National
Center for
Earth-surface
Dynamics

2004 Annual Report

An NSF Science and Technology Center

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Key to acronyms and abbreviations used in this report:

ACRR	Angelo Coast Range Reserve (NCED field site)
AISES	American Indian Science and Engineering Society
ANAMS	*ando-giikendaasowin* Native American Math and Science Camps
APEXES	Academic Programs for Excellence in Engineering and Science
CALFED	A State of California and the United cooperative research project in the Sacramento-San Joaquin River Delta and San Francisco Bay (Bay-Delta)
CENS	Center for Embedded Network Sensing (NSF STC)
CSDMS	Community Surface Dynamics Modeling System
CUASHI	Consortium of Universities for Advancement of Hydrologic Science, Incorporated
DLESE	Digital Library for Earth System Education
EAB	External Advisory Board
ERP	Ecosystem Restoration Program, CALFED
ESTREAM	Earth Science Teacher Researchers Exploring Active Modeling
FDLTCC	Fond du Lac Tribal and Community College
ITCEP	Institute of Technology Center for Educational Programs
LES	Large Eddy Simulation
LIDAR	LIght Detection And Ranging
LSAMP	Louis Stokes Alliances for Minority Participation (NSF HRD)
MNDNR	Minnesota Department of Natural Resources
MSI	Minority-Serving Institution
NAS	National Academy of Sciences
NASA	National Aeronautics and Space Administration
NCALM	National Center for Airborne Laser Mapping
NCEAS	National Center for Ecological Analysis and Synthesis
NCED	National Center for Earth-surface Dynamics
NRC	National Research Council
NRCEN	National Science Foundation Research Center Educators Network
NSF	National Science Foundation
ONR	Office of Naval Research
PI	Principal Investigator
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)
SIP	Strategic Implementation Plan
SMM	Science Museum of Minnesota
STC	Science and Technology Center
STEM	Science Technology Engineering Mathematics
U of M	University of Minnesota
USGS	United States Geological Survey
USIP	Undergraduate Summer Internship Program
XES	eXperimental EarthScapes facility (“Jurassic Tank”)

I. General Information

1. Cover sheet

1a. Cover table

Date submitted	May 1, 2004
Reporting period	April 1, 2003 through March 31, 2004
Name of the Center	National Center for Earth-surface Dynamics
Name of the Center Director	Chris Paola
Lead University	University of Minnesota
Contact information, if changed since last reporting period	Email address of the Director is now: cpaola@umn.edu
New participating institution:	
Institution Name	University of Wyoming, Department of Civil and Architectural Engineering
Contact Person	Gregory V. Wilkerson
Address	P.O. Box 3295, Bldg. 2091 University of Wyoming Laramie, WY 82071
Phone Number	(307) 745-4381
Fax Number	(307) 766-2295
Email Address of Center Director	gw@uwyo.edu
Role of Institution at Center	Research in river restoration and river engineering

1b. New Faculty Biographical Information

Two new faculty (Jacques Finlay and Greg Wilkerson) formally joined NCED last summer – their biographical data is in Appendix A.

2. Executive Summary

2a. Center Vision and Mission

NCED's vision is to promote landscape sustainability through research, education, and Knowledge Transfer.

As the human population expands, it continues to constrain, divert, modify and, often, reverse the natural processes occurring on the Earth's dynamic surface. It is becoming clearer that the consequences of this expansion have often been negative and occasionally catastrophic. Similarly, efforts to mitigate past depredations often either fail or engender their own set of negative consequences. NCED believes that it is both possible and desirable to live sustainably on our planet, and that a major impediment to this vision is lack of integrated, practical and predictive models for the behavior of its dynamic surface.

NCED's mission is to develop integrated ecogeodynamic models of the channel systems that shape the Earth's surface through time, in support of landscape restoration, environmental forecasting, and resource development.

Channels and channel systems are arguably the major influence on the Earth's landscapes, especially those most sought-after by human populations. Our mission is to bring together the disciplines of geology, geomorphology, hydrology, hydraulics, biology, ecology and the social sciences to create truly integrated and predictive models of these channels and channel systems and the landscapes they create and maintain. Critical to the success of such models will be our ability to constrain and inform them with the full range of channel network dynamics that our planet is capable of producing. Study of the long-term stratigraphic record will provide NCED researchers with this menu of surface configurations, process interconnections, and rates of change that occur on planetary time scales.

We will foster the rapid application of these advancements to land-use planning, environmental forecasting and landscape restoration efforts, and to the education of future leaders in these fields.

2b. Center Goals

1. To become a leading international resource for channel and channel-system science;
2. To promote and carry out research to create interdisciplinary, predictive models of channel and channel-system dynamics across a range of space and time scales;
3. To put our results into practice by developing close working partnerships with government and private organizations involved in environmental forecasting and policy, landscape restoration, and resource development;
4. To use the intrinsic appeal of landscapes and surface dynamics to engage diverse communities in the study of Earth-surface science at all levels;
5. To work with education partners to develop effective methods of communicating Earth-surface science to formal and informal learners; and
6. To do all of the above in such a way that NCED becomes self-sustaining within ten years.

2c. Center Plans

In addition to furthering our work on the Center's long-term goals, NCED plans to accomplish the following in the coming year:

1. Creating and implementing a formal formative evaluation system for our Knowledge Transfer, Education and Diversity components;
2. Implementing at least four Working Groups (see Research section for descriptions);
3. Developing an integrated plan for how NCED can best contribute to river restoration, the primary focus of our environmental Knowledge Transfer program. This will likely include components in communication (e.g. a newsletter), education (e.g. web-based course material), and research (e.g. improved techniques for dam removal);
4. Testing a new approach to attracting underrepresented minorities to the Center's scientific disciplines;
5. Implementing a local field site for NCED K-12 Education programs;
6. Creating broader opportunities for graduate student professional development through Center programs and alternative internships/teaching experiences;
7. Initiating sustained research partnerships with two or more Partners;
8. Developing an Educators' portal on website;
9. Promoting further integration across research focus areas through collaborative projects at our common field site (Angelo Coast Range Reserve); selection of a second common site; our synthesis postdoc group; and integration of NCED and external research via Working Groups;
10. Finalizing the site plan and produce initial data sets and analyses for the Angelo Coast Range Reserve common field site; and
11. Participating in an initial proposal for the CSDMS project.

Details of specific research plans for this year are provided in the Focus Area sections.

2d. Performance and Management Indicators

Overall performance of the Center is evaluated against the seven major goals outlined above. Each individual Center component has a specific set of performance and management indicators, and these are described in their sections, below.

2e. Significant Changes from the Original Plans

NCED management, at the strong suggestion of both its External Advisory Board and the Year 1 Site Visit Team, dedicated a great deal of its time in Year 2 to the focusing of its vision, mission and research activities. The result of these efforts, we believe, is a significant improvement in both the integration of our research activities and the standards we use to judge new proposals. Our new research structure is discussed fully in Section II: Research.

A highlight of our new structure is the formal inclusion of several Integrative Activities whose purpose is to integrate our research within NCED, with our Partners and with our larger scientific community.

2f. Progress Toward Meeting 2nd Year Objectives

Our primary goal was to improve the focus and integration of our research program. To accomplish this, we revamped our mission and vision statements; the new versions were approved by the Principal Investigators (PIs) in October and by our External Advisory Board in January. More importantly, we introduced a set of focus questions, discussed in more detail in the Research Overview section, to serve as a bridge between the broad goals laid out in our mission statement and the specific projects we work on day-to-day.

Another aspect of improving research focus was to choose one of more common field sites. In October we settled on Angelo Coast Range Reserve in northern California as our first common field site. It is already functioning to help unify the PI group through joint field campaigns and refocusing of some of the research programs to adapt them to the Angelo site.

Progress in meeting other objectives is detailed in Appendix E.

2g. Overview of significant accomplishments

NCED is very much a "learning organization". In our second year, we are still evolving new ideas and strategies for carrying out our goals and learning to function well as a Center. Highlights of our Year 2 evolution are:

Overall:

12. We refined our vision and mission statements, based on input from the site visit committee and from our External Advisory Board, but primarily through discussion with the PI group; and
13. Based on input from our site visit and EAB groups, we developed a set of written bylaws for Center procedures.

Research: Progress was made in all areas of NCED Research. Advances were made in the following areas: the spatial organization and scaling of geomorphologic and hydrologic fluxes, storages, and forms in channelized systems; the identification of key issues in restoration geomorphology and sustainable landscapes; the development of observational and analytical tools for modeling and measuring the effects of channels on the Earth's surface; the integration of hydraulics, hydrology and ecology in understanding the bio-physical behavior of channel systems; and the establishment of the connections between engineering and planetary time scales in the dynamics of channel systems and networks.

Specific details of these and other advances can be found in the research section of this report.

In addition:

- NCED researchers produced 85 publications comprising 2 book chapters, 23 conference proceedings, and 60 refereed publications (19 Submitted, 16 in press, and 25 published).
- We developed a stepwise-refinement process for connecting individual research projects to our vision and mission. The key element in this process is a set of research focus questions, developed and refined by the PI group, which serve as a bridge between the overall goals of the Center (vision and mission) and specific research projects.
- We decided, based partly on input from our External Advisory Board and site visit panel, that we needed to focus our field efforts on no more than two common field sites. We identified the first

focus field site, Angelo Coast Range Reserve in northern California, in October and will work on identifying a second one this year.

- To further strengthen the integration of NCED research, we will use funds set aside for postdoctoral researchers to create a "Synthesis Group" of postdocs. Each will work directly with at least two PIs as well as with the other members of this group to build cohesion across NCED research.
- To integrate the human dimension into our modeling efforts, we convened a Social Science workshop to develop recommendations on how this might be best accomplished.

Knowledge Transfer: The major highlight of the year for Knowledge Transfer was the meeting of our Environmental Partners in October 2003. Our Partners expressed enthusiasm for NCED's work and a strong desire for collaboration both with us and among themselves. In addition:

- We decided to use some of the funding originally allocated to our visitors' program to support a program of Working Groups in key topic areas. The Working Groups are modeled after the successful Working Group program of the National Center for Ecological Analysis and Synthesis (NCEAS), headquartered at the University of California, Santa Barbara. We identified five potential areas for Working Groups. The first group meets in May, 2004. We intend to have four to five groups going by mid-fall.
- Based on a meeting last August that we co-sponsored with NAS, and on our Environmental Partners meeting in October, we determined that our major area of Knowledge Transfer and application would be river restoration. We have initiated a River Restoration Initiative (see Research and Knowledge Transfer sections), which will develop an overall strategy for how NCED can best support river restoration.

Education and Diversity: A very large amount of the Center's time and effort were put into the Science Museum of Minnesota's new outdoor science park (called "The Big Backyard"), which includes a miniature golf course whose theme is "Source to Sink" and several other exhibits based on NCED science. The Big Back Yard (BBY) is under construction as of this writing and will open June 26th, 2004. More details of this huge undertaking can be found in the Research and Education sections, and a description of the park can be found in Appendix F. In addition:

- We made a major effort to make sure our graduate students were fully participating in the Center: and have included them in both PI retreats and weekly videoconferences.
- We initiated a new program that we call "Graduate Museum Assistantships" to place NCED graduate students in the Science Museum of Minnesota for one semester.
- We developed a new strategy for our Diversity program, emphasizing personal contacts with selected Minority-Serving Institutions (MSI), in addition to our existing undergraduate summer research internship program (USIP).
- We began systematic formative evaluation of our Education, Diversity, and Knowledge Transfer programs and plan to extend this to the rest of NCED.

II. Research

1. Overview

1a. Mission and Structure

The research group's mission is to develop integrated ecogeodynamic models of the channel systems that shape the Earth's surface through time, in order to:

1. Support efforts to restore and sustainably manage channelized landscapes;
2. Contribute channel and channel system components to practical models of environmental forecasting and hazard assessment; and
3. Develop practical models for understanding and predicting the subsurface structure of the sedimentary deposits that provide reservoirs for water and hydrocarbons, and host economic mineral deposits.

Focus Questions: Organizing our research projects

To organize our research projects, we devoted considerable time during two PI retreats and ongoing email and videoconference collaborations to survey the scientific landscape covered by our mission and to identify what the significant scientific needs were. We then formulated these as a set of Focus Questions. Now a "research trajectory" exists between each project and the mission (see Figure 1), with the trajectory connections provided by the Focus Question(s) each project addresses.

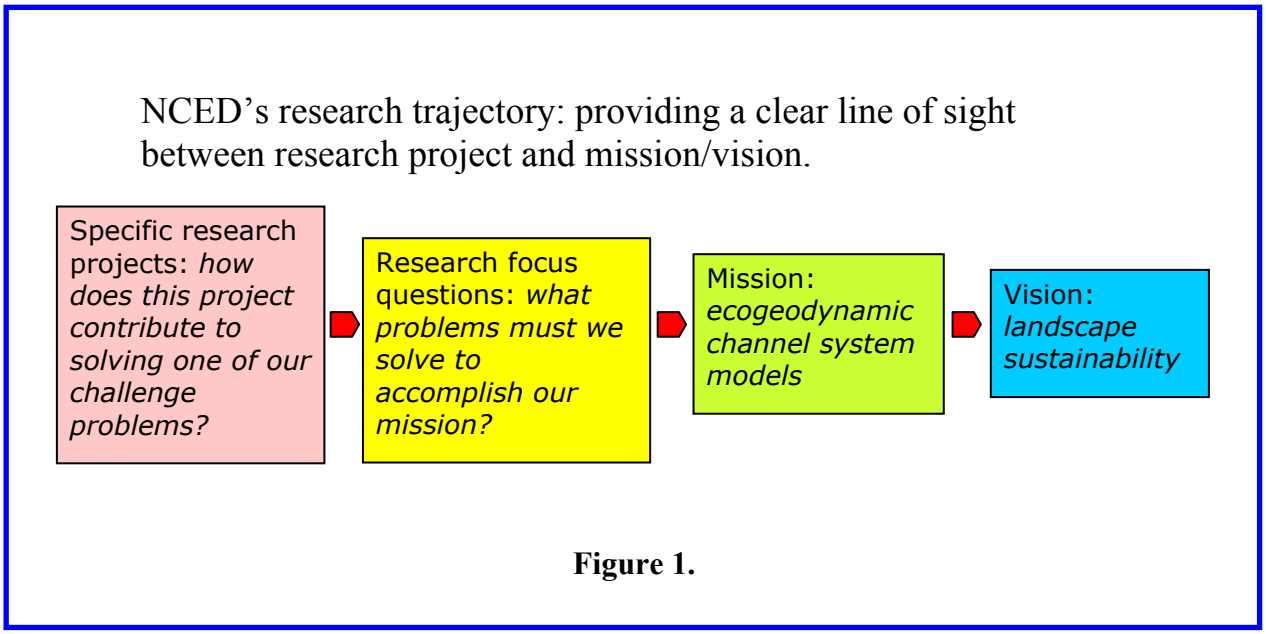


Figure 1.

These Focus Questions are:

1. How does the interaction of physical and biologic processes lead to the creation of floodplains and channels, and how can we model floodplain-channel interactions over a range of time scales?
2. How do channel and floodplain morphology mediate nutrient flow and ecosystem structure?

3. How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence hydrologic response, ecosystem structure and local channel dynamics?
4. How do distributary channel networks compare in structure and dynamics with tributary channel networks?
5. How can understanding of subaerial channel systems improve our understanding of submarine channel systems and vice versa?
6. What are the most effective mathematical techniques for modeling channel systems, including localization, scaling, instability, and coupling of physical and biological dynamics?
7. What are the mechanisms and dynamics of critical channel processes: initiation, switching, bifurcation, net deposition and erosion, sediment flux and sorting, flow resistance, width variation, and bar/bend evolution?
8. What are the sources and dynamics of stochastic behavior in channel systems? How does stochastic behavior set limits to predictability of channel system evolution?
9. How can we use channel deposits in sedimentary strata to gain insight on the natural variability of channel systems and their response to tectonic and climatic signals?

New Directions: In addition to addressing our Focus Questions, NCED will be breaking new ground in three new research domains. The common theme in these domains is the integration of models and techniques from traditionally unrelated scientific disciplines to innovative NCED-related questions:

1. **Ecogeomorphology:** Integrate ecology, hydrology, geomorphology and physics to form a "biophysics" approach to river systems; and try to answer Bill Dietrich's question: what is the geomorphic signature of life?
2. **Turbulent Landscapes:** The application of turbulence/atmospheric science/hydrology techniques to understand landscapes as stochastic systems: natural variability, material fluxes, evolution, and predictability - especially on medium-to-long time scales.
3. **Social Landscapes:** Integrating social, economic and political causes and effects into our models for landscape restoration and sustainability.

Focus Areas: Organizing PI Teams

One of the hallmarks of NCED's research mission is the broad range of space and time scales involved (see Figure 2 on next page). In this environment, the management challenge in creating an integrated Center research approach is to provide a structure in which each different space/time scale domain is investigated with its appropriate tools, and yet in which interactions and interdependencies between scales can be readily recognized and exploited by the PIs.

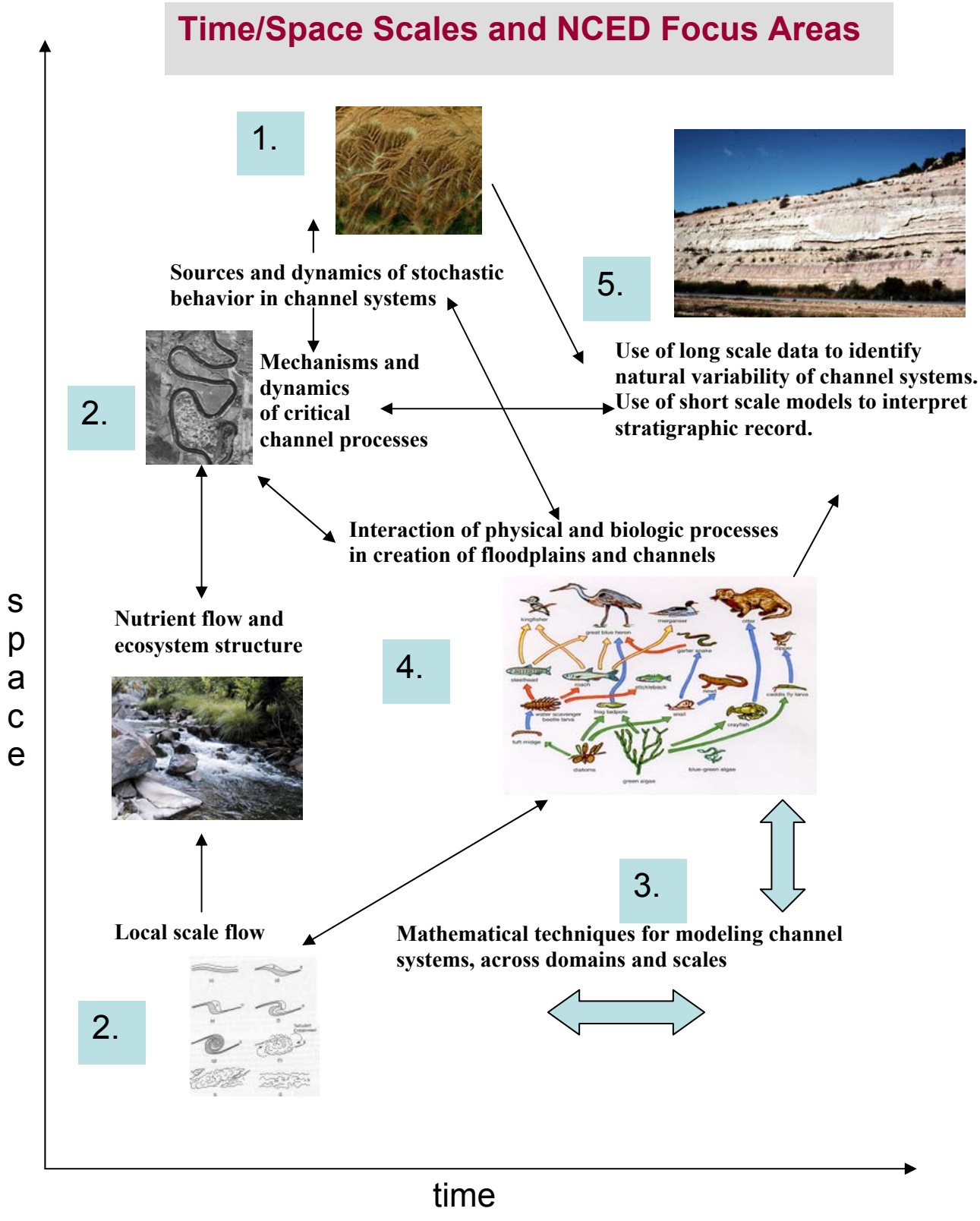

Time/Space Scales and NCED Focus Areas
1.
Sources and dynamics of stochastic behavior in channel systems
5.
Use of long scale data to identify natural variability of channel systems.
Use of short scale models to interpret stratigraphic record.
2.
Mechanisms and dynamics of critical channel processes
Interaction of physical and biologic processes in creation of floodplains and channels
Nutrient flow and ecosystem structure
4.
3.
Local scale flow
Mathematical techniques for modeling channel systems, across domains and scales
2.
space
time

Figure 2.

In meeting this challenge we used our Focus Questions to identify where in the space-time map our specific research needs occurred, and then used this information to establish our specific Focus Areas:

1. Channel Network Dynamics and Scaling: Global Processes
2. Channel and Floodplain Dynamics: Unit Processes
3. Advanced Mathematical and Observational Methods
4. Ecogeomorphology
5. Long-term Dynamics

See next Section ("Research Structure") for full descriptions of our Focus Areas and for a table showing the integration of our Focus Areas and Focus Questions.

Integrative Activities

Our Focus Questions and Focus Areas also provided the impetus and structure for several new Integrative Activities initiated by NCED this year. These activities are specifically designed to promote the integration of research within NCED, with the Earth Sciences community, with our Partners, and with the public. These activities are (ordered from "most internal research" to "most Knowledge Transfer"):

1. **The Angelo Coast Range Reserve Integration Project**: Using our common field site at Angelo Coast Range Reserve, we plan to create a predictive model of the Earth-surface processes over the entire basin, integrating research from all five Focus Areas. This initiative is described more fully below.
2. **Synthesis Group**: This group will consist of several (3-6) postdoctoral researchers. Each will be assigned to work with multiple NCED PIs with the explicit goal of integrating research findings within and across Focus Areas. In addition, they will work with each other to find other research synergies they can capitalize on. The main outputs of this group will be models and modeling algorithms that contribute to the "predictive models" at the core of NCED's mission.
3. **Working Groups:** These "think tank"-like groups will combine NCED PIs with top-level researchers from other institutions AND from our Partners with the goal of applying interdisciplinary, innovative thinking to specific problems relevant to our Focus Questions.
4. **Visitors Program**: NCED's Visitors Program supports researchers from non-NCED institutions to conduct research in support of NCED's mission at NCED facilities. The goal of the program is to regularly expose NCED's research efforts to outside perspectives, and to engage the wider scientific community in NCED's mission. This program is more fully described in Section IV "Knowledge Transfer."
5. **Community Initiatives:** NCED has also emerged as a true 'community center' that is working to integrate and strengthen the research communities of which it is a part. Major examples include launching a series of informal open forums on the future of sedimentary geology (co-organized with NSF), leadership in helping launch the Community Surface Dynamics Modeling System (CSDMS) initiative, an emerging collaboration with CUAHSI, and a major workshop on river restoration (co-sponsored with the NAS).

6. **River Restoration Initiative:** In addition to the significant research contributions that NCED expects to make to this field, we plan to act as an integrative force by championing a multi-disciplinary approach, by proactively involving and engaging our Environmental Partners, and by promoting Social Science perspectives as keys to short- and long-term success. This initiative is described more fully below.
7. **Social Science Initiative:** NCED is working to incorporate the human dimension into its research, and will spend significant effort in Year 3 making this incorporation tangible. Based on the recommendations of our External Advisory Board and on the results of the Social Science Workshop (see Appendix H) held immediately afterwards, we believe NCED can best achieve this objective, and have the most significant impact, by incorporating this initiative into our River Restoration Initiative.

See next Section ("Research Structure") for more details on several of these Initiatives.

Contribution to Education Mission

A key education initiative in NCED has been to incorporate NCED research into formal and informal education experiences housed at the Science Museum of Minnesota (SMM).

The signature collaboration of this effort has been the design and construction of a major outdoor science park at SMM, called the Big Back Yard. The objective is, through a miniature golf course and interactive exhibits, to introduce and engage visitors in the critical concepts of Earth-surface dynamics.

In order to ensure that the science is both assessable and correct, NCED researchers are heavily involved in the design and building of the holes and exhibits in the Big Back Yard. Through video conferencing and retreats, this involves general participation from all of the NCED PI's. Specific and on-going input is provided by PI's Efi Foufoula, Chris Paola, Gary Parker, Vaughan Voller, NCED Engineer Jeff Marr , Knowledge Transfer Director Karen Campbell, and staff members Michael Kelberer and Paul Morin. The collaboration involved hundreds of person-hours of meetings at SAFL and SMM, principally with NCED/SMM PI Pat Hamilton and exhibit developers Peder Thompson, Ken Kornack, and Jim Roe. Overall, because of the strict schedule for developing the BBY exhibits, the NCED/SMM collaboration in Year 2 was unusually intensive. We felt the effort was worth our highest priority and look forward to spending more time on other educational activities in Years 3 and beyond.

Specific collaborative activities included:

1. Development of all golf holes and free-standing exhibits to reflect NCED and other appropriate surface-related science, to ensure scientific accuracy in form and process;
2. Exhibit prototyping at SAFL to check functionality and public appeal;
3. Provision of images for exhibit signage and graphics; and
4. Reading and scientific input on all exhibit signage and graphics.

This process enabled a day-to-day collaboration between NCED researchers and NCED/SMM personnel and established a direct link that allowed the physical models used in NCED research to be placed, and interactively used in a public forum. As a result, when the Big Back Yard opens June, NCED research will be well represented in exhibits based around source to sink (erosional landscapes, braided and meandering rivers) and river engineering (spillway, dam removal) concepts. The on-

going collaboration between research PIs and NCED/SMM will be maintained and strengthened, as the Big Back Yard project continues, by the use of Graduate Museum Assistants, research students of the PIs, working at NCED/SMM.

The next major component of integration of research and education is through the training of graduate students and postdocs. In Year 2, NCED has been involved in training 47 graduate students; it is worth stressing that this includes graduate students from outside NCED institutions, as a result of the Visitors program. Specific NCED graduate student projects are summarized in the Research focus area reports immediately following this section, and those by visitors in the Knowledge Transfer section.

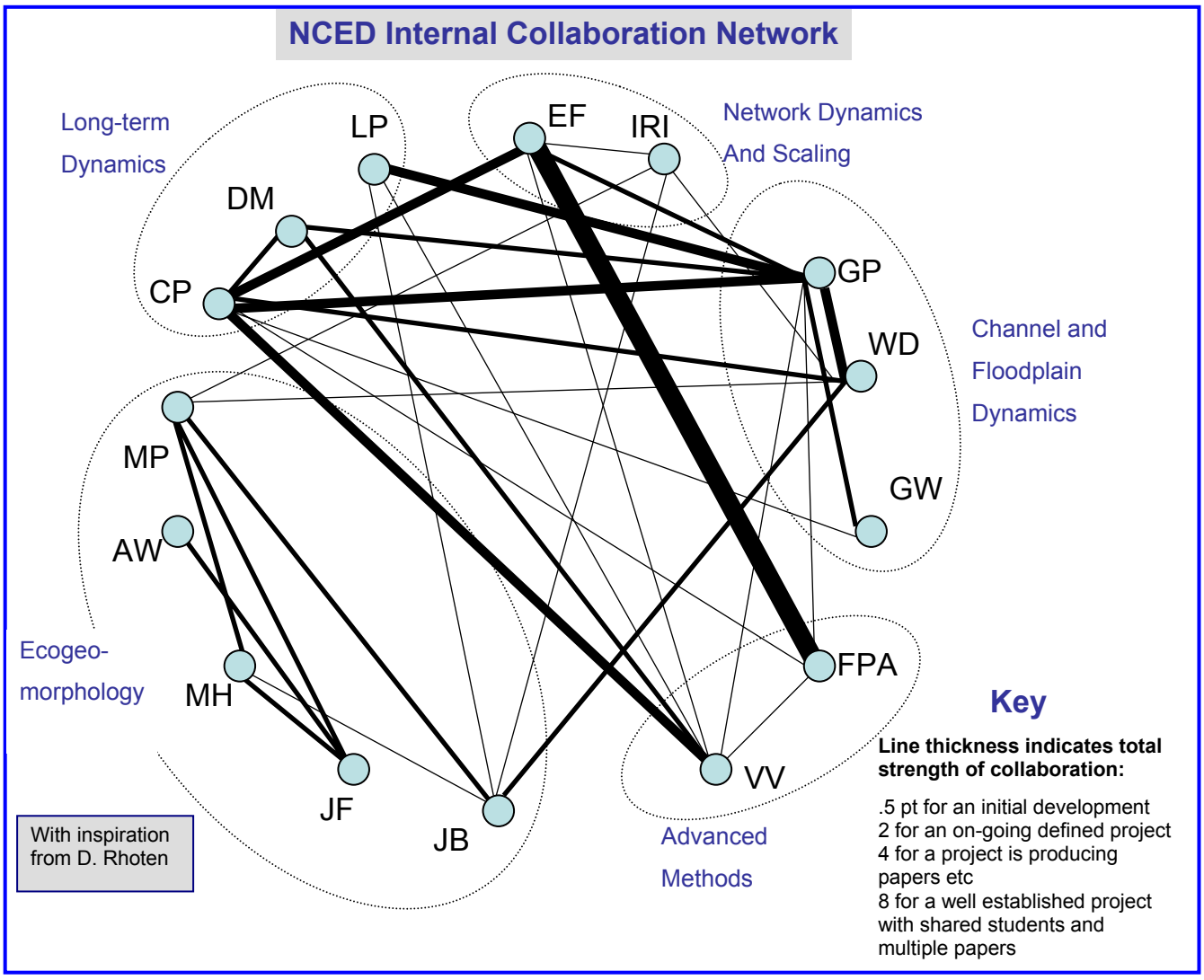
NCED had five postdoctoral participants in Year 2. We expect this number to increase in Year 3 through our Synthesis Postdoc group. Participation in this strongly integrative group will also provide a unique "Center" experience for the postdocs.

Additional elements of Research-Rducation integration that are more directly based in our Education program are discussed in the Education section.

1b. Research Management and Performance Indicators

To track our progress toward fulfilling our research mission, we will use the following indicators:

1. Papers in refereed journals
2. Papers in Conference Proceedings
3. Invited papers and presentations
4. Additional Leveraged Support
5. Working Groups Indicators:
    - Feedback from Working Group members
    - Comments from recipients (researchers, partners) of Working Group outputs
    - Publications, including special issues, volumes and white papers, resulting from Working Group efforts
    - Special sessions on Working Group outputs at meetings
    - New resulting collaborations
6. Measures of Collaboration: (see next page for our visual tracking of these measures)
    - Joint projects initiated and in progress
    - Established projects producing papers
    - Joint papers
    - Joint students



1c. Research Challenges

Year 2:

Following the strong urgings of last year's site visit team and our External Advisory Board, we undertook a major effort in Year 2 to refine and refocus our research activity. In this effort, we were guided by two major objectives:

1. To provide a structure to our research projects that served both to organize our existing efforts and to provide meaningful criteria for the initiation of new projects.
    - To achieve this objective, we devoted a significant amount of time at two PI retreats, each followed by intensive email and videoconference discussions, to formulating a list of significant research needs in our mission area, and casting them as Focus Questions to guide the selection and execution of our research projects.

2. To organize our PIs into teams that effectively covered the multiple space and time scales over which channels and channel systems operate.
    - To achieve this objective, and mindful of the wide variety of spatial and temporal scales covered by our mission area, we used our Focus Questions to identify where in the space-time map our specific research needs occurred, and then used this information to establish our specific Focus Areas.

The result of these efforts is a research agenda that is very tightly bound up with our mission, and a PI organization which maximizes synergy between PIs.

Year 3:

After an intensive year of refining and refocusing our research structure, we feel we have our "Center" legs firmly beneath us. The main challenge for the coming year will be to shift this high-energy momentum into production mode. We intend to:

1. Continue using our Focus Questions to keep a tight connection between our research projects and our mission;
2. Take our common field site at Angelo Coast Range Reserve to the next level as an integrative force in our research and as a model interdisciplinary field site;
3. With our experience at Angelo to guide us, select a second field site and begin developing it;
4. Continue to make integration of our research with our Knowledge Transfer, Education and Diversity programs a top priority throughout the Center; and
5. Develop and implement a specific plan for integrating a Social Science perspective into our overall research.

2. Research Structure

Focus Questions Chart

Our Focus Questions are listed in Table 1, which also shows the connections between our Focus Questions and our Focus Areas. Table 2 (at end of this section) provides a detailed research project list, with PI collaborations and project links to Focus Questions both indicated.

Table 1: Focus Question / Focus Area Interconnections

	Research Question Focus Area:	Glob proc	Unit proc	Adv Meth	Eco-Geo	LT Dyn
1	How does the interaction of physical and biologic processes lead to the creation of floodplains and channels, and how can we model floodplain-channel interactions over a range of time scales?	X	X	X	X	X
2	How do channel and floodplain morphology mediate nutrient flow and ecosystem structure?	X	X		X	
3	How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence ecosystem structure and local channel dynamics?	X	X	X	X	X
4	How do distributary channel networks compare in structure and dynamics with tributary channel networks?	X	X		X	X
5	How can understanding of subaerial channel systems improve our understanding of submarine channel systems and vice versa?	X	X			X
6	What are the most effective mathematical techniques for modeling channel systems, including localization, scaling, instability, and coupling of physical and biological dynamics?	X	X	X	X	X
7	What are the mechanisms and dynamics of critical channel processes: initiation, switching, bifurcation, net deposition and erosion, sediment flux and sorting, flow resistance, width variation, and bar/bend evolution?	X		X		
8	What are the sources and dynamics of stochastic behavior in channel systems? How does stochastic behavior set limits to predictability of channel system evolution?	X	X	X		X
9	How do long-term and short-term processes interact in channel systems, and how can we use information recorded in landscapes and sedimentary strata to better understand these interactions?	X	X	X		X

Focus Area Descriptions

Focus area 1: Channel Network Dynamics and Scaling: Global Processes

This area is focused at a large end of the space scale (the channel network of a drainage basin), and short- to-medium time scales. The mission of the Channel Network Dynamics and Scaling focus area is to develop an understanding of the coupled ecological, geomorphological and hydrological dynamics of channels and channel systems and develop a quantitative framework for modeling and prediction over a range of scales.

Focus area 2: Channel and Floodplain Dynamic: Unit Processess

This area addresses small-to-medium space scale dynamics on relatively short time scales. A typical research project might ask what controls the transition between a braided or meandering channel system, or investigate local deposition and erosion in a channel, or characterize the influence of turbulence structures on small-scale life forms.

Focus area 3: Advanced Mathematical and Observational Methods

This area focuses on methods of modeling and coupling Earth-surface dynamics processes and phenomena both within and across all of the time/space domains covered by NCED. The mission of the Advanced Methods focus area is to identify and develop effective mathematical techniques for modeling channel systems, including localization, scaling, instability, and coupling of physical and biological dynamics.

Focus area 4: Ecogeomorphology

This area is aimed at understanding landscape-ecosystem interactions down drainage networks, and addresses issues at the small-to-medium end of both time and space scales. The major goal of this focus area is to investigate interactions of physical, biological and biogeochemical processes in channels and floodplains, including effects of channel and floodplain morphology and channel network organization on ecosystem structure and function; and influences of biota on landscape evolution.

Focus area 5: Long-term Dynamics

This area is aimed at understanding channel network processes on large time and space scales. The mission of the Long-term Dynamics focus area is to understand and model the behavior of channels and channel systems on planetary (geologic) time scales, in order to better predict the geometry of subsurface sediment bodies; constrain pre-anthropogenic conditions in modern systems; and provide information on average long-term trends and variability in surface systems based on information recorded in landforms and sedimentary strata.

Integrative Activities Detailed Descriptions

Angelo Coast Range Reserve Integration Project

One of the main advances made in focusing NCED research in Year 2 was the decision to focus our efforts primarily on two field sites, one erosional and one depositional. At the October 2003 PI retreat we identified Angelo Coast Range Reserve (ACRR) in northern California as our primary erosional site, and decided to focus on establishing the NCED research program there first, and to use what we learn to inform our selection of a depositional site.

The ACRR site was chosen on the basis of a number of criteria, including:

1. One of the highest known rates of erosion and sediment production in North America;
2. A large, protected area completely devoted to research;
3. An extensive ecological database;
4. Good logistics (facilities, access, etc.); and
5. An extensive associated depositional record available from the ONR Strataform program.

The overall science plan for our work at ACRR is still under development by the PIs (Mary Power, Bill Dietrich, Ignacio Rodriguez-Iturbé, Jill Banfield, Chris Paola, and Miki Hondzo have contributed to it so far). We plan to start with an empirical, map-based approach concentrating on key geomorphic and ecologic parameters (elevation, sediment flux, long-term erosion rate, nutrient flux (C, N, P, etc.), nutrient sheds from isotopes, distribution of key species in relation to basin and channel morphology, microbial dynamics). The mapping will make extensive use of visualization techniques and be initially static. The initial maps become dynamic through measurement and (eventually) prediction of fluxes (sediment, nutrients, and organisms). Thus the model evolves via a tightly coupled cycle of mapping-measuring-modeling. The state variables are grouped into dependent and independent, and existing data and/or non-NCED measuring programs will be used to extend the data base of state variables and flux measurements.

The overall goal of the research program at ACRR is to develop and field-test methods for ecogeomorphic forecasting using the site as a natural laboratory, and in so doing to demonstrate the power of our integrated approach. We expect that many, though not all, of the NCED PIs and postdocs (especially those in the Synthesis Group) will be part of this effort. NCED work at ACRR started formally last summer with joint field work by Hondzo, Power, Finlay and Dietrich as well as their and other NCED graduate students. Rodriguez-Iturbé spent two months at NCED/ Berkeley as part of a sabbatical; during that time he and Banfield visited the site and began developing plans to study the large-scale spatial structure of the ACRR ecosystem, including microbial components with emphasis on N dynamics (this is an N-limited system). We also determined that we needed additional high-resolution topography from the site via LIDAR. Funds were reallocated within NCED to allow for this; we hope to have the data in hand by this fall. Finally, we recognized that it will be critical to coordinate our work at ACRR with other research in the Eel River basin, and decided that the best way to do that would be by holding a workshop for researchers working in the area.

Working Groups

These "think tank"-like groups will combine NCED PIs with top-level researchers from other institutions and from our Partners with the goal of applying interdisciplinary, innovative thinking to specific problems relevant to our Focus Questions. Currently existing/planned Working Groups are:

1. **Novel Methods for Modeling the Surface Evolution of Geomorphic Interfaces**: this group has been created, and will hold its first multi-day session in May, 2004. Its goal will be to learn to what extent tools employed by advanced physical and mathematical surface modelers from *outside* the Earth Science community may be applied to NCED research.
2. **Carbon Storage:** this group will address issues in the storage and release of carbon in channel/floodplain systems, a topic which has been addressed separately by several Earth Science disciplines, and a key topic in building an integrative, predictive model of Earth-surface dynamics.
3. **River Restoration**: As part of NCED's River Restoration Initiative (see description below), a River Restoration Working Group will hold its first meeting later this year to bring together Earth-surface scientists, Environmental Partners, and social scientists to focus on identifying critical and outstanding issues in river restoration, and to identify which of these would benefit from attention by the group itself in future meetings.
4. **Eel River Basin Model**: As part of NCED's Angelo Coast Range Reserve Integration Project (see full description above), we will convene an initial Working Group to focus on determining the outstanding issues of whole-basin modeling, and from this list, to create an agenda for future meetings of this or other Working Groups.

Community Initiatives

Currently, NCED is actively involved in the Community Surface Dynamics Modeling System (CSDMS), and the Sedimentary Geology Initiative.

