf (38.1% of the 189 visitors to Hole 4), while Hole 9 had the smallest percentage (11.8% of the 186 visitors to Hole 9).
- The hole with the most non-golfers, not with golfer visitors was Hole 9 (34.8%). The holes where non-golfing groups had the longest median times were Hole 3 (39 seconds) and Hole 6 (37 seconds).
- Visitors were most likely to see and interact with staff at Hole 3 (staff present for 25.6% of the 215 visits to Hole 3).

Labels

- Of the 39 labels in the Big Back Yard, the most labels a visitor looked at was 29 labels. Golfers looked at the most labels (median of 4 labels). Non-golfers, not with golfers looked at the least labels (median of zero labels).
- Label 27 "Pollution's Secret Passage", located at the beginning of Hole 4, was looked at by the most visitors (24%). This was also the label where the most interactions with another visitor took place.
- Three of the two-sided labels "Food Webs" or "Can a Park Be a Garden?" had the least number of visitors look at them.

Stand-Alone Exhibits (3D Map of the World, Erosion Recorder, Braided River, Dam Removal)

- The Braided River was the most frequently visited exhibit with 60.7% of visitors spending time there. Of the four stand-alone exhibits, it also had the longest maximum time (38 minutes, 6 seconds).
- Visitors spent the highest median time at the Dam Removal exhibit (54 seconds).
- Golfers were the most frequent visitors to the stand-alone exhibits. There was a significant difference between the number of different visitor types (golfers, non-golfers, with golfers, and non-golfers, not with golfers) who visited the Erosion Recorder, Braided River, and Dam Removal exhibits.
- Of the 81 visitors to the 3D Map of the World, 34.6% interacted with the map. 80.2% of the visitors who glanced or looked at the map did so without looking at any of the labels for the exhibit.
- Of the 138 visitors to the Erosion Recorder, 48.6% manipulated the exhibit, which was defined as moving the lever or tank. Museum staff were present while 1 of the 138 visitors was at the Erosion Recorder although there was no visitor-staff interaction.
- Of the 196 visitors to the Braided River, 23.5% manipulated the exhibit, which was defined as moving water spouts, making dams, moving sand, and/or moving pipes. Museum staff was present when 59 of the 196 visitors were at the Braided River. Of these 59 visitors, 13 interacted with the staff.
- Of the 150 visitors to Dam Removal, 49.3% manipulated the exhibit, which was defined as moving the dam. Museum staff was present when 2 of the 150 visitors were at the Dam Removal exhibit. Of these two visitors, one interacted with the staff.

Other Big Back Yard Features (Prairie Maze, Panning for Gems, Erosion Recorder, Dam Removal)

- Panning for Gems was visited the most frequently of the four features with 60.1% of the visitors visiting this exhibit. This exhibit also had the longest maximum time of 42 minutes, 58 seconds.
- The exhibit with the highest median time was the Science House where visitors spent a median of 3 minutes, 22 seconds.

II. Principal Findings: Exit Interviews

Group exit interviews took place between August 13, 2004 to September 2, 2004. A total of 92 interviews were conducted, with 271 participants (145 adults and 126 children under age 18). Note: Visitors interviewed were not necessarily the same visitors who were observed in the tracking portion of this study.

Overall Impressions of the Big Back Yard

- Overall, the visitor response to the Big Back Yard was very positive. Eighty-three of the 92 groups knew of the exhibit prior to visiting the museum on the day they were interviewed. In 63 of the group interviews, visitors noted that they enjoyed and appreciated the combination of the educational content with the fun and recreation of miniature golf.
- Interview findings indicate that the addition of miniature golf did not overwhelm the educational content of the exhibit. Visitors were able to relate some aspect of the educational content in all but eight of the group interviews conducted. Many visitors reported that rather than overwhelm, the addition of mini-golf actually helped them grasp some of the concepts presented.

Perceptions of Main Ideas Presented in Earthscapes Minigolf

Earth's Changing Surface

- In 55 interviews at least one member of the group expressed some aspect of the processes that shape the Earth's surface. However, the themes that emerged from these responses provided evidence that there were variations in the level of understanding or awareness of visitor responses
  - Source to Sink. Nine of the groups (6 adult and 3 child comments) gave responses during the interview that indicated an awareness of the overall idea of source to sink, including the processes of erosion, transport, and deposition.
  - Erosion. Erosion came up frequently in the interviews with 27 groups mentioning something about erosion (36 adult, 6 teenage, and 2 child comments). Although some visitors talked about erosion as one of the processes that shape the Earth's surface, a majority of the comments about erosion were couched in terms of environmental concerns. The responses indicated that these visitors saw erosion as a primarily negative event aggravated by human activities, which consequently required human intervention to be slowed or stopped.
  - Transport and Deposition. Mention of the transport or deposition of sediment occurred less frequently than erosion. Sixteen groups spoke about sediment transport or deposition (14 adult, 1 teenage, and 5 child comments).
  - Types of Rivers. Twenty-two groups referred to the meandering river, part of Hole 7, either by name or description (15 adult, 5 teen and 5 child comments.) Twenty groups referred to the braided river, either by name or description (17 adult, 3 teen and 3 child comments). Where the meandering river was a form many visitors recognized as something they had seen in Minnesota, the braided river was less familiar. There was a clearer distinction between the responses made by people who had previous knowledge of braided rivers and those that did not.