- **CSDMS:** CSDMS has been described as "a virtual National Science Foundation Lab existing in each of our computers. The scientific ideas contained within are never out of date because of continuous updates by the community. A national infrastructure links modelers together, reduces duplication, and facilitates model testing. Applications of models to problems of societal interest are promoted as non-specialist users assemble models in a user-friendly, graphical environment, requiring relatively little knowledge of computers or computer programming." (Syvitski et al., *Building a Community Surface Dynamics Modeling System Rationale and Strategy,* March 2003.) CSDMS complements NCED's research efforts by providing a sophisticated model-building framework. NCED plans to support and promote CSDMS' efforts, and, through our research, to provide key channel and channel network portions of the model.
- **Sedimentary Geology Initiative:** The Sedimentary Geology Initiative is a community-based effort, co-sponsored by NCED, SEPM, and NSF, to build a stronger and more cohesive sedimentary-geology community. In particular, the group recognizes that research focused on the Earth's sedimentary carapace, despite its importance as the source of our energy and groundwater supplies as well as the record of four billion years of Earth's history, have to date been relatively scattered and isolated. The SGI will sponsor a series of Forums aimed at unifying these efforts, both by developing a common research vision and by promoting collaboration and cross-sharing of results. Two NCED PIs serve on the SGI Steering

Committee (Chris Paola (Chair) and David Mohrig), and NCED is organizing its first Forum at the SEPM annual meeting in April 2004.

River Restoration Initiative

NCED's focus on channel and channel systems provides a unique opportunity for the Center to take a leadership role in channel and river restoration. Year 2 involved initial discussions among the PIs, and input from our Environmental Partners (see Knowledge Transfer), on the form NCED's River Restoration Initiative would take. Year 3 will involve implementation of these initiatives. The primary goals of this Initiative are:

1. To facilitate communication and scientific exchange between river restoration communities, including agencies, consultants, scientists and policy makers;
2. Through extensive collaboration with all stakeholders, to identify the fundamental research needs of the river restoration community;
3. To provide leadership and guidance in the formation of a national network of laboratories focusing on river restoration research;
4. To conduct as well as support basic research in river restoration through physical and numerical modeling;
5. To support or provide opportunities for education in river restoration science; and
6. To promote a multidisciplinary approach to restoration by including geomorphology, engineering, ecology, and social sciences.

NCED's River Restoration Initiative goals will be met through four primary initiatives. These initiatives involve Knowledge Transfer and Research programs.

Initiative 1. Support an ongoing Working Group in River Restoration

Approximately eight NCED PIs, five members of NCED's Environmental Partners group and several outside experts will participate as members of a Working Group focused on River and Channel Restoration. The first meeting of this group will occur in the fall of 2004, and will focus on determining what the significant outstanding issues are in the field. Subsequent meetings of this same group and/or newly created groups will focus on any of these issues that would benefit from Working Group attention (Goal 4).

Initiative 2. Publish a River Restoration Newsletter

NCED will take the lead in producing a periodic newsletter whose audience will be the national network of river restoration practitioners. The content of the newsletter will include a main article on a restoration topic, a technical transfer section, an announcement section (conferences, courses, etc.) and an annotated bibliography of new and pertinent publications. The newsletter will serve to improve communication between the currently disparate river restoration communities (Goal 1) and promote a multidisciplinary, science-based approach to river restoration (Goal 6).

Initiative 3. Conduct basic research in River Restoration within NCED facilities

NCED current research projects will naturally add to the knowledge base of river restoration science. Starting in Year 3 new research projects will be initiated to specifically address issues relating to river

restoration (Goal 3 and Goal 4) highlighted by the Working Group described in Initiative 1. Research topics will include dam removal and bank stabilization through bioengineering techniques.

Initiative 4. Produce a publication (book or manual) on science-based river restoration design considerations

The Center will sponsor a collaborative effort between NCED PIs and outside experts in river restoration that will produce a publication that will support river restoration practitioners in the design of restoration projects (Goal 5). The publication will be available both in print and via the web, and will provide introductory material on river mechanics, geomorphology and ecology as well as more in-depth information on regionally specific restoration design and project management issues (Goal 6).

Table 2: Focus Question / Research Project Interconnections

		Principal Investigators						Focus Questions								
	Research Project	PI1	PI2	PI3	PI4	PI5	PI6	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
0	Investigate the relationship between prognostic evolution equations for landscape evolution and the Navier-Stokes equations.	FPA	EF							X			X			
1	Study debris flow incision into bedrock	WD	GP	DM										X		
2	Investigate channel formation by sediment-laden flows entering still water	WD	GP	DM										X		
3	Study the geochemical processes involved in channel incision and hillslope development	WD	JB					X						X		
4	Eel River: develop a basin-wide model that couples landscape and ecosystem evolution	ALL						X	X	X	X		X	X	X	
5	Eel River: Develop tools for land use and restoration geomorphology	WD	GP	MP	GW	LP		X	X	X						
6	Field studies of river metabolism	JF	MH	MP	AW			X								
7	Model food webs in drainage networks	JF	MH	AW	IRI			X								
8	Investigate watershed nutrient biogeochemistry	JF	JB					X	X							
9	Determine the spatial scales of food web interactions in rivers	JF	MH					X	X				X			
10	Identify the spatial and temporal variability of nutrient fluxes at Angelo	MH	MP	JF	IRI	JB			X				X			
11	Establish laws for nutrient flux at sediment/water interface	MH	JB					X					X			
12	Determine empirical scaling laws for distributary networks	IRI	CP	EF				X		X	X					
13	Investigate vegetation-braiding interactions	CP	MP	JF	AW	MH			X							
14	Investigate how tectonic information is transmitted to fluvial depositional systems	CP														X

		Principal Investigators						Focus Questions								
	Research Project	PI1	PI2	PI3	PI4	PI5	PI6	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
15	Investigate interactions between autogenic and external processes in creating the strat record	CP														X
16	Quatify/model fluvial bedrock channel incision	GP	WD											X		
17	Quantify/model submarine channel incision	GP	DM									X		X		
18	Develop new techniques for the use of cosmogenic radionuclides as channel and basin tracers	GP	LP										X			
19	Apply LES modeling to channelized turbidity currents	FPA	GP	DM									X			
20	Improve quantitative measures of environmental conditions, ecosystem productivity and food web response	MP	MH	JF	JB			X	X							
21	Study the effect of fines on juvenile steelhead and the food webs that support them	MP	MH													
23	Investigate connections between geomorphic structure and hydrology, and the special distribution of vegetation/soil, microbial populations, and biochemical fluxes	IRI	JB	MP				X	X	X						
24	Based on the project above, investigate drainage network metabolism, measure at Angelo	MP	MH	JF	IRI	JB			X							
25	Develop continuum mechanics description of surface transport laws across scales	VV	CP	WD	EF			X					X	X		
26	Develop tools that allow communication between domains and track domain boundaries	VV	CP	GP									X			

		Principal Investigators						Focus Questions								
	Research Project	PI1	PI2	PI3	PI4	PI5	PI6	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
27	Develop analytical tools for evaluating bank stabilization techniques	GW	VV					X					X	X		
28	Quantify spatial variability of geomorphic/hydraulic processes over a range of scales	EF	FPA					X		X			X			
29	Study generalized statistical-physical connections between runoff and sediment production, and channel network geometry	EF						X					X			
30	Model hydrology of braided river systems	EF	CP					X		X						
31	Investigate interactions of microbes and environmental conditions in food webs	JB	MP	MH					X							
32	Investigate the influence of river patterns on organism distributions and species interactions	MP	JF	MH					X							
33	Manipulate carbon sources to headwater food webs to find out how food web structure, energy flow to predators, and carbon retention change with source conversion	MP	JF	MH					X	X						
34	Study scaling of metabolism with drainage area and associated changes in organisms and species interactions	MP	JF	MH					X	X						
35	Investigate seepage channel formation on Mars as possible sites for life	WD	JB					X								
36	Model the interactions of rivers and shoreline	VV	CP	GP						X						X
37	Investigate how ecological, geomorphological and hydrological dynamics govern spatial patterns of vegetation in semi-arid river basins.	IRI						X	X	X						

		Principal Investigators						Focus Questions								
	Research Project	PI1	PI2	PI3	PI4	PI5	PI6	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
38	Describe quantitative signatures of ecological and hydrological features in drainage networks	IRI								X						
39	Measure the equilibrium time required to establish steady-state submarine landscape	DM	CP									X				X
40	Channel incision and sediment transport in mountainous landscapes	WD	GP	CP										X		X
42	Develop Large-Eddy Simulation techniques (LES) to solve landscape evolution problems	FPA	EF										X			
43	Parameterize subgrid-scale fluxes based on self-similarity and fractal characteristics of river networks	EF	CP	VV						X			X		X	
44	Compare the evolutions of submarine and terrestrial channel networks	DM										X				
45	Modeling and analysis of bed form evolution in river channels	DM	VV	CP												
46	Development of Meandering Channels in a Laboratory: Initial Experience	GW								X				X		
47	Measuring and Scaling Streambank Resistance to Shear Using the Vane-Shear Test	GW												X		
48	Establishing long-term baseline erosion rates: calibrating cosmogenic nuclide-derived erosion rates in steep, temperate basins (Eel River).	LP											X		X	
49	Sedimentary sleuthing: statistical distribution of sediment near-surface residence times to trace sediment production, transport, and deposition.	LP											X	X	X	

		Principal Investigators						Focus Questions								
	Research Project	PI1	PI2	PI3	PI4	PI5	PI6	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
50	Study linkage between erosion and deposition in alluvial fan systems	LP									X				X	X
51	Study rates and processes of floodplain formation	WD	GP					X	X							X
52	Conduct physical modeling studies to guide stream restoration	WD	GP	GW										X		

Research Focus Area 1: Channel Network Dynamics and Scaling

Lead PIs:

Rodriguez-Iturbé and Foufoula-Georgiou

Participating PIs:

Paola, Porté-Agel, Parker, Dietrich

Focus Area Mission:

The mission of the Channel Network Dynamics and Scaling focus area is 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.

Research Accomplishments:

In the last year, research in this focus area has concentrated on two main themes:

1. Quantify the spatial organization of geomorphologic and hydrologic fluxes, storages, and forms in channelized systems over a range of scales. In particular:
   - Seek statistical-physical connections between channel/floodplain geometry and streamflow-sediment loads.
   - Quantify the geomorphologic signature on flood statistics.
2. Develop a quantitative framework for the integration of the geomorphological, ecological and hydrological dynamics within channel networks. In particular:
   - Understand the coupled manner by which ecological, geomorphological and hydrological dynamics govern spatial patterns of vegetation in semi-arid river basins.
   - Describe the quantitative signatures of ecological and hydrological co-organization arranged around the template of the drainage network and its accompanying system of hillslopes.

Major accomplishments in the channel morphology/hydrology connections

Generalization of the classical Hydraulic Geometry (HG: relationships between channel morphometry and discharge) to account for scale-frequency dependence (Dodov and Foufoula-Georgiou, 2004a).

Based on recent empirical evidence that the parameters of at-site HG depend systematically on the contributing area (scale) and that the parameters of downstream HG depend on the frequency of discharge, we proposed a multiscaling formalism within which to model and interpret both at-site and downstream HG in a homogeneous region. In particular, we postulated and tested multiscaling models

for cross-sectional area and discharge and derived generalized HG relationships that explicitly account for scale-frequency dependence. The multiscaling formalism was tested in several basins in Oklahoma and Kansas for drainage areas ranging from 2 to 20,000 km^2 and showed good agreement with observations (see Figure 1). To quantify the effects that scale-dependence in HG has on the hydrologic response of a basin, a geomorphologic non-linear cascade of reservoirs model was used to compute attributes of a representative hydrologic response function for various levels of catchment-averaged effective rainfall and different basin orders. The numerical experiment showed substantial differences in hydrologic response when using classical versus generalized HG.

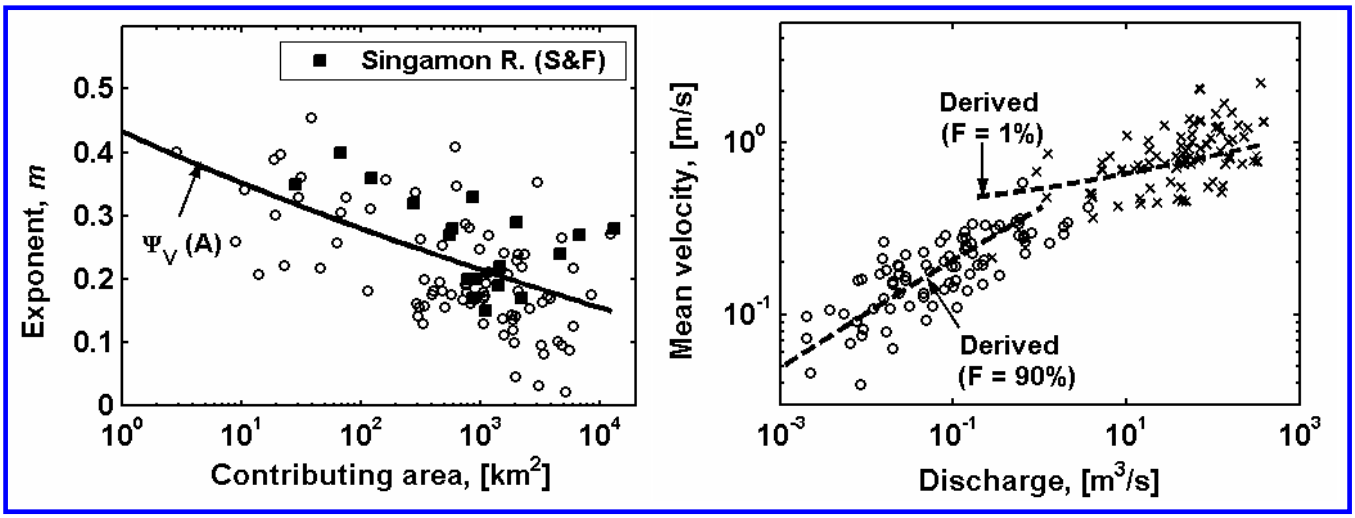


Figure 1. Demonstration that at-site Hydraulic Geometry (HG), $V = kQ^m$, depends on scale (left panel shows the empirical exponents m as a function of scale) and that downstream HG depends on frequency of discharge (right panel). A generalized HG model was derived and the predictions are shown by the lines in the above Figures.

Provided a physical explanation for the scale-dependence of HG in terms of fluvial instability (Dodov and Foufoula-Georgiou, 2004b).

We posed the hypothesis that the scale-dependent HG arises from the scale-dependence of fluvial instability which induces systematic variation in river planform geometry (e.g., sinuosity, meander wavelength and radius of curvature) and consequent variations in channel cross-sectional area with scale. To test this hypothesis we employed a physical model of meandering rivers which is based on linearization of the fully coupled equations of mass and momentum balance of water and sediment. We showed that the HG emerging from this physical model is scale-dependent and agrees with the empirical observations and the statistical model. This work provides a much needed connection between physical and statistical theories. It also provides the means to generate physically-based HG in ungauged catchments for the purpose of hydrologic modeling.

Interpretation of the scaling theory of floods in terms of channel/floodplain dynamics (Dodov and Foufoula-Georgiou, 2004c).

We provided a connection of a specific parameter in the scaling theory of floods, namely, the critical area A_c at which scaling in the flood statistics breaks and variability of floods starts decreasing with area, to a geomorphologic signature of the landscape, namely the appearance of a well-developed

floodplain. Specifically, we posed the hypothesis that A_c coincides with the area at which the floodplain develops in a permanent manner, and the system shifts from a mostly erosional to a mostly depositional regime. We tested this hypothesis via extensive analysis of bankfull and floodplain morphologies over a large geologically and hydrometeorologically homogeneous region in Kansas/ Oklahoma. The implication of this finding is important to hydrologists as they can estimate A_c, needed for regional flood frequency analysis, from a geomorphologic analysis of the landscape. We also revisited the concept of the so-called "dominant discharge" which has been typically assumed to be the bankfull discharge of return period of approximately 1.5 years. We showed that the frequency of exceedance of the bankfull discharge varies with contributing area: channels draining larger areas go overbank much less often (in terms of return period) but stay overbank for much larger periods (in terms of days per year) than channels draining smaller areas (see Figure 2). This has important implications for the statistical properties of floods and sediment transport rates as a function of scale (Figure 3).

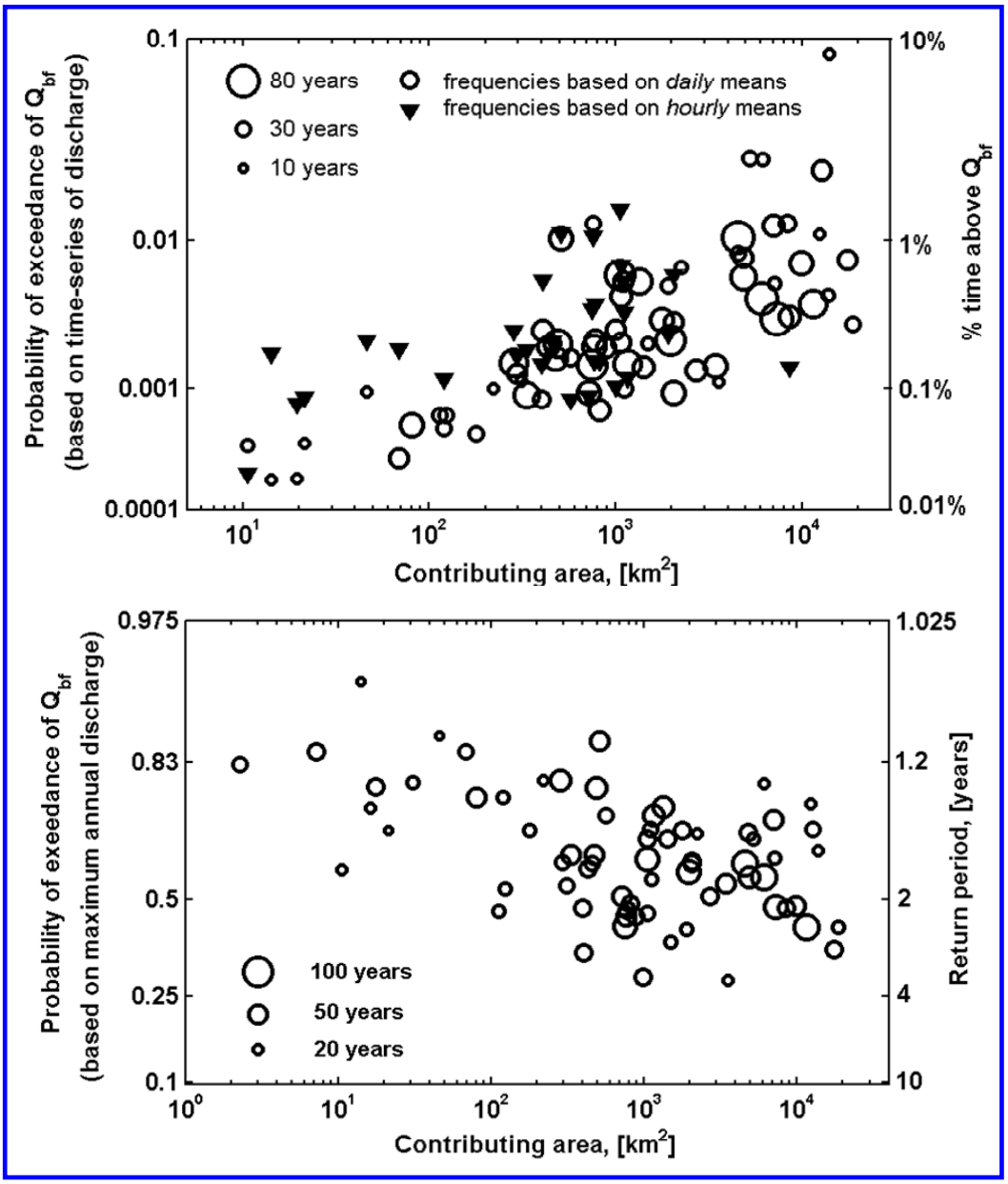


Figure 2. Frequency of exceedance of bankfull discharge Q_{bf} as a function of scale based on daily and hourly time series (top) and maximum annual series (bottom). Note that channels draining large areas flood less often (in terms of return period) but stay overbank much longer (in terms of days per year) than channels draining small areas. This has an important impact on the scaling of floods and suspended sediment loads.

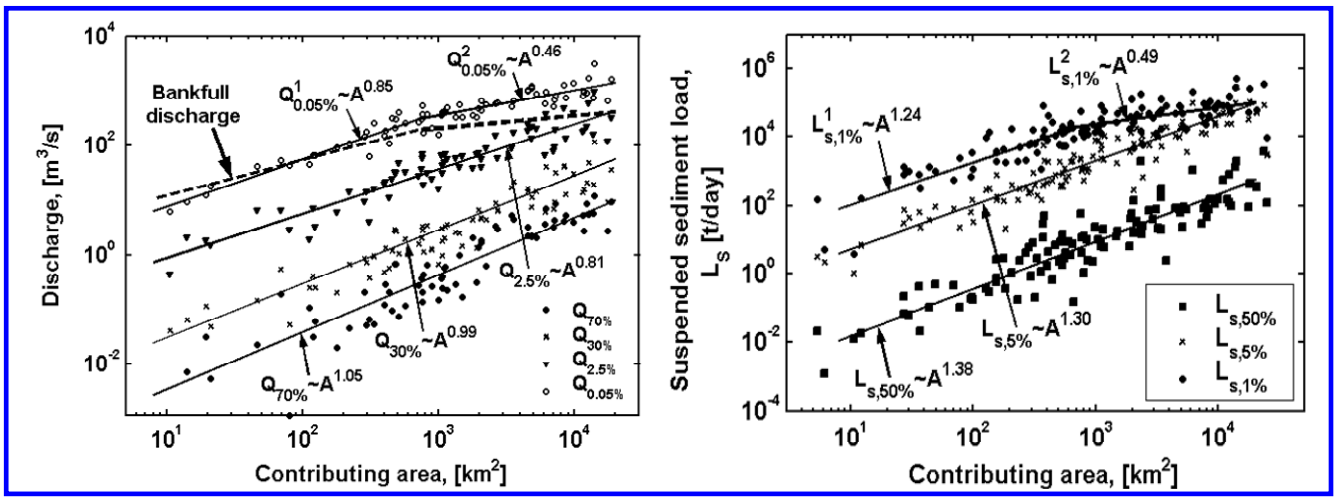


Figure 3. Scaling of empirical daily discharge quantiles (left) and suspended sediment load quantiles (right). Notice the scaling break which is associated with a scaling break in bankfull morphometry and a changing frequency of exceedance of bankfull flows. The scale of break is also associated with the scale at which the fluvial regime changes from net-erosional to net-depositional and a well developed floodplain is established.

Investigation of simulation models and subgrid-scale closures for multiscale processes exhibiting spatial and temporal scaling (Basu et al., 2004; Venugopal et al., 2004).

We are exploring a Langevin-type model, called the Kardar-Parisi-Zhang (KPZ) model, extensively used for simulation of fully developed turbulence and, more recently in our group, simulation of space-time rainfall (Sapozhnikov and Foufoula-Georgiou, 2004), for the purpose of simulating erosional landscapes that show the same scaling characteristics as real landscapes. This work is currently in progress in collaboration with Fernando Porté-Agel. We are also in the process of exploring new subgrid-scale closures for large-eddy simulation (LES) landscape models, borrowing from those we have developed for stratified boundary layer flows and passive scalars [Basu et al., 2004a, 2004b].

Major accomplishments in the ecology/geomorphology/hydrology connections

1. *Coupled geomorphological and ecohydrological organization of river basins* (Caylor et al., 2004a). We have examined mechanisms leading to organization of vegetation patterns within the network structure of a semiarid New Mexico river basin under the controlling influence of water stress. A recently formulated framework for the water balance at the daily level has been used to link the observed patterns of basin organization to the soil moisture dynamics. We have investigated the presence of organization through the analysis of the spatial patterns of the steady-state soil moisture distribution, as well as in the distribution of observed vegetation patterns, simulated vegetation dynamic water stress and hydrological fluxes such as transpiration. In particular, we have explored the hypothesis that in water controlled ecosystems the drainage network acts as a template for the spatial distribution of vegetation which self-organizes through local stress optimization within the network flow paths of the basin (see Figure 4, next page). Our analyses suggest the existence of a balance between the large-scale determinants of vegetation pattern reflecting optimality in the response to water stress and the random small-scale patterns that arise

from local factors and ecological legacies caused by dispersal and founder effects as well as by the effect of different kinds of disturbances.

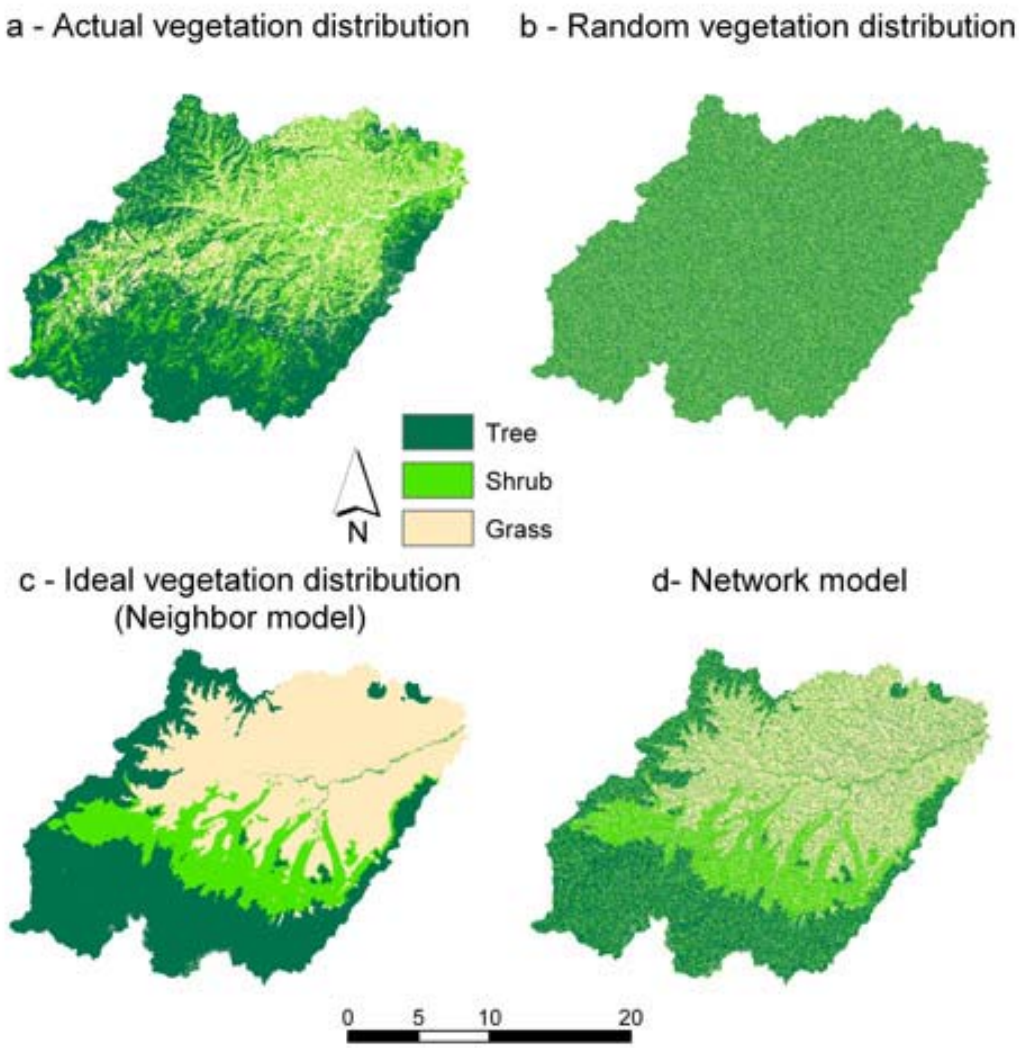


Figure 4 – Observed and simulated spatial distribution of land cover within the Rio Salado basin. **a**, Actual vegetation distribution in the upper Rio Salado river basin. **b**, A random distribution of vegetation representing equal amounts of each land cover type. **c**, The pattern of land cover that arises from an algorithm of local optimization of vegetation water stress that ignores the network structure starting from the initially random condition represented in panel b. **d**, A feasibly optimal pattern of vegetation that arises from local optimization of vegetation water stress within the network flow path starting from an initially random condition represented in panel b. Scale bar measures distance in kilometers.

2. *Feasible optimality of vegetation patterns in river basins* (Caylor et al., 2004b) We have explored the hypothesis that the pattern of actual vegetation observed within a semi-arid 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. We find that the distribution of vegetation within our research study basin corresponds to a pattern of vegetation water stress that is not globally optimal (i.e., vegetation water stress is minimal everywhere), but instead is bounded by the water stress experienced by random and optimal configurations of vegetation pattern. We demonstrate that a model of local interaction is incapable of generating the observed 'sub-optimal' pattern unless local interactions are limited to those defined through the network structure (see Figure 5, next page). This result connects the dynamics of vegetation pattern formation in river basins to the physical principle of feasible optimality previously demonstrated to be present in patterns formed by other open, dissipative systems.

Contributions to NCED Research Questions

Question 3: How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence hydrologic response, ecosystem structure and local channel dynamics?

Our research has indicated that a property that emerges from channel organization is the scale dependence of hydraulic geometry. This scale dependence arises from the scale dependent fluvial instability and cross-sectional channel asymmetry and has important implications for hydrologic response and the regional flood frequency analysis.

Our analyses also suggest the existence of a balance between the large-scale determinants of vegetation pattern within basins reflecting optimality in the response to water stress and small-scale patterns that arise from local interactions mitigated by basin network structure.

Question 6: What are the most effective mathematical techniques for modeling channel systems including localization, scaling, instability, and coupling of physical and biological dynamics?

Our research on multi-scale analysis of precipitation, soil moisture and boundary layer turbulence is slowly adopted to address important problems in the multi-scale structure of landforms. For example, the Kardar-Parisi-Zhang (KPZ) model extensively used for turbulence, and proposed by us for modeling space-time rainfall, is currently emerging as a promising model for studying the evolution of landforms. Issues of nonlinearity, stochastic vs. deterministic forcing, emergence of chaos, scaling, etc., are explored via empirical analysis of landscapes (e.g., braided rivers) and via numerical simulations of the KPZ and other Langevin-type of equations.

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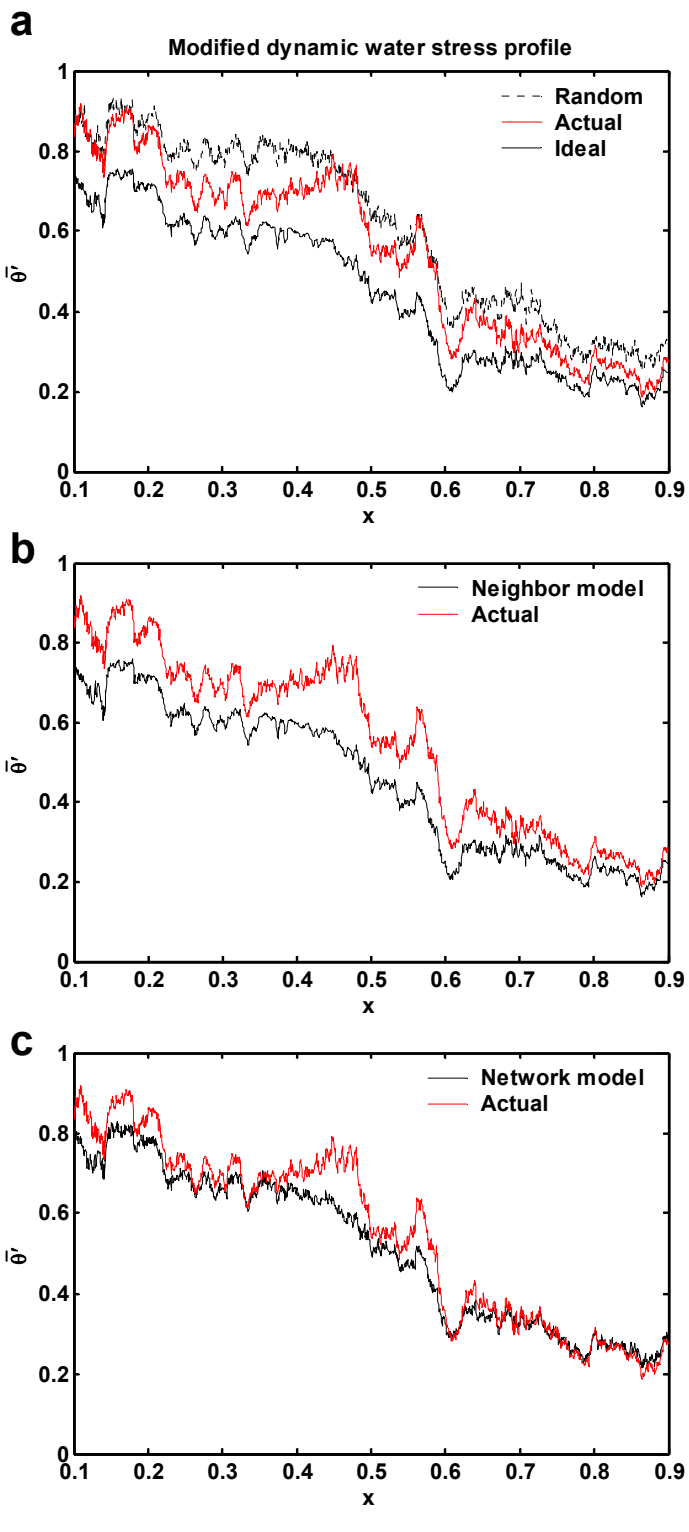

Figure 5 - Modified dynamic water stress profiles for the Rio Salado basin, which measure vegetation water stress in the basin ($\bar{\theta}'$) according to the normalized flow path distance from the basin outlet (x).

a, Modified dynamic water stress profile for the actual vegetation pattern (red line), a random vegetation pattern (dashed line) and the optimal vegetation pattern (solid line).

b, Modified dynamic water stress profile for the actual vegetation pattern (red line) and the neighbor model at statistical steady state (solid line).

c, Modified dynamic water stress profile for the actual vegetation pattern (red line) and the network model at statistical steady state (solid line).

Question 7: What are the mechanisms and dynamics of critical channel processes: initiation, switching, bifurcation, net deposition and erosion, sediment flux and sorting, flow resistance, width variation, and bar/bend evolution?

An overlooked critical channel process is that of overbank flooding which creates a "floodplain river network" with its own scaling characteristics, distinct from that of the (in-bank) channel network. The floodplain river network seems to be the controlling factor of the scaling of extreme floods, and in particular to explain the scaling break and decreased variability of flood magnitude with scale beyond a critical contributing area A_c. We have posed the hypothesis that A_c coincides with the area at which the floodplain develops in a permanent manner, and the system shifts from a mostly erosional to a mostly depositional regime. Thus A_c (which is important for hydrologists) can be predicted based on geomorphological analysis of a landscape. Further testing of this hypothesis is underway.

Research Plans

The research on understanding the effects of channel/floodplain morphometry on the dynamics and statistics of floods will continue. An important further step will be to analyze a region of different geological and climatological characteristics where the transition from one scaling regime to another is not necessarily expected to be the result of a change in the fluvial regime. Another important direction we plan to pursue (in collaboration with Parker) is the development of scaling laws for sediment loads, that is, generalization of the Leopold and Maddock (1953) Hydraulic Geometry for suspended sediment load versus discharge as a function of scale and frequency of discharge. A longer-term project is the development of a probabilistic statistical-physical streamflow prediction system which incorporates the variability of all planform properties (sinuosity, radius of curvature, etc.) and channel morphometry properties with scale, as well as the river network topology in predicting streamflow statistics in ungauged basins.

In the area of braided river systems, we plan to be able to have well calibrated spatially variable fields of water depth so we can proceed (in collaboration with Paola) with scaling analysis of the hydrology in both un-vegetated and vegetated regimes. The exploration of Langevin-type non-equilibrium interface equations for the modeling of landscapes that exhibit spatial and temporal scaling will also be continued in collaboration with Porté-Agel.

An important next step in NCED's efforts to integrate the geomorphological, ecological and hydrological dynamics of river basins, is a close investigation (both by experimental and modeling research) of the Eel River basin. The focus in that system will be on understanding the role of the drainage network and its geomorphological characteristics as a template for organization of the riparian vegetation communities, metabolic scaling, and organization of stream biodynamics within the river network. This research will be pursued in collaboration with Power, Banfield and Dietrich.

Integrative Activities

Foufoula-Georgiou's research has greatly benefited from extensive discussions with Parker (on hydraulic geometry, fluvial instability, physically-based modeling of meandering rivers, sediment transport), Paola (braided river systems, nonlinear dynamics, stochastic geomorphology), Voller (numerical methods for solving stochastic partial differential equations, scaling arguments), Mohrig

(emergence of organization in subareal systems), and NCED visitor Kelin Wipple (on floodplain development).

Foufoula-Georgiou's most direct collaboration has taken place with Porté-Agel (on nonlinear stochastic growth equations for modeling turbulence and landscapes and on subgrid-scale closures models; co-advisor on students Sukanta Basu and Paola Passalacqua) and with Paola (on organization of braided river systems: co-advisors on student Lisa Tilman). Their collaborations are centered upon the development of a quantitative framework for the integration of the geomorphological, ecological and hydrological dynamics within the NCED core research study area of the South Fork Eel River basin. Their efforts within the Eel river basin involve collaboration with fellow NCED members Dietrich (channel geomorphology), Banfield (catchment biogeochemistry), and Power (stream ecology). Activities will include studying the co-organization of channel networks and riparian corridor vegetation communities, modeling the seasonal probabilistic soil water balance across the Eel River basin, and investigating metabolic scaling and the organization of stream biodynamics within river networks.

Rodriguez-Iturbé's collaborations are centered upon the development of a quantitative framework for the integration of the geomorphological, ecological and hydrological dynamics within the South Fork Eel River basin, and involve collaboration with fellow NCED PIs Dietrich (channel geomorphology), Banfield (catchment biogeochemistry), and Power (stream ecology). Activities will include studying the co-organization of channel networks and riparian corridor vegetation communities, modeling the seasonal probabilistic soil water balance across the Eel River basin, and investigating metabolic scaling and the organization of stream biodynamics within river networks.

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).

Leverage and Other Funding - Received

A number of Efi Foufoula-Georgiou's NCED-related activities have leveraged funding:

- An NSF grant entitled "Hydrology of Braided River Systems" is co-funding the research of graduate student Lisa Tilman.
- A University of Minnesota Graduate School Dissertation Fellowship is co-funding PhD student Sukanta Basu.
- A Minnesota Supercomputing Institute (MSI) post-doctoral fellowship provides half of the funding for post-doctoral associate Boyko Dodov.
- A NASA grant from the Land-Surface Hydrology program, focused on multiscale model verification and data assimilation, provides partial funding for M.S. student Rohit Gupta and postdoctoral associate Venugopal Vuruputur.
- A University of Minnesota McKnight Professorship non-restricted research award for the period 2003-2008.

Additionally, an NSF Biocomplexity award provides partial funding for Rodriguez-Iturbé.

Research Focus Area 2: Channel and Floodplain Dynamics

Lead PIs

W. Dietrich, G. Parker, G. Wilkerson

Participating PIs

E. Foufoula-Georgiou, D. Mohrig, C. Paola, F. Porté-Agel, I. Rodriguez-Iturbé, V. Voller,

Focus Area Mission:

The mission of the Channel and Floodplain Dynamics focus area is 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.

Research Accomplishments

River Restoration

Research on river restoration has involved the following NCED researchers: PIs Dietrich, Paola, Parker, Wilkerson and NCED engineer Jeff Marr.

During this past year Dietrich has participated in basic studies on the Sonoma and Napa watershed to identify how land use practices have influenced the abundance and distribution of salmon. For the 1000 km^2 Napa River watershed, his group has obtained topographic data at roughly 1 m spacing from airborne laser swath mapping. These data, while offering a significant opportunity to improve landscape modeling, also present significant challenges in data processing. With a post-doctoral fellow, Christine May, he has developed a study plan for the US Forest Service to conduct a cumulative watershed effects study in the Klamath River watershed to identify the linkages between land use and channel characteristics. He is basing this plan on an analytical reference state model, developed earlier, that uses digital terrain data to estimate channel habitat characteristics to guide empirical estimates of biotic attributes and to perform a limiting factors analysis.

Wilkerson has been performing research related to the NRC Committee to Review Methods for Establishing Instream Flows for Texas. An instream flow requirement is the flow regime adequate to sustain an ecologically sound environment in streams and rivers, including riparian and floodplain features, and necessary for maintaining the diversity and productivity of ecologically characteristic fish and wildlife and the living resources on which they depend. Instream flow studies generally consider hydrology, biology, geomorphology, water quality, and connectivity. The charge of this committee is to critically evaluate the scientific methods and related technical aspects of proposed studies to determine the physical, chemical, and biological needs for instream flows in selected subbasins within

Texas. Specifically, as a member of this committee Wilkerson has been assigned the task of leading an evaluation of relevant aspects of hydrology, hydraulics, and sediment transport.

Parker and Paola are working with a postdoctoral fellow, A. Cantelli, and a graduate student, M. Wong, to develop a model describing the process by which a channel incises into a reservoir deposit after sudden removal of a dam. The research reveals the phenomenon of incisional narrowing. The work has direct applications to dam removal, a process that is often part of river restoration projects. Publications related to the work include Cantelli et al. (2004) and Wong et al. (2004).

Parker has developed a software package that can be used to study the effect of the restoration flood flows downstream of a dam on gravel texture. The package can be used to design schemes using controlled flood releases combined with gravel feeding to restore degraded river reaches downstream of dams. The work is being conducted jointly with M. Hassan of the University of British Columbia and P. Wilcock of Johns Hopkins University. The latest results are contained in Parker (2004).

Marr and Parker have been involved in an effort on bioengineering which can contribute to "soft" approaches to bank protection.

Parker is working with J. Pitlick of the University of Colorado Boulder to develop a set of dimensionless regime relations for gravel-bed streams that can be used in the design of river restoration projects.

Bedrock Incision

Research on bedrock incision has involved the following NCED researchers: Dietrich, Parker and Mohrig. In addition Voller has contributed to modeling aspects. Some highlights are given below.

Experiments on incision due to debris flows. Dietrich and his graduate student Leslie Hsu worked with Parker to design a unique large rotating drum to study bedrock incision by debris flows. The problem is important because fluvial incision ends before a basin divide, and the remainder of the incision must be accomplished by landsliding and debris flows. Hsu has performed numerous experiments on the subject using a smaller drum. Dietrich, Hsu and Parker have had frequent discussions about design and modeling issues. Dietrich also maintains a major field effort on bedrock incision by debris flows with his (former) student John Stock.

Figure 1. Incisional channels cutting into a tableland.

Numerical modeling of fluvial bedrock incision. Parker and his student Phairot Chatanantavet have embarked on a research program on modeling of channel bedrock incision due to wear, plucking and macroabrasion (see Figure 1). The research is being conducted in close cooperation with Dietrich and his student Leonard Sklar, and uses aspects of their model. The research is being focused on a) steady-state profiles, and b) a moving-boundary treatment of non-steady-state evolution with knickpoint migration. Voller provides advice about moving-boundary analysis. Other collaborators include K. Whipple and A. Howard.

Adaptation of bedrock incision models to the submarine environment. Parker, Dietrich and Mohrig continue discussions as to how to adapt models of bedrock incision to the submarine environment. It appears as though the best type of adaptation will involve a relation including both boundary shear stress and near-bed sediment concentration.

Related efforts. In related efforts, Dietrich and Yager are studying bedload transport in boulder-strewn streams and Dietrich and Casadei are studying shallow landslide occurrence. Parker is working with D. Furbish to study the evolution of slot canyons.

Channel-Floodplain Interaction

Field effort on floodplain sedimentation. In June 2003, Dietrich, two post-doctoral fellows, two graduate students and a graduate student of Parker collected hundreds of sediment cores along the Strickland River, Papua New Guinea to document the rate of floodplain sedimentation. The Strickland sedimentation rates will be compared with that found on the Fly River by Geoff Day. It is hypothesized that the 7 times higher sediment load on the Strickland has caused the floodplain to be more fully developed than on the Fly and that, consequently, a much smaller proportion of its load is lost to the floodplain. This is a collaborative project, mostly funded by NSF, with Parker.

Tie channels. On lowland floodplains with meander loop cutoffs, channels may form where the sediment-laden flow enters the oxbow lake. These channels, referred to as tie channels, are similar to delta channels. Dietrich's graduate student Joel Rowland has collaborated with Mohrig in an attempt to form such channels in the laboratory. Rowland is currently performing experiments in NCED/Berkeley to explore what leads to their formation. Mohrig and Parker are providing advice.

Numerical modeling of channel-floodplain interaction. One of Parker's graduate students, J. W. Lauer, is currently developing a model of how river channels and floodplains interact when subjected to aggradation driven by, for example, sea level rise. The model has been applied to the Minnesota River, where data are abundant. As data from the Strickland River (see Figure 2), Papua New Guinea becomes available, it will be applied to that case as well. Early results are given in Lauer and Parker (2004). Dietrich's group is closely cooperating with the effort.

Figure 2: Scroll bars on the Strickland River

Scale modeling of meandering channel. Wilkerson is developing a laboratory model of a meandering channel. Parker and Dietrich are cooperating with Wilkerson in channel design. This study is the first in a series of studies being conducted to establish protocols for dynamics-based physical modeling of stream reaches (having lengths on the order of tens to hundreds of meters) and segments (having lengths on the order of kilometers). To date results from our studies have provided direction for modeling meandering channels that are stable (displaying rates of lateral shifting that are slow or imperceptible) and in equilibrium (sediment inflow equals sediment outflow).

Field evaluation of channel bank erodibility. In a related study, Wilkerson is developing a vane-shear test for scaling bank strength to channel migration rates. In particular, research is being conducted to establish the relationship between streambank soil strength, as determined using the vane-shear test (see ASTM Standard No. D2573-01), and soil erodibility. Results from this work will provide a foundation for (1) relating soil strength to channel migration and (2) developing a rational method for scaling bank strength (the ability to scale bank strength will enable us to model streambank dynamics in the laboratory.

Interaction of channels, floodplains and vegetation. Paola and student Tal are conducting experiments on channel-floodplain interaction in the presence of vegetation. They work in close cooperation with Foufoula-Georgiou. The vegetation in question consists of alfalfa sprouts. The original motivation of this work was that vegetation effects are an important element of river dynamics that has never been included in stratigraphic experiments such as those described above. Hence the researchers wanted to investigate it separately both to see what could be learned about how plants affect rivers, and to investigate the possibility of eventually including vegetation effects in stratigraphic experiments.

The experimental strategy is based on thinking of the interaction of plants and channels as a dynamic competition between what might loosely be termed “vegetation pressure” – the tendency of plants to colonize bar tops and hem the channel in – and the tendency of the channels to clear paths for themselves by widening and by migrating laterally. The experiments, done in an experimental channel 2 m wide with well sorted medium sand, involve alternating long periods of low discharge with short periods of high discharge. The researchers begin with an ordinary braided network formed at the high discharge. The exposed bed is seeded with alfalfa with the discharge at its low value. The alfalfa is allowed to grow for one week; the discharge remains low. Then the discharge is raised to its high value (5 times the low value), for one hour. During this time it erodes and deposits sediment, typically removing vegetation in vulnerable areas by undermining or burying it. This year, the main experiment was one in which we repeated this cycle of growth and destruction 15 times. This design transformed the initial braided channel into a sinuous single-thread channel. After several cycles, the channel was able to remove vegetated area at the same rate it was being created by colonization. We believe this is the first time this form of dynamic equilibrium between vegetation and channel dynamics, which we believe to be characteristic of natural streams, has been documented.

Bankfull geometry of rivers. Foufoula-Georgiou and her postdoctoral researcher B. Dodov have worked in collaboration with Paola and Parker to generalize the classical hydraulic geometry (HG - relationships between channel morphometry and discharge) to account for scale-frequency dependence (Dodov and Foufoula-Georgiou, in press). They have provided a physical explanation for the scale-dependence of HG in terms of fluvial instability [Dodov and Foufoula-Georgiou, submitted(a)]. Finally, they have interpreted the scaling theory of floods in terms of channel/floodplain dynamics [Dodov and Foufoula-Georgiou, submitted(b)].

Rivers and Deltas

Effect of sea level rise on long reaches of sand-bed rivers. The effect of the 120-m sea level rise experienced at the end of the last glaciation on river profiles have long been debated. The Fly-Strickland River System in Papua New Guinea has proved an ideal site at which to study the effect. The existence of blocked-valley lakes along the river floodplain many hundreds of km upstream of the delta argue for a strong effect of sea level rise on the entire river profile. Parker, Dietrich and Parker's postdoctoral researcher Yoshihisa Akamatsu have developed a numerical model describing the effect of "autoretreat" induced by sea level rise on the long profile of rivers. The model is predicting that 120 m of sea level rise over 12000 years has a very substantial effect on the river profile for up to 700 km upstream of the delta. The effect is sufficiently strong to drive the gravel-sand transition upstream. T. Muto of the University of Nagasaki is a close collaborator.

Experimental studies on sea level rise. Paola's group has been conducting a number of experiments on the effect of base level change on basin stratigraphy. Collaborators include Mohrig and J. Swenson of the University of Minnesota, Duluth. More information about these experiments can be found in the section for the focus area "Long-term Dynamics."

Bedform-Channel Interaction

Role of bedforms in rivers. Mohrig and graduate student Doug Jerolmack are studying the evolution of sandy river bottoms dominated trains of dunes and bars. They are particularly interested in determining the role that interactions between dunes have in setting patterns of river-bottom sedimentation and erosion and in determining stage/discharge relationships. They began their study with a series of laboratory experiments designed to define how one bedform can interact with and affect another. They found that styles and rates of bedform interaction are very sensitive to the bedform topography itself. This sensitivity of bed deformation to boundary conditions has led them to explore descriptions for an evolving river bed using interface equations (see Figure 3, previous page). They are presently examining the utility of the BCRE equations for describing natural variability within evolving bottom topography, including bedform merging and splitting. They are, in effect, seeing how well the evolution of surface topography can be predicted by the geometry of the topographyitself.

Sediment sorting by bedforms in rivers. In a related effort, Parker and postdoctoral researcher A. Blom are developing a model of sediment sorting by dunes in rivers. Mohrig serves as a cooperating researcher. Blom is permanently based at the University of Twente, the Netherlands, but is an NCED postdoctoral researcher for one-fourth of each year. This year she will visit both Mohrig at MIT and Parker at Minnesota in order to coordinate research. The focus of the present research is sorting by dunes in the presence of aggradation and degradation.

Tracers

Tracers in gravel-bed streams. Parker and graduate student Wong are developing a model of tracer stones in gravel-bed streams that is thoroughly integrated with a model of sediment transport. The research includes field, experimental and numerical components. Collaborators within NCED include Perg, Dietrich and Mohrig: in addition, S. Burges and P. De Vries of the University of Washington, P. Wilcock of the Johns Hopkins University and NCED postdoctoral researcher A. Blom are close collaborators.

Cosmogenic radionuclides. Parker is working with Perg to develop a general conservation model for cosmogenic radionuclides. Early results highlight the role of fluctuations in topography in increasing

the time to achieve a new steady state after an impulsive change in the erosion rate (Parker and Perg, to be submitted before the site visit). This research is also discussed in the section for the focus area "Long-term Dynamics."

Submarine Channels

Depositional signature of hydraulic jumps. Turbidity currents often emanate from steep, incisional canyons onto relatively flat depositional zones. A turbidity current may be expected to undergo an internal hydraulic jump at such a location. Many authors have speculated that such a jump may leave a depositional signature. Parker and his NCED postdoctoral fellow, S. Kostic, have developed a model that explains this signature in terms of a competition between erosion and deposition (Kostic and Parker, to be submitted before site visit). The research is being coordinated with D. Mohrig.

Conditions for the lack of occurrence of a hydraulic jump. An offshoot of the above research is the determination of a condition for which no hydraulic jump occurs at a slope transition. This condition is reached when the rate of deposition from the turbidity current is sufficiently strong. The research is summarized in Parker and Kostic (to be submitted before site visit).

Ponding of turbidity currents. Research on the subject of turbidity currents ponded in submarine minibasins continues. The research involves Parker, S. Kostic, Y. Akamatsu and a former graduate student who finished in December 2004, J. Violet. Relevant publications are Lamb et al. (2004) and Violet et al. (submitted). Related work includes Harbitz et al. (2004) and Toniolo et al. (2004). At present the work focuses on experimental and numerical modeling of ponded turbidity currents.

Incision by turbidity currents. Ongoing discussions between Parker, Mohrig and Dietrich on a mechanistic model for channel incision due to turbidity currents were mentioned above in the section on bedrock incision.

Submarine channel networks. Mohrig and graduate student K. Straub have acquired acoustically generated, high resolution bathymetric data from continental slope of offshore Brunei Darussalam. Networks of channels, both distributary and tributary-like in form, are in the process of being mapped and interpreted using these submarine DEMs. Geometric and statistical data from these networks will be compared to better studied terrestrial networks with the cooperation of E. Foufoula and I. Rodriguez-Iturbé. The evolutions of these submarine networks will also be compared to evolutionary histories of river-channel networks.

Contributions to NCED Research Questions

The work of the Channel and Floodplain Dynamics group addresses the following NCED research questions:

Question 1: How does the interaction of physical and biologic processes lead to the creation of floodplains and channels, and how can we model floodplain-channel interactions over a range of time scales?

Question 5: How can understanding of subaerial channel systems improve our understanding of submarine channel systems, and vice versa?

Question 7: What are the mechanisms and dynamics of critical channel processes: initiation, switching, bifurcation, net deposition & erosion, sediment flux & sorting, flow resistance, width variation, and bar/bend evolution?

The work also casts light on the following questions:

Question 3: How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence hydrologic response, ecosystem structure and local channel dynamics?

Question 4: How do distributary channel networks compare in structure and dynamics with tributary channel networks?

Question 6: What are the most effective mathematical techniques for modeling channel systems, including localization, scaling, instability, and coupling of physical and biological dynamics?

Question 8: What are the sources and dynamics of stochastic behavior in channel systems? How does stochastic behavior set limits to predictability of channel system evolution?

Other NCED-related Research

Parker has hosted or will host three visitors during the report period who are performing NCED-related research. A. Bateman of the Polytechnic University of Catalonia, Spain is studying scour in rivers. H. Takebayashi of Tokushima University, Japan, is studying bars in gravel-bed rivers. S. Francalanci of the University of Florence, Italy will study seepage effects on sediment transport.

Research Plans

All the researchers associated with the focus area "Channel and Floodplain Dynamics" are to develop collaborative research programs involving the Angelo Coast Range Reserve field site and nearby areas. Research is to focus on a) bedrock incision, b) channel sampling for cosmogenic radionuclides, and c) floodplain processes.

Research on river restoration is to be expanded to include a) an experimental program on dam removal and b) data collection for the determination of relations for channel design. A workshop on river restoration is planned for the fall of 2004. Major aid supplied by CALFED to Dietrich's group will greatly extend the use of experimentation in the study of river restoration. An effort will be begun to produce tools for the design of river restoration, including software.

The experimental facility for the study of incision by debris flows will be completed and a major experimental campaign will be carried out. Meanwhile, theoretical/numerical investigations of fluvial bedrock incision will be extended. The first steps will be taken toward integrating this research into a general model of drainage basin evolution.

In the next year the analysis of data from the Strickland River, Papua New Guinea should allow for a major step in the development of predictive models for channel-floodplain morphodynamics. It is planned that the first general model describing this process should be ready by the summer of 2005. Results from experimental studies of channel-floodplain interaction with vegetation will be integrated into the work.

The research on cosmogenic radionuclides will be extended to a) regolith reworking by landslides and bioturbation and b) whole-basin conservation laws. The numerical model of tracers in gravel-bed rivers will be tested against experimental data obtained in Washington. The first steps will be taken toward generalizing the model to sediment mixtures.

Experimental studies on meandering channels with self-formed bed and banks will be completed. The results of these experiments and field data will be used to determing protocols for dynamic modeling of rivers.

Research on channel incision in the submarine environment will intensify. In addition, a comparative study of subaerial and submarine channel networks will be commenced.

At the present point the link between the focus area of "Channel and Floodplain Dynamics" is not sufficiently strongly linked with "Ecogeomorphology." A joint workshop is contemplated in order to build better linkages.

Integrative Activities

In the area of *river restoration*, the main collaborators are Dietrich, Parker, Wilkerson and NCED engineer J. Marr. Other major contributors include Perg and Paola. As work progresses in this area, it is foreseen that Power, Finlay and Hondzo will become more closely involved.

Research on *bedrock incision* presently involves Dietrich, Parker and Mohrig, with participation from Perg and Voller.

Research on *channel-floodplain interaction* is very broadly based within NCED, with the cooperating researchers including Dietrich, Parker, Wilkerson, Foufoula-Georgiou, Paola, Mohrig and Perg.

Rivers and deltas is also an area with a broad base in NCED, including Dietrich, Parker, Paola, Mohrig, Foufoula-Georgiou and Wold.

The area of *bedform-channel interaction* presently is represented by Mohrig, Paola, Parker and Perg.

Tracers are being studied by Perg, Parker and Dietrich, with input from Mohrig.

The research topic of *submarine channels* is one where Mohrig, Parker, Paola and Foufoula-Georgiou interact.

Collaborations Outside NCED

The NCED researchers in the area of Channel and Floodplain Dynamics have developed a broad network of non-NCED collaborators. Some of these are enumerated below.

River restoration

Y. Cui and others, Stillwater Science, Berkeley

M. Garcia, University of Illinois Urbana

M. Kondolf, University of California, Berkeley

G. Pasternack, University of California Davis

M. Ramey and others, R2 Associates, Redmond

L. Sklar, San Francisco State University

P. Wilcock, Johns Hopkins University

Bedrock incision

D. Furbish, Vanderbilt University

A. Howard, University of Virginia

B. McArdell, Swiss Federal Institute for Forest, Snow and Landscape

M. Schmeekle, Arizona State University

L. Sklar, San Francisco State University

K. Whipple, Massachusetts Institute of Technology

Channel-floodplain interaction

R. Aalto, University of Washington

S. Apte, CSIRO, Australia

M. Hicks, NIWA New Zealand

C. Nittrouer, University of Washington

M. Stacey, University of California, Berkeley

Rivers and deltas

J. Milliman, Virginia Institute of Marine Science

C. Nittrouer, University of Washington

J. Swenson, University of Minnesota, Duluth

J. Syvitski, University of Colorado, Boulder

T. Tornqvist, University of Illinois, Chicago Circle

Bedform-channel interaction

D. Furbish, Vanderbilt University

Tracers

S. Mukhopadhyay, Harvard University

A. Heimsath, Dartmouth University

D. Granger, Purdue University

Submarine channels

R. Beaubouef, ExxonMobil

C. Pirmez, Shell Oil

L. Pratson, Duke University

J. Imran, University of South Carolina

Leverage and other Funding

Dietrich has received funding from:

NSF Margins program: Processes controlling depositional signals of environmental change in the Fly River sediment dispersal system: Rates and mechanisms of floodplain deposition (collaborative with Gary Parker)

NSF supported Center for Airborne Laser Mapping (NCALM). Funded August 2003 to provide high resolution topographic data and training for NSF PIs (in collaboration with Ramesh Shrestha and Bill Carter of the University of Florida).

NASA Astrobiology Grant: BioMars proposal. This 5 year project, started in August 2003, will support field, experimental and theoretical studies of channels formed by seepage erosion.

American Chemical Society: The formation of channels by sediment-laden flows entering still water: Experimental study of floodplain tie channels.

Water Resources Center (California): Sediment transport processes in steep channels

California Regional Water Control Board: 1) Sediment budget analysis of Napa River watershed; 2) Mapping watershed attributes from Napa LIDAR data; and 3) Limiting factors analysis for Sonoma Creek Watershed.

US Forest Service: Cumulative Watershed Effects and Best Management Practices in Northern California.

Parker has received funding from:

National Science Foundation CTS: Mechanics of downstream fining in long reaches of large, low-slope sand-bed rivers

National Science Foundation MARGINS: Collaborative research: processes controlling depositional signals of environmental change in the fly river sediment dispersal system: rates and mechanics of floodplain deposition (with Bill Dietrich).

National Science Foundation EAR: Sedimentation of particles of varying size and density from turbidity currents originating from grainflows and suspension dispersions under hot and cold conditions.

National Science Foundation EAR: Collaborative research: tracer stone studies; field and flume

ExxonMobil Upstream Research: Morphodynamics of eroding and depositing turbidity currents on the continental slope

Shell Oil: Turbidity currents and submarine gravity flows

In addition to the above, Parker's postdoctoral researcher Yoshihisa Akamatsu is supported by a grant from the Japan Society for the Promotion of Science.

Research-related Knowledge Transfer and Education Activities

Throughout the year Dietrich met periodically with staff from the local Regional Water Control Board to discuss collaborative projects on the Sonoma and Napa Rivers. He also participated in a workshop with the Sonoma Ecology Center and participated in the field site review of the Napa River.

April 24 –28, 2003. Dietrich co-organized a workshop on airborne laser altimetry at the University of Florida. There were about 45 participants from across the country and included individuals from government agencies.

August 14-15, 2003. Dietrich participated in an NAS-NCED sponsored workshop on Stream Restoration.

September 4-7 2003. Dietrich participated in NSF-sponsored planning workshop to solicit guidance (and seek collaboration and support) for future research directions at the Angelo Coast Range Reserve.

November 30 –Dec 3 2003. Dietrich participated in Workshop to review the US Forest Service Boise Aquatic Laboratory.

December 13, 2003. Dietrich hosted the approximately 20th annual Gilbert Club meeting at the NCED/Berkeley. There were about 150 attendees, including many individuals from government agencies and consulting firms.

Parker has been involved in the general design of the exhibits of the Science Museum of Minnesota, with special emphasis on a) an exhibit on dam removal and b) an exhibit on the sinuosity of meandering streams and c) an exhibit on turbidity currents.

Parker played an organizational role in the NRC-NCED sponsored workshop on River Restoration, August 14-15, 2003.

Parker is working with Jeff Marr, NCED Engineer, to develop a program for Knowledge Transfer in the area of river restoration.

Parker distributed 50 advance “beta” copies of his e-book on the morphodynamics of rivers and turbidity currents at the December 2003 meeting of the American Geophysical Union in San Francisco.

Wilkerson was a participant in “Social Sciences Workshop” (Jan. 2004). Held high-level discussions about integrating Social Science research and research on Earth Science. Sponsored by NCED.

Wilkerson organized cross-discipline seminar at the University of Wyoming titled “Time Scales and Fluvial Systems” for spring semester 2004. Responsibility for teaching this graduate seminar is shared by six faculty members from four Departments.

Wilkerson was a participant in “Stream Restoration Workshop” (August 2003). Sponsored by the National Research Council, Water Science and Technology Board and the National Center for Earth-surface Dynamics.

Wilkerson was a participant in the NRC Committee to Review Methods for Establishing Instream Flows for Texas.

Research Focus Area 3: Advanced Mathematical and Observational Methods

Lead PIs

F. Porté-Agel and V.R. Voller

Participating PIs

C. Paola, D. Mohrig, E. Foufoula-Georgiou, G. Parker, M. Power

Focus Area Mission:

The mission of the Advanced Methods focus area is 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.

Research Accomplishments:

In the last year there have been two major themes in our research.

1. The development of numerical methods for characterizing interfaces. Interfaces in Earth-surface dynamics can occur in a variety of forms including:
   - The evolution of bed forms in river channels;
   - Interfaces between biological and physical regimes; and
   - The movement in geological time of shorelines in ocean basins and sediment toes in desert sediment fans in response to fluvial and tectonic processes.
2. Exploiting similarities between river networks and turbulence. This includes
   - Understanding the relation between prognostic evolution equations for landscape evolution and the Naviér-Stokes equations and their low-dimensional analogues such as the Burgers equation.
   - Development of simulation techniques analogous to Large-Eddy Simulation (LES) of turbulent flows to solve the spatially filtered prognostic equations for landscape evolution.
   - Development of parameterizations for subgrid-scale fluxes based on self-similarity and fractal characteristics of river networks.

Developing tools to analyze the dynamics of interfaces and “turbulent” landscapes will improve our understanding and ability to model river network dynamics and contribute significantly to the overall NCED research mission

Major accomplishments in modeling interfaces

Significant accomplishments have been made in modeling moving boundaries associated with ocean basins and desert sediment fans. Of particular note are:

1. The development of a fixed-grid numerical scheme that can track the sediment deposition and shoreline movement in a subsiding depositional basin. Previous methods for tracking Earth-surface moving boundaries are based on deforming numerical grids (Swenson et al., 2000). The development of fixed grid schemes is seen as a major advance in the solution technology since, unlike deforming grid schemes, fixed grid schemes can be easily extended to multidimensional problems and readily modified to include additional physical features. Figure 1 below shows an example calculation of the movement of the shoreline into an ocean basin with variable basement topography in both the off shore and long shore directions. In the case shown the shoreline establishes a "bay" like feature that mirrors the topology of the basement. Once established the "bay" moves as a fixed feature, with the advanced regions feeding the lagging regions of the shoreline.

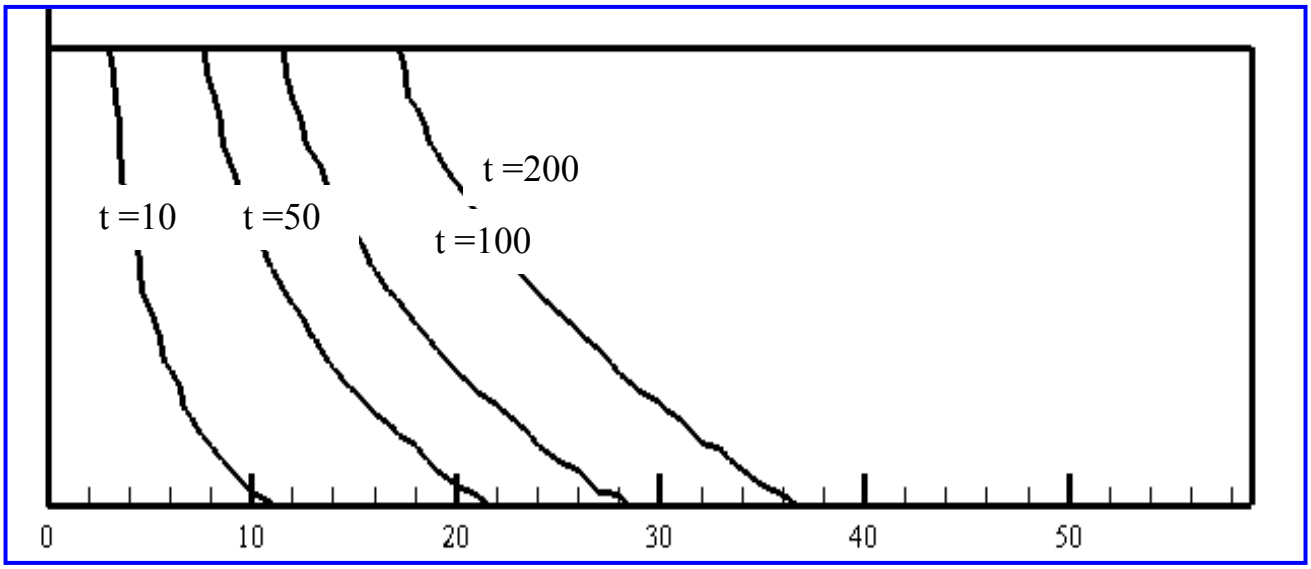

Figure 1: Movement of shoreline into an ocean with a variable basement topology

2. A full analytical solution for the shoreline movement in a basin with no tectonic subsidence of the Earth's crust. To become fully operational a numerical model needs to be verified (Do the numerics solve the governing equations?) and validated (Do the governing equations model the physics?). The full analytical solution, developed this year, is an excellent device for the verification of numerical methods for shoreline tracking
3. Experimental validation of numerical algorithms to track the sediment fronts. Validation of the Earth-surface moving boundary models has and continues to be a critical part of the research effort. The sediment fan experimental work reported this year included extensive comparisons of model predictions with laboratory-scale experiments. Analysis of experimental work is ongoing to provide a fundamental validation of the ocean shoreline tracking model.

A number of efforts were also initiated this year to develop more general numerical approaches for interfaces in Earth-surface dynamics problems. Developments in this context by the Methods group include:

1. The development of an "enthalpy" like method for treating unsaturated flow problems, a method that could have wider applications in dealing with Earth-surface dynamics problems that involve regimes with ill-defined boundaries.
2. The development of a "Lattice Boltzmann"-like scheme for tracking moving boundaries in filling problems. This work employs a discrete model and not only has direct application in the tracking of geomorphic interfaces (e.g., shorelines) but could also be applicable in coupling discreet and continuous processes in Earth-surface environments.
3. The establishment of an NCED Working Group: **Novel methods for modeling the surface evolution of geomorphic interfaces.** The objective of this group is to bring together researchers from the physics, numerical methods and geological communities who have a common interest in studying the evolution of interfaces. A particular objective is to begin to explore how current state of the art interface tracking tools such as, enthalpy, phase-field, Lattice Boltzmann and level set methods can be applied to Earth-surface dynamics problems. The first meeting of this workshop will be at MIT in May 2004.

Major accomplishments in applications of turbulence modeling

In terms of developing and applying turbulence modeling tools to landscapes the main accomplishment is the 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 (which could be termed '*Large-Basin Simulation'*) 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. Two main issues have been identified that need to be addressed to make LES a reliable tool in simulations of river networks: *(a)* the form of the prognostic evolution equations, and *(b)* the formulation of the subgrid-scale model(s). In order to tackle these issues, the following research activities have been carried out:

1. The large-eddy simulation technique has been applied to simulations of selected one-dimensional equations. Two candidate equations have been considered for their potential to simulate realistic fields: *(a)* The noisy *Kardar-Parisi-Zhang* (KPZ) equation, which has been shown to reproduce the correct power law in the spectrum of elevation fluctuations. The KPZ equation is equivalent to Burgers equation with additive noise. This equation is considered a low-dimensional analogue of the Naviér-Stokes equations and has received substantial attention in the physics and turbulence communities. One limitation of this equation is the need for stochastic forcing. *(b)* The *Kuramoto-Sivashinsky* equation, which has been extensively used to simulate surface-growth processes, includes a fourth derivative term that produces deterministic chaotic behavior. Different subgrid-scale models (described below) have been explored and the results compared with direct numerical simulations (resolving all scales) of the two equations.
2. Two new subgrid-scale models have been developed that take advantage of the scale-invariant, multi-affine characteristic of the system.

- *Fractal SGS models*. Fractal interpolation has been proposed as an efficient way to construct subgrid-scale models for numerical solution of coarse-grained Navier-Stokes equations. It is based on synthetically generating a scale-invariant small-scale field and analytically evaluating its effects on large resolved scales. The multiaffine fractal interpolation scheme preserves the fractal dimension and the higher-order structure functions and the non-Gaussian probability density functions of the velocity increments (see Figure 2).
- *Scale-dependent dynamic SGS models*. The model formulation consists of a standard eddy-diffusion model for which the model coefficient is computed at every time step and position based on the dynamics of the resolved scales. The procedure takes advantage of the fact that the coefficient is scale invariant when the filtering (cutoff) scale is in the inertial subrange (where fluctuations of the dependent variable scale as a power law with the system size). In addition, the model is able to account for scale dependence of the eddy-diffusion coefficient in those regions of the domain where the filter scale falls outside of the inertial subrange. The model has been successfully applied in large-eddy simulations of the 1-D Burgers equation as well as 3-D turbulent boundary layer flow.

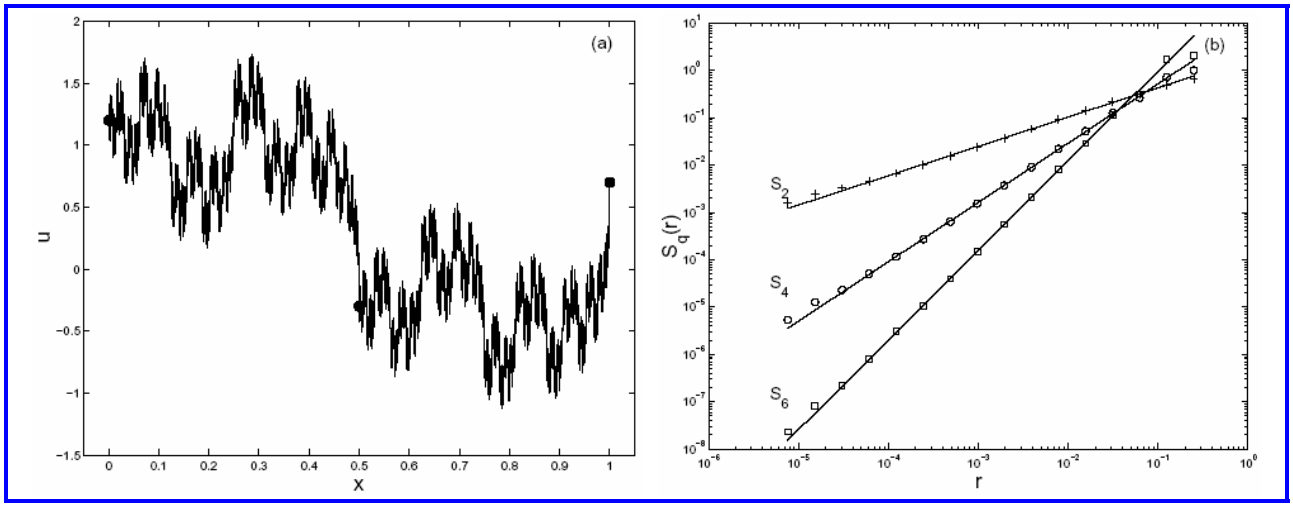

Figure 2: (a) Synthetic fractal signal obtained with the Fractal Interpolation SGS model. The black dots denote initial interpolating points. (b) Structure functions of order 2, 4 and 6 computed from the signal.

Major accomplishments in Observational Methods

NCED senior engineer Jim Mullin, working with the XES experimental stratigraphy group (Long-term Dynamics focus), has developed a unique new method of imaging arbitrarily large quasi-flat areas at extremely high resolution. The method is based on use of a telecentric lens system coupled to a relatively low-resolution CCD device. The lens, mounted in a periscope-like tube, is scanned over the surface to obtain many (hundreds to thousands) of small, undistorted images that are then stitched automatically to produce a single continuous image. The combination of the telecentric lens and customized stitching software produces images with a resolution of approximately 0.2 mm over unlimited areas (e.g., our largest images so far are approximately 5 m long by 1.2 m high, about 700 Mb of data in raw form). The system is being used now to image experimental stratigraphy deposits, but could be applied anywhere a continuous high-resolution image of a large quasi-flat area is desired.

Though it took over a year of intensive work to develop, the system is not that expensive to build; we plan to make the design available to other researchers this year.

Other NCED-related Research

The PIs in the advanced methods group have also undertaken additional NCED research outside of the focus of landscape interfaces and turbulence. This has included

A crack spacing model (D.H. Timm, et al., Int. J. Solids and Structures 2003) to analyze the influence of overburden pressure and shear strength on the crack spacing in jointed rocks. This work, in the process of writing up, will inform the modeling of channel bed erosion by the "plucking" mechanism which removes the rock between joint spacing. An NSF proposal centered on this topic is under review.

PI Voller has had a long interest in developing bio-degradable polymers. In this context a proposal has been prepared to investigation of how bi-degradable polymer devices can be designed and used for river restoration activity.

Contributions to NCED Research Questions

Question 6: What are the most effective mathematical techniques for modeling channel systems, including localization, scaling, instability, and coupling of physical and biological dynamics?

All of the Advanced Methods research efforts contribute to answering Question 6.

In particular the work on the Lattice Boltzmann is seen as a means of coupling multi-scale phenomena across environments and the application of LES approaches is seen as a rigorous approach for handling scaling.

Question 3: How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence ecosystem structure and local channel dynamics.

Question 11: How can we apply turbulence/atmospheric science/hydrology techniques to understand landscapes as stochastic systems: natural variability, material fluxes, evolution, and predictability - especially on medium-to-long time scales.

Our current research activities in turbulence applications contribute both of Questions 3 and 11.

Question 7: What are the mechanisms and dynamics of critical channel processes: initiation, switching, bifurcation, net deposition and erosion, sediment flux and sorting, flow resistance, width variation, and bar/bend evolution?

Since the channel dynamics influence the processes that control how shorelines migrate, the shoreline work is also contributing to understanding the features that result from critical channel processes.

Question 9: How do long-term and short-term processes interact in channel systems, and how can we use information recorded in landscapes and sedimentary strata to better understand these interactions? Understanding the shoreline movement and deposition dynamics and can also be used to understand the effects of climate and tectonic forcing. Hence the shoreline work is also contributing to Question 9.

Research Plans

Work in the exciting area of applying turbulence models to landscape processes will continue. This is an area that has created widespread interest both within and outside of NCED, and we expect that a number of new collaborations and research projects will be initiated in the coming year.

Our research-related to the development of modeling techniques for multi-scale analysis should also grow in the next year, particular the development of hybrid solution approaches, e.g., particle dynamics plus finite element analysis.

We are also looking forward to participating in NCED's first Working Group meeting in May 2004. This Working Group will bring together an international group of geologists, physicists, and mathematicians (in approximately equal numbers) to explore and develop novel ways of tracking the evolution of geomorphic surfaces such as river bedforms and ocean shorelines. We anticipate that this group will generate several interdisciplinary research projects that will be of value to NCED researchers, as well as researchers outside of the NCED community.

To further develop key observational methods, a team of NCED researchers working in the Angelo Coast Range Reserve field site will visit a demonstration set up by the STC Center for Embedded Network Sensing (CENS) at James Reserve, California, in May. The purpose is to investigate how CENS autonomous monitoring and data capture techniques could be applied in ACRR and other NCED locations.

Integrative activities

By its nature, the research in the advanced methods focus area is driven by collaboration with many other NCED PIs.

There continues to be extensive discussions between PIs Voller, Foufoula-Georgiou F. Porté-Agel and Paola, with input from Parker, Power and Mohrig, on identifying computational and analytical tools that can be used to model landscape dynamics. This has involved a number (~5) of 2-4 hour meetings to discuss and exchange research ideas and literature searches. Initial research has been undertaken to investigate the applications of fractals, fractional derivatives and turbulence. The result of some of these efforts is reflected in the turbulence research rePortéd above.

Porté-Agel and Foufoula-Georgiou co-advise two graduate students, Sukanta Basu and Paola Passalacqua. Basu has developed a fractal SGS model and is currently studying the performance of different SGS models in simulations of the 1-D Burgers and Kuramoto-Sivashinsky. This collaboration is documented by a number of research publications (see publication list). Passalacqua is currently studying the multiscale properties of the KPZ equation.

Voller and Paola co-advise graduate student Wonsuck Kim. Kim is analyzing experimental data and developing models associated with shoreline dynamics. The Voller-Paola collaboration is documented by a number of submitted research publications. Research is ongoing to provide experimental data to validate the shoreline modeling work. This work is in the process of writing up.

There is a developing collaboration between Voller and Mohrig. Through contacts at PI meetings, etc., Mohrig has begun to explore, with the suggestions and guidance of Voller, techniques that can be used to study the evolution of surfaces with a focus on channel bed-forms. This collaboration has resulted in Voller and Mohrig initiating the first NCED Working Group - Novel methods for modeling the surface evolution of geomorphic interfaces (described in detail above).

Collaborations Outside NCED

Voller is also collaborating on NCED-related work with faculty NCED affiliates:

- With K. Stelson , Department of Mechanical Engineering at the University of Minnesota, Voller is exploring the possible applications of bio-degradable materials in river restoration. Stelson brings expertise on manufacturing of starch base polymer parts to this project.
- With B. Guzina, Department of Civil Engineering, University of Minnesota, Voller is working on developing models to describe the joint spacing in layered rocks. Guzina brings expertise in geo-mechanics to this project.