Interactions between Humans and the Landscape

Over half of the groups interviewed (53 groups with 70 adult, 3 teen, and 16 child comments) indicated that they thought general environmental concern was one of the main ideas of the exhibit.

Some comments were more specifically tied to the content presented in the exhibit. Of those comments, dams were referred to most frequently (28 groups), followed by storm sewers (26 groups), and field drainage and hard surface runoff (19 groups).

Factors Affecting Visitor Experience

Group Composition

- Sixty-one of the groups interviewed were comprised of adults and children of various ages. During the interviews, we witnessed several examples of adult-child interactions, which referred to instructional conversations that had taken place earlier in the Big Back Yard.
- There was a clear difference in the types of experiences non-golfing groups and golfing groups reported. Only 2 of the 14 non-golfing groups reported investigating the Big Back Yard in any depth. One group expressed surprise at being allowed to do any exploring as they had not paid to play golf.

Tee-times

- People commented that they didn't feel they could stop too long to read the signs because there were other golfers behind them. These comments occurred whether tee times were being used or not.

Formative Evaluation
of the
2004 Earthscapes Summer Teacher Institute
National Center for Earth-Surface Dynamics
August 2nd - August 13th, 2004

Submitted to Karen Campbell
January 3, 2005

Prepared by Stacey J. Grimes

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The author gratefully acknowledges the following people for their invaluable support: Amy Grack and Mary McEathron, University of Minnesota graduate students, and Professor Jean King, Educational Policy and Administration Department, University of Minnesota.

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SECTION I: EXECUTIVE SUMMARY

As part of its Education mission, the National Center for Earth Surface Dynamics (NCED), a National Science Foundation Science and Technology Center at the University of Minnesota, is to conduct annual Summer Teacher Institutes, whose intended participants are middle-school science teachers. The first Summer Teacher Institute was held August 2 – 16, 2004 and was subsequently evaluated using surveys given at the beginning and the end of the Institute. In addition, Institute participants also toured the Science Museum of Minnesota's new outdoor exhibit, the Big Back Yard, and gave feedback on it from their perspective as middle-school science teachers.

Findings of the Summer Teacher Institute

The Summer Teacher Institute had two broad evaluation questions: The effect of the Institute on participants' knowledge and understanding of Earth-surface process science and the extent to which the Institute impacted a teacher's curriculum or method of teaching. In both cases, the Institute seems to have had a positive effect.

It appears that the Summer Teacher Institute increased participants' knowledge of river system processes and tools used in the study of them as well as inquiry-based methods for teaching this information. While the level of learning varied among participants, all participants showed an increased knowledge of Earth-surface process science and related tools on the Post-Survey. It is reasonable to assume that this increased knowledge can be attributed directly to the participants' exposure to Earth-surface process science knowledge and use of scientific methods (i.e., making hypotheses, collecting data, and drawing conclusions) and tools while participating in the Institute's various components (i.e., the field trips, Science Museum presentations, and the NCED lab). It is, however, difficult to know if certain components were more effective than others in transmitting this information.

The Institute also appears to have helped participants to formulate more concrete plans for future lesson plans about river systems (with the ten participants at the end indicating at least some coverage of river processes in 2004-2005, an increase from the five who covered river processes in 2003-2004). In addition, participants indicated an increase in the frequency with which they planned to use various scientific methods in the classroom. As noted in Section IV: Results of the Surveys, six of the ten scientific methods showed notable increases in prior frequency to planned frequency of use.

Selected Recommendations for Future Institutes

These results indicate that the opportunity to participate in inquiry-based learning was stimulating for the participants. Knowledge of the topic increased, as did direct classroom applications of scientific methods and the tools used. Participants referred to this when they noted that "Teachers remember and will be more willing to use activities that they have participated in" and "NCED lab time demonstrated potential ways to model river structures that could be brought into the classroom." Every opportunity should be made to expose participants to experiences that can be transferred to the classroom.

Given that participants enter with varying levels of knowledge of river systems, program staff might consider gathering participants' current level of knowledge before the program begins so that program staff can be sure to cover areas where participants lack knowledge. In addition, to better ascertain the amount that participants' knowledge increases between the beginning and end of the two weeks, program staff may wish to consider incorporating a pretest and posttest of the Earth-surface process science domain with closed-ended rather than open-ended questions.