Porté-Agel collaborates on NCED-related work with

- I. Marusic, Department of Aerospace Engineering and Mechanics, University of Minnesota; and
- K. McNaughton, Earth Sciences, University of Edinburgh, Scottland.

Leverage and Other Funding - Received

A number of the Advanced Methods research activities have leveraged funding:

1. PhD student Sukanta Basu currently working on subgrid-scale models for LES has a Dissertation fellowship from the Graduate School of the University of Minnesota. This provides full support from 9/03-5/04.
2. PhD student Rob Stoll is supported from Porté-Agel's NSF CAREER award that focuses on the use of LES of atmospheric boundary layers.
3. PhD student Matthew Carper is supported from a NASA award that aims at understanding surface heterogeneity effects on regional scale fluxes in the atmospheric boundary layer using LES.
4. PhD student Sukki Sohn, currently working on joint spacing, has received a fellowship from the Department of Civil Engineering, University of Minnesota. This provides full support from 9/03-5/04.

Leveraged and Other Funding - Proposed

The following proposals would, if approved, provide additional leveraged funding:

1. An NSF proposal related to the study of crack spacing is under review: Intrinsic Length Scales in Cracked Film-Substrate Systems.
2. An IREE (an internal University of Minnesota seed program for the development of environment al engineering solutions) for biodegradable river devices is under review: Starch Based Biodegradable Devices for River Restoration.

Research-related Knowledge Transfer and Education Activities

11/25/03-11/28/03. **Voller** was invited to visit the Geophysics research group in the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge. Extensive discussions on Earth-surface dynamics were undertaken with faculty and students. A seminar entitled "Moving Boundary Problems in Earth Surface Dynamics" was presented.

11/24/03. **Voller** met with researchers at Imperial College to talk about modeling techniques for multi-scale phenomena. These ideas were explored in an invited seminar entitled “Modeling microsegregation in metal alloys.”

Research Focus Area 4: Ecogeomorphology

Lead PIs

M. Power, J. Banfield, J. Finlay, M. Hondzo, A. Wold

Participating PIs

W. Dietrich, C. Paola, G. Parker

Focus Area Mission:

The major goal of the Ecogeomorphology focus area is 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 restoration to our Partners and the restoration community at large.

Research Accomplishments:

We have focused this year on initiating coordinated "physiology to food web" surveys in nine watersheds within the South Fork Eel River basin that range in drainage area from 1 to 260 km^2. In the near future, we plan to expand this to larger watersheds. We survey biota and biogeochemistry to relate food web and ecosystem structure at different landscape positions to the partially predictable changes down drainage networks in environmental conditions and regimes. In the future, we plan to select focal species with wide network distributions, and compare their vital rates, trophic interactions and carbon sources, stoichiometric relationships, and other features that differ at different drainage network positions. Differences in habitat structure, insolation, and water and chemical fluxes affect disturbance and productivity regimes and performances and interactions of species. In some cases, abundances and activities of biota will have reciprocal influences on weathering, erosion or sediment transport rates that will feed back over time to influence landscape evolution.

Research accomplishments over the last year include:

1. Hondzo, Finlay, and Power and their students and postdocs initiated whole ecosystem metabolism measurements over nine reaches of the upper South Fork Eel watershed differing in watershed area, stream morphometry, and vegetation cover. Preliminary measurements indicated that physical processes, including turbulence intensity and photosynthetically active radiation, control photosynthesis and respiration in channels. The analysis of nutrient fluxes revealed spatial and temporal heterogeneities, possibly related to pool-riffle sequences with associated fluid-flow conditions.

2. Banfield and Power designed experiments to quantify effects of various archaea and bacteria on oxidation of pyrite and generation of sulfuric acid in acid mine drainage food webs.

3. Power and Dietrich analyzed 16 years of previous data on the relationship between the flood hydrograph, the magnitude of algal blooms, and dynamic control by fish over lower trophic levels in the mainstem South Fork Eel River food web.

4. Hondzo and his students examined bacteria in stream sediment samples, with associated DNA and amplified *nirK* sequences, coding bacteria for denitrification, as illustrated in Figure 1. The quantity of bacteria from upstream to downstream can be perceived from the strength and intensity of the bands. Above the riffle few bacteria were detected; bacterial densities increased sharply in the riffle, as indicated by the intense, multiple bands tapering down slightly after the riffle.

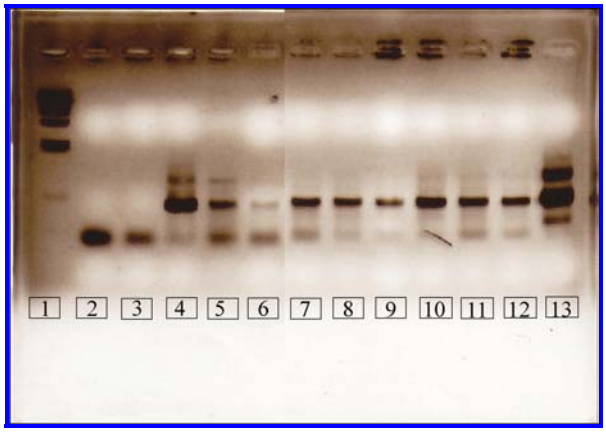

Figure 1. *nirK* electrophoresis gel of South Fork Eel at Jane's Riffle and Elder. 1 Lambda template marker; 2 negative control; 3 SFK upstream (before riffle); 4 (at riffle); 5 (after riffle); 6 SFK downstream; 7 Elder upstream; 8 Elder upstream; 9 Elder upstream; 10 Elder upstream; 11 Elder upstream; 12 Elder downstream; 13 positive control.

With Finlay, Power, and Banfield, Hondzo will extend this research to investigate interactions among physical processes, bacterial physiology, and organic material production and decomposition (autotrophy and heterotrophy) in channels and channel systems. Characteristic space-and-time scales and scaling parameters will provide a basis for formulating predictive models of primary production, respiration, and nutrient fluxes in these environments. In summer 2004, field measurements will be conducted at higher spatial and temporal scales focusing on the pool-riffle sequence and confluences where small tributaries enter main streams. Understanding the interaction among physical, ecological, and geomorphological processes in these stream discontinuua will provide information to form a "biophysics" approach to stream systems.

5. Banfield initiated (with Power, Dietrich, Rodriguez-Iturbé and others) a new biogeochemical study in the South Fork Eel watershed. The objective of this work is to determine how combined physical, hydrological, and biogeochemical factors combine to determine biodiversity in the soil, and in particular, the distribution of the ecosystem-critical role of nitrogen fixation.

6. Banfield designed (with Power) experiments to quantify structure and function in acid mine drainage fluvial food webs. The major focus has been on bioreactor design and development. This has involved working with Maria Goodrich (student of Power), a post doc (Mike Zach, supported by a UC Berkeley Miller Fellowship) and Chris Belnap (student of Banfield).

7. Banfield, with Dietrich, analyzed soil and saprolite chemistry and distribution across the Nunnock River hill slope in order to quantify solute fluxes and physical transport as a function of landscape position (referenced to transport distance, soil thickness, and saprolite depth). They found that chemical weathering rates are relatively constant in the saprolite and as a function of position relative to the escarpment. Differences in landscape lowering are attributed primarily to differences in erosion rates. Modeling results also quantified soil chemical fluxes as a function of transport distance and determined that solute loss is comparable to, and can exceed physical transport.

8. Hondzo investigated Mass Flux at the Sediment Water Interface in a Turbulent Flow. The mass flux at the sediment-water interface of a flow over a smooth bed was investigated under laboratory conditions. Detailed microprofiles of the dissolved oxygen and nitrate concentrations were conducted under the range of Reynolds numbers similar to those occurring in channels. A universal power-law scaling wass derived and verified for dissolved oxygen concentration. An example of this power-law scaling is provided in Figure 2.

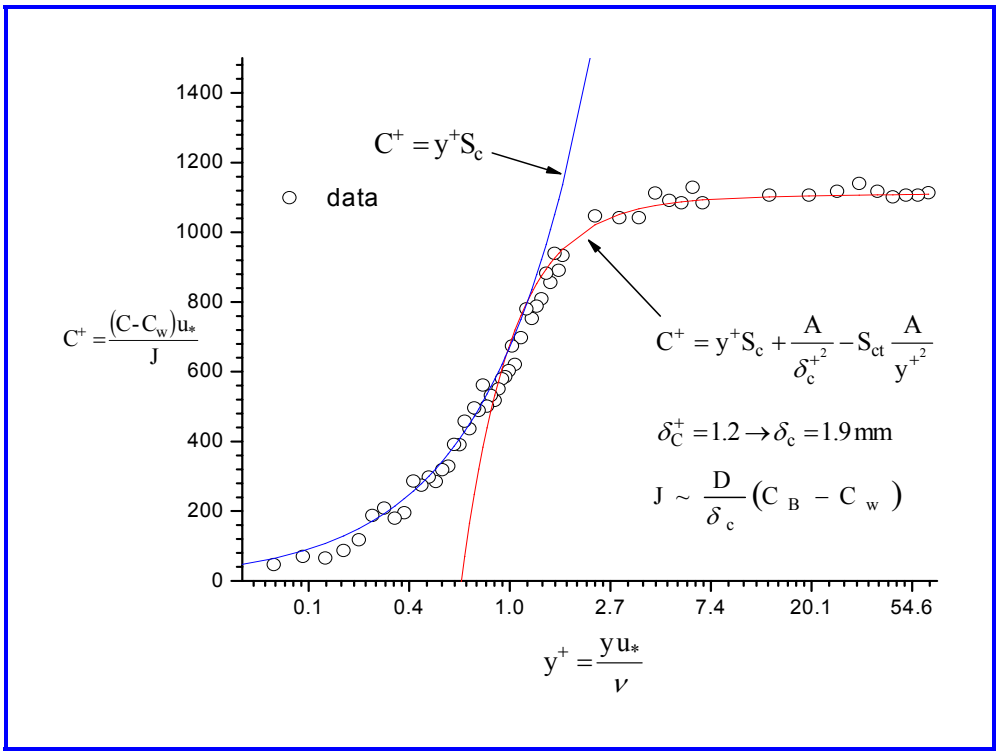

Figure 2. Mass flux at the sediment-water interface: Power-law scaling. J is the mass flux, C is the mass concentration, C_w is the concentration at the sediment-water interface, y is the vertical distance, u_* is the friction velocity, S_c is the Schmidt number, S_{ct} is the turbulent Schmidt number, δ_c is the diffusive sublayer thickness, ν is the kinematic viscosity, and D is the molecular diffusion coefficient.

Contributions to NCED research questions

Our efforts are primarily focused on answering NCED Research Questions 2 and 3:

Question 2: How do channel and floodplain morphology mediate nutrient flow and ecosystem structure?

Question 3: How do channel networks organize themselves, what properties emerge from that organization, and how does network structure influence ecosystem structure and local channel dynamics?

At the Angelo Coast Range Reserve, we have a unique opportunity to integrate approaches to these questions across scales, and across the land-water boundary. Extensive background research, pristine watersheds, and integration of new techniques and approaches are helping us reveal underlying physical and biological mechanisms structuring food webs and mediating ecosystem processes. Ongoing research will examine key geomorphic influences on nutrient transport from forests to streams, and within stream food webs by integrating stoichiometric techniques and theory. Laboratory studies at SAFL will complement field work to demonstrate how channel conditions mediate stream ecosystem photosynthesis, respiration, and nutrient fluxes. Nutrient fluxes, bacterial physiology, photosynthesis, organic material production and decomposition and respiration in channels are mediated by physical processes in channels and channel systems. Our research will reveal what the physical conditions are.

The research being designed by Banfield and Rodriguez-Iturbé at the Angelo Coast Range Reserve contributes to the NCED focus on river channels and ecosystem structure by emphasis on (i) biogeochemical and physical processes in the source regions of river systems and (ii) ecosystem structure and dynamics using a model fluvial system that is unique in its simplicity due to the extreme solution chemistry. The newly developed focus on biogeochemical hill slope processes in the Angelo Coast Range Reserve contributes to the effort to develop unified models that describe ecosystem dynamics in the riparian and adjacent non-riparian zones. This research will dovetail with studies planned by NCED postdoc Jill Welter and Finlay and Power, on influence of landforms such as river terraces on nitrogen fluxes from watersheds to channels in the South Fork Eel River basin.

Research Plans

To support the collaborative field study of the Angelo Reserve, we are in the process of building infrastructure to support wireless communications throughout the reserve (see Figure 3). M. Hondzo, M. Power, P. Morin, and C. Bode will visit fellow-STC Center for Embedded Networked Sensing (CENS) to consult with colleagues there about developing a wireless sensor and camera network to monitor key sites throughout the reserve. Specifically, we will install systems for environmental monitoring of PAR (photosynthetically active radiation), temperature, soil moisture, nutrients, and possibly dissolved gases where studies of topographic (moisture driven) effects on soil microbes (Banfield and Cruz), and woody vegetation (Rodriguez-Iturbé and Caylor) are in progress, and where Hondzo, Finlay, Power, and their labs are studying stream metabolism, and algal, invertebrate, and riparian biota down drainage networks. W. Dietrich and C. Paola have also arranged with the National Center for Airborne Laser Mapping (NCALM) to expand LIDAR coverage of the 300 km^2 study basin so that high resolution coverage of all tributary basins is complete. Warnaars and O'Connor (Hondzo lab) will analyze results from 2003 and 2004 field work on stream metabolism, bacteria, chemistry, and periphyton, and prepare manuscripts on results relating these variables to drainage network position. McNeely (Power lab) will write up her results on the life histories, abundance, and impacts of stream grazers as a function of drainage network position. Several members of the Power lab will begin a manipulative experiment examining the interactions of bacteria and algae down drainage networks, using nutrient diffusing flower pots with algicide and antibiotic treatments as experimental substrates. Interactions of bacteria with algae are predicted to change qualitatively down river gradients, as algae become less light (C) limited, and more nitrogen limited. Power lab graduate students (Limm, Goodrich) and postdocs (Clinton, Schade, Welter) will also investigate litter quality,

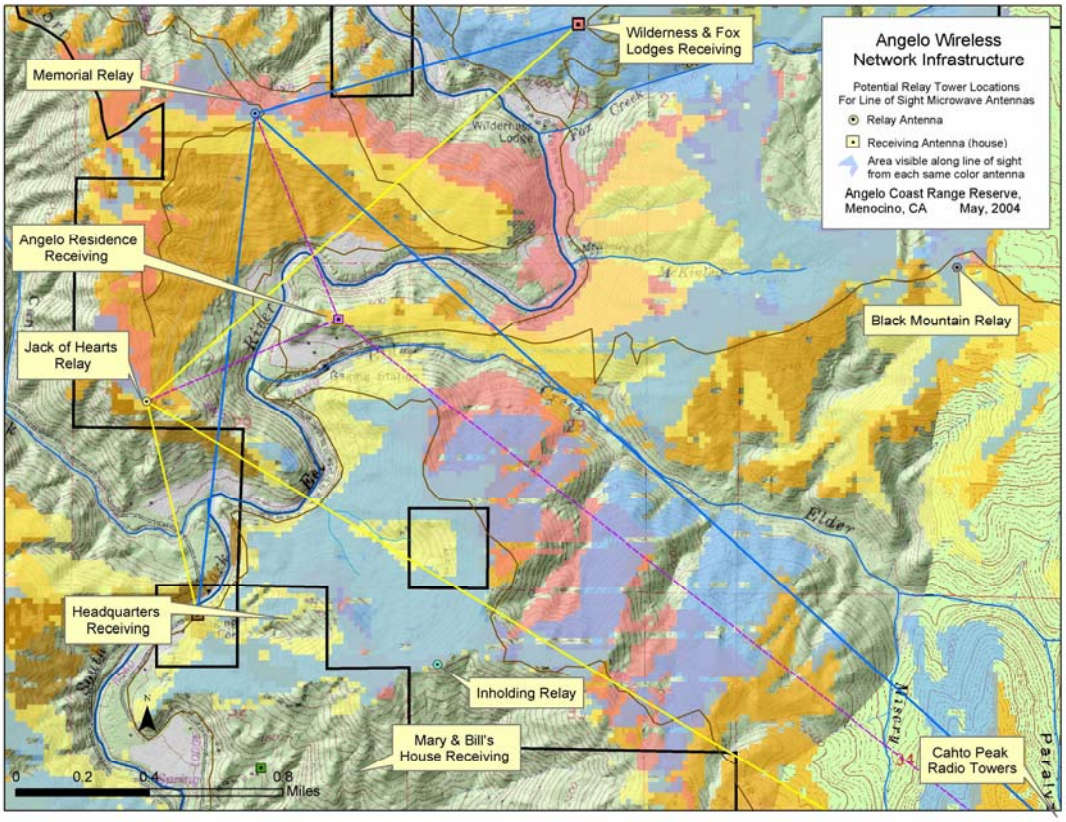

Figure 3. Angelo Wireless Network Plan

input rates, and transport and decomposition rates down drainage networks. Litter food quality for riparian and aquatic consumers is predicted to decrease downstream, as vegetation C:N:P ratios increase with light availability. Limm and Power will initiate studies of the abundance of river lampreys at various network positions, and in collaboration with J. Howard, will study their interactions with the other major large deposit feeder in the food web, freshwater mussels. The spatial scales over which these and other particle feeders collect their food will be examined in various hydraulic environments using tracers. Suttle (Power lab) will continue his manipulative experiment of effects of precipitation on a river terrace meadow food, and Welter and Schade will begin studies of the activity of soil bacteria involved in nitrogen cycling on plots that have received ambient or doubled (as predicted by climate change models) rainfall for five years.

Finlay, Wold and Hondzo will survey food webs and biogeochemistry in northern Minnesota streams, focusing on the influences of geomorphology and hydrology on stream metabolism, nutrient dynamics and food web interactions and possible influences of these factors on wild rice productivity.

Integrative Activities

In summer 2003, Finlay, Hondzo, Power, and their students and postdocs began field investigations of whole ecosystem metabolism (community photosynthesis and respiration), algal assemblages, nutrient fluxes, and channel morphology at nine river reaches down the South Fork Eel River drainage network that range from 1 to 260 km^2 in drainage area. This field work will resume in May 2004, with the help

of two post docs Schade and Welter starting in the spring of 2004, and will expand to incorporate measurements of watershed nitrogen fluxes on patterns of drainage network ecosystem metabolism.

Wold and Finlay have developed research plans over the past year and in summer 2004 will launch studies in northern Minnesota rivers and lakes related to the influence of catchment hydrology on food web interactions.

Banfield is collaborating with Rodriguez-Iturbé and Power to develop a focused biogeochemical study of hill slope processes in the Angelo Coast Range Reserve. These discussions have also involved Hondzo, who shares an interest in understanding controls and dynamics of microbial processes, especially the cycling of nitrogen in this nitrogen-limited ecosystem. These efforts will contribute to studies of whole ecosystem metabolism in different positions within the upper South Fork Eel drainage network. Rodriguez-Iturbé's group will study patterns of vegetation and soils in the river network and my group will contribute analysis of the soil geochemistry and profile the distribution, abundance, and diversity of microorganisms involved in nitrogen fixation in a region of the Eel Basin.

Collaborations outside NCED

Finlay is collaborating with two food web ecologists (John Sabo and David Post,) on an NSF funded project to examine the influence of channel morphology, disturbance, and productivity on food web structure in rivers.

Wold collaborates with George Host of the University of Minnesota, Duluth's Natural Resources Research Institute on wild rice lake restoration.

Power is collaborating on NCED related work with faculty at the University of California, Davis (Jeff Mount, Department of Geology, and Jim Quinn, Division of Environmental Studies). With her CALFED-funded research associate Bill Rainey, she is studying how vegetative structure and hydrologic regime affect insect emergence and the activity of insectivorous bats on the Cosumnes River floodplain. This site is an experimental floodplain restoration initiated by The Nature Conservancy on the only remaining free flowing river draining from the Sierra to the San Francisco Bay.

Banfield is collaborating on NCED-related work with faculty at the Australian National University (Susan Welch) and at Dartmouth (Arjum Heimsath).

Hondzo is discussing collaborative work with Dr. Jack Judy, Center for Embedded Networked Sensing (CENS), an NSF Science and Technology Center, UCLA. Power, Collin Bode, Christopher Ellis, and Hondzo will visit the CENS in May, 2004 to explore the possibility of applying their revolutionary technology to channel and channel networks.

Hondzo has established a collaboration with Dr. Timothy LaPara, Department of Civil Engineering, University of Minnesota. Dr. LaPara has provided laboratory guidance on isolation and quantification of nitrifying and denitrifying bacteria.

Power is collaborating with economist David Zilberman on an invited paper for Frontiers in Ecology on the future of freshwater ecological science, including its contribution to environmental valuation of ecosystem services. This collaboration was launched during the NCED Social Science meeting in January 2004.

Leverage and other Funding - Received

Based on a collaboration developed during preparation for the NCED Site Review during the STC competition in 2002-2003, Banfield (PI) and Power (Co-PI) (with Wayne Getz, a modeling colleague at U.C. Berkeley) were awarded a four-year NSF grant: "BioComplexity: Analysis of factors determining the ecological function and resilience of microbial communities in Acid Mine Drainage".

Banfield has also obtained three other sources of leveraged funding related to NCED research:

1. A three-year grant from the NSF for a graduate student's dissertation work ;
2. A two-year grant from the UC Berkeley Miller Foundation for a microprobe study of mineral interactions; and
3. An NSF award for the study of "Biogeochemical weathering controls on soil formation and landscape development."

In addition to the collaboration listed above with Banfield on the NSF Biocomplexity award, **Power** has obtained:

1. A dissertation research grant;
2. And EPA STAR Fellowship Agreement for student Kenwyn Suttle ; and
3. A five-year grant from CALFED to study the influence of flood regimes, vegetative and geomorphic structures on the links between aqa Terrestrial systems.

Power also obtained funding for an NSF planning workshop at the Angelo Coast Range Reserve: National Science Foundation (Biological Field Stations and Marine Labs) (2001-2003): FSML: Research and facilities planning for the Angelo Coast Range Reserve.

Wold has leveraged current funding that helps to support NCED related research through the USDA with a Tribal College Research Grant that supports wild rice research, and a USDA Tribal College Extension Grant that supports the FLDTCC's St. Louis River-River Watch program.

Leverage and other Funding - Proposed

The following proposals would, if approved, provide additional leveraged funding:

1. Hondzo has submitted an NSF proposal now under review with NCED PI Patrick Hamilton, Science Museum of Minnesota (SMM), for educational outreach.
2. Hondzo has submitted a proposal to CLEANER: Options for field facilities and cyber-infrastructure in America's heartland, Miki Hondzo, Raymond Hozalski, Paige Novak, Shashi Shekhar, Patrick Brezonik, NSF (EBS), (under review).
3. Hondzo has submitted a proposal for development of field and laboratory systems for the *in situ* measurement of the fluid dynamics impact on microbiological physiology, Miki Hondzo, William Herb, NSF (Biogeocomplexity-IDEA), (under review).
4. Hondzo has submitted a proposal entitled "Physical processes regulating the balance of autotrophy and heterotrophy in lakes, Miki Hondzo, Patrick Hamilton, James Cotner, Heinz Stefan, Robert Megard, NSF (Biogeocomplexity), (under review).

5. Finlay and colleagues: NSF-LTER Proposal to establish a Long Term Ecological Research site on Lake Superior. There is a high potential for LTER-NCED interactions on Lake Superior research if funded.
6. Finlay and colleagues: NSF-IGERT Integrative Graduate Training Program Proposal, with Ecology and Engineering faculty. NCED will be a partner is this graduate-training grant proposal.
7. Finlay and colleagues: NSF-Ecosystems and NASA Carbon Cycle Science Program. Proposals submitted for research on carbon and nutrient interactions in permafrost catchments could create opportunities for NCED interactions. Finlay has been working with Paul Morin to analyze influence of watershed geomorphology on stream biogeochemistry at high latitudes. Additional funding would help expand and formalize this collaboration.

Research-related Knowledge Transfer and Education Activities

March, 2004: **Honzo** presented "The influence of physical processes on small-scale biological growth" at Minnesota Water 2004: Policy and Planning to Ensure Minnesota's Water Supplies.

Summer, 2003: With Rainey, Mount, and Quinn, and Michael Eaton of the California Nature Conservancy, **Power** led a field trip to the Cosumnes River reserve to demonstrate insect sampling and bat acoustic detection in various floodplain habitats to Gillian Harris, Liz Epstein, and Ezra Neale, National Fish and Wildlife Service, Lauren Hastings and Marti Kie, Science and Monitoring section of the ERP's Program Integration and Evaluation branch, Donna Podger who staffs the CALFED Environmental Research Program Environmental Water Quality Implementation section, and Bellory Fong, Environmental Program Manager with the CALFED Science Program.

Research Focus Area 5: Long-term Dynamics

Lead PIs

D. Mohrig, C. Paola, L. Perg

Participating PIs

W. Dietrich, E. Foufoula-Georgiou, G. Parker, F. Porté-Agel, I. Rodriguez-Iturbé, V. Voller

Focus Area Mission:

The mission of the Long-term Dynamics focus area is to understand and model the behavior of channels and channel systems on planetary (geologic) time scales, in order to:

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

Research Accomplishments

This year we have focused on three main theme areas:

1. Characterization and averaging of short-term fluctuations. A major issue in understanding long-term dynamics involves averaging fluctuations ranging from the passage of bedforms to major channel avulsions. Long-term records allow us both to estimate statistical properties of these processes, which often occur too rarely to measure directly on human time scales, and to observe their time-averaged effects. This theme includes:
    - Determination of appropriate length and time scales for averaging;
    - Measuring and modeling autogenic fluctuations and their stratigraphic signature; and
    - Developing techniques for accounting for the effects of fluctuating erosion rates on estimates of erosion and exhumation derived from cosmogenic radionuclides (CRNs).
2. Long-term sediment production and flux rates and the effect these have on transport systems. This effort is part of the broader goal within the Long-term Dynamics Group of providing information about long-term trends and pre-anthropogenic conditions in drainage and depositional basins. Current efforts include:
    - Improved estimates of long-term sediment production and delivery using CRNs and age-constrained seismic records;
    - Development of techniques for using CRNs as sediment tracers; and
    - Experimental measurements of how changes in sediment flux are recorded stratigraphically.
3. Effects of base-level change on fluvial systems and how these are recorded stratigraphically. This effort contributes to the Long-term Dynamics group's overall goal of understanding how channel systems respond to and record external signals (sea level, climate, tectonics). This year we focused on:

- Autogenic and externally forced variations in shoreline position and how these relate to fluvial processes during base-level change;
- Processes of formation, recording, and filling of incised valleys; and
- High-resolution study of creation of preserved channel complexes.

Major accomplishments: characterizing and averaging short-term fluctuations

Graduate student Doug Jerolmack and Mohrig are studying the evolution of sandy river bottoms dominated by trains of dunes and bars. We are particularly interested in determining the role that interactions between dunes have in setting patterns of river-bottom sedimentation and erosion and in determining stage/discharge relationships. We began our study with a series of laboratory experiments designed to define how one bedform can interact with and affect another. We found that styles and rates of bedform interaction are very sensitive to the bedform topography itself. This sensitivity of bed deformation to boundary conditions has led us to explore descriptions for an evolving river bed using interface equations (see Figure 1). We are presently examining the utility of the BCRE equations for describing natural variability within evolving bottom topography, including bedform merging and splitting. We are, in effect, seeing how well the evolution of surface topography can be predicted by the geometry of the topography itself.

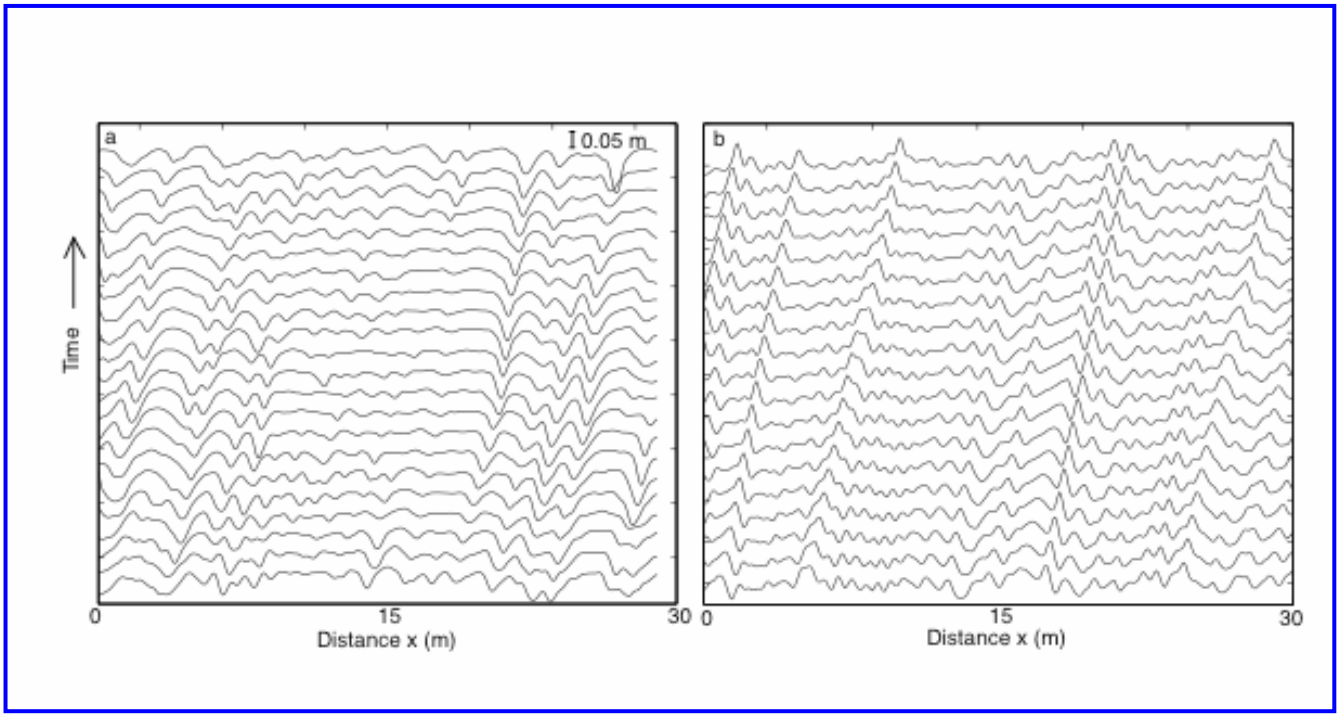

Figure 1. Sequential bed profiles of (a) the N. Loup River, and (b) bed generated from interface equations. Profiles are shown at 360 s intervals, scale bar is indicated in (a).

Mohrig and Graduate student William Lyons made the first direct measurements of the equilibrium time required to establish an approximately steady-state submarine landscape. These measurements have been made using a data set for the Pliocene and Quaternary sections of the Fisk Basin in the Gulf

of Mexico, made available to us by an NCED industrial partner, Shell Exploration and Production Company. Combining 3D seismic data with wellbore data that includes conventional core and dated assemblages of microfossils, we have been able to map and quantify differences between patterns of sediment accumulation and patterns for space created via basin subsidence over a range of time intervals. Differences between the two patterns show an exponential decrease in magnitude as a function of time, and we use the e-folding length associated with this exponential decay to describe the equilibrium time for the system. Mohrig and Lyons used an e-folding length to characterize the equilibrium time for a constructional landscape as first proposed by NCED graduate student Ben Sheets and Paola for experimentally generated systems. The MIT group's analyses show that the equilibrium time changes when the submarine landscape is dominated by largely aggradational, braided-like channels versus single-thread channels, still net aggradational, but with a greater erosional component to their histories. Equilibrium times for the submarine braided-like system versus the transport system dominated by single-thread channels are 4.64×10^5 years and 2.45×10^5 years, respectively.

Perg and Parker have developed a new method of incorporating the effects of fluctuating erosion rates into long-term erosion measurements using cosmogenic radionuclides (CRNs). Currently, the use of CRN concentrations to provide basin-averaged erosion rates assumes that the erosion is steady and thin-skinned, with no spatial variability.

$$\varepsilon = \frac{P_0 z^*}{C},$$

where ε is erosion rate (cm/yr), P_0 is surface production rate (atoms/g/yr), z^* is the 1/e depth of CRN (cm), and C is the measured CRN concentration (atoms/g). The timescale to reach equilibrium, or the effective residence time (T_{eff}) is generally assumed to be the time necessary to remove one to three e-folding depths, or:

$$T_{eff} \approx \frac{2z^*}{\varepsilon}.$$

Under this assumption, even very moderate erosion rates of ~0.1 mm/yr are adequate to reach an erosional equilibrium CRN concentration within the span of the Holocene. The new analytic model developed by Parker and Perg allows changes in erosion rate and also incorporates the more realistic spatial fluctuations in erosion rate around a mean. The results show that when perturbing the erosion rate, the CRN concentrations require two to three times the time span previously assumed to fully reflect the new erosion rate [1, 2]. This is important because many samples previously assumed to reflect purely Holocene erosion rates also convolve Pleistocene erosion rates into their signal.

Graduate students Ben Sheets and John Martin worked with PI Paola on high-resolution measurement of topography in depositional systems to determine how short-term fluctuations are recorded stratigraphically. One of the major results of this work has been to measure the highly composite nature of preserved surfaces: a surface that "looks like" a single, well-preserved channel may in fact be the composite result of multiple periods of occupation.

Major accomplishments: long-term sediment fluxes

Graduate student Christina Kaba and PI Mohrig have finished mapping the Cretaceous-Paleocene continental margin preserved in the subsurface of the North Slope of Alaska (National Petroleum

Reserve, Alaska). They are using a regional grid of seismic lines covering about 9000 km^2. Core and well logs tied to the seismic data have been used to calibrate the interpreted seismic geometries. The data was supplied by NCED partner USGS. We are now using the basin-filling modeling package, STRATA, in conjunction with our subsurface data set, to place quantitative estimates on the sediment flux delivered to the margin from the eroding Brooks Range over geologic time. We are particularly interested in determining whether sediment discharge was approximately steady, or whether sedimentation volumes and margin geometries are consistent with a secular trend in sediment delivery to the system. This nearly continental scale analysis will be available to NCED researchers and others interested in modeling temporal trends in sediment production and transport via channel networks in mountainous environments.

Graduate student Nikki Strong and Paola finished an analysis of the effects of shifts in long-term distribution of deposition in an experimental fluvial basin. They found that most of the changes in preserved channel architecture in vertical strike (cross-sectional) panels could be accounted for by externally forced changes in mass balance (see Figure 2), in this case associated with changes in fluvial slope and associated shoreline migration.

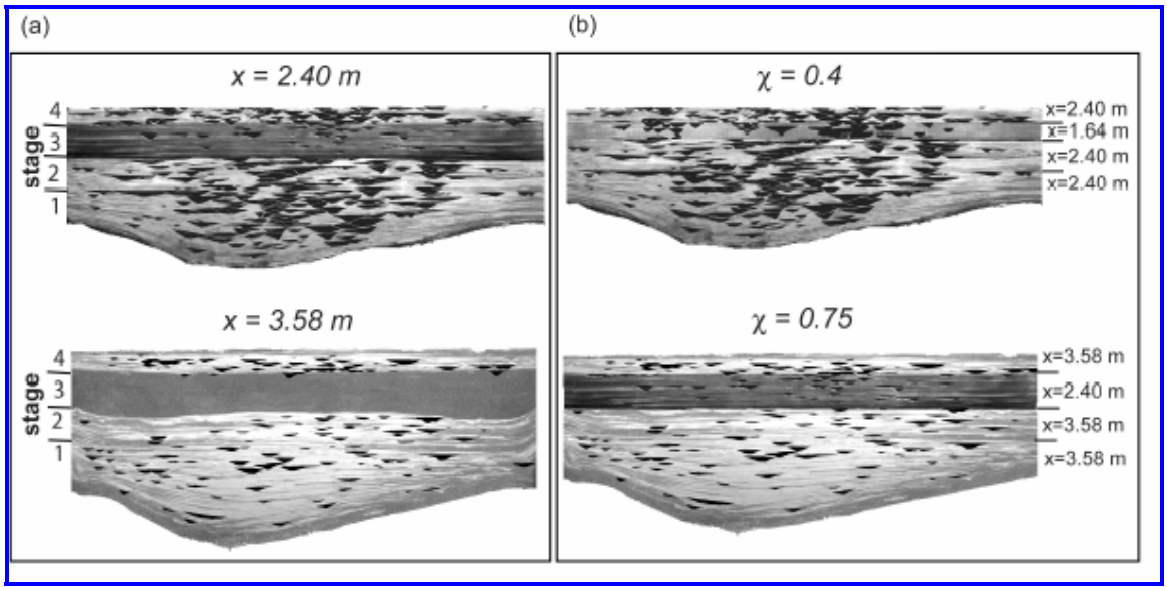

Figure 2. Photographic panels of experimental stratigraphy showing how accounting for mass-balance effects can explain apparent differences in channel stacking. The left panels show differences in stacking density at two downstream locations associated with changes in base level and sediment supply. The bottom panels show composite sections as locations defined by fractional deposition (chi) rather than downstream distance; they are much more consistent than the panels at left (Strong et. al., in press).

PI Perg has finished setting up her new CRN laboratory and is gearing up for measurement this summer of long-term sediment fluxes derived from uplifting terrains. One of the immediate target areas will be the NCED field site at Angelo Coast Range Reserve. Although some basins have similar long-term cosmogenic radionuclide erosion rates and short-term historic records of sediment transport (e.g. Perg et al., 2003), it is quite common for the interpreted long-term erosion rates to be up to ten times higher than the short-term sediment transport. Possible explanations for this include:

1. That measuring suspended sediment only provides a fraction of the total denudation, underestimating chemical weathering and/or bedload transport;
2. That the historic record is too short to capture the rare, large events in a stochastic system; or
3. That the erosion rate is not steady over the effective age of the sediment, either due to convolving Pleistocene erosion rates or short-term climate fluctuations in the Holocene.

The ACRR field site provides an excellent opportunity to test these conjectures. 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 associated NCED PI 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 in the short- and long-term fluxes should then provide a good estimate of the stochasticity of the system, giving an important field constraint for the NCED work in this area.

Major accomplishments: fluvial response to base-level changes

Graduate student Nikki Strong demonstrated that the ongoing reworking of preserved erosional structures introduces shape biases into the record, so that, for example, preserved incised-valley structures are typically broader, with more gentle side slopes, than the actual topographic features they develop from. Although the valley is predominantly formed during the falling limb of the base-level cycle, much of this widening is driven by deposition during the base-level rise.

Graduate student Wonsuck Kim and Paola and Voller worked on modeling the interrelation of shoreline fluctuations associated with base-level changes and autogenic fluvial dynamics. They found that the rate of shoreline migration could be predicted well from the fluvial sediment delivery rate, sea-level change rate, and pre-existing topography using a simple fluvial-marine boundary condition developed in part by Voller and Paola. They also found that autogenic shoreline variations interact strongly with imposed base-level rise and fall to produce much larger fluctuations during rises than during falls.

Graduate student Miguel Wong, working with Parker and Paola, has developed a new model of valley narrowing during base-level fall. The model shows how this results from a self-reinforcing tendency to concentrate shear stress along the centerline of a concave channel and allows prediction of the minimum fall rate for which this effect dominates the intrinsic tendency of channels to widen by eroding their banks. The model is quite general and should be useful in practical problems such as erosion during dam removal, as well as valley formation during sea-level falls.

NCED-related Research

Paola and Voller, working with colleague John Swenson and graduate student Jere Mohr of the University of Minnesota, Duluth, have shown how small changes in transport conditions offshore can control aggradation and degradation in coastal fluvial systems. Paola is also working with postdoctoral researcher Juan-Jose Fedele on a model of long-term sediment retention and stratal architecture in fluvial systems. This model will integrate diffusion-based models of long-term fluvial dynamics with existing predictive models of channel stacking and alluvial architecture. Our ultimate goal is that they will be integrated into a comprehensive long-term model of continental margin evolution being developed with colleague Mike Steckler of Lamont-Doherty Earth Observatory.

Contributions to NCED research questions

The primary contribution of the Long-term Dynamics focus area is to *Question 9: How do long-term and short-term processes interact in channel systems, and how can we use information recorded in landscapes and sedimentary strata to better understand these interactions?*

In addition, the group is working on channel-floodplain interactions on long time scales (because it controls the architecture of alluvial channel deposits), which contributes to *Question 1: How does the interaction of physical and biologic processes lead to the creation of floodplains and channels, and how can we model floodplain-channel interactions over a range of time scales?*.

The planned new initiative on the spatial structure of deltaic channel systems, a joint effort with the Channel Network Dynamics and Scaling group, will contribute directly to *Question 4: How do distributary channel networks compare in structure and dynamics with tributary channel networks?*

Through our experimental and seismic-based research on submarine channel deposits, the LT group also contributes to *Question 5: How can understanding of subaerial channel systems improve our understanding of submarine channel systems and vice versa?*. Members of the LT group are also working closely with the Advanced methods group on mathematical techniques (new equations, applications of turbulence methods), especially ones capable of handling autogenic variability and moving boundaries, both of which are key issues in modeling channel-system dynamics on planetary time scales.

Our study of autogenic behavior also connects the Long-term Dynamics group's research with *Question 8: What are the sources and dynamics of stochastic behavior in channel systems? How does stochastic behavior set limits to predictability of channel system evolution?*

Research Plans

The Long-term Dynamics group will continue working on the themes it has pursued this year. Mohrig and his group plan to continue development of their BCRE-based modeling approach, with input from the Novel Methods for Modeling the Surface Evolution of Geomorphic Interfaces Working Group that will meet in May 2004. They will also continue using well-constrained seismic records to estimate long-term fluxes, work which will inform the choice of a second (depositional) NCED field site, which we expect to make this year. Paola's group will work with Foufoula-Georgiou and her group on application of advanced data-analysis methods to the experimental stratigraphic data they have collected. Two immediate target applications are (1) to determine how topographic signals are aggregated as a function of time scale, which will improve our understanding of the relation of long-term and short-term fluctuations in deposition and erosion; and (2) to improve pattern recognition and extraction in experimental stratigraphic images.

Perg will continue working on the model she has developed with Parker by incorporating effects of bioturbation and landslides. She will also pursue development of CRN based tracer techniques. If a geomorphic system receives sediment from two sources that have different near-surface residence times, the differing cosmogenic radionuclide concentrations can be used as a sediment tracer. A more general analytic model demonstrating this concept for different sediment input systems was developed this year [3]. Further theoretical work will examine the statistical distribution of residence times in a sediment system, not just the mean residence time. Due to the low concentration of cosmogenic radionuclides (^{10}Be, ^{26}Al, ^{36}Cl, ^{14}C) in sediment (e.g., ~10^5 atoms ^{10}Be / g qtz) and resultant large sample sizes, information about the statistical distribution of concentrations is lost. This distribution of

residence times in a geomorphic system, particularly the standard deviation and skewness, is potentially important in investigating the physical processes producing and transporting the sediment. If the statistical distributions are distinctive, they could be used to "fingerprint" different production and transport mechanisms. In addition, it would expand the use of CRNs as a sediment tracer. At the moment, use is currently limited to systems with sediment inputs that have different mean sediment concentrations, while this could open the field to systems that have inputs with different standard deviations and/or skewness.

An overall goal will be to strengthen ties between Long-term Dynamics and the other NCED research focus areas. In the coming year we plan to begin work on using CRN data to constrain long-term sediment production rates in the Angelo Coast Range Reserve field area; this information will be integrated with shorter-term sediment dynamics work there by Dietrich and others. We are starting a new initiative with Rodriguez-Iturbé, Foufoula-Georgiou, and Paola to study the spatial organization of deltas and how this is recorded stratigraphically. Finally, Mohrig and Paola are exploring the feasibility of a new direction that we term "environmental stratigraphy": the analysis of the stratigraphic record with the specific aim of providing data and insight to support environmental science. This is a new and relatively untested application area. We are exploring it in the context of NCED's efforts to catalyze new initiatives in the larger sedimentary geology community.

We plan to run an XES experiment this year on the effect of local basement uplift and subsidence on channel pattern and stacking in the subsurface. The goal is to test a model we have developed that relates the degree of tectonic control to the ratio of a tectonic time scale to a channel-mobility time scale. The experiment should be done this summer and initial results available in the fall.

Integrative Activities

Paola and **Mohrig** collaborate on a number of common interests focused on using the sedimentary record, preserved in basins and on continental margins, to quantify processes influencing landscape evolution at very long time and very large length scales. One topic under investigation by both research groups involves developing methods to characterize and distinguish between the internally generated variability of a transport system (autogenic variability) and the externally forced variability associated with changes in initial and/or boundary conditions for the transport system (allogenic variability). They are working together to apply analysis techniques from the oil industry to the 3D subsurface structure of channel bodies created in our experimental stratigraphy experiments. They are also working together on applications of long-term dynamics to shorter-term problems of environmental management and forecasting.

Paola's major NCED collaboration is with PI Vaughan Voller. They share a graduate student, Wonsuck Kim, in analyzing experiments and developing models associated with the interaction of fluvial systems and shoreline. The basic idea is to apply techniques Voller has developed for study of heat transfer and phase changes to a new class of problems in which channelized systems interact with moving boundaries like the shoreline. This collaboration is documented by a number of research publications [3-5].

Paola also collaborates with Foufoula-Georgiou, Porté-Agel, and Parker. The goal of collaboration with Foufoula is to apply techniques from statistical hydrology to analysis and understanding of stream braiding, stratigraphy, and other morphodynamics problems. Paola is also working with Porté-Agel, Foufoula, and Voller on applying turbulence methods to landscapes. Paola and Parker are collaborating on development of a model for chanel incision and narrowing that will have a wide range of

applications from width dynamics in active rivers to dam removal to formation of large-scale incised valleys.

Through graduate student Michal Tal, Paola's group is developing closer collaboration with the ecology group in NCED (Power, Finlay, and Hondzo). Tal will be working at Angelo Coast Range Reserve this summer on vegetation-sediment interactions in concert with the rest of the ACRR team. His group is also looking forward to working with the ecology group to improve our modeling of vegetation effects on channels experimentally and numerically.

Mohrig collaborates with Parker studying the processes influencing development of submarine channels and comparing the evolution of terrestrial channels to the evolution of submarine channels. To date this collaboration has involved sharing results collected by our respective research groups and discussions of work necessary to advance our understanding of submarine transport processes.

Mohrig's collaboration with Dietrich is centered on understanding the development of tie channels – important water, sediment and ecological conduits between primary river channels and their floodplains. Dietrich's graduate student, Joel Rowland, spent one week of August, 2003, in Mohrig's laboratory at MIT attempting to experimentally develop tie channels. They explored a large portion of parameter space including grain size, sorting, sediment concentration, and water discharge. They also varied channel width and depth and basin-floor geometry. Even so, they were not able to propagate a self-formed channel out into a standing body of water. This work is continuing.

Collaboration with Voller has resulted in Voller and Mohrig initiating the first NCED Working Group - Novel Methods for Modeling the Surface Evolution of Geomorphic Interfaces.

Perg's most active collaboration is with Parker, in developing analytic models to further develop the use of cosmogenic nuclides to investigate long-term surface processes. This collaboration is documented in the publications this year.

A developing collaboration for Perg is with Voller, developing numerical models of fan lobe switching processes and resulting sediment records. A future goal is to obtain a graduate student to aid in implementing some of these numerical modeling ideas.

Another developing collaboration for Perg is with Banfield. Through contacts at PI meetings and through email Banfield and Perg have been discussing collaborations combining long-term denudation rates obtained through cosmogenic nuclide concentrations measured in soil profiles, and biogeochemical weathering rates. The ACRR field site provides an attractive target for these collaborations.

Perg is also collaborating with the other PIs in the Long-Term Dynamics Focus Area, Paola and Mohrig. Perg's work provides a field component complementing the experimental and numerical strengths of the group. The research on the linkages between erosion and deposition in alluvial fans will provide a field prospective on projects.

Collaborations Outside NCED

Paola is working with John Swenson, University of Minnesota, Duluth, and Lincoln Pratson, Duke University. We are working on modeling the coupling between the fluvial and offshore systems on continental margins.

Perg is 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 from data

generated in a collaborative project with M. Oskin, Department of Geological Sciences, University of North Carolina, Chapel Hill.

Perg is also 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.

Leverage and other Funding - Received

Paola has received an NSF/OCE grant for Collaborative Research: Experimental and theoretical study of linked sedimentary systems, for 4/10 thru 3/04.

Paola has received a grant from our Oil Industry Consortium for Collaborative research: Experimental study of basin stratigraphy, for 8/03 thru 7/04.

Paola has received a grant from the NSF for the Community Surface Dynamics Modeling workshop (5 co-PIs).

Paola and Foufoula-Georgiou have received a grant from the NSF to study the Hydrology of Braided River Systems, for 8/02 thru 7/04.

Paola has received a grant from the ONR to study Theoretical and experimental study of strata formation, for 3/04 thru 2/06.

Mohrig has received a grant from Shell International Exploration & Production, Inc. for project entitled "3D geometry & connectivity of submarine channel fills." This project focuses on experimental study of interactions between turbidity currents and channel forms and resulting evolution of channel-form geometries. Results complement NCED-directed research on similarities and differences between terrestrial and submarine channelization.

Mohrig has received a grant from the NSF for the research proposal entitled "COLLABORATIVE RESEARCH: Quantitative reconstruction of paleohydraulics of the Kayenta Formation - Implications for paleoclimate reconstruction." This project is being carried out in collaboration with Dr. Paul Heller of the University of Wyoming. Mohrig is focusing on quantifying the processes controlling construction rates of sandy channel-bottom topography in a number of midwestern rivers. This work is directly relevant to the NCED focus area *Channel and floodplain dynamics: unit processes*.

Perg has received an NSF grant, "Collaborative Research: Testing tectonic geodesy from fault slip rates across the Eastern California Shear Zone." Although the primary goals of the project are to constrain fault slip rates and improve cosmogenic nuclide surface exposure dating on alluvial fans, the data generated in this project (fan ages and surface roughness) will be used to examine alluvial fan lobe switching dynamics.

Leverage and other Funding – Proposed

Perg: A Grant-in-Aid (an internal U of M seed program primarily for junior faculty), "Sedimentary sleuthing: new applications for terrestrial cosmogenic nuclides," ~$30K, is under review. This proposal requests funding for fieldwork and initial seed cosmogenic nuclide measurements for the following three field projects: Angelo Coast Range Reserve long-term catchment erosion rates, ^{3}He measurements in olivine to examine the statistical distribution of sediment residence times, and linkages between erosion and deposition in alluvial fans.

Research-related Knowledge Transfer and Education Activities

August 2003: Paola organized and led oil industry consortium meeting.

April 2003: Paola organized and led industry short course, ExxonMobil Corp, 20 participants.

Spring 2003: Mohrig developed and taught a new class in environmental Earth-surface science entitled *Experimental Investigations of the Charles River*. This hands-on class uses the Charles River as a natural laboratory to study fluid dynamics, sediment transport, and the impact that people have on the river. Students collect and analyze a wide variety of data, including river depths, flow rates, temperature, turbidity and salinity. Course development was funded by a MIT D'Arbeloff Award for Excellence in Education to Mohrig.

10/02/03. Perg met with researchers on the University of Minnesota, Duluth campus. A particular highlight was talking with NCED affiliate J. Swenson about exploring the relationship between erosion rates and cosmogenic nuclide concentrations using experimental techniques. The invited seminar was titled "Mixing it up: cosmogenic nuclides as sediment tracer."

10/22/03. Perg presented a talk to the Minnesota Chapter of the Association for Women in Geosciences, to an audience composed primarily of students, government researchers, and industry geologists. The focus of the talk ("Cosmogenic nuclides: a tool for erosion rates and sediment provenance") was on the practical applications of cosmogenic nuclides, particularly in Minnesota.

11/14/03. Perg met with researchers to talk about the application of cosmogenic nuclides to long-term surface processes questions at Iowa State. The ideas of using cosmogenic nuclides as a sediment tracer and the time span required to reach erosional equilibrium were explored in an invited seminar entitled "Balancing the budget: Cosmogenic nuclides in the Swiss Alps."

3/30/04. Perg organized two career panels for "Choosing a Path in the Geosciences." The purpose was to expose undergraduate and graduate students to different career paths in industry, government, K-12 education, and higher education. Along with University of Minnesota Geology and Geophysics students, students from Civil Engineering, Geography, and surrounding undergraduate institutions were also invited. Perg also participated on the "Academia and Higher Education" panel where she related her experiences as a tenure-track professor at a research institution.

III. Education

1a. Mission and Accomplishments

Mission

The mission of NCED Education is to develop, promote, evaluate and sustain inquiry-based education programs, informed by NCED research, for students at all levels and the general public, in particular those interested in Earth-surface processes and channel systems, in order to:

1. Promote integrated cross-disciplinary education in Earth-surface dynamics;
2. Incorporate NCED research methods and content into undergraduate and graduate education;
3. Promote public understanding of Earth-surface dynamics; and
4. Promote K-12 student and teacher understanding of contemporary research methods and content in Earth-surface dynamics, with an emphasis on inquiry-based learning.

Program Summary

See Figure 1 for a chart showing the relationship between NCED Education and Diversity programs and their target age and ethnic groups.

1. Graduate Students (participate in NCED Research and unique Center opportunities)
   - Graduate Museum Assistantships (interpret NCED research at museums)
   - Interdisciplinary seminars
2. Undergraduate Students
   - Formal and informal research experiences
   - Interdisciplinary courses
   - USIP (See Diversity section)
3. ESTREAM Teacher Research (Secondary School teachers experience NCED research at an NCED facility)
4. Earthscapes (informal and K-12 programs at SMM):
   - Big Back Yard (outdoor science park)
   - Teacher Institute (summer program for secondary school teachers)
   - School Contact (assembly, materials and classroom program for middle-schools)
   - Youth Science Center (after school high-school program; youths also serve as interpreters in the Big Back Yard)
5. K-12 Native American Programs
   - *ando-giikendasowin* high-school camp (see Diversity)
   - *gidakiimanaaniwigamig* Year Round Camp (see Diversity)

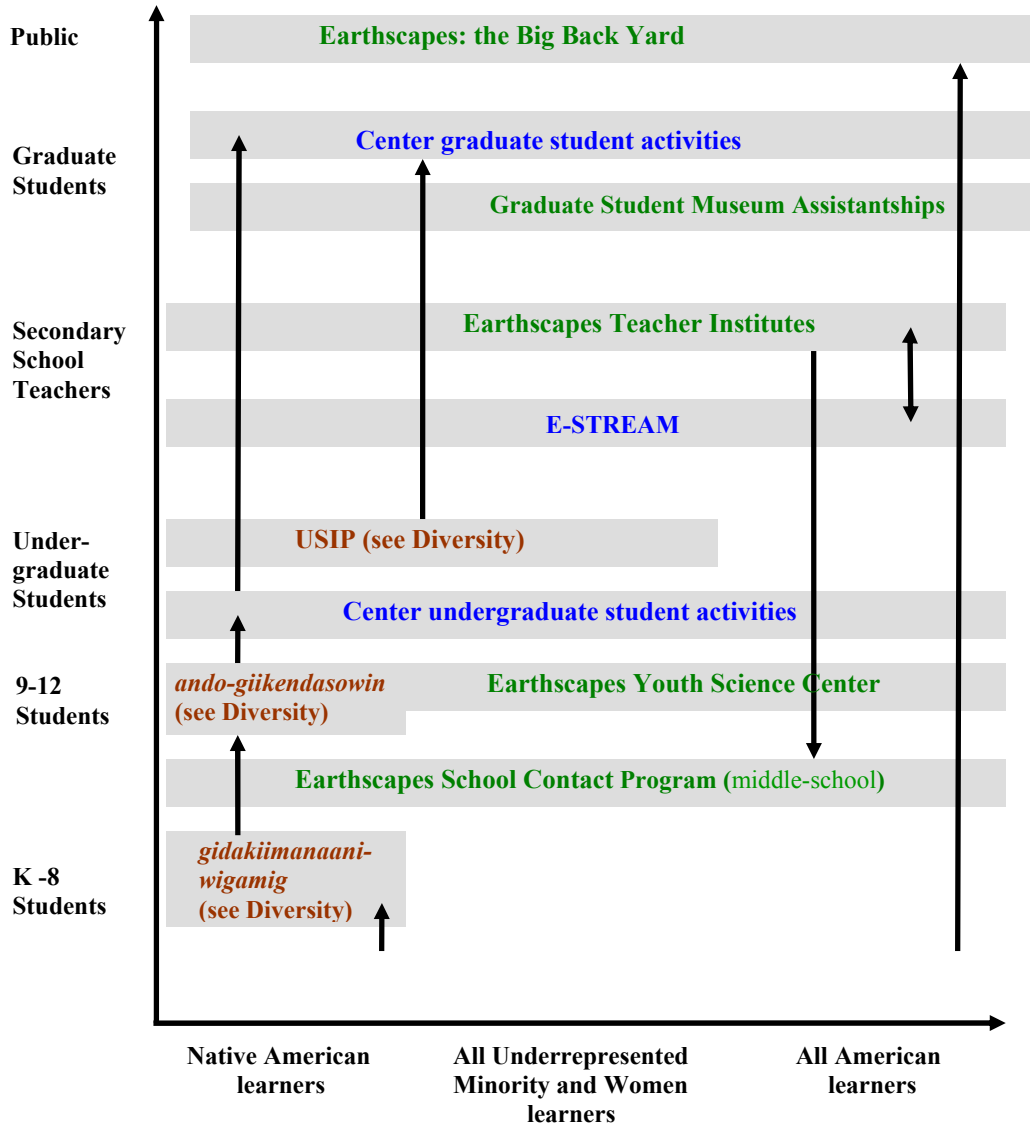

Figure 1. Education and Diversity Programs: Target Age and Ethnic Group Matrix
Legend: vertical axis is age group, horizontal axis is ethnic group. Arrows indicate pathways for learners to move from one program to another.

Accomplishments

NCED's intense, stimulating, collaborative Earthscapes program shines as our major Educational accomplishment in Year 2. This program, in which NCED/SAFL and NCED/SMM PIs, students and staff collaborate to design an outdoor science park (the Big Back Yard--BBY) and related school and after school programs has also been immensely rewarding. Under a very ambitious timeline from BBY conception to Opening Day (June 26, 2004), NCED/SAFL and NCED/SMM Research, Education, Knowledge Transfer and Exhibit staff worked hundreds of person hours to ensure that the park effectively conveys NCED research methods and content to visitors in a consistent "source to

sink" theme. Every hole in the interactive miniature golf course, every associated interactive exhibit and every word and image in supporting interpretive exhibits represents a joint effort involving NCED and Museum staff at every level. Every activity and explanation in the BBY will introduce NCED's vision to the public and enhance public understanding of NCED's mission to develop predictive models in support of sustainable landscape management. We are especially excited by the emerging and sustainable collaborations in youth education and development offered by Earthscapes, as NCED/SAFL Graduate Museum Assistants work to develop training and interpretive activities for NCED/SMM youth and volunteers to use in introducing school visitors and the general public to Earth-surface processes and inquiry-based scientific discovery. Finally, Year 2 brought intense cooperative planning for the three major Earthscapes Education activities: Teacher Institute, School Contact Program and Youth Science Center (see detailed program descriptions below).

In addition, Year 2 has provided exciting opportunities to expand the graduate experience at each of NCED's participating institutions to be a "Center" experience. Graduate students have enthusiastically participated in weekly videoconferenced seminars, conducted joint field research at NCED's first common field site, the Angelo Coast Range Reserve, participated in NCED informal education activities such as the NCED Graduate Museum Assistantship and *gidakiimanaaniwigamig* science immersion program, and led various Partner activities, such as deep and shallow-water shortcourses. NCED graduate students are learning that they are part of something bigger than any one NCED institution and are beginning to take full advantage of all the opportunities Center participation affords them for research and professional development.

In Year 2, NCED has begun formal involvement with K-12 science teachers, greatly expanded our collaboration with Native youth (see Diversity section) and developed and assessed print-based three-dimensional visualizations of channels and channel systems.

Finally, NCED has begun a formative assessment of all Education programs. NCED PIs, staff and students collaboratively developed a comprehensive, formative plan to evaluate our Education, Diversity and Knowledge Transfer programs. We were guided in this effort by a PhD candidate in Education Policy, Mary McEathron, whose objectivity and professional program evaluation skills helped us clarify goals and develop measurable performance indicators by program. This activity is resulting in a set of evaluation instruments which will help NCED continuously refine and improve its Education Programs. Sustained use of instruments and data implemented as a result of this research will help NCED develop an effective Educational assessment program at all student levels.

1b. Performance and Management Indicators

Internal: Graduate Education Indicators:

1. Attendance and presentations at weekly Center videoconferences
2. Attendance, planning involvement and presentation at Center annual retreat
3. Participation in research or field work with PIs other than own advisor
4. Participation in Museum Assistantships
5. Units prepared for and taught in NCED Teacher, K-12 and Diversity programs
6. Student evaluations of NCED programs

External: Teacher Education program (ESTREAM: Earth Science Teachers/Researchers Engaged in Active Modeling) Indicators:

1. Teacher uses of classroom projects developed during ESTREAM participation
2. Classroom tested projects collected and published in timely manner by NCED
3. Number of teachers in program
4. Teacher evaluations of program

External: Earthscapes: Big Back Yard Indicators (BBY):

1. Number of visitors to BBY per month
2. Visitor evaluation of BBY experience
3. Number of educational events conducted in BBY
4. Media coverage of BBY

External: Earthscapes: Teacher Institute Indicators:

1. Teacher use of Teacher Institute educational tools, projects and activities, and maps in their classrooms
2. Teacher attendance at follow-up workshop to demonstrate use of Teacher Institute plans in their classrooms
3. Number of teachers participating
4. Participant evaluation of program

External: Earthscapes: School Contact Program Indicators:

1. Number of students who attend program
2. Scientific curiosity generated
3. Level of interest in STEM careers

External: Earthscapes: Youth Science Center (YSC) Indicators:

1. Number of students who choose to pursue STEM careers
2. Volunteer satisfaction with training
3. SMM staff satisfaction with training
4. Feedback from Big Back Yard visitors on experience with docents

1c. Challenges in Meeting Center Goals

Some specific initiatives planned for Year 2 were not fully implemented:

Internal programs:

1. Explore the possibility of creating a unified surface process curriculum for all NCED graduate students; and
2. Incorporate themes from NCED research into all relevant undergraduate courses

Planning continued in both of these areas; two pilot integrative graduate seminars and one undergraduate class were taught, at three NCED institutions, in Year 2. NCED will build on these efforts in Year 3.

External programs:

1. Establish speakers' bureau, identify audiences and speakers;
2. Plan and implement traveling Mississippi River exhibit; and
3. Set up scholarship committees for ANAMS and PATH scholarships.

In the first two cases, efforts already underway by other local agencies, such as the Minnesota Historical Society, the National Park Service, and the Grand Excursion Committee, of which NCED was originally unaware, duplicate some of what we had envisioned. It also became clear that NCED's 3D maps and other visualizations have a great deal of potential for use in the area of public outreach, so time has been devoted to evaluating how they may be used in this way. NCED's partnership with PATH has been scaled back to enable NCED to devote more time and energy to working with the Native American community.

2a. Internal Education Activities

NCED's internal Education activities support NCED Center Goal 5:

To work with education partners to develop effective methods of communicating Earth-surface science to formal and informal learners.

Note: detailed Activity Tables are at the end of this section.

General Graduate Student Education

Description: NCED believes a critical responsibility and central function of an NSF STC is to ensure that Center graduate and post-graduate students have a uniquely "Center" experience, enhancing traditional educational and research experiences, while providing opportunities in support of the following goals:

Goals: NCED Graduate Students:

1. Understand NCED's vision, mission and goals;
2. Participate in interdisciplinary/inter-institutional research;
3. Have opportunities to interact with NCED Knowledge Transfer Partners in agencies and industry;
4. Experience or consider formal or informal K-12 and public Earth Sciences education as careers and/or community service options; and
5. Are increasingly American citizens from *underrepresented* minorities and are aware of the scientific community's responsibility to increase minority representation in the professoriate.
6. Experience enhanced graduate experience (e.g. career development, workshops, ethics training, etc.)

Outcomes: In Year 2, NCED graduate students, across institutions, have become well-integrated into Center activities. Particularly exciting outcomes have been:

1. Regular and growing graduate student participation in many unique cross-Center Research and Knowledge Transfer activities, such as attending and presenting Center-wide videoconferences, meeting informally with NCED Visitors, attending formal NCED/SAFL seminars presented by

Visitors, working with our Stratigraphic Partners, meeting and working with new colleagues at other NCED institutions, and presenting NCED research to visitor groups at NCED?SAFL;

2. Piloting two integrative NCED graduate seminars (see table for details);
3. Direct participation by NCED graduate students in the annual PI retreat;
4. Enthusiastic participation by graduate students Nikki Strong and Michal Tal in NCED's first Graduate Student Museum Assistantships (see below);
5. Growing participation by graduate students in Diversity and K-12 and Teacher Education programming: supervising USIP interns, planning and participating in *gidakiimanaaniwigamig*, participating in school visits to NCED/SAFL, helping in Earthscapes Teacher Institute planning; and
6. Development and teaching of two integrative graduate seminars (see table for full details).

Graduate Student Museum Assistantships: In Year 2, we launched a formal program of Graduate Museum Assistantships designed to enrich the graduate experience by complementing the standard assistantships in teaching and research. NCED graduate students participated in our first formal Museum Assistantship at the Science Museum of Minnesota. Nikki Strong and Michal Tal, University of Minnesota geology PhD candidates, are spending spring term 2004 working with SMM staff to develop interpretive materials and activities for use in the Big Back Yard. Michal Tal is developing a set of resources, print and web-based, to help SMM staff and volunteers, including Youth Science Center teenaged interpreters, understand more deeply the science content implicit in the park's "erosion, transport, deposition" theme. Nikki Strong is working with the Youth Science Center teens to develop specific activities and recommend equipment for instructional use in the Park. She is also working with NCED's pre-service teacher to develop 3D maps for use in these activities and provide a field trip on regional geology to the core YSC staff. SMM staff, volunteers and youth report this intense involvement of graduate students is greatly increasing their understanding of NCED research. Strong and Tal (both of whom brought to the experience some prior exposure to teacher and K-12 instruction) report tremendous enthusiasm and personal satisfaction from the experience as well as a new appreciation for informal education and K-12 teaching.

2b. Participation of Center Students in Professional Development Activities.

In addition to the activities described above, NCED graduate students participated in 13 Conference Abstracts and 15 Conference Proceedings.

Graduate Education: Plans for Year 3:

1. Continue high level of participation by graduate students in all Center-wide activities;
2. Continue NCED's successful innovative Graduate Museum Assistantship program at NCED/SMM;
3. Expand graduate student program to include:
   - Possible teaching assistantships at NCED/FDLTCC;
   - Involving graduate students in Working Groups;

- Developing a student volunteer program for NCED Education activities in addition to tours; and
- Creating an interinstitutional NCED Graduate Student Council, with the ability to apply for funding for professional development and other activities (such as funds to travel to one another's institutions); and

4. Explore the possibility of creating a unified surface process curriculum for all NCED graduate students.

Undergraduate Student Education

Description: NCED's programs in undergraduate education include undergraduate research experiences for students from within and outside NCED institutions, a pilot experience for pre-service K-12 teachers, and ongoing efforts to incorporate interdisciplinary research into undergraduate instruction. NCED also collaborates with external partners to test and evaluate the effectiveness of three-dimensional and other Earth-surface visualizations in the undergraduate curriculum. Finally, various NCED institutions, including SAFL, open their doors to undergraduate classes from various institutions and professional organizations for tours and field or experimental work.

Goals:

1. Promote integrated cross-disciplinary education in Earth-surface dynamics; and

2. Incorporate NCED research methods and results into undergraduate education.

Outcomes:

In Year 2, NCED sponsored four undergraduate summer interns, three from external institutions. (See Diversity Section of this report for greater detail). A former NCED summer intern was a co-author on a paper submitted by two NCED PIs. (Kawakami, Damien,Voller,V. R., Paola, C., Moving Boundary Problems in Earth-Surface Dynamics, Moving Boundaries VII: Computational Modeling of Free and Moving Boundary Problems, Edited by: A.A. Mammoli and C.A. Brebbia, WIT Press, 2003.). NCED supported the NCED REU program of Dr. Julie Maxson (Gustavus Adolphus College, St. Peter, MN), with a pre-field work introduction to St. Anthony Falls Laboratory and a post-field-work opportunity for REU students to conduct model studies at SAFL. Several undergraduate classes from institutions outside NCED visited NCED's St. Anthony Falls Laboratory for lecture-demonstrations of NCED research and modeling.

David Mohrig developed and taught a new class in environmental Earth-surface science entitled *Experimental Investigations of the Charles River*. This hands-on class uses the Charles River as a natural laboratory to study fluid dynamics, sediment transport, and the impact that people have on the river. Students collect and analyze a wide variety of data, including river depths, flow rates, temperature, turbidity and salinity. Course development was funded by a MIT D'Arbeloff Award for Excellence in Education to Mohrig.

One uniquely integrative undergraduate experience commenced in Year 2. A University of Minnesota "special status" student (Ben Freisen) enrolled in an undergraduate course taught by NCED PI Lesley Perg, to enable him to complete additional credits needed for a post-baccalaureate Masters in Education degree and Middle-school Earth Science licensure. Through Perg, the student learned of NCED and is spending spring term both employed by NCED and conducting independent research for credit with NCED visitor Chris Bromley. In an additional paid role, he is working closely with NCED

Education staff, graduate students, and NCED/SMM staff to develop materials and activities for use on NCED's website, and in the Earthscapes Big Back Yard , Teacher Institutes and School Contact Program.

Year 3 Undergraduate Education Plans

In Year 3, NCED will

- Host undergraduate summer interns at NCED/SAFL and NCED/Wyoming;
- Evaluate the effectiveness of minority undergraduate research experiences in increasing Diversity within NCED (see also Diversity section);
- Collaborate with U of M Geology and Geophysics summer UROP program;
- Continue its collaboration with U of M pre-service teacher and evaluate this experience;
- Continue to develop and evaluate effectiveness of three-dimensional and other Earth-surface visualizations in the undergraduate curriculum;
- Offer an undergraduate seminar in Earth-surface dynamics at the U of M; and
- Continue hosting visits to NCED facilities by undergraduate student classes from outside NCED institutions;
- Work on extending the range of NCED content used in undergraduate courses across the Center.

2.c NCED External Educational Activities.

NCED's external Education activities support NCED Center Goal 5:

To work with education partners to develop effective methods of communicating Earth-surface science to formal and informal learners.

Note: detailed Activity Tables are at the end of this section.

ESTREAM

Description: Middle- to high-school teachers join NCED research teams to work on specific research projects. The educators are integral members of the research teams, participating at the level of an undergraduate intern. Teachers create classroom-ready activities which will be tested in their own classrooms and other local schools. The activities are evaluated and collected, then broadly disseminated through Earthscapes Programs (see below) and the NCED website.

Goals:

1. Middle- and high-school teachers participate in NCED research to experience contemporary Earth-surface science modeling methods; and
2. Teachers themselves contribute classroom-tested, NCED-related activities to NCED educational programs and the wider community.

Outcomes: In Year 2, ESTREAM was piloted with two teachers selected from a pool of six applicants. Kent Gordon (middle-school Earth Science teacher) and Kris Nelson (high-school Chemistry teacher) were paired respectively with Carissa Carter and Chris Bromley (NCED visitors) and worked closely with them in designing and executing the respective visitors' physical modeling

studies at SAFL. Each teacher developed a series of activities which they tested in their own or colleagues' classrooms.

In addition, both teachers became enthusiastic members of the NCED community. Gordon and Campbell organized an evening at SAFL for the Minnesota Earth Science Teachers Association (of whose Board Gordon is a member). Nelson served as member of the Geology Career panel organized by Perg and Campbell for Earth Science graduate and undergraduate students throughout Minnesota. Gordon and Campbell will both attend the annual meeting of the Minnesota Science Teachers and Environmental Educators associations, along with NCED EAB member Anthony Murphy, NCED pre-service teacher Ben Friesen and Earthscapes Teacher Institute staff, establishing a strong collaborative presence for NCED in the Minnesota science teacher community.

Plans for Year 3: Fully implement ESTREAM program by:

1. Evaluating Year 2 experiences and teacher-developed activities;
2. Posting these activities on NCED's website;
3. Increasing participation by minority or minority-serving teachers;
4. Developing opportunities for ESTREAM teacher research to be conducted at NCED-related field sites; and
5. Investigating inclusion of pre-service and informal educators.

Earthscapes Programs (NCED/SMM

Earthscapes overall description

Earthscapes Programs incorporate NCED research into formal and informal education experiences for museum visitors and school audiences throughout Minnesota. Our signature collaborative project has been the design and construction of a major outdoor science park, called the Big Back Yard, in which a miniature golf course, interactive exhibits and a natural landscape engage visitors with "source to sink" concepts of erosion, transport and deposition. (The BBY is described in detail in Appendix F.) In addition, Earthscapes comprises three programs in which K-12 students and teachers experience content conveyed in the park in greater depth, while also becoming familiar with NCED research methods and interacting directly with NCED staff, students and PIs. This collaboration, bringing a research university and a museum together as Center participants, serves as a national model of ways in which museums and Centers can work together to promote public understanding of scientific research and the societal relevance of such research. The cutting-edge nature of this partnership was underscored in a keynote address by Marco Molinaro, Education Director at the Center for Biophotonics Science and Technology, at the March 2004 NSF Research Center Educators Network (NRCEN) conference, where he described it as the "most integrated and ambitious end-member of museum-NSF-Center collaboration".

Each component of the Earthscapes program will be described in greater detail below.

Outcomes:

In Year 2, Earthscapes was the forum for intense, productive, mutual engagement of NCED-SMM staff and youth and NCED-Research, Education, Diversity and Knowledge Transfer staff and students in integrating NCED research with education. This collaboration produced dedicated enduring partnerships at all levels, as evidenced by regular communication, goals and deadlines easily met, and

ideas and opportunities for additional collaborations/leveraging emerging on a regular basis. From NCED/SMM and NCED/SAFL staff jointly conducting field trips and presentations at one another's professional association meetings, to joint investigation of new funding opportunities, this major partnership is something we look forward to celebrating with national visibility when the Grand Excursion (http://www.grandexcursion.com/), commemorating America's first railroad connection to the Mississippi River, culminates in the Twin Cities on July 4, 2004, with featured activities at NCED/SMM.

Earthscapes: the Big Back Yard

Description: The Big Back Yard is a 1.2-acre outdoor space, accessible from the Science Museum of Minnesota, overlooking North America's major channel system, the Mississippi River, as it flows through St. Paul, Minnesota. It combines innovative landscaping, interactive exhibits and a nine-hole miniature golf course to engage visitors of all ages with the myriad ecogeodynamic processes that shape Earth's surface, focusing on channel and channel network processes (see Appendix F). The golf course will be a regulation course, attractive to sporting enthusiasts from around the world and available for championship play. The unifying theme of the Big Back Yard is: erosion, transport, deposition. We are very excited about the ways in which NCED's most public face will utilize golf, a sport which puts the player in touch with topography as no other, to engage BBY visitors with NCED research themes in a uniquely interactive way.

Goals:

1. Raise public awareness and understanding of Earth's changing and evolving surface;
2. Foster an appreciation among visitors for the complex interaction between humans and landscapes; and
3. Introduce audiences to the science of modeling the systems and processes that shape the Earth's surface.

Outcomes: While important conceptual work on Big Back Yard design took place in Year 1, detailed exhibit and golf course design and prototyping, interpretive signage development and physical site preparation and foundation work all took place in Year 2. This activity involved hundreds of person hours on the part of PIs from all NCED institutions, including SMM staff.

Plans for Year 3:

1. Construction will be completed by the end of May, 2004; a limited number of visitors will be admitted for a final operational tune-up June 19 and the BBY's grand opening will take place June 26, 2004;
2. During July 2004, direct visitor feedback will be collected and used to refine BBY activities and exhibits; in August, an external evaluator will perform summative evaluation;
3. While the BBY is closed (October 2004-mid April 2005), youth and adult classes will be held in Science House, the BBY's "green" classroom building; and
4. Earthscapes Educational programming will continue into Year 3 and beyond; April 2005 will offer the first intensive opportunity to test use of the BBY with school field trip groups.

Earthscapes Education: Teacher Institute, School Contact Program, Youth Science Center

To further interpret content introduced in the BBY and develop understanding of this content in K-12 teachers and students, at SMM, in the field, and in their own classrooms, NCED's Earthscapes program has three education components: a summer teacher institute, a school visit program and an after-school/summer program for urban youth. Each program is described more fully below. All have specific goals but share these common goals:

1. Earthscapes education outreach programs will introduce teachers and students to the ways in which NCED scientists observe, interpret, model and predict the processes that shape the Earth's surface through time; and
2. With the help of visualizations, physical models, and inquiry-based instruction, teachers and students will be able to recognize and identify erosion, transport, and deposition processes occurring on their own landscapes.

Earthscapes: Teacher Institute

Description: Up to twenty middle-to-high-school teachers are recruited, in interdisciplinary teams, to study river systems in the field and in the laboratory from a variety of "NCED perspectives". They learn current integrative approaches to understanding river behavior and gain direct experience of the ways in which field measurements and physical models can be combined to create predictive computational models for river and basin management. Teachers work with scientists and educators from NCED and the wider community to master content, explore methods, develop classroom plans and share their experiences in follow-up workshops.

Goals: Middle- and High-School teachers:

1. Acquire experiential knowledge of contemporary and interdisciplinary research topics and methods in Earth-surface science;
2. Participate in research activities at NCED field sites and experimental facilities;
3. Become aware of NCED educational tools on website; and
4. Develop plans to bring this experience into their classrooms, utilizing inquiry and standards-based approaches.

Outcomes: Visits with researchers at NCED/SAFL and NCED/FDLTCC, as well as educators at the Maltby Nature Reserve have helped structure an innovative, active, field-based summer experience for the anticipated 20 teacher participants.

Plans for Year 3: Conduct inaugural Teacher Institute: During the two-week institute (August 2-13, 2004), teachers will spend two days at Maltby Nature Reserve on the Cannon River in southeastern Minnesota and two days near the FDLTCC on the St. Louis River in northeastern Minnesota actively observing, developing questions, and conducting team investigations related to river dynamics and ecosystems. Scientists will support this field research and will integrate appropriate content as needed. Week two will move the teachers' experiments indoors to create models at NCED/SAFL and to study current research at the facility. Visualization resources will be included during this week as well as outdoor work in the Big Back Yard. Two follow-up sessions during the school year will enable teachers to share with one another their classroom experiences in providing Earth-surface science concepts in their classrooms.

Earthscapes School Contact Program

Description: The Earthscapes School Contact Program will bring NCED research to Minnesota schools via school assemblies, classroom visits, and teacher resources. Students will discover the Earth's "living skin", in which physical, chemical, biological, and human processes come together to shape the surface of our planet.

The topics covered will include:

1. Types of surface forms and their distribution on Earth;
2. Basic physical, biological, and chemical processes that shape the Earth's surface, and how they are interconnected;
3. How life has shaped and been shaped by surface processes and topography;
4. How the surface environment has affected human settlement and culture; and
5. How humans have shaped and are shaping the surface environment.

The School Contact program will make extensive use of the visualizations that are being created as part of our Knowledge Transfer program.

Goal: To create scientific curiosity in U.S. K-12 students and promote Science (and particularly Earth Science), Technology, Engineering, and Mathematics (STEM) careers to that audience.
Outcomes: Over the past year school outreach staff have focused on the background research necessary to develop the Earthscapes outreach programs for middle-school audiences. In addition to program content, staff have monitored the revision of the Minnesota Science Standards and identified connections between state and national standards and NCED. Staff have attended Earth Science teacher meetings and conferences to discuss and gather input from teachers to identify their instructional needs regarding Earth-process science with an emphasis on basis systems. Joel Halvorsen, SMM Education Technology Fellow, has prototyped a portable "geowall" 3D high-definition computer server and projection system to be used by the program.

Plans for Year 3: By the time the Earthscapes Teacher Institute takes place this summer, the SMM outreach department will have purchased and assembled the hardware and software for the portable geowall and projection system for the Earthscapes outreach programs. Pilot versions of the large group assembly program, classroom activities, and portable exhibit resources will be previewed at the Institute for teacher input and suggestions. Based on the teacher and NCED staff feedback, outreach staff will develop revised and completed versions of each program by late summer. School outreach staff will begin presentation and program delivery to the participating schools beginning in fall 2004 and throughout the 04/05 school year. The programs will be modified throughout the year based on the presenter's experiences and participant evaluations.

Earthscapes Youth Science Center (YSC)

Description: The three components of the Youth Science Center's (YSC) role in Earthscapes are: (1) outreach to community after-school sites with NCED-inspired activities, (2) youth staffing of the Big Back Yard, and (3) youth internships at NCED/SAFL. In the past year the YSC has spent time planning and implementing the community outreach program and the youth staffing of the Big Back Yard. The YSC works with many community partners that offer after-school programs.

Goals:

1. To teach NCED concepts to SMM volunteers and paid youth interns in order to enable them to educate the public about these processes, especially those working as docents in the Big Back Yard;
2. To provide youths from underrepresented groups a research experience at NCED; and
3. To assist youths from underrepresented groups to prepare for Science, Technology, Engineering, and Mathematics (STEM) careers.

Outcomes: The Youth Science Center has hired a team of high-school students who will be staffing the Big Back Yard this summer. Recruitment of adult volunteers for the park will begin shortly. An NCED graduate student, Michal Tal, is preparing the background materials that will be used to train both the youth staff and adult volunteers about the science content of the park. Another NCED graduate student, Nikki Strong, is in the midst of developing an NCED–related activity that youth staff and adult volunteers will be trained to present to park visitors.

In the past year, the YSC evaluated the way in which it brings science to these programs. The evaluation was timely for the development of the Earthscapes YSC outreach program. A team of seven YSC youth employees developed a format for outreach to communities using the suggestions provided in the evaluation, including multiple visits from a consistent group of youth employees so that the younger children can form relationships with the older youth. Between January and March 2004, the YSC piloted this outreach format using NCED content with three after-school sites in St. Paul reaching a total of 60 children for three visits each. YSC youth employees designed three 1.5-hour hands-on sessions that were conducted with each of the three after-school programs. Two of the three sessions were done at the community sites, while the third one was held at the Museum. The group got positive feedback on the format and content of the program. Based on this success, the NCED/YSC outreach program will use this format in the coming year.

The Big Back Yard will be staffed in part by a YSC team called "Park Crew". During March 2004, 12 youth began this position. These youth will work along side adult volunteers and Museum staff to help visitors during their park visits. The team of 12 is a diverse group of youth ranging in age from 15 to 17. Nine of the youth have previous YSC experience; the remaining are new to the program. The team is composed of seven girls and five boys. Six of the crew members are youth of color. Since hiring, the team has been meeting twice per week to get immersed in NCED content so that they can effectively and accurately communicate concepts to the museum visitors in the BBY. Two NCED graduate students, Nikki Strong and Michal Tal, have been working closely with the team. The meetings have entailed such activities as visits to SAFL to learn about current research, trips to field sites, and development of hands-on activities to be used in the Big Back Yard and at community outreach sites. This is the first exposure to research scientists and scientific labs for most of the youth on this team. YSC staff report that youths in their program are already responding to their relationship with NCED graduate students by increased curiosity about and motivation to pursue science careers. "*It is clear that many of the youth had never seen a working lab like SAFL. They talked or wrote about the fact that they had heard people had jobs like this but they didn't really know how it worked. They also wondered how you got a job like Karen's, Nikki's or Michal's.*"

The YSC has also participated in the planning and implementation of Fond du Lac *gidakiimanaaniwigamig* winter and spring camps for young people from the Ojibwe School. This winter, the YSC director attended winter camp and this spring some members of the Park Crew will act as camp counselors for groups of middle-school students during Spring Camp May 7, 2004. The Park Crew will be trained to help facilitate activities at the spring camp and will work with a specific group

of participants throughout the weekend as they experience inquiry-based introductions to NCED concepts in a field location in northern Minnesota.

Plans for Year 3: During the next year, the Park Crew will continue to learn about and experience NCED concepts. This will include running an experiment at SAFL with Nikki Strong and running experiments with Michal Tal on equipment set up at the Museum. After the opening of the park on June 26, the youth will spend the majority of their work time through October working with visitors in the park. Between October and March, this team will visit community sites in the outreach program. The general format of the program will be the same as the pilot outreach program, but the content and activities will be richer and the number of days spent with each site will increase. Finally, the Park Crew and Managers will continue to participate with NCED/SAFL staff in the planning and implementation of *gidakiimanaaniwigamig* year round programming for young people from the Fond du Lac Ojibwe School.

2d. Research-Education Integration.

As NCED's vision, mission and research focused in Year 2, and Social Science and Partner activities emphasized the societal benefits of NCED research, methods of and opportunities for integration of education with research crystallized. The programs listed below involved direct participation by NCED researchers in activities with formal and informal education settings. Graduate student research is an important element in integrating Research and Education. Details of graduate student research are given in the Research focus area reports.

1. A major NCED activity integrating research and education was the collaborative development of the Big Back Yard. This is described in detail in 2c of this section and in Appendix F.
2. An undergraduate student, Ben Friesen, preparing for a Master of Education degree and middle-school Earth Science certification is developing 3D maps and associated activities, working with YSC on activities for the Big Back Yard and working with visitor Bromley on his modeling study on dam removal;
3. NCED graduate students Michal Tal and Nikki Strong are preparing activities and supporting material for the Big Back Yard via the new Graduate Museum Assistantship;
4. NCED graduate students lead tours of St. Anthony Falls Laboratory for school and professional groups;
5. ESTREAM—K-12 teachers experience NCED research first-hand and develop classroom activities that communicate both content and method;
6. Earthscapes Teacher Institute—being developed to reflect NCED's research process, with the result that participating teachers will be able to communicate it in their classrooms and impart the excitement and relevance of scientific research to their students; and
7. Educational uses of NCED's erosional research field site, the Angelo Coast Range Reserve, and its educational field sites in Minnesota will also reflect NCED's research process.

Activity Tables

Year 2 Activities	**Graduate Education**		
Intended Audience	**NCED Graduate students**		
Date	**Location**	**Led by**	**Attendees**
Ongoing	SAFL	Campbell	NCED graduate students 300 tour attendees
Graduate student volunteers are trained to present NCED research and facilities to school groups, teachers, conference attendees, agency and professional association groups who attend tours of SAFL			
Ongoing	Angelo	Power, Rodriguez-Iturbé, Hondzo	5 NCED graduate students and 1 post-doctoral fellow
Joint field research, across NCED disciplines and institutions			
June-August 2003	SAFL	Dalbotten	Nikki Strong, Michal Tal, Diana Dalbotten, Tom Coulthard NCED Visitor), Karen Campbell, Jim Roe (SMM)
Supervised USIP undergraduate intern research, attended final poster session, planned and participated in a field trip, and a visit to SMM to learn about BBY development			
October 2003	Cloquet, MN	Paola and Voller	10 NCED graduate students
Universities of Minnesota and Wyoming NCED students attend PI retreat, participate in sessions, and discuss plans for next year.			
Spring 2004	NCED/SAFL	Paola and Vuruputur	12 NCED graduate students
Piloted unique NCED graduate seminar—content and enrollment cut across NCED themes from scaling to unit process to long term dynamics, seminar was co-taught by PI Chris Paola and post-doctoral fellow, Venugopal Vuruputur. Students participating are the advisees of 5 NCED PIs and one SAFL alumnus.			
March 2004	University of Minnesota	Perg, Campbell	Lesley Perg, Karen Campbell, Kris Nelson (ESTREAM teacher), Rebecca Soileau (Environmental Partner) 30 student attendees

Career panel for undergraduate and graduate students in geology; NCED students invited to attend; receive career guidance			
February-July 2004	SAFL	Campbell	Up to 15 Geoscience graduate students from around the US, DLESE representatives
SAFL plans, sponsors NAGT/DLESE graduate professional development pre-meeting workshop, as part of the On the Cutting Edge series			
Spring 2004	University of Wyoming	Wilkerson	Wyoming graduate students
Organized cross-discipline seminar at Univ. Wyoming titled "Time Scales and Fluvial Systems" for Spring 2004 semester. Responsibility for teaching this graduate seminar is shared by six faculty members from four Departments.			

Year 2 Activities	**Weekly Research Seminar**	
Intended Audience	**U of M NCED graduate students and researchers**	
Date	**Presenter & Affiliation**	**Subject**
May 2003	Murray Hicks, National Institute of Water and Atmospheric Research Ltd. (NIWA), Christchurch, New Zealand**;** NCED Visitor	New Zealand river braiding research: field work and models
June 2003	Tom Coulthard, University of Wales at Aberyswyth; NCED Visitor	Computational and physical model studies of anabranching river systems
October 22, 2003	Kelin X. Whipple, MIT	Tectonics from Topography: Procedures, Promise, and Pitfalls
November 5, 2003	Gregory B. Pasternack, University of California, Davis, NCED Visitor	River Restoration as a Science-based Design Problem
December 2003	Colin Thorne, University of Nottingham (advisor of NCED visitor Chris Bromley)	The Three Gorges Dam project: a physical and social sciences perspective
February 25, 2004	Jon Pelletier, University of Arizona	Arroyos and drumlins: Examples of pattern-forming instabilities in geomorphology

March 3, 2004	David Furbish, Vanderbilt University (NCED EAB)	Biologically driven soil transport and hill slope evolution

Year 2 Activities	**Weekly NCED Videoconference**	
Intended Audience	**NCED Graduate students and researchers**	
Date	**Presenter/Affiliation**	**Subject**
October 21, 2003	Chris Paola	Paola Research Group (Sedimentary Geology)
October 28, 2003	Jacques Finlay	An update on watershed ecology research
Nov. 18, 2003	Greg Wilkerson	Flow through trapezoidal channels with rigid cylinders
Nov. 11, 2003	Joel Rowland (advisor: David Mohrig)	Flood Plain Tie Channels
Dec. 2, 2003	Paul Morin	Visualizing Topography
Feb 3 **,** 2004	Pat Hamilton	Big BackYard: NCED's park at the Science Museum of Minnesota
Feb 10, 2004	Gary Parker	Cosmogenic nuclides
Feb 17, 2004	Efi Foufoula	Scaling in hydrologic response
Feb 24, 2004	Jon Pelletier, University of Arizona	A tale of two landforms: Discontinuous ephemeral streams and drumlins
March 2, 2004	David Furbish, Vanderbilt University (NCED EAB)	Biologically driven soil transport and hill slope evolution
March 9, 2004	Camille McNeeley, (advisor: Mary Power),	Caddisfly grazing in the South Fork Eel River Watershed
March 23, 2004	Michael Kelberer, Chris Paola, Vaughan Voller	Annual Report preparation
March 30, 2004	Ben Sheets (advisor: Chris Paola)	Assembling the alluvial stratigraphic record: Sedimentation in experimental channel networks across time scales

Year 2 Activities	**NCED Graduate Student Museum Assistantship**		
Intended Audience	**NCED Graduate students; museum educators, volunteers and youth**		
Date	**Location**	**Led by**	**Attendees**
December 2004	FDLTCC	Dalbotten	Nikki Strong
NCED graduate students participate in *gidakiimanaaniwigamig* camps, teaching NCED science to middle-school students			
Spring 2004	SMM/SAFL	Paola, Hamilton	Theresa Burrell, Karen Campbell, Diana Dalbotten, Pat Hamilton, Chris Paola, Nikki Strong, Michal Tal
Strong and Tal serve as interns at SMM, developing content and activities for BBY staff and volunteers who will interpret the park to the public			

Year 2 Activities	**Undergraduate education**		
Intended Audience	**Undergraduate students within and outside NCED institutions**		
Date	**Location**	**Led by**	**Attendees**
Ongoing	SAFL	Campbell, Paola, Sheets	150 students, 4 external faculty
Tours, lectures and experiments for visiting undergraduate classes.			
Spring 2004	SAFL	Campbell, Morin, Paola	Ben Friesen, Chris Bromley, Nikki Strong
U of M pre-service teacher conducts research with NCED visitor Chris Bromley and prepares 3D maps and activities for use in Earthscapes education and BBY; organizes field trip for YSC staff and students with NCED graduate student and Graduate Museum Assistant Nikki Strong			
Ongoing	U of M	Morin	Kent Kirkby (U of M), Anthony Murphy (College of St. Catherine and EAB), Karen Campbell
Evaluation of effectiveness of 3D maps in undergraduate and secondary classrooms and laboratories.			

Year 2 Activities	**ESTREAM**		
Intended Audience	**Middle to** High-school **Earth Science teachers**		
Date	**Location**	**Led by**	**Attendees**
July-December 2003	SAFL	Campbell	Karen Campbell, Chris Bromley, Kent Gordon, Kris Nelson, Carissa Carter
Two teachers work with SAFL visitors, complete research, complete classroom projects, projects			

now under evaluation, and being classroom tested.			
February 2004	SAFL	Campbell, Gordon	30 MN Earth Science teachers
Field trip to SAFL for attendees of Minnesota Earth Science Teacher Association; overview of NCED research and teacher opportunities, tour of facilities, introduction to the Big Back Yard.			
February 2004	SAFL	Campbell	30 Minnesota science teachers, MN state science specialist, Paola, Perg, Voller
Presented NCED research and teacher opportunities, including Big Back Yard, to members of Minnesota's Quality Teacher Network, a state-wide group of Master Teachers charged with supporting all state science teachers in adopting new teaching, licensing and testing requirements.			
March 2004	U of M	Perg, Nelson, Campbell, Soileau	40 student attendees, 10 panel members
ESTREAM teacher Nelson and NCED Environmental Partner Soileau participate in Careers panel organized by Perg and Campbell			

Year 2 Activities	**Earthscapes: Big Backyard**		
Date	**Location**	**Led by**	**Attendees**
Intended Audience	**General public, teachers and students**		
Ongoing	SMM and SAFL	Marr	Karen Campbell, Efi Foufoula, Pat Hamilton, Jeff Marr, Michael Kelberer, Ken Kornack, Paul Morin, Chris Paola, Gary Parker, Jim Roe, Ben Sheets, Peder Thompson (additional SMM exhibit staff)
SMM and SAFL collaborate on prototyping exhibit components, final mechanical engineering and modeling work on the miniature golf holes, the development of graphic panels, and the creation of an overall landscape design for the entire park			
Summer 2003	SAFL/SMM	Roe	Jim Roe, Jeff Marr, Karen Campbell
The "playability" and ADA (Americans with Disabilities) accessibility of the course carefully reviewed by an external consultant experienced in both aspects of golf course design.			
November 2003	SMM	Hamilton	Chris Paola, Karen Campbell
Presentation to ASTC attendees about NCED and BBY; Twin Cities geology field trip			
November 2003	SMM	Paola	50 attendees

Presentation about NCED to ASTC attendees			
January 2004	Berkeley, CA	Campbell	Karen Campbell, Pat Hamilton, Chris Paola, Rochelle Storfer, Vaughan Voller
Visit to outdoor geology park at Lawrence Berkeley Hall of Science; familiarize museum community with Park; learn from LHS' experience			
March 2004		Kornack	Campbell, Jeff Marr, Hamilton
Park construction resumed; grand opening scheduled for Saturday, June 26.			
March 2004	Gainesville, FLA	Marco Molinaro	Karen Campbell, Diana Dalbotten, 50 attendees from NSF Centers
BBY is featured in presentation to NRCEN by Marco Molinaro, Biophotonics STC Campbell, Dalbotten attend, answer questions; promote museum/STC partnerships			
Spring 2004	SMM	Hamilton	Burrell, Campbell, Dalbotten, Freisen, Paola, Steiner, Strong, Tal
Youth Science Center high-school student and adult volunteers for the park recruited and trained; training materials and activities developed by NCED Graduate Museum Assistants Michal Tal and Nikki Strong			
Ongoing	SMM, SAFL, Berkeley, Illinois	Hamilton	Karen Campbell, Pat Hamilton, Paul Morin, Gary Woodard
Discussions with SAHRA, Water Campus, NCED about a traveling 5,000-square-foot national exhibit about the role of water in large-scale global processes to complement Park; establish additional museum/STC partnerships outside NCED			

Year 2 Activity	**Earthscapes: Teacher Institute**		
Intended Audience	**Middle to** High-school **teachers, primarily Science teachers**		
Date	**Location**	**Led by**	**Attendees**
May 2003	Redwing MN	Campbell	Karen Campbell, 200 K-12 students and teachers

Campbell presents as part of CGEE-Audubon Arc river science days for all Red Wing area middle- and high-school students. This experience provided the first of several opportunities to test the use of NCED's 3D maps to engage teachers and students in understanding channel systems			
July 2003	SAFL	Campbell	Chris Bromley, Karen Campbell, Sara Johnson, Jeff Marr, Carrie Sheehy
Four-day lab experience on dam removal for 15 high-school students in UM ITCEP program; pilot experience for possible incorporation in teacher programs			
July 2003	Boulder, CO	Dalbotten	
Attend DLESE annual meeting; learn how DLESE can be incorporated in teacher institutes			
November 2003	Minneapolis	Campbell, Paola	Karen Campbell, 100 K-12 science teachers
KC presentation : "The Secret Life of Topography" on NCED's model of understanding channel systems to National Science Teachers Association; 30 in session; 100 attended open session afterward			
February 2004	SAFL	Campbell, Gordon	Dawn Cameron, Karen Campbell, Kent Gordon, 30 middle-school Earth Science teachers
Presentation and tour for 30 attendees of Minnesota Earth Science Teachers Association meeting (see also ESTREAM)			
February 2004	SAFL	Campbell	Karen Campbell, Chris Paola, Lesley Perg, Vaughan Voller
Presentation and tour for 30 attendees of Minnesota Quality Teacher Network standards meeting (see also ESTREAM)			
March 23, 2004	Randolph, MN	Campbell	Dawn Cameron, Karen Campbell, Nils Halker, Lee Schmitt
Meet with Jeff Maltby and staff to tour Maltby Preserve, discuss potential partnerships between NCED, SMM and Maltby, including use of Preserve staff and location for programs such as Teacher Institute			

Year 2 Activities		**Earthscapes: School Contact Program**	
Intended Audience		**Middle-school students in Minnesota**	
Date	**Location**	**Led by**	**Attendees**
October 2003	Duluth, MN	Larry	Karen Campbell, Paul Morin, Diana Dalbotten,

		Thomas	Larry Thomas and approximately100 school children
Kids Plus conference for disadvantaged youth; presented geowall and 3-d map activities to as a pilot activity for School Contact Program			
December 2003	SMM	Hamilton	Karen Campbell, Diana Dalbotten, Larry Thomas, Nills Halker, Chris Paola, Vaughan Voller, Mary Ann Steiner
Meeting of all NCED staff involved in Earthscapes programming to develop goals			
September 2003	SAFL	Thomas	Karen Campbell, Larry Thomas, SCP staff
Meet with SCP staff to learn more about NCED, maps, Geowall			
February-May 2004	SAFL, SMM	Campbell, Morin	Karen Campbell, Ben Freisen, Nikki Strong, Paul Morin
Pre-service teacher develops 3-d maps, instructions for compiling them and activities			
Spring 2004	SAFL	McEathron Dalbotten	McEathron Dalbotten
Design ongoing formative evaluation			

Year 2 Activities	**Earthscapes: Youth Science Center**		
Intended Audience	**Inner-city middle and high-school students from the Minneapolis/St. Paul metro area**		
Date	**Location**	**Led by**	**Attendees**
June 2003	Aurora IL	Diana Dalbotten	Ronan Mir, SciTech Museum
Visit to Sci-Tech Museum to tour outdoor science park, explore partnerships, discuss possibility of hosting museum interns at NCED			
July 2003	Angelo Reserve	Diana Dalbotten	Karen Campbell, Mary Ann Steiner, Patricia Steele, Mary Power, grad students
Meeting to discuss possible joint NCED/Angelo and NCED/SMM youth programming.			
October 2003	FDLTCC	Diana Dalbotten	Holly Pellerin (FDLTCC), Mary Ann Steiner (SMM), Patricia Steele (Angelo Reserve), Greg Wilkerson (Wyoming), David Mohrig

			(MIT)
Meeting to begin planning and discussing funding options for an integrated national Native American youth science immersion program; program will be modeled on *gidakiimanaaniwigamig*, but linking Native youths across NCED partner sites.			
November 2003	SMM	Diana Dalbotten	Theresa Burrell (YSC, SMM), YSC students
Exhibit building workshop, American Science and Technology Conference.			
November 2003	SMM	Mary Ann Steiner	Diana Dalbotten, Theresa Burrell, NCED graduate students
Youth Science Center Open House during ASTC with NCED graduate students on hand to work with visitors.			
November 2003	SAFL	Paul Morin	Chris Paola, Karen Campbell, Paul Morin, Ronin Mir
Visit of Ronin Mir, Director of SciTech Museum in Aurora, IL, to explore partnership possibilities with NCED and YSC.			
Ongoing	FDLTCC	Mary Ann Steiner	Diana Dalbotten, Holly Pellerin
Youth Science Center developing partnership with *gidakiimanaaniwigamig*. Youth Science Center students and staff act as mentors for students in *gidakiimanaaniwigamig*.			
Ongoing	SAFL/SMM	Diana Dalbotten	Mary Ann Steiner, Mary McEathron, Theresa Burrell
Design formative evaluation for YSC.			

IV. Knowledge Transfer

1a. Mission and Accomplishments

Mission

The mission of NCED Knowledge Transfer is to develop, promote, evaluate and sustain effective communication between Center researchers and the Earth-surface Dynamics professional community generally and NCED's Partners in particular, in order to:

1. Ensure NCED research is informed by Partner and community needs and perspectives;
2. Develop and maintain research collaborations between and among NCED and Partners; and
3. Ensure broad, timely, efficient access by Earth-science professionals (and, with the Education program, educators) to NCED research results, data, tools, and models.

Program summary

NCED's formal Knowledge Transfer programs consist of:

- Partners (Environmental and Stratigraphic): agencies and industries engaged in issues of environmental forecasting, landscape sustainability, and resource management whose practitioners and researchers share data, models, methods, and tools with NCED.
- Outreach to Policymakers: (a program in development) identifying opportunities to share NCED research results with individuals and organizations charged with decision making related to environmental forecasting, landscape sustainability, and resource management.
- Visitors: small grants (with requested match) to assist researchers from outside NCED institutions to conduct research at NCED experimental or field facilities.
- Visualizations: acquisition and manipulation of new and legacy data to produce print and projected images that assist NCED researchers, Partners, Education programs and the public in more fully understanding the dynamic processes shaping Earth's surface.
- Website/data archive: Virtual NCED: a place to share data, visualizations, general information, planning tools, online conversations, and videoconference presentations with internal and external NCED participants.

Accomplishments

The Year 2 highlight for Knowledge Transfer was our inaugural Environmental Partners meeting. Our Partners' genuine enthusiasm for collaborative participation in NCED research and with one another was rewarding and stimulating. In many ways, this enthusiasm built on that generated at the August 2003 Stream Restoration meeting co-sponsored by NCED and the National Academy of Sciences, and continued through our January 2004 External Advisory Board and Social Sciences Workshop. Together with meetings at the December 2003 American Geophysical Union, all of these events pointed to an emerging leadership role for NCED in the river restoration community. The model studies of many NCED Visitors in Year 2 accentuated NCED's central role in modeling restoration theory and practice; in particular, visitor Chris Bromley's physical model study of dam removal on Washington's Elwha River provided a focal point, resulting in media coverage and host of integrative Knowledge Transfer and Education activities. As a result, as mentioned elsewhere in this report,

NCED has begun a River Restoration Initiative, which will serve as a major ongoing focus for Knowledge Transfer activities.

The clear applicability of the research of some Year 2 Visitors to NCED's more focused mission led to productive refining of the Visitor Program to more closely support that mission. The emergence of NCED's Working Group Program was warmly welcomed by Partners and the wider community; a clear indication that there is strong external interest in, and need for, NCED research outside the Center. NCED continued its successful partnership with industry, through ongoing collaboration and shortcourses for our Stratigraphic Partners, researchers in the oil industry. This program offers particular opportunities for NCED students to interact with industry and provides a model for developing partnerships with our Environmental Partners.

NCED's tools for communicating our research to the wider community, our website and Visualization Programs, both developed significantly in Year 2. Maps and images for printed and projected three-dimensional viewing became a major visualization tool for NCED researchers, students at all levels and the public. Through acquisition of existing remotely sensed data and application of new computational modeling techniques, NCED developed maps and imagery that serve as major tools for communicating NCED research to all audiences. NCED also piloted techniques for creating virtual representations of field areas and physical models that are generating much enthusiasm. NCED's website and data archive matured into the major forum for Center communication internally and with the wider community. Two major legacy datasets (some 1,500 records of laboratory and field data on streams and rivers – creating one of the largest such reference data sets in existence) were added to the website, and are already being accessed by outside researchers, while a full set of internal resources, from Annual Report writing tools to streams of Center wide videoconferences, were developed.

Finally, NCED PIs, staff and students collaboratively developed a comprehensive, formative plan to evaluate our Education, Diversity and Knowledge Transfer programs. We were guided in this effort by a PhD candidate in Education Policy, Mary McEathron, whose objectivity and professional program evaluation skills helped us clarify goals and develop measurable performance indicators by program. This activity is resulting in a set of evaluation instruments which will help NCED continuously refine and improve its Knowledge Transfer activities.

1b. Performance and Management Indicators

As described immediately above, NCED has refined our Knowledge Transfer goals in Year 2 so that they are clearer and measurable and developed suitable performance indicators for each program. These goals and indicators do not differ significantly in spirit or intent from those submitted in Year 1.

Partners Program Indicators:

1. Regular communication of Partner research interests to NCED PIs
2. Partner feedback on research direction and results
3. Joint research projects between Partner agencies and NCED
4. Data, tools and models developed and shared among Partners and NCED
5. Partner data sets hosted by or linked to from NCED website

Visitor Program Indicators:

1. Visitor feedback
2. NCED PI and student feedback
3. Visitor publications (paper, conference, poster)
4. Visitor interactions with NCED PIs and graduate students and other visitors
5. Visitor involvement with other aspects of the Center such as Education, Diversity, or media

Website/Data Archive Indicators:

1. Timely submission and deployment of data by NCED PIs
2. External requests for more information
3. Use of website by NCED staff, students and researchers find administrative information
4. Use of website by Partners to access or contribute data
5. Participants in NCED Education programs and the wider educational community use materials and data posted on NCED website

1c. Knowledge Transfer Challenges.

The first annual meeting of NCED's Environmental Partners group (October 2003, described below and in Appendix G) was a stimulating event, attended by 20 individuals, and got us off to a good start in ensuring that NCED's research is informed by the needs and perspectives of our Partners. Genuine enthusiasm for partnerships between NCED and its Partners – and among the Partners themselves – was evident throughout the two days, and numerous specific suggestions for ongoing collaboration were made by our Partners. However, it has proven challenging to maintain this momentum, in part because our long effort to refocus our research precluded us from offering specific venues for further interaction. Now that our research agenda is set, we can and will address this challenge by integrating NCED's Environmental Partners into a variety of NCED research activities, starting with our Working Group and River Restoration initiatives.

2a. Organizations with which Knowledge Transfer Occurs:

Knowledge Transfer occurs with two major groups of organizations:

Environmental Partners: Governmental and corporate organizations involved with environmental remediation and forecasting; and

Stratigraphic Partners: Oil companies interested in interpretation and prediction of stratigraphy created by channels and channel systems.

See **Section V: External Partnerships** for a list of group members.

Knowledge Transfer Activities:

NCED's Knowledge Transfer activities support NCED Center goal 3:

To put our results into practice by developing close working partnerships with government and private organizations involved in environmental forecasting and policy, landscape restoration, and resource development.

Note: Detailed Activity Tables are at the end of this section.

Environmental Partners Meeting

Description: The first annual NCED Environmental Partners Meeting lasted for two days and involved representatives from 20 Partner organizations along with 14 NCED participants. Each agency gave a brief presentation outlining its current efforts in Earth-surface dynamics and ideas for collaborating with NCED.

Meeting Goals:

1. To identify fundamental **science questions** at the intersection of the interests of NCED, its Partners, and society; and
2. To determine the most effective **means of collaborating** between NCED and its Partners.

Meeting Outcomes:

1. The most immediate result of the Environmental Partners meeting was that NCED became more fully aware of the scope and dimensions of river restoration as an integrative scientific and societal issue and of the many Partners with whom we need to engage to make an effective, innovative contribution in this area. Thus, NCED's Year 2 follow-up activities are aimed at defining understudied aspects of this topic in which NCED can make the most significant contributions. In addition, the meeting played a significant role in helping us focus and define our Social Science initiative.
2. Finally, the meeting made us more acutely aware of the many areas in which NCED's uniquely interdisciplinary quantitative approach to channel system modeling can help agencies grapple with issues of riparian habitat management, particularly those involving the scalability of short-term, local habitat studies in assessing habitat response on a large scale to climatic and other environmental disturbances. NCED's role in this area will be to facilitate communication among Partners.

See Appendix G for a more detailed meeting report.

Stratigraphic Partners Shortcourses

Description: The shortcourses engage researchers from the Stratigraphic Partner organizations in lectures, demonstrations and exercises based on NCED research. These activities enable the Partner researchers to more accurately interpret field and remotely sensed data used in their resource management and discovery activities. As part of our internal Education activities, NCED graduate students help design and execute the experiments and demonstrations that make up each course.

Goals:

1. To ensure that NCED research results are used by industries involved in the practices of land use planning, resource management, or landscape restoration; and
2. To foster and maintain an intimate, two-way communication of needs and results between NCED and its Stratigraphic Partners.

Outcomes: Early in Year 2, both a shallow-water and a deep-water shortcourse were held for Stratigraphic Partners. The courses, based on past offerings by St. Anthony Falls Laboratory, were enhanced by the participation and availability of additional NCED research and technical staff. While NCED's industry Partners have formally evaluated the courses from their perspective, a formal evaluation from NCED's perspective was initiated.

Stratigraphic Partners Annual Meeting

Description: The Stratigraphic Partners Annual Meeting provides a forum for NCED to present its stratigraphic research results from the preceding year, to receive input from our Partners on research priorities for the upcoming year(s), and for NCED graduate students to present their specific research to an audience of industry professionals.

Goals:

1. To ensure that NCED research results are used by industries involved in the practices of land use planning, resource management, or landscape restoration; and
2. To foster and maintain an intimate, two-way communication of needs and results between NCED and its Stratigraphic Partners and between the Partners themselves.

Outcomes: The meeting met both of its goals. Several graduate students made research presentations to the Partners, giving them both practice and exposure to possible future employers. A meeting session on future directions laid out plans for the next XES Basin experiment: a relay-ramp scenario to assess the effect of syndepositional extension on alluvial architecture.

Outreach to Policymakers

Description: At its 2003 External Advisory Board meeting, NCED was encouraged to investigate opportunities and methods for bringing Center research into the policy-making arena. Subsequent Social Science workshop discussions underscored the importance of this aspect of Knowledge Transfer. Our close partnership with STC SAHRA has provided us many fruitful discussions and well developed models of how to do this important work. While individual NCED PIs have often been active in this area, it is new to NCED as a Center and will be developed into a full program in Year 3. Specific outcomes in Year 2 are detailed below.

Goals:

1. Identify key local and federal policymakers and bodies with issues or interests to which NCED research may be relevant; and
2. Develop effective ongoing communication with these individuals and organizations.

Outcomes: An important first step into the policymaking arena for NCED took place January 20, 2004 when the Mississippi Watershed Management Organization (MWMO) held its Board of Commissioners meeting at NCED/SAFL. The MWMO (http://www.mwmo.org) is one of several watershed organizations in Minnesota; its boundaries encompass many municipalities along a significant reach of the Mississippi River as it runs through Minneapolis, as well as a wide swath of land that drains to the river along that reach. MWMO's mission is to improve the quality of water and the quality of life in the Mississippi Watershed, providing for the long-term management of the river's water and associated land resources through the development and implementation of projects, programs, and policies that respect ecosystem principles and reflect changing community values.

At its January 2004 Board meeting, the MWWO Board met with Jeff Marr, Chris Paola, Karen Campbell and Omid Mohseni (of SAFL) to learn more about the work of NCED and its research facility, SAFL. A presentation, discussion period and tour acquainted these policymakers with NCED Research, Education and Knowledge Transfer. Members of the Board represent four municipalities and the Minneapolis Parks and Recreation Board; together they represent the approximately 700,000 people living in the Mississippi River's watershed as it runs through Minneapolis and St. Paul.

Visitors Program

Description: NCED's Visitor Program is a small grants award program to enable primarily post-graduate researchers from outside NCED institutions to conduct research in support of NCED's mission at NCED facilities. Visitors receive financial, logistical and technical support from NCED and participate in Center events such as seminars, video-conferences, informal research discussions with faculty and students and education, Knowledge Transfer and media activities.

Goals:

1. To seed additional research in support of NCED's mission;
2. To provide access to NCED's unique facilities and field site, and its interdisciplinary approach, to scientists from the wider research community; and
3. To expose NCED PIs and students to research efforts in the wider community.

Outcomes: The majority of the research proposed in Visitor grants awarded in Year 1 was conducted in Year 2. All of this research took place at NCED's St. Anthony Falls Laboratory facility. In reviewing the effectiveness of this program and the relevance of the research conducted to NCED's refined Vision and Mission, we decided that in Year 3 the number of awards will be greatly reduced, a funding match will be required and awards will be made to those prospective visitors whose proposals most closely support NCED's mission. Plans for ongoing evaluation of the program were made and a review procedure was established (NCED's Executive Committee reviews proposals).

Visualizations

Description: This is a multidisciplinary activity, touching on Research, Education, Diversity and Knowledge Transfer. NCED's visualization specialist, Paul Morin, develops visualizations that interpret NCED research to all of NCED's communities, from internal research applications, to external Research, Education and Knowledge Transfer communities. These visualizations of NCED's physical and computational models and related legacy data sets can be printed or projected for viewing in three dimensions. NCED staff and students regularly utilize these visualizations in research, formal and informal education settings. The visualizations themselves form the basis for several emerging collaborations with internal and external NCED Partners and initiatives, such as the Angelo Coast Range Reserve erosional field site, fellow STC's SAHRA and CENS, SMM Earthscapes programming, Diversity activities and Knowledge Transfer agency partnerships. In addition, Paul Morin, with a variety of internal and external colleagues, develops complementary interpretive activities and studies educational effectiveness of these visualizations.

Goals: To develop effective digital visualizations for use across NCED's research and educational endeavors, with an emphasis on visualizations that enhance comprehension of field based observations, predictive computational models and related physical model studies by researchers, students, practitioners and the public.

Outcomes:

Our Digital Visualization focus in Year 2 has been two-fold.

1. Particular emphasis has been placed on acquiring and visualizing legacy data related to the Angelo Coast Range Reserve, exploring the ways in which NCED researchers wish to utilize this data, and finding effective ways to both display existing data and utilize emerging technologies to "instrument" the Angelo field site to provide online, real-time "observatory" data.
2. At the same time, a concerted initiative has focused on developing and evaluating three-dimensional maps, images and related activities for use in formal and informal educational settings. Maps developed this year were presented at poster sessions, finalized for use in the Big Back Yard, used at both ANAMS and *gidakiimanaaniwigamig* camps, and incorporated into the work of NCED's undergraduate teacher intern and SMM graduate interns. The maps will be a focal point of Earthscapes School Contact and Teacher Institute programs.

In addition, Karen Campbell, Paul Morin, Kent Kirkby (University of Minnesota) and Anthony Murphy (College of St. Catherine, member EAB) have obtained a University of Minnesota grant to further test and evaluate the use and effectiveness of these visualizations in the K-12 classroom.

Website and Data Archive

Description: NCED's website and data-archive comprise a single entry point for NCED's internal and external communities, and the general public, to learn about the Center and its activities in Research, Education, Diversity and Knowledge Transfer. Portions of the site are accessible by password only, allowing the Internet to serve as an "intra-net" for all NCED students, staff and faculty, regardless of location. In addition, NCED-generated data and educational materials may be searched and downloaded from the site. Data may be directly uploaded to the site by faculty or students and such date sets are "discoverable" by an internal search engine as well as by external agents such as Google. Additional features, such as communication forums and "current awareness" alerts are yet to be implemented but are planned.

Goals:

1. For NCED personnel, Partners, and the wider research and educational communities, the NCED website and data archive should:

- Be user-friendly, comprehensive, and up to date ;
- Contain searchable data archives (both NCED data and Legacy) and the highly relevant links; and
- Be functionally compatible with wider scientific community data infrastructure efforts.

2. For NCED personnel, the website should:

- Be an up-to-date source for current Center information and schedules;
- Be an easily assessable resource for Center-wide activities; and
- Enhance communication between and among Center personnel.

Outcomes: In Year 2, the website and its underpinning architecture were moved to a permanent home at the University of Minnesota's Digital Technology Center, utilizing both new hardware and new

software. Robust mirroring and back-up systems were established. A website and data archive manager was designated (Michael Kelberer). In Year 2:

1. The functionality of the new software was systematically tested and debugged.
2. A system for web-based transmittal and archiving of NCED and legacy datasets was developed and implemented. Two important legacy data sets are now available on the site, and have been accessed several times by scientists unrelated to NCED.
3. A Members' Portal was implemented, and is now used as a primary resource for internal information on our weekly videoconference, Center-wide communications, internal and external meetings, and our Annual Report. Increasingly, Center-wide e-mails simply call attention to material available on the website, eliminating the need for duplicative personal filing of Center documents and maintaining version control.
4. A Partners' Portal was implemented, and is now in use as a means of disseminating meeting information (both planning and results).

NCED's Visualization Specialist, Paul Morin, researched and secured access rights to a large variety of remotely sensed data sets, many of which he used to construct imagery for the Big Back Yard and education activities. In addition, he began assembling similar data sets for the Angelo Coast Range Reserve and Fond du Lac field areas. Finally, in cooperation with the eXperimental EarthScapes Basin research group, he developed new methods of modeling and imaging experimental stratigraphy. All of this activity has resulted in a large body of visual data that will be added to the NCED data archive in Year 3.

Working Groups

Description: NCED Working Groups will be small (10-20) mixed groups of NCED PIs, Partners, students and academic, agency or industry researchers from outside NCED *(see Research Section II for a full description of these groups)*. The Knowledge Transfer aspect of these groups will be to serve as a venue for research collaborations, data analysis and tool exchange between NCED, its Partners and the wider community.

Goals:

1. To foster and maintain an intimate, two-way communication of needs and results between NCED and its Partners, and among the Partners themselves; and
2. To promote a multi-disciplinary theoretical and applied approach to issues of land use planning, resource management, and landscape restoration.

Outcomes: In Year 2, the idea for the Working Groups was conceived, based on positive reports from within and outside NCED of the National Center for Ecological Analysis and Synthesis (NCEAS) model. Following extensive discussions with NCEAS about best practices and lessons learned and discussions at NCED's PI Retreat, an NCED Working Group program was initiated. Four initial topics have been identified: River Restoration, the Eel River Basin Model, the Novel Methods for Modeling the Surface Evolution of Geomorphic Interfaces, and Carbon Storage. Discussions have begun with both Environmental and Stratigraphic Partners regarding potential participation in three of these Working Groups.

2c. Plans for Year 3

Environmental Partners

Partner interactions in Year 2 made clear the potential for NCED leadership in the river restoration community and the importance of this issue to NCED's Environmental Partners. A major Knowledge Transfer focus for Year 3 will be ensuring active Partner involvement in NCED's emerging River Restoration Initiative.

Additional Environmental Partner plans for Year 3:

1. Establish specific venues for NCED involvement for each Partner;
2. Establish specific projects for joint field, experimental and/or modeling work;
3. Ensure appropriate Partners become members of Working Groups;
4. Establish a means whereby data, models and/or algorithms can be shared with NCED and among Partners;
5. Look for opportunities for our Partners to contribute to NCED's Education and Diversity programs, particularly in the areas of graduate education and Native American education and land management issues; and
6. Explore with our Partners areas of public policy to which NCED could meaningfully contribute both scientific expertise and multidisciplinary perspectives.
7. Develop formal agreements with new potential Environmental Partners, including:
    - CALFED (a partnership between the State of California and the United States to cooperatively develop a long-term plan to address chronic water supply and environmental problems in the Sacramento-San Joaquin River Delta and San Francisco Bay (Bay-Delta)
    - U.S. Army Corps of Engineers
    - U.S. Environmental Protection Agency
    - Minnesota Geological Survey

Stratigraphic Partners

1. Continue conducting short courses at NCED/SAFL for NCED Stratigraphic Partners;
2. Identify opportunities for Stratigraphic Partner participation in Working Groups; and
3. Continue to improve and enhance both instrumentation and visualization of the physical stratigraphic models used by our Stratigraphic Partners.

Visitors Program

1. Improve the relevance of Visitors Program research to NCED's mission;
2. Solicit and award Visitor grants that include a field and/or modeling component which supports one of NCED's Integrative Activities: The Eel River Basin Project and River Restoration; and
3. 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.

Website and Data Archive

1. Develop private Partner portal(s) that provide:
   - Interactive forums to facilitate communications between NCED and its Partners, and among Partners, and scientific issues;
   - Timely intra-group communications: contact information, meeting plans and results, links; and
   - Downloadable data, tools, and visualizations.
2. Develop a public Education portal that makes available:
   - Materials prepared by ESTREAM teachers, once tested and evaluated; and
   - Materials developed in cooperation with SMM education programs.
3. Post three-dimensional, interactive and remotely updated visualizations and images to form an image gallery of ecogeodynamic processes on the Earth's surface.
4. 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

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. Ensure that Working Group data analyses, reports or tools (algorithms, models) are made available to Partners through Partner web portals; and
3. Assess additional direct methods to involve Partners in Working Groups and Working Group formation, such as videoconference- or web-based discussions.

2d. Research-Knowledge Transfer Integration

In Year 2, as NCED research attained new focus, the applicability of this research to NCED's Partners and wider community became extremely clear. Four particular accomplishments highlight how this integration is taking shape:

1. The call from the wider community for NCED to assume a leadership role in river restoration theory and practice;
2. The continued success of our Stratigraphic Partners programs;
3. The increased connection of Visitor Program applicant proposals to NCED's mission; and
4. The regular use of NCED's data archive by external researchers;
5. The interest in joint research with Environmental Partners developed at the October 2003 Partners' Meeting and followed up by repeated contacts with specific Partners.

In addition, Knowledge Transfer activities driven directly by PIs range from interactions with local agencies and policymaking bodies to seminars at academic institutions outside NCED-participating institutions to leadership in national initiatives. These PI-driven activities are described in the Focus Area sections of this report. Highlights include:

- August 14-15, 2003. Dietrich, Foufoula, Paola, Parker, and Wilkerson participated directly in and/or were organizers of an NAS-NCED sponsored workshop on Stream Restoration; Marr and Campbell were observers;
- Major aid supplied by CALFED to Dietrich's group will greatly extend the use of experimentation in the study of river restoration, producing tools, including software, for use by the community;
- Parker distributed 50 advance "beta" copies of his e-book on the morphodynamics of rivers and turbidity currents at the December 2003 meeting of the American Geophysical Union in San Francisco.
- Voller visited the Geophysics research group in the Department of Applied Mathematics and Theoretical Physics at the University of Cambridge (November 2003), to present an invited seminar entitled "Moving Boundary Problems in Earth Surface Dynamics". Extensive discussions on Earth-surface dynamics were undertaken with faculty and students.
- Hondzo presented "The influence of physical processes on small-scale biological growth" at Minnesota Water 2004: Policy and Planning to Ensure Minnesota's Water Supplies.
- With her CALFED-funded research associate, Dr. Bill Rainey, Power is studying how vegetative structure and hydrologic regime affect insect emergence and the activity of insectivorous bats on the Cosumnes River floodplain, an experimental floodplain restoration initiated by The Nature Conservancy on the only remaining free flowing river draining from the Sierra to the San Francisco Bay. A summer, 2003 field trip to this area included representatives of:
    - National Fish and Wildlife Service,
    - CALFED ERP's Program Integration and Evaluation branch,
    - CALFED Environmental Research Program Environmental Water Quality Implementation section
    - CALFED Science Program.
- Perg presented a talk to the Minnesota Chapter of the Association for Women in Geosciences, to an audience composed primarily of students, government researchers, and industry geologists. The focus of the talk was on the practical applications of cosmogenic nuclides, particularly in Minnesota – Cosmogenic nuclides: a tool for erosion rates and sediment provenance.

Activity Tables

Knowledge Transfer Activity Name: 2003 Annual Environmental Partners Meeting		
Led by	**Karen Campbell, Chris Paola**	
Date	**October 2003**	
	Attendee Name, Affiliation	**Address**
1	Yantao Cui Stillwater Sciences	2855 Telegraph Ave., Suite 400 Berkeley, CA 94705
2	Jack Davis US Army Engineer R & D Center	(CEERD-HC-T) 3909 Halls Ferry Road Vicksburg, MS 39180-6199
3	Paul DeVries R2 Resource Consultants	15250 NE 95th Street Redmond, WA 98052
4	Peter Downs Stillwater Sciences	2855 Telegraph Ave., Suite 400 Berkeley, CA 94705
5	Tom Drake Coastal Geosciences Program, Code 321CG Office of Naval Research	800 N. Quincy Street Arlington, VA 22217
6	Bill Goran US Army Corps of Engineers Engineer Research and Development Center	Construction Engineering Research Laboratory 2902 Newmark Drive Champaign, IL 61826
7	John Gray US Geological Survey Office of Surface Water	415 National Center 12201 Sunrise Valley Drive Reston, VA 20192
8	Kate Hanson National Park Services	111 East Kellogg St. Paul, MN 55101
9	Leo Holm Minnesota Department of Transportation Office of Environmental Services	Transportation Bldg 395 John Ireland Blvd. Mail Stop 620 St. Paul, MN 55155
10	Robert Jacobson US Geological Survey - CERC	4200 New Haven Road Columbia, MO 65201
11	Yong Lai Sedimentation and Hydraulics Group U. S. Bureau of Reclamation	Denver, CO 80225

12	Jim McKean USDA Forest Service	316 E. Myrtle Street Rocky Mountain Research Station Boise, ID 83702
13	Jay Michels Minnesota Erosion Control Association	PO Box 17 Lake Elmo, MN 55042
14	Ann Pierce Regional Plant Ecologist Southern Region MNDNR	2300 Silver Creek Road Rochester, MN 55906
15	Andrew Simon National Sedimentation Laboratory	USDA - Agricultural Research Service PO Box 1157 598 McElroy Drive Oxford, MS 38655
16	Rebecca Soileau St. Paul District, U.S. Army Corps of Engineers	CEMVP-ED-H 190 5th Street East St. Paul, MN 55101
17	Elise Striz U.S. Environmental Protection Agency	Robert S. Kerr Environmental Research Lab PO Box 1198 Ada, OK 74821
18	Harvey Thorleifson University of Minnesota, Minnesota Geological Survey	2642 University Avenue W. St. Paul, MN 55114
19	David Toll Code 974, Hydrological Sciences NASA/Goddard Space Flight Center	Greenbelt, MD 20771
20	Chih Ted Yang Sedimentation and Hydraulics Group U. S. Bureau of Reclamation	Denver, CO 80225

Knowledge Transfer Activity Name: Stratigraphic Partners Short Courses	
Description	Shallow Water Course – long term dynamics of sedimentary basins
Led by	John Martin, Chris Paola
Date(s)	April 2000
Organizations Involved	
ExxonMobil	

Knowledge Transfer Activity Name: Stratigraphic Partners Shortcourses	
Description	**Deep Water Course – short term dynamics of submarine systems**
Led by	Gary Parker, Jeff Marr, Jake Violet
Date(s)	April 2003
Organizations Involved	
ExxonMobil	

Knowledge Transfer Activity Name: Annual Stratigraphic Partners Meeting	
Led by	John Martin, Chris Paola
Date(s)	August 2003
Organizations Involved	
Anadarko Petroleum Corporation	
ChevronTexaco	
ConocoPhillips	
ExxonMobil	
Japan National Oil Company	

Year 2 Activities	**Visitors Program**	
Intended Audience	**Research community outside NCED PIs**	
Visitor	**Affiliation**	**Research Topic**
Robert Anderson	University of California, Santa Cruz	Experimental development of slot canyons
John Buffington	University of Idaho	Effects of channel morphology on intergravel flow within the shallow hyporheic zone of gravel-bed rivers; implications for channel restoration and aquatic habitat
Chris Bromley	Oregon State University	A laboratory investigation of the variables that control the rate and volume of sediment movement through and out of impoundments during dam removal

Tom Coulthard	University of Wales, Australia	Experimental physical modeling of anabranching river evolution
Suzanne Leclair	University of Ottawa	Experiments on the investigation of turbidite-system sedimentation: The origin of Waftites (sandy deposited from suspension with no traction)
Murray Hicks	National Institute of Water & Atmospheric Research Limited, New Zealand	Study of braided rivers
Yoichi Okura	Forestry and Forest Products Research Institute, Erosion Control Laboratory, Japan	Experimental study of subaerial landslides
Aaron Packman	Northwestern University	Solute transport in armored and sorted streambeds
Greg Pasternak	University of California, Davis	Transfer in Aid of Field Studies of Natural Hydraulic Jumps in Mountain Channels
Lincoln Pratson	Duke University	Flow dynamics and rheology of mud-rich gravity flows
Horacio Toniolo	University of Alaska, Fairbanks	Experiments on reservoir sedimentation
Kelin Whipple	Massachusetts Institute of Technology	Flume experiments on river incision into bedrock
Peter Wilcock	Johns Hopkins University	Sand routing over a coarse immobile streambed

Year 2 Activities	**Digital Visualization**		
Intended Audience	**Educators, Researchers, Partners**		
Date	**Location**	**Led by**	**Attendees**
June 2003	Flagstaff	Morin	Karen Campbell, Paul Morin, 15 others
Organize, present and lead discussions at GeoWall Summit			
December 2003	San Francisco	Morin	Karen Campbell, Paul Morin, 50 visitors

AGU Education poster session on Geowall and 3-D maps			
Ongoing 2003/4	University of Minnesota	Morin	Karen Campbell, Ben Friesen, Paul Morin, Anthony Murphy
Develop 3-D maps for use in test K-12 classrooms and Earthscapes education activities, develop key maps and images that engage students with NCED concepts, develop and test instructions for creating maps that, along with NCED-developed images, can be posted on NCED website for educators nationwide to use in creating their own maps and images.			
Ongoing	SAFL	Morin	Brian Davis USGS EROS Data Center, Paul Morin, Karen Campbell, Jim Roe (SMM)
World map development for SMM (large map to be displayed in BBY, maps and images for use in BBY interpretive graphics). Collection and analysis of imagery related to river deltas around the world as well as all imagery and data related to Angelo Coast Range Reserve.			
Ongoing	SAFL, Berkeley	Morin	Paul Morin, Tim Tierney, Alexandria Digital Library, UC Santa Barbara.
Collaboration to assemble all imagery and data held by the State of California related to Angelo Reserve.			
Ongoing	SAFL	Morin	Karen Campbell, Paul Morin, Kent Kirkby (U of M), Anthony Murphy (College of St. Catherine/EAB), Ben Freisen
University of Minnesota community grant received to fund design, production, testing and distribution of 3-D maps in area middle to high schools			
Ongoing	SAFL	Morin	Peter Guth, US Naval Academy., Paul Morin, Miki Hondzo, Fernando Porté-Agel;
Co-development of GIS software to analyze basin scale high resolution topographic data derived from LIDAR surveys for the purpose of providing input to biogeomorphological models to be developed by Morin and Hondzo and atmospheric models to be developed by Porté-Agel.			
Ongoing	U of M	Morin	Frank Rack, Director of the Integrated Ocean Drilling Program, Emi Ito, Director of the Limnological Research Center and LacCore, Jason Leigh of the Electronic Visualization Lab, University of Illinois, Chicago

Development of a geologic interpretation system to be installed in shore and ship based core labs and repositories worldwide. It uses the GeoWall2, a 25-100 million pixel tiled display demonstrated at AGU in the Fall of 2003. This system will be adapted for use with the eXperimental EarthScapes Facility at NCED.			
Ongoing	U of M	Glen Schuster, US Satellite Laboratory	Paul Morin
Develop and make available NCED imagery for use in Signals of Spring, web-based professional development package that provides training for teachers and integrated science curricular materials including data interpretation and applications for teachers and students			
Ongoing	U of M	Morin	Steve Reynolds and Julia Johnson, Arizona State University, Mike Kelly, Northern Arizona University and Chuck Carter, Illustrator, National Geographic and Chief Artist, Electronic Arts
Co-authoring an undergraduate, non-major introductory Earth Science textbook to be published with McGraw Hill. This textbook will use GeoWall technology and anaglyph maps developed at NCED. Book to be published Summer 2005			
Ongoing	SAFL	Morin	Richard Sedlock, Professor, San Jose State University and Codirector Bay Area Earth Sciences Institute
NCED has supported Sedlock in training over 200 Bay Area teachers per year in understanding sustainable landscapes using NCED's stereo maps and other visualizations.			

Year 2 Activities	**Website and Data Archive**
Intended Audience	**NCED internal and external community**
Led by	**Karen Campbell, Michael Kelberer**
Additional staff	Charles Nguyen

Year 2 Activities	**NCED Working Groups – Partner Interactions**
Intended Audience	**Partners**
Led by	**Karen Campbell**
Additional staff	Jeff Marr

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 Consultant		Environmental consulting firm
Stillwater Sciences		Environmental consulting firm
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 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 Oil 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	Museo di Storia Naturale http://www.iltempodellanatura.it	Museum
Purpose: Paola provided content and advice for exhibit development		
2	Association for Women Geoscientists, Minnesota chapter	Professional association
Purpose: connections to local professionals, career development for students; Karen Campbell, President, Lesley Perg, Treasurer		
3	Geowall Consortium http://www.geowall.org/	Consortium
Purpose: exchange visualizations, tools and methods with 3-D developers worldwide; Paul Morin, organizer		
4	SciTech Hands On http://scitech.mus.il.us/	Museum
Purpose: develop joint proposals, share exhibit and 3-D visualization expertise		
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 (Woodard participate in NCED's Social Science workshop, Campbell reviewed SAHRA's annual report), joint development of traveling Water Exhibit (in proposal phase) with SMM.

Environmental Partnerships in development	
Name	**Type**
CALFED Bay-Delta Program	State Government
Collaboration on river restoration issues	
US Army Corps of Engineers	Federal Government
Research sharing on channel dynamics	
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	

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
Jointly sponsored river restoration workshop August, 2003.		
2	University of Colorado/INSTAAR	University
Coordinated development of Community Surface Dynamics Modeling System		
3	Universidad Nacional del Litoral	University
Joint studies of large river systems and river engineering		
4	Universidad Central de Venezuela	University

Joint research on rivers and debris flows

Partnerships in development		
Name		**Type**
1	CENS (Center for Embedded Network Sensing)	NSF STC
Purpose: Joint development of advanced observational techniques (Focus Area 3)		
2	CUAHSI (Consortium for the Advancement of Hydrologic Sciences, Inc.)	Consortium
Purpose: Purpose: Joint development of advanced modeling techniques (Focus Area 1)		

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	SACNAS: Society for the Advancement of Chicanos and Native Americans in Science	Minority Professional Organization
NCED's Education Directors are members and NCED exhibits at annual meeting for recruiting purposes		
3	AIHEC: American Indian Higher Education Consortium	Consortium of tribal colleges.
NCED participates in their conferences, recruiting students at their career fairs. This year NCED gave a presentation at their spring meeting.		
4	Get Ready! Minnesota Higher Education Services Office	Government
Collaborates with NCED on middle-school diversity programming		
5	Division of Indian Work	Non-Profit
Collaborates with NCED on middle-school diversity programming		
6	Fond du Lac Ojibwe School	Public School

Partners with NCED on *gidakiimanaaniwigamig* Native American youth science immersion program		
7	Cloquet Forestry Center	University of Minnesota
Provides facilities for middle- and high-school camps		
8	SAHRA	NSF Center
Collaborates on joint recruiting of underrepresented undergraduate and graduate students		
9	Center for Embedded Network Sensing	NSF Center
Collaborates on joint recruiting of underrepresented undergraduate and graduate students		
10	QEM	NSF funded program
Partners with STCs in recruiting underrepresented groups for graduate and post-doc positions		
11	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.		
12	The University of Minnesota Materials Research Science and Engineering Center (MRSEC)	University
Collaborates on joint recruiting of underrepresented undergraduate and graduate students.		
13	Graduate School Outreach Office, University of Minnesota	University
Partners with NCED on recruiting and hosting underrepresented undergraduate students for our Undergraduate Summer Internship Program		

VI. Diversity

1a. Mission and accomplishments

NCED strives for increased participation by United States citizens, nationals, lawfully admitted permanent resident aliens of the United States, and especially women and members of *underrepresented* groups in all NCED activities. NCED recognizes that diversity is both an institution-centered ongoing challenge and a long-term societal goal. Our specific goals are:

1. To immediately increase participation of underrepresented groups in NCED research and activities; and
2. To provide opportunities for youths from underrepresented groups, especially Native Americans, to discover and gain necessary skills for pursuing careers in science, technology, engineering, and mathematics careers.

These goals are addressed through the following programs:

1. Undergraduate/Graduate Recruiting and research opportunities, including an Undergraduate Summer Internship program which brings undergraduates from underrepresented groups to NCED institutions for 10 weeks in the summer to do research on NCED topics.
2. Native American youth science enrichment and immersion programs, which offer youths from underrepresented groups, primarily Native Americans, an opportunity to explore STEM careers and learn about Earth-surface dynamics during seasonal camps and after-school activities.

Details about these programs are provided in the sections below.

Accomplishments

In Year 2, NCED did a comprehensive review of our Diversity programs to evaluate how they were meeting the challenges outlined in these two areas. Our efforts to bring more individuals from underrepresented groups into NCED have resulted in several new partnerships with other NSF Centers both within and outside the University of Minnesota to enhance our recruiting activity. One indication of the success of these partnerships is that we were able to significantly increase the number of applications to our Undergraduate Summer Internship Program, increasing our number of applications from 18 to 86 in the first year of joint recruiting. Contacts made at minority professional conferences have led to the creation of a contact list of 47 minority student advisors from schools around the country who are interested in helping us reach out to their students In Year 3, NCED plans to work with other departments and federally-funded centers within the Institute of Technology, University of Minnesota, to evaluate where and how we recruit for our undergraduate and graduate programs and explore opportunities to work with minority serving institutions and organizations. In addition to these efforts, NCED plans to take part in writing a Louis Stokes Alliance for Minority Participation (LSAMP) proposal with others in the Institution of Technology, U of M. This NSF-funded program is designed to fund Universities who are determined to increase participation of underrepresented groups in their science and engineering programs.

In order to meet our second goal, in Year 2 NCED has launched *gidakiimanaaniwigamig* (Our Earth Lodge), a science immersion program for Native American middle-school youths that is focused on keeping youths involved in science enrichment activities throughout the school year as well as in the summer. In conjunction with the *ando-giikendasowin* Native American Math and Science Camps

sponsored by NCED, these programs will provide opportunities for youths on the Fond du Lac reservation, in the Twin Cities, and students from across the country, to participate in science programming throughout middle-school and high-school. Discussions with faculty from Fond du Lac Tribal and Communiy College and other youth workers who work with Native youths indicated that NCED could play a unique role in the Native community in Minnesota. Programs tend to come and go through the dictates of funding and youths who have opportunities at one grade level may find themselves without opportunities as they move to another grade level. NCED is working to form a network with programs in the Twin Cities and throughout the state in order to identify opportunity gaps and work to fill them.

1b. Performance and Management Indicators

Native American youth science immersion program

The goal of the Native American youth science immersion programs is to create a long-term sustained program which drives scientific curiosity and academic progress for the Native youths in the program. Progress will be evaluated by the following:

1. Achievement, as measured by grades and test scores
2. School progress
3. Interest and understanding of science by youths in programs
4. Sustained contact: repeat incidents in NCED programs

Diversity in undergraduate and graduate education

The goal of programs enhancing diversity in NCED's undergraduate and graduate programs is to increase the number students from underrepresented groups receiving degrees, and to enhance the quality of students' educations through innovative academic experiences.

1. Number of students who apply to our programs
2. Number of students accepted
3. Student retention
4. New institutional structures put in place to foster diversity
5. Percent of American students, percent who are underrepresented
6. Student satisfaction with education

1c. Challenges

1. **Undergraduate/Graduate:** A relative lack of underrepresented students who are undergraduates in environmental sciences makes it difficult to recruit them as graduate students for NCED. At the NSF HRD Joint Annual Meeting, Margaret Leinen spoke of the special diversity problem facing the Geosciences: the Geosciences have the smallest minority undergraduate participation among science disciplines funded by NSF and these numbers are not increasing. There is a perception that there are no jobs and only a small percentage of US high school graduates have had any Earth science preparation. We can expand our pool of candidates by enhancing awareness that **any** science major can become an Earth scientist, since "Earth science is all science". Recruiting

through traditional methods and channels is not likely to bring NCED to the attention of the small number of underrepresented students in the Geosciences. NCED needs to develop new, innovative approaches to reaching out to these students. Working in partnership with the University of Minnesota's Institute of Technology, NCED plans to target recruiting efforts to minority serving institutions (MSIs) that graduate a significant number of students in majors that are compatible with NCED research themes. Through recruiting trips to these schools and development of relationships with their faculty, NCED will work on increasing visibility at these schools.

2. **Native American K-12 students:** Working along with Native Americans who want to improve science, math, engineering, and technology career choice by youths in their communities, NCED has identified several challenges that must be met in order to be successful in this project. Through meetings with Native elders, community leaders and educators, we know that the major issues that must be addressed are student retention, gaps in programming that allow students who have been performing successfully in math and science to drift away from their interest in pursuing STEM careers, and concern about moving away from the community to pursue higher education. Our goal is that a number of these students will eventually decide to pursue research careers. NCED's approach to these challenges is to bring youths into a long-lasting program with repeat contacts by identifying gaps in programming and addressing those gaps; to involve community leaders they trust, such as elders, parents, and teachers; to make connections to traditional Native culture; to provide high-quality hands-on science and involve scientists working on NCED research; and to keep it fun! In Years 1 and 2, NCED has developed a core group of programs designed around these principles which encourage Native students in K-12 to develop an interest in and prepare themselves for careers in science, technology, engineering and math. These programs have already been enthusiastically attended by youths and teachers from the Fond du Lac reservation in northern Minnesota. Other Minnesota tribal communities have expressed an interest in participating in upcoming camps and we are looking for ways to expand to include more youths in Year 3. We are also exploring ways to expand our programming to Native American youths from the Twin Cities area. NCED's high-school *ando-giikendasowin* Math and Science camps include youths from around the country. In Year 2, NCED made a direct link between the two camps by moving the NCED-sponsored year of programming to the Fond du Lac community and began designing coordinated curriculum for the two programs.

3. **Native American Undergraduates**: The major focus of NCED's Diversity programs has been to increase the number of Native Americans choosing and participating in STEM careers. With a very few exceptions, students graduating from tribal colleges are not moving directly or indirectly into STEM graduate programs related to Earth Science. In order to be able to successfully bring Native American students into research centers such as NCED, the gap from tribal college to graduate school needs to be bridged. We are determined to work with tribal colleges to discover existing barriers keeping students from successfully pursuing research careers and to find ways to remove those barriers. In Years 1 and 2, our Native American programming was focused on K-12 education to begin addressing "pipeline" issues that prevent students from completing high school and attending college. In Year 2, we have begun a systematic process of identifying potential avenues for partnership between tribal colleges and our Center that can have a meaningful impact in overcoming these barriers. In Year 3, NCED will conduct a systematic needs assessment research program in conjunction with Fond du Lac Tribal and Community College faculty and other tribal colleges to determine best practices for partnership between tribal colleges and research institutions. In order to develop successful pathways to undergraduate and graduate level

involvement with NCED for tribal college students, we need to actively solicit the advice and participation of faculty members from tribal colleges in the design and implementation of Center efforts at this level. In Year 2, Diana Dalbotten and Holly Pellerin hosted a forum on building partnerships between research centers and tribal colleges at the annual American Indian Higher Education Consortium meeting, which was attended by 10 participants, all of whom were staff, faculty, or students at tribal colleges. We are now in the process of establishing a core group of tribal college faculty from NCED/FDLTCC and other tribal colleges willing to collaborate with us on this effort. Moving from research to program implementation at the undergraduate level will be a major challenge for NCED in Year 3. Programs we are considering and have received positive feedback on include:

- Bringing NCED faculty to tribal colleges using distance education technologies;
- Exploring the option of offering graduate assistantships to NCED graduate students who would then spend a semester teaching at a tribal college; and
- Creating an undergraduate "bridge" program that would bring tribal college students to NCED institutions to spend time over the summer learning about science and engineering research careers.

1d. Integrative Activities

NCED's Diversity programs are closely interwoven with all other NCED activities. NCED's Research program will be a model for creation of a field site and related research activities for NCED's *gidakiimanaaniwigamig* (Our Earth Lodge) and *ando-giikendaasowin* (Seek to Know) camps. Faculty, graduate students and staff from all NCED institutions have been very enthusiastic participants in NCED's Diversity programs, working directly with youths in the program or assisting Education staff in creating the science content for our programs. In particular, staff members from the Youth Science Center at the Science Museum of Minnesota have helped to plan and staff the *gidakiimanaaniwigamig* program events. We are also working to integrate our Diversity programs by bringing teachers from these programs into NCED Education programs. In summer 2004, three teachers from the Ojibwe school who have been most involved in the *gidakiimanaaniwigamig* program will be ESTREAM participants. All of NCED's K-12 Diversity programming will be closely tied to NCED's K-12 education programs, with shared activities, educational resources, and participants. Underrepresented undergraduate participants in NCED's Undergraduate Summer Internship Program have been mentored by faculty and staff from the NCED/SAFL and the NCED/Wyoming.

2a. Activities.

NCED Diversity activities support Center Goal 4:

To use the intrinsic appeal of landscapes and surface dynamics to engage diverse communities in the study of Earth-surface science at all levels

Note: Detailed Activity Tables are at the end of this section.

K-12 level: gidakiimanaaniwigamig (Our Earth Lodge)

Description: *gidakiimanaaniwigamig* is NCED's science immersion program for middle-school Native American youths and their teachers. Four seasonal camps and other after-school field trips and programs bring scientists to the Fond du Lac reservation to teach hands-on science while everyone

learns about Native culture, traditions and science from Ojibwe elders. We spend our time out of doors, learning about "Our Earth Lodge" by studying the streams, fields, and lakes of the Fond du Lac reservation and how we can become better stewards of the land.

Goals: The goal of the *gidakiimanaaniwigamig* program is to create a long-term sustained middle school program which drives scientific curiosity and academic progress for the Native youths in the program.

Outcomes: NCED held a summer camp in August 2003, a winter camp in December 2004 and is in the process of planning spring and summer camps for 2004. Fifty-two youths participated in this program in Year 2 (42 of those attended 2 *gidakiimanaaniwigamig* activities, 14 attend three activities and seven attended four activities). Staff and students from the SMM Youth Science Center have begun acting as mentors for the *gidakiimanaaniwigamig* students. Students from *gidakiimanaaniwigamig* have also had several science field trips. NCED helped sponsor the Ojibwe School's science fair this year, offering seven top students a chance to compete in the AISES National American Indian Science and Engineering Fair in Albuquerque, New Mexico. Five of the *gidakiimanaaniwigamig* students won a medal at the science fair and one of our students, Jillian Beaufeux, won a chance to participate in the international science fair this May. In response to the advice of our 2003 Site Visit Team, NCED has hired Holly Pellerin, a Native American elder and youth educator from Fond du Lac, to be program coordinator for *gidakiimanaaniwigamig*.

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

Description: High-school students recruited nationally spend ten days at the Fond du Lac Tribal and Community College in Cloquet, MN, studying "Earth, Water, and Wildlife" with NCED researchers and education staff. Students explore the local topography, waterways, and wildlife while learning about the culture of the Ojibwe from Fond du Lac reservation elders.

Goals: The goals of the *ando-giikendaasowin* Native American Math and Science Camps are to increase students' interest, confidence, and abilities in math and science by exposing them to a curriculum rich in Native history, culture, and values. The specific goal of NCED's collaboration with the *ando-giikendaasowin* program is to present NCED research in a culturally and historically relevant Native American context.

Outcomes: NCED held its second year of *ando-giikendaasowin* high-school summer camps at Fond du Lac Reservation Tribal and Community College in August 2003. In 2003, 35 youths participated in the *ando-giikendaasowin* camps, 13 of whom were at the NCED Fond du Lac camp. By bringing one year of this camp to the Fond du Lac Reservation, we integrated a field investigations component and the cultural experience of a visit to Fond du Lac to the camps, which are taught to Native American youths from across the country. Students also had the opportunity to combine research in the field and in the laboratory.

Higher Education Diversity Programs and Achievements

Description: NCED strives to enhance the diversity of our graduate students through enhanced recruiting efforts at national minority professional and scientific conferences. We also have created five undergraduate summer research internships specifically targeting students from underrepresented groups. NCED provides direct funding for 43 graduate students annually. Of current graduate students 27 are American citizens or permanent residents; of these 10 are women, and none are from underrepresented groups.

Goals: The goal of programs enhancing diversity in NCED's undergraduate and graduate programs is to increase the number of students from underrepresented groups receiving degrees, and to enhance the quality of students' educations through innovative academic experiences.

Outcomes: The NCED Undergraduate Summer Intern Program provided funding for four undergraduate students to participate in research at SAFL in summer 2003. One of these students, a woman, is currently enrolled in graduate school with PI Greg Wilkerson as her advisor. The other three are finishing their undergraduate degrees at their home institutions. Two of these students, both undergraduate women from Puerto Rico, will participate in other research internships this summer, one at a university in Spain through a study-abroad program.

For Year 3, members of underrepresented groups have been recruited for our undergraduate summer internships and for graduate study in conjunction with the University of Minnesota's Graduate School Outreach Program and through recruiting efforts at minority conferences such as the American Indian Science and Engineering Society National Conference and the Society for the Advancement of Chicanos and Native Americans in Science National Conference.

We have also begun joint recruiting efforts with other NSF centers. This year we had a joint recruiting booth at SACNAS and AISES with four other environmental science and engineering centers and worked with them to develop coordinated posters and brochures. We are also taking part in a larger STC effort which involves joint recruiting at national minority science and professional conferences, creation of posters and brochures, and a website. These efforts led to an increase from 18 to 86 in applications to our USIP program in the first year of joint recruiting.

2b. Impacts on Enhancing Diversity at the Center

In Year 2, diversity at NCED was enhanced through adding PI Greg Wilkerson (African American) and, in response to advice from our Site Visit Team last year, hiring Holly Pellerin (Native American) as our Education Program Coordinator. Program activities also increased the number of K-12 and undergraduate students from underrepresented groups who were interacting with the Center. Significant milestones include:

1. Undergraduate Summer Internship Program. In summer, 2003, four students participated in our internship program: three are members of underrepresented minorities and all four are women.
2. In summer, 2003, we began our *gidakiimanaaniwigamig* middle-school program for Native American youths. 52 youths and their teachers participated in year 2 in our camps and after-school programming.
3. In summer 2003, we held our second year of camp programming for the *ando-giikendasowin* high-school program for Native American youths. Thirteen students participated in the NCED environmental camps that make up one of the three years of camp programming. Overall, 35 students participated in the *ando-giikendasowin* camps in summer 2003.
4. A new partnership has been developed with the Youth Leadership Development Program, Division of Indian Work, in Minneapolis, MN, to create science enrichment opportunities for inner-city Native American youths. NCED will bring science enrichment activities to approximately 20 youths from this group in summer 2004.

2c. Plans for Year 3

In addition to continuing and improving programming initiated in Years 1 and 2, our plans for Year 3 include:

1. Initiation of an NCED/FDLTCC sponsored American Indian Regional Science Fair for Native American K-12 and tribal college undergraduate students in northern Minnesota.
2. Development of an integrated network of science immersion programming modeled on *gidakiimanaaniwigamig* that will include youths from NCED institutions University of Wyoming, MIT, University of California, Berkeley, and University of Minnesota.
3. Development of a partnership with the Youth Leadership Development Program, Division of Indian Work, to create a 6-week program of weekly field trips for Native American youths on the theme of the urban Mississippi River.
4. Creation of an integrated K-12 program curriculum based on national science standards that will make use of a permanent field site on the FDLTCC reservation and will be patterned after the NCED ACRR research plan, our current model for collaborative research within NCED. Development of field site for use by K-12 students, undergrads at FDLTCC, Ojibwe school science classes, SMM YSC interns, and ESTREAM teachers. Creation of a data archive for that field site.
5. Performance of a systematic needs assessment research program in conjunction with Fond du Lac Tribal and Community College faculty and other tribal colleges to determine best practices for partnership between tribal colleges and research institutions.
6. Creation of a group within the University of Minnesota's Institute of Technology to coordinate undergraduate and graduate recruitment of underrepresented minorities. NCED will be involved in writing an LSAMP proposal with this group.

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Activity Tables

Year 2 Activities	*gidakiimanaaniwigamig*		
Intended Audience	**Native American middle-school students and their teachers**		
Date	**Location**	**Led by**	**Attendees**
August 2003	FDLTCC	Karen Campbell, Jeff Marr, Diana Dalbotten, Sara Johnson, Andrew Wold, Holly Pellerin, Paul Morin, Mark Bellcourt	*gidakiimanaaniwigamig* summer camps
gidakiimanaaniwigamig 10-day summer camp at FDLTCC, taught by Campbell, Wold, including Morin/Campbell geowall visit to summer camp, Campbell/Wold participation in joint *gidakiimanaaniwigamig / ando-giikendasowin* activities; Campbell led field trip for both camps in Minneapolis.			
October 2003	FDLTCC	Diana Dalbotten	Holly Pellerin (FDLTCC), Mary Ann Steiner (SMM), Patricia Steele (Angelo Coast Range Reserve), Greg Wilkerson (Wyoming), David Mohrig (MIT)
Educators attend PI retreat to begin planning and discussing funding options for an integrated national Native American youth science immersion program; program will be modeled on *gidakiimanaaniwigamig*, but linking Native youths across NCED partner sites.			
November 2003	SMM/Excel Energy Center	Diana Dalbotten	Holly Pellerin, Lowanna Greensky
Pellerin and Greensky attended the American Science and Technology Center conference at the Excel Energy Center to get new ideas about running summer camps, after-school programming, and partnering with science museums.			
January 2004	NCED/SAFL	Diana Dalbotten	Chris Paola, Vaughan Voller, Diana Dalbotten, Karen Campbell, Mark Bellcourt, Holly Pellerin, Lowanna Greensky, other participants from U of M and local Native American educators
All day forum on forming partnerships for science education for Native American youth			

January 2004	FDLTCC	Diana Dalbotten	Mark Bellcourt, Holly Pellerin,
Participated as judges and organizers in Ojibwe middle- and high-school science fair. NCED sponsored seven students who won prizes for excellence to attend NAISEF science fair.			
January 2004	NCED	Diana Dalbotten	Holly Pellerin
Holly Pellerin hired as Program Coordinator for *gidakiimanaaniwigamig*.			
February 2004	U of M	Diana Dalbotten	Holly Pellerin, Lowanna Greensky
Attended Minnesota Minority Education Partnership Conference: Building Alliances for Student Success.			
March 2004	NCED	Karen Campbell	Dalbotten, Strong, Waarners, Stoll, Smedsmoe
Tour of SAFL for 100 minority high-school students from Wellstone International High-school and follow-up school visits.			
March 2004	Albuquerque	Diana Dalbotten	Mark Bellcourt, Holly Pellerin, 4 teachers and 7 students from Ojibwe school
Attended AISES National American Indian Science and Engineering Fair, Albuquerque, NM. Five of the seven students won medals at the science fair. One student, Jillian Beufeux, was chosen as one of six students at the fair who will go on to represent AISES at the International Science Fair in Oregon in May 2004.			
Aprril 2004	NCED	Diana Dalbotten	Karen Campbell, Mary Ann Steiner, Pat Hamilton, Holly Pellerin, teachers and students from Ojibwe schools, NCED grad students
Field trip to the Twin Cities for students in Ojibwe schools who have successfully earned a grade of A or B in both Math and Science during winter quarter. Students toured NCED, visited the U of M campus (sponsored by APEXES), and visited the SMM.			
Ongoing	NCED	Diana Dalbotten	Karen Campbell, Louise Mattson (Division of Indian Work)
Form partnership, plan activities with Division of Indian Work summer environmental science program for urban Native American youth. NCED will provide six field trips or activities for students in their summer program in summer 2004. Discussions are ongoing to form a chapter of			

gidakiimanaaniwigamig in the Twin Cities metro area.			
Ongoing	SAFL/SMM/ FDLTCC	Diana Dalbotten	Diana Dalbotten, Mary McEathron, Holly Pellerin, Lowanna Greensky
Design formative evaluation program for *gidakiimanaaniwigamig*			
Ongoing	NCED	Diana Dalbotten	Andy Wold, Holly Pellerin, Mark Bellcourt, Karen Campbell, staff from FDLTCC Environmental Institute and Riverwatch Program
Establish a field site at FDLTCC for use in all K-12 education programs.			

Year 2 Activity	***ando-giikendaasowin***		
Intended Audience	**Native American high-school students from the United States**		
Date	**Location**	**Led by**	**Attendees**
August 03	FDLTCC	Karen Campbell, Jeff Marr, Diana Dalbotten, Sara Johnson, Andrew Wold, Holly Pellerin, Paul Morin, Mark Bellcourt	National high-school students
Recruit, plan, execute *ando-giikendasowin* 10-day summer camp at FDLTCC, taught by Campbell, Wold, including Morin/Campbell geowall visit to summer camp, Campbell/Wold participation in joint *gidakiimanaaniwigamig /ando-giikendasowin* activities; Campbell led field trip for both camps in Minneapolis.			
March 2004	Billings, MT	Diana Dalbotten	Holly Pellerin
Booth at AIHEC advertising NAMS camps			
March 2004	Albuquerque	Diana Dalbotten	Mark Bellcourt
Booth at AISES NAISEF recruiting for NAMS summer camps.			
Ongoing	SAFL/SMM/ FDLTCC	Diana Dalbotten	Diana Dalbotten, Mary McEathron, Mark Bellcourt
Design formative evaluation program for *ando-giikendasowin*			

Ongoing	NCED	Diana Dalbotten	Andy Wold, Holly Pellerin, Mark Bellcourt, Karen Campbell, staff from FDLTCC Environmental Institute and Riverwatch Program
Establish a field site at FDLTCC for use in all K-12 education programs.			
Ongoing	NCED/U of M General College/ FDLTCC	Diana Dalbotten	Mark Bellcourt, Karen Campbell, Jeff Marr
Planning for summer 04 camp.			
Ongoing	Excel Center	Mark Bellcourt	Diana Dalbotten
Volunteer fundraising for travel scholarships for 4th year camp.			

Year 2 Activities	**Higher Education Diversity programs**		
Intended Audience	**Undergraduate students, graduate students, and post-graduates at NCED institutions**		
Date	**Location**	**Led by**	**Attendees**
February 2004	U of M	Diana Dalbotten	Diana Dalbotten
ASCE graduate school fair, NCED has a booth for recruiting new students, generally and from underrepresented groups			
February 2004	SAFL/SMM	Karen Campbell	Michal Tal, Nikki Strong,
Two NCED graduate students serve as research assistants at SMM; work with students in Youth Science Center, including students from underrepresented groups.			
March 2004	Gainesville, FL	Karen Campbell, Diana Dalbotten	Campbell, Dalbotten
Attend NRCEN Conference; learn about best practices at other NSF centers for undergraduate and graduate education and professional development.			
ongoing	SAFL	Karen Campbell	NCED grad students
Coordinate graduate student volunteers for NCED/SAFL tours, train them to work with K-12 students and public on interpreting research to other communities.			
Ongoing	FDLTCC	Diana Dalbotten	Nikki Strong, Michal Tal
NCED graduate students participate in *gidakiimanaaniwigamig* camps, teaching NCED science to middle-school students			

VII. Management

1a. Overall Organizational Strategy

NCED's overall Center organizational strategy is essentially unchanged from last year. The number of co-Directors was reduced from two to one, and a new Director (Chris Paola) was named. A current organization chart is presented in Appendix B.

1b. Performance and Management Indicators

The overall objectives of NCED management are:

1. To provide a structure that helps coordinate NCED's Research, Knowledge Transfer, Education, and Diversity programs in support of our mission;
2. To allocate and manage NCED's finances in accordance with federal and university regulations; and
3. To continually improve the functioning of the Center through listening, synthesis, innovation, and evaluation.

To meet these objectives, we have set the following specific goals:

1. To articulate clear objectives;
2. To provide clear expectations for NCED personnel;
3. To make effective decisions on issues affecting Center performance;
4. To organize and promote effective communication among Center personnel;
5. To promote NCED and its work to our research community, other stakeholders, and the public;
6. To organize Center-wide activities;
7. To monitor and evaluate NCED's progress; and
8. To collect, organize, and disseminate products of Center activities.

We will track our progress toward meeting these goals using the following indicators:

1. Articulate objectives: feedback from the PIs, the EAB, site visit panels and NSF personnel; the extent to which PI research reflects a shared commitment to NCED objectives;
2. Provide clear expectations: feedback from PIs, postdocs, students, and visitors; monitoring the extent to which their performance is consistent with our expectations;
3. Make effective decisions: The quality of decisions is indicated by the sum of all the other measures of Center performance, i.e., if the Center is performing well, we are making good decisions overall. The quality of specific decisions is gauged by feedback from NCED participants and evaluation groups such as the EAB and site visit panels;
4. Organize and promote effective communication: attendance at Center communication events, retreats and other meetings, and videoconferences; measures of research collaboration (listed under research indicators);

5. Promote NCED and its work: number and impact of NCED 'contact events', i.e., appearances or references in media (TV, radio, newspapers, etc.), website hits, inquiries about NCED participation, and other contacts from non-NCED parties;
6. Organize Center-wide activities: frequency of occurrence of, and attendance at, Center-wide activities
7. Monitor progress: the extent to which all aspects of NCED activities, as listed in the SIP and annual reports, have appropriate indicators, and the extent to which these are updated and monitored by the administrative group;
8. Make NCED output available: extent to which NCED output is available on our website, the extent to which our research is presented, written up and published in a timely manner (see next section), and the extent to which our work is shared with our Partners via Partner meetings and other communications.

1c. Challenges and Plans

The major challenge to management is to promote integration and focus in all NCED activities. This will always be a challenge for an STC, particularly one such as ours that draws on fields with little tradition of large-group collaborative projects. Our philosophy is that collaboration and integration begin with effective communication, and that is what we have emphasized this year (via retreats, joint field and experimental work, the members' website, and videoconferences). We plan to continue in this vein next year, aiming for even stronger participation in these activities across the Center. We believe that continuing these successful activities plus two new programs we started this year (Working Groups and synthesis postdoc group) will create an atmosphere in which collaboration and integration will continue to flourish.

The other major challenge facing NCED management is to coordinate and support the wide range of activities in which NCED participates as efficiently as possible. We believe that overall we have an excellent administrative team in place, but we continue to search for ways in which we can deploy our people better.

Some members of our External Advisory Board are unable to attend its meetings, and we will carefully search for suitable replacements.

2. Management and Communications Systems

1. Biannual retreats for NCED PIs, Directors, administrative staff and graduate students;
2. Weekly videoconference: Although mainly devoted to disseminating research projects and results, these meetings are also used to discuss administrative issues;
3. Weekly staff meeting: The NCED Directors and administrative staff meet weekly to promote internal communication and bring up and resolve issues;
4. Website: We are making increasing 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, per our new bylaws, consists of the Director (Chris Paola), co-Director (Efi Foufoula-Georgiou, with Vaughan

Voller currently acting as Interim co-Director), 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 C has a list of current members and the report from our Year 2 meeting last January.

4. Changes to Strategic Plan

The overall strategic plan remains substantially unchanged. As discussed at length in the Research Section Overview, NCED devoted a considerable amount of time to more tightly focusing our research efforts. A new Strategic Implementation Plan reflecting these changes will be available this summer.

5. Ethics Training

In Year 2, we continued plans made in NCED's first year to ensure appropriate training in research ethics for NCED PIs, students and staff. On May 14, 2003, guest lecturer Patrick L. Brezonik, University of Minnesota Professor of Civil Engineering and Director, Water Resources Research Center, presented a seminar on research ethics which was presented via videoconferencing to all NCED participants. An archived version of the seminar is available for viewing by new members of NCED and was used with our summer undergraduate interns. In addition, all NCED/SAFL PIs, students and staff receive mandatory Safety and Ethics training each September. Lastly, Karen Campbell, Diana Dalbotten and Rochelle Storfer participated in an STC-wide discussion of Centers' ethics programs at the August 2003 STC Directors' Meeting, at which Karen Campbell was designated NCED's contact for any STC-wide ethics initiatives.

VIII Center-Wide Outputs and Issues

1a. Publications

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

Refereed Papers - Published

Leclair, S. , and Arnott, R. W. C, Coarse-tail graded, structureless strata: indicators of an internal hydraulic jump, In: Roberts, H.A., Rosen, N.C., Fillon, R.H. and Anderson, J.B., editors, Shelf Margin Deltas and Linked Downslope Petroleum Systems. Gulf Coast Section of the Society for Sedimentary Research.

Abreu, V., Sullivan, M. Pirmez, C., and Mohrig, D., Lateral accretion packages (LAPs): an important reservoir element in deep water sinuous channels, Marine and Petroleum Geology, v. 20, p. 631-648.

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1b. Conferences

Conference Abstracts - Published

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Caylor, K. K., S. Manfreda, and I. Rodriguez-Iturbé, On the coupled geomorphological and ecohydrological organization of river basins, American Geophysical Union meeting, San Francisco, December 2003, Abstract published in EOS Trans. AGU 84(46), Fall Meet. Suppl., Abstract NG12A-03, 2003.

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Swenson, J. B., Paola, C., and Pratson, L., Clinoform response to sea level: Phase relations between shoreline and rollover, development of compound clinoforms, and the timing of margin progradation, Geological Society of America (GSA) Annual Meeting, Seattle, WA, Nov. 2-5, 2003.

Swenson, J. B., Paola, C., Pratson, L., and Voller, V. R, Modeling clinoform development as a three-dimensional, moving-boundary problem, ComDelta—Open Conference on Comparing Mediterranean and Black Sea Prodeltas, Aix-en-Provence, France, Oct. 26-28, 2003.

Swenson, J. Paola, C., Sheets, B., Strong, N., Kim, W., and Pratson, L., Continental margin response to sea level: Theory and experiment, American Geophysical Union (AGU) Annual Meeting, San Francisco, CA, Dec. 7-12, 2003.

Tal, M., Paola, C., Tilman, L., Channel patterns as the result of self-organization within the flow-sediment-vegetation system, AGU Fall Meeting San Francisco, CA, Dec. 8-12, 2003.

Conference Proceedings - Published

Basu, S., and Foufoula-Georgiou, E., Multiscale noise removal of chaotic geophysical signals, EGS-AGU-EUG Joint Assembly, April 6 - April 11, 2003, Nice, France.

Basu, S., Dodov, B. and Foufoula-Georgiou, E., A novel measure for QPF verification and its usefulness in multimodel ensemble forecasting, EGS-AGU-EUG Joint Assembly, April 6 - April 11, 2003, Nice, France.

Basu, S., Porté-Agel, F., and Foufoula-Georgiou, E., Statistical characterization of stably stratified atmospheric boundary layer turbulence, American Geophysical Union Fall Meeting, December 9 - December 12, 2003, San Francisco, California.

Basu, S., Venugopal, V., Foufoula-Georgiou, E., Porté-Agel, F., Dodov, B., Synthetic turbulence, fractal interpolation and large-eddy simulation, 2003 Fall Meeting of the American Geophysical Union. San Francisco, California.

Carper, M. A, Porté-Agel, F., Stoll, R., A-priori laboratory study on subgrid-scale physics for LES of boundary layers over heterogeneous surfaces, 2003 Fall Meeting of the American Geophysical Union, San Francisco, California.

Carper, M. A., Porté-Agel, F., Subfilter-scale dissipation and coherent structures in the atmospheric surface layer, 2003 Annual Meeting of the European Geophysical Society, Nice, France.

Dodov, B., and Foufoula-Georgiou, E., A multiscaling model for stream hydraulic geometry: implementation for runoff routing in ungauged basins through the geomorphologic nonlinear reservoirs in network (GNRN) concept, EGS-AGU- EUG Joint Assembly, April 6 - April 11, 2003, Nice, France.

Dodov, B., and Foufoula-Georgiou, E., Physical insights into the scaling of at-site hydraulic geometry and scaling of flood peaks, American Geophysical Union Fall Meeting, December 9 - December 12, 2003, San Francisco, California.

Foufoula-Georgiou, E., Basu,S., Porté-Agel, F., Statistical characterization of stably stratified atmospheric boundary layer turbulence, 2003 Fall Meeting of the American Geophysical Union, San Francisco, California.

Gupta, R., Venugopal, V., and Foufoula-Georgiou, E., Scale-recursive estimation of precipitation using expectation-maximization algorithm based system identification of multiscale stochastic models: Application to model Validation and multisensor data fusion, American Geophysical Union Fall Meeting, December 9 - December 12, 2003, San Francisco, California.

Jerolmack, D., and Mohrig, D., Modeling bedform evolution as an interface problem: comparing bedform kinematics generated by advection-diffusion equations against reality, conference volume for MARID 2004 International Workshop, Enschede, the Netherlands, March 2004.

Kawakami, Damien,Voller,V. R. Paola, C., Moving Boundary Problems in Earth-Surface Dynamics, Moving Boundaries VII: Computational Modelling of Free and Moving Boundary Problems Edited by: A.A. Mammoli and C.A. Brebbia, WIT Press, 2003.

Kong, F., Droegemeier, K., Venugopal, V., and Foufoula-Georgiou, E., Application of scale-recursive estimation to ensemble forecasts: A comparison of coarse and fine resolution simulations of a deep convective storm, American Meteorological Society Annual Meeting, Seattle. Washington, 2004.

Kostic., S. and Parker, G., Physical and numerical modeling of deltaic sedimentation in lakes and reservoirs, Proceedings, XXX Congress, International Association of Hydraulic Research, Thessaloniki, Greece, August 24-29, 2003.

Paola, C., From human to planetary time scales: effects on river systems, UNESCO-ICCORES Workshop 2003 From watershed slopes to coastal areas: sedimentation processes at different scales, Venice, Italy, 2003.

Paola, C., Improving public understanding of scientific research: a view from the research side, ASTC Annual Meeting, Science Museum of Minnesota, St Paul, Minnesota, 2003.

Parker, G. and Muto, T., 1D numerical model of delta response to rising sea level, Proceedings, 3rd IAHR Symposium, River, Coastal and Estuarine Morphodynamics, Barcelona, Spain, September 1-5, 2003.

Parker, G., and Perg, L. A., Conservation relations for cosmogenic radionuclides: Application to erosional landscapes, Eos, Transactions of the American Geophysical Union Supplement 84

Parker, G., Persistence of sediment lumps in approach to equilibrium in sediment- recirculating flumes, Proceedings, XXX Congress, International Association of Hydraulic Research, Thessaloniki, Greece, August 24-29, 2003.

Perg, L. A., and Parker, G., Cosmogenic nuclides: New uses as sediment tracers and in developing sediment budgets, XVI INQUA Congress, 2003.

Porté-Agel, F., Carper, M. A., Stoll, R., Bjelogrlic, N., Scale-dependence and subgrid- scale modeling for LES, Proceedings of the 15th Symposium on Boundary Layers and Turbulence. Wageningen, The Netherlands, July 2002.

Porté-Agel, F., Bjelogrlic, N. Carper, M.A., Stoll, R., Scale dependence and subgrid modeling in large-eddy simulation of the atmospheric boundary layer, 2003 Annual Meeting of the European Geophysical Society. Nice, France.

Smedsmo, J., Venugopal, V., Foufoula-Georgiou, E., Kong, F., and Droegemeier, K., A study of the spatial and vertical structure of modeled hydrometeor profiles: Insights for weather prediction modeling and rainfall retrieval from remote sensors, American Geophysical Union Fall Meeting, December 9 - December 12, 2003, San Francisco, California.

Stoll, R., Porté-Agel, F., Scale-dependent dynamic models for LES of the atmospheric boundary layer over heterogeneous surfaces: sensitivity to averaging schemes, 2003 Fall Meeting of the American Geophysical Union. San Francisco. California.

Syvitski, J., C. Paola, R. Slingerland, D. Furbish, P. Wiberg, and G. Tucker, Building a Community Surface Dynamics Modeling System: Rationale and Strategy, University of Colorado, Boulder, Colorado, 2003.

Venugopal V., Carper, M. A., Porté-Agel, F., Foufoula-Georgiou, E., Multiscale interactions between surface shear stress and velocity in turbulent boundary layers, bibl. 2003 Annual Meeting of the European Geophysical Society. Nice, France.

Venugopal, V., Stoll, R., Porté-Agel, F., and Foufoula-Georgiou, E., Scale-effects of surface heterogeneity on atmospheric boundary layer turbulence, EGS-AGU- EUG Joint Assembly, April 6 - April 11, 2003, Nice, France.

Wilkerson, G. V., Predicting Depth Averaged Velocities in Trapezoidal Channels, Proceedings of the World Water and Environmental Resources Congress 2004. Reston, VA: ASCE.

Wong, M., Does the bedload equation of Meyer-Peter fit its own data?, Proceedings, XXX

Congress, International Association of Hydraulic Research, Thessaloniki, Greece, August 24-29, 2003.

1c. Invited Presentations

Caylor, K. K., University of California – Berkeley, Environmental Science, Policy and Management Department (March 2003).

Dietrich, W., University of Minnesota, Stream Restoration Workshop, August 2003.

Dietrich, W., Is there a topographic signature to life on Earth?, MIT, Earth Systems Institute first sympsium, March 2004.

Dietrich, W., The Holocene evolution of the Fly River and its response to a large increase in sediment load due to mining, University of Papua New Guinea, June, 2003.

Dietrich, W., The notion of geomorphic transport laws: key to modeling the linkages among tectonics, climate and landscape evolution, Caltech

Dietrich, W., The notion of geomorphic transport laws: key to modeling the linkages among tectonics, climate and landscape evolution, University of Michigan, October 2003.

Dietrich, W., What if there was never life on Earth?, Philosophical Club, New York City, first meeting, March 2004

Dodov, B., and Foufoula-Georgiou, E., A multiscaling formalism of hydraulic geometry: downstream variation of channel stability and its effect on hydrologic response and scaling in floods, European Geosciences Union General Assembly, April 25 - April 30, 2004, Nice, France.

Foufoula-Georgiou, E., The Scale-frequency continuum in hydrologic response: A Myth or a Reality?, European Geosciences Union General Assembly, April 25 - April 30, 2004. Nice, France (Invited Paper in the Session on "Visions and Perspectives in Hydrology and Water Resources")

Foufoula-Georgiou, E., Water as a complex environmental system: Do clouds, rocks, trees and scaling theories relate to water resources engineering?, National Technical University of Athens, Greece., 2003.

Green, EG., Welch, S.A., Dietrich W.E, and Banfield J.F., Contributions of chemical weathering and physical erosion of soil to landscape lowering in a granitic terrain, American Geophysical Union, December 2003

Hondzo, M., The influence of fluid motion on small-scale biological growth, Johns Hopkins University, May, 2003.

Paola, C., Adventures in experimental stratigraphy, Tulane University, New Orleans, LA, March 4, 2004.

Paola, C., Voller, V., Foufoula-Georgiou, E., Towards a statistical mechanics of landscapes, Canadian Geophysical Union, Banff, Alberta, May 12, 2003.

Porté-Agel, F., Scaling, subgrid models, downscaling and parameterization session, European Geophysical Union, April 2003, Nice, France.

Power, M.E., Extending the food web: consumer-resource dynamics at the aquatic terrestrial

interface, North American Benthological Society meetings in Athens GA, May 27-31 2003.

Rodriguez-Iturbé, I., at Duke University's Global Change Seminar Series (March 2004).

Rodriguez-Iturbé, I., California Colloquium on Water at the University of California, Berkeley (February 2004).

Rodriguez-Iturbé, I., Civil and Environmental Engineering Department at the University of California, Berkeley (February, 2004).

Rodriguez-Iturbé, I., University of California, Berkeley Environmental Science, Policy and Management Research Colloquium (March 2004).

Voller, V., Moving Boundary Problems in Earth-Surface Dynamics. Moving Boundaries 2003, November 2003.

2. Awards and Honors

Awards and Honors
Dietrich was elected Fellow of the American Academy of Arts and Sciences.
Dietrich was elected Fellow of the National Academy of Sciences.
Foufoula-Georgiou was elected in 2003 to the Executive Committee of the Consortium of Universities for the Advancement of Hydrologic Science (CUAHSI).
Foufoula-Georgiou was named "Distinguished McKnight University Professor" in 2003, a permanent title while at the University of Minnesota.
Foufoula-Georgiou was elected a Member of the European Academy of Sciences in 2003.
Doug Jerolmack (NCED-sponsored graduate student of Mohrig) received an Outstanding Student Paper Award from the Nonlinear Geophysics focus group of the American Geophysical Union at the 2003 Fall Meeting for *Dynamic interaction of bedforms at low transport stage*.
Mohrig received a Best Poster Award at the 2003 Submarine Slope Systems Conference, co-sponsored by the International Association of Sedimentologists, for *Using the stratification produced by climbing dune to estimate the filling histories of submarine turbidite channels.*
Paola was elected second vice-chair, GSA Sedimentary Geology Division for 2004-2005.
Paola was selected to the SEPM Pettijohn Medal committee.
Perg was invited to serve on the Fall 2003 Geology and Paleontology review panel.
Porté-Agel received a McKnight Land-Grant Professorship from the University of Minnesota for the period 2003-2005.
Power was awarded the John and Mary Gompertz Chair of Integrative Biology by her department at Berkeley for 2003-2008.
Power was invited to edit:, Polis, G.A., Power, M.E. and Huxel, G. 2004. Food webs at the landscape scale. Univ. Chicago Press, Chicago IL. published late in March 2004.

Awards and Honors
Power was selected to receive the 2004 "Kempe Award for Distinguished Ecologists", made possible by a grant to the University of Umea, Sweden, from the Kempe foundation. One Kempe Award is given out every two years.
Voller was a guest editor of: N. El-Kaddah and V.R. Voller, Guest Editor, *Applied Mathematical Modeling*, 28, 2004.
Voller was invited to contribute a chapter to: "Numerical Methods for Phase Change Problems," Chapter 19 in *Handbook for Numerical Heat Transfer*, submitted 2003.

3. Graduated Students*

Student	NCED Advisor	Degree/year	Years in Program	Placement
Dodov, Boyko	Foufoula-Georgiou	PhD/2003	4	NCED post-doc
Hasbargen, Les	Paola	PhD/2003	6	Indiana University
Lima, Violetta	Voller	MS/2003	1	INGEA, Barcelona, Spain
Sklar, Leonard	William Dietrich	PhD/2003	8	San Francisco State University
Stock, John	William Dietrich	PhD/2003	7	Mendenhall Fellow: USGS
Toniolo, Horacio	Parker and Vaughan	PhD/2003	3	University of Alaska, Fairbanks
Wright, Scott	Parker	PhD/2003	4	USGS

Note: We have settled on a reporting period for Annual Reports of April 1 – March 29. Several of the students listed above were listed in last year's report as well.

4. General Outputs of Knowledge Transfer

No licenses, patents, startup companies were created or are anticipated for our Center.

5a. Participants

[Section removed from this edition.]

5b. Affiliates

[Section removed from this edition.]

6. Summary Listing of Partners

	Organization Name	Type of org.	Address	Contact Name	Type of Partner	160 hours
1	AISES: American Indian Science and Engineering Society	NGO	AISES P.O. Box 9828 Albuquerque, NM 87119-9828	N/A	Education & Diversity	N
2	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
3	AIHEC: American Indian Higher Education Consortium	NGO	121 Oronoco Street Alexandria, Virginia 22314	N/A	Education & Diversity	N
4	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
5	Division of Indian Work	NGO	1001 East Lake Street Minneapolis, MN 55407	Louise Mattson	Education & Diversity	N
6	Fond du Lac Ojibwe Schrols	NGO	1720 Big Lake Rd. Cloquet, MN 55720	Rachel Brecken-ridge	Education & Diversity	Y
7	Cloquet Forestry Center	University	175 University Road Cloquet, MN 55720-9594	Bob Stine, Coordin-ator	Education & Diversity	N
8	Center for Embedded Network Sensing	Federal Government	UCLA, Hilgard Ave., 3731 Boelter Hall, Los Angeles, CA 90095	Deborah Estrin, Director	Diversity, Education Know-ledge Transfer, Research	N
9	QEM	Federal	1818 N Street, NW, Suite 350	Dr. Shirley	Education &	N

		Government	Washington, DC 20036	McBay	Diversity	
10	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
11	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
12	Graduate School Outreach Office, University of Minnesota	University	101 Pleasant Street SE 322 Johnston Hall Minneapolis, MN 55455	Kather-ine Johnson	Education & Diversity	N
13	Museo di Storia Naturale http://www.iltempodellanatura.it	Museum	Università di Firenze Via G. La Pira, 4 50121 FIRENZE ITALY	dott.ssa Elisabetta Cioppi Conser-vatore	Know-ledge Transfer	N
14	Association for Women Geoscientists, Minnesota chapter	professional	NA	Karen Camp-bell, president Lesley Perg, treasurer	Know-ledge Transfer	N
15	(CUAHSI Consortium for the Advancement of Hydrologic Sciences, Inc.)	consortium	Consortium for the Advancement of Hydrologic Sciences, Inc.	Efi Foufoula Foufoula is board	Know-ledge Transfer	

	http://www.cuahsi.org/		(CUAHSI) 2000 Florida Avenue, NW Washington, DC 20009	member		
16	Geowall Consortium	Consortium	http://www.geowall.org/	Paul Morin	Knowledge Transfer	N
17	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 Washburne	Diversity and Knowledge Transfer	N
18	SciTech Hands On http://scitech.mus.il.us/	Museum	18 W. Benton Street Aurora IL 60506	Ronen Mir, Executive Director	Knowledge Transfer	N
19	Stillwater Sciences	Corporation	2855 Telegraph Ave., Suite 400 Berkeley, CA 94705	Yantao Cui	Knowledge Transfer	N
20	R2 Resource Consultants	Corporation	15250 NE 95th Street Redmond, WA 98052	Paul DeVries	Knowledge Transfer	N
21	Office of Naval Research	Federal Government	800 N. Quincy Street Arlington, VA 22217	Tom Drake	Knowledge Transfer	N
22	US Geological Survey Office of Surface Water	Federal Government	415 National Center 12201 Sunrise Valley Drive Reston, VA 20192	John Gray	Knowledge Transfer	N
	US Geological Survey CERC	Federal Government	4200 New Haven Road	Robert Jacobson	Knowledge	N

			Columbia, MO 65201		Transfer	
23	US Bureau of Reclamation – Sediment and Hydraulics Group	Federal Government	Denver, CO 80225	Yong Lai	Know-ledge Transfer	N
24	US Forest Service	Federal Government	316 E. Myrtle Street Rocky Mountain Research Station Boise, ID 83702	Jim McKean	Know-ledge Transfer	N
25	Anadarko Petroleum Corporation	Corporation	1201 Lake Robbins Drive The Woodlands, Texas 77380	Todd Green/ James Parr	Know-ledge Transfer	N
26	ChevronTexaco	Corporation	4800 Fournace Place Bellaire, TX 77401	Martin Perl-mutter	Know-ledge Transfer	N
27	ConocoPhillips	Corporation	P.O. Box 2197 Houston, TX 77252-2197	Al Shultz	Know-ledge Transfer	N
28	ExxonMobil Upstream Research Co.	Corporation	P.O. Box 2189 Houston, TX 77252-2189	Penny Patter-son	Know-ledge Transfer	N
29	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
30	Shell International Exploration and Production Company	Corporation	3737 Belaire Blvd., Houston, Texas 77025	Carlos Pirmez	Know-ledge Transfer	N

6. For internal NSF reporting purposes, provide a Summary Table with the following information:

[Section removed from this edition.]

Section IX: Indirect / Other Impacts

None to report this year.

Section X: Budget

[Section removed from this edition.]

Appendix A: New Faculty Biographies

Jacques C. Finlay

Professional Preparation

University of New Hampshire, Natural Resources BS, 1990

University of California, Berkeley, Integrative Biology PhD, 2000

University of Wisconsin, Madison, Ecology/Limnology, 2000-2001

USGS-National Research Program, Ecology/Limnology, 2001-2002

Appointments

Assistant Professor, University of Minnesota, 2003-present

Post-Doctoral Research Fellow, USGS-NRP, 2001-2002

Post-Doctoral Research Fellow, University of Wisconsin, 2000-2001

Research Assistant, University of New Hampshire, 1991-1994

Honors and Fellowships

NRC Post Doctoral Fellowship, 2001-2002

NSF Doctoral Dissertation Improvement Grant, 1999-2000

NASA Global Change Fellowship, 1996-1999

EPA Fellowship (declined), 1996

UC Berkeley Regents Fellowship, 1995

ARCS Scholarship Award, 1995

Selected Publications

Finlay, J.C. *In press*. Patterns and controls of lotic algal stable isotope ratios. Limnology and Oceanography.

Finlay, J.C. 2003. Controls of streamwater dissolved inorganic carbon dynamics in a forested watershed. Biogeochemistry 62: 231-252.

Finlay, J.C., S. Khandwala, and M.E. Power. 2002. Spatial scales of carbon flow through a river food web. Ecology 82:1052-1064.

Bastow, J.L, J. Sabo, J. Finlay and M.E. Power. 2002. A basal aquatic-terrestrial trophic link in rivers: algal subsidies via shore-dwelling grasshoppers. Oecologia 131: 261-268.

Finlay, J.C. 2001. Stable carbon isotope ratios of river biota: implications for energy flow in lotic food webs. Ecology 84: 1052-1064.

Finlay, J.C., M.E. Power, and G. Cabana. 1999. Effects of water velocity on algal carbon isotope ratios: implications for river food web studies. Limnology and Oceanography 44: 1198-1203.

Arscott, D., W.B. Bowden, and J.C. Finlay. 2000. Effect of desiccation, temperature, and irradiance on the metabolism of two arctic stream bryophytes. Journal of the North American Benthological Society 19: 263-273.

Harvey, C.J., B.J. Peterson, W.B. Bowden, L.A. Deegan, A.E. Hershey, M.C. Miller, and J.C. Finlay. 1998. Biological responses of Oksrukuyik Creek, a tundra stream, to fertilization. Journal of the North American Benthological Society 17: 190-209.

Finlay, J.C. and W.B. Bowden. 1994. Controls on production of bryophytes in an arctic tundra stream. Freshwater Biology 32: 455-465.

Bowden, W.B., J.C. Finlay, and P.E. Maloney. 1994. Long-term effects of PO_4 fertilization on the distribution of bryophytes in an arctic tundra stream. Freshwater Biology 32: 445-454.

Synergistic Activities

International research collaboration and scientific development program in Russia (NSF RAISE project in Cherskii, Siberia)

Collaborators & Other Affiliations

Collaborators

C. Briggs, M.E. Power & V. Vrendenburg (University of California, Berkeley), E.H. Stanley (University of Wisconsin, Madison), J. Neff (University of Colorado, Boulder), J. Sabo (University of Arizona), J. Bastow (University of California, Davis), F.S. Chapin, J. Jones, R. Ruess (University of Alaska, Fairbanks), D. Post (Yale), R. Sterner (University of Minnesota), W.B. Bowden (University of Vermont), M. Mack & T. Schuur (University of Florida)

Graduate and Postdoctoral Advisors

M.E. Power (University of California, Berkeley), E.H. Stanley (University of Wisconsin, Madison), R. Striegl (USGS)

Gregory Wilkerson

Major Research Interests

Research and development of solutions to water resource problems, multi-disciplinary approaches to stream restoration, river mechanics, sedimentation and erosion, environmental hydraulics, engineering hydrology, and statistics.

Education

Doctor of Philosophy
Colorado State University, Fort Collins, CO (1999)
Dissertation Title: *Near-Bank Processes, Bioengineering, and the Dormant Willow Post Method*

Master of Science in Civil Engineering
Colorado State University, Fort Collins, CO (1995)
Thesis Title: *Use of Rock Tests and Petrographic Data to Predict Sandstone Riprap Erosion Rates*

Bachelor of Science in Civil Engineering
Georgia Institute of Technology, Atlanta, GA (1989)

Experience

University of Wyoming, Laramie, WY ***8/99-Present***
Assistant Professor of Civil Engineering
U.S. Army Corps of Engineers, Waterways Experiment Stattion, Vicksburg, MS ***10/97-12/97***
Visiting researcher. Participated in a collaborative research effort with Corps personnel to assess the effectiveness of experimental bank stabilization techniques. Responsibilities included experiment design and execution, and data analysis.
Colorado State University, Fort Collins, CO ***1/97-5/97***
Volunteer tutor of physics for undergraduate physics classes.
Colorado State University, Fort Collins, CO ***7/97-12/97***
Volunteer Graduate Teaching Assistant. Graded assignments, led recitation classes, and tutored students in undergraduate hydraulic engineering course. Instructed class on using computers for problem solving.
Colorado State University, Fort Collins, CO ***6/94-12/94***
Graduate Research Assistant. Performed research to assess the erosional characteristics of sandstone riprap and developed a model for predicting sandstone riprap quality and durability. Contracted and coordinated the activities of four independent laboratories while working on this project.
Bettigole, Andrews & Clark Inc., New York, NY ***1990-1993***
Civil Engineer. Primary duties included the detailed and conceptual design of highways, highway drainage systems, and hydraulic appurtenances. Also performed hydrologic and hydraulic studies, bridge inspections, and bridge scour analyses.
Parsons, Brinckerhoff Inc., New York, NY ***1989-1990***
Civil Engineer. Primary duties included preparing conceptual designs of alternative highway alignments and site development plans.
Parsons Brinckerhoff/Tudor Engineering Co., Atlanta, GA ***1986-1989***
Civil Engineer. Assisted in the design and construction management of projects as required by the needs of the Metropolitan Atlanta Rapid Transit Authority.

Publications

Conference Proceedings

Wilkerson, G. V. (2004, in press). Predicting Depth Averaged Velocities in Trapezoidal Channels. Proceedings of the World Water and Environmental Resources Congress 2004. Reston, VA: ASCE.

Wilkerson, G. V., and Watson, C. C. (2000). Flow through rigid streambank vegetation. Joint Conference on Water Resources Engineering and Water Resources Planning and Management. Reston, VA: ASCE.

Wilkerson, G. V., and Watson, C. C. (2000). Measuring vegetation density with the horizontal point frame [CD-ROM]. In R. Walton and R. E. Nece (Eds.), 1999 International Water Resources Engineering Conference. Reston, VA: ASCE.

Wilkerson, G. V. (1998). Evidence of Willow Post Induced Deposition. In S. R. Abt, J. Young-Pezeshk, and C. C. Watson (Eds.), Water Resources Engineering '98 (vol. 1, pp. 435-440). Reston, VA: ASCE.

Wilkerson, G. V., Abt, S. R., and Johnson, T. L. (1996). Predicting sandstone riprap erosion rates. Tailings and Mine Waste '96 (pp. 229-237). Rotterdam, The Netherlands: Balkema.

Published Abstracts

Wilkerson, G. V. (2003). Assessing the erosion potential of coal bed methane surface water discharges in the Powder River Basin, WY. Eos. Trans. AGU, 84(*46*), Fall Meeting. Suppl., Abstract H41C-1020.

Wilkerson, G. V. (2002). A GIS model for evaluating the impacts of coal bed methane surface water discharges. Geological Society of America Abstracts, 34(*6*). Denver, CO: GSA.

Awards

*Mortar Board Top Professo*r, Univ. Wyoming (Nov. 2003).

Faculty Growth Award, Univ. of Wyoming (1999).

National Science Foundation Trainee/Fellow (1995-1999*).*

Finalist in 1997-1998 Martin Luther King Scholarship competition at Colorado State Univ. This award provides one year of full academic support for a graduate student. Selection criteria includes academic excellence and service to the advancement of minority education.

National Society of Black Engineers-Alumni Extension (NSBE-AE) National Technologist of the Year (1997). This award is presented to recognize outstanding contributions in leadership, for advancing the overall mission of NSBE, and for professional achievement.

NSBE-AE Region VI Technologist of the Year (1997).

NSBE Torchbearer (1996). Recognition granted to NSBE members for academic achievement

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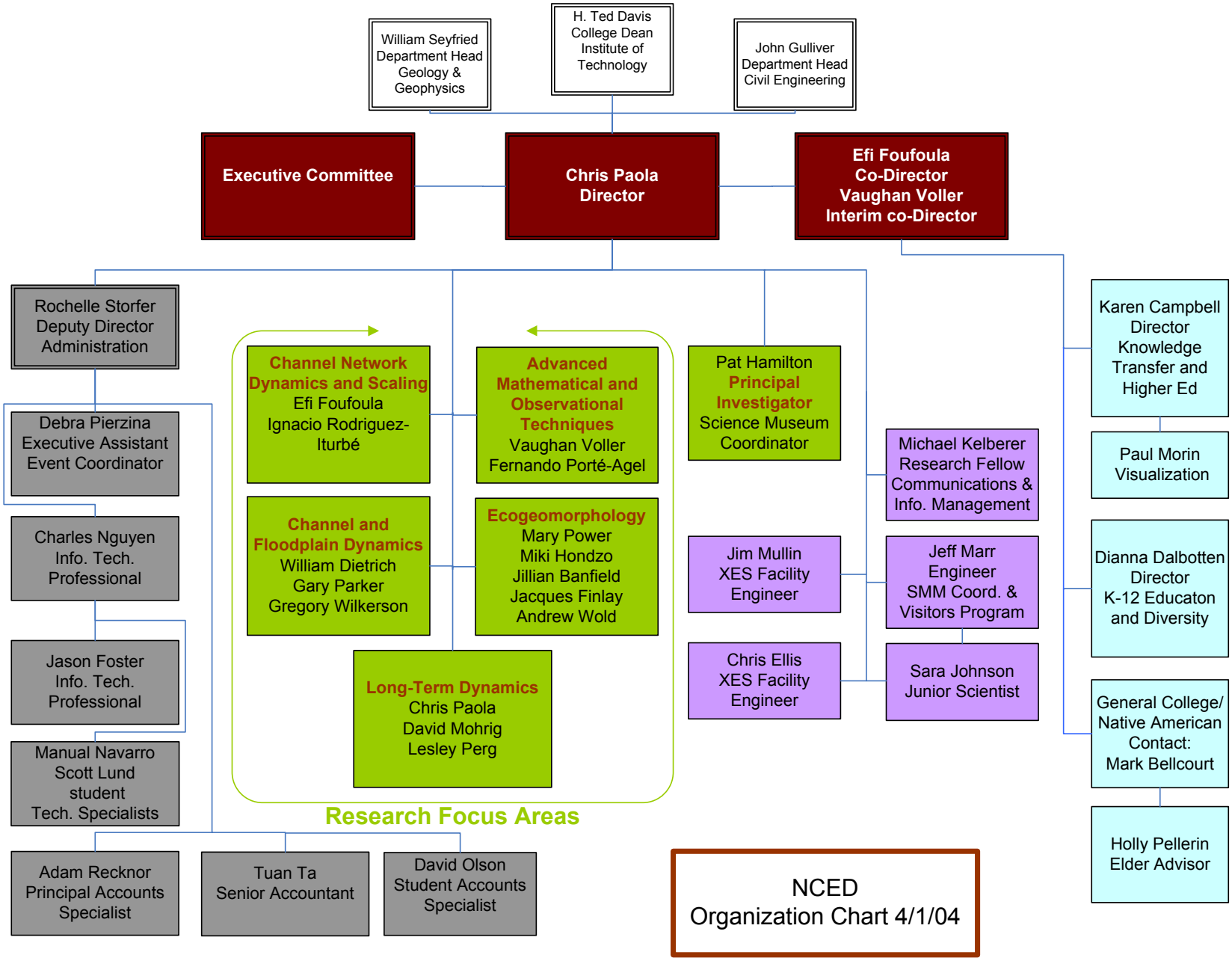
William Seyfried
Department Head
Geology &
Geophysics
H. Ted Davis
College Dean
Institute of
Technology
John Gulliver
Department Head
Civil Engineering
Executive Committee
Chris Paola
Director
Efi Foufoula
Co-Director
Vaughan Voller
Interim co-Director
Rochelle Storfer
Deputy Director
Administration
Debra Pierzina
Executive Assistant
Event Coordinator
Charles Nguyen
Info. Tech.
Professional
Jason Foster
Info. Tech.
Professional
Manual Navarro
Scott Lund
student
Tech. Specialists
Adam Recknor
Principal Accounts
Specialist
Tuan Ta
Senior Accountant
David Olson
Student Accounts
Specialist
Channel Network
Dynamics and Scaling
Efi Foufoula
Ignacio Rodriguez-
Iturbé
Advanced
Mathematical and
Observational
Techniques
Vaughan Voller
Fernando Porté-Agel
Channel and
Floodplain Dynamics
William Dietrich
Gary Parker
Gregory Wilkerson
Ecogeomorphology
Mary Power
Miki Hondzo
Jillian Banfield
Jacques Finlay
Andrew Wold
Long-Term Dynamics
Chris Paola
David Mohrig
Lesley Perg
Research Focus Areas
Pat Hamilton
Principal
Investigator
Science Museum
Coordinator
Jim Mullin
XES Facility
Engineer
Chris Ellis
XES Facility
Engineer
Michael Kelberer
Research Fellow
Communications &
Info. Management
Jeff Marr
Engineer
SMM Coord. &
Visitors Program
Sara Johnson
Junior Scientist
Karen Campbell
Director
Knowledge
Transfer and
Higher Ed
Paul Morin
Visualization
Dianna Dalbotten
Director
K-12 Educaton
and Diversity
General College/
Native American
Contact:
Mark Bellcourt
Holly Pellerin
Elder Advisor
NCED
Organization Chart 4/1/04

Appendix C: External Advisory Board

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Second Report of the External Advisory Board
of the
National Center for Earth-surface Dynamics (NCED)
14 January 2004

NCED has made major strides in implementing the suggestions made by EAB one year ago. Particularly notable was the sharpening of the focus of the research and the sense that a research team is coalescing. This time around, the investigators who made presentations and whom we talked to seemed to know where they fit in and were excited by the new, collaborative work they are doing.

Progress toward the goal of interdisciplinary research could be seen in: 1) the ecogeomorphologic work at Angelo; 2) the seascape-landscape comparisons. The evolution that has occurred (seen in their new directions research efforts and in the revised focus areas) indicates the strength of the group (which is beginning to operate as a team, rather than a collection of individual investigators) and a commitment and focus.

There are still major issues, identified by the Director and Co-Directors in their presentations, that need attention, in order for the NCED group to make substantial progress on their ambitious mission and to position themselves for renewal in just fourteen months. In order to organize our comments, we adopt the outline of nine major issues for NCED that was presented by Director Chris Paola, but also add a few items of our own.

1. Improving Research Coherence and Focus

The focus problems listed in Chris Paola's Powerpoint presentation are very good, in that they play to the strengths and expertise of the group while requiring collaborations and a "stretch" on the part of the PIs to meet the very ambitious mission. The video conference calls and the adoption of the Angelo Field Site as a place where PIs and graduate students can work together, the PI and grad student retreats are good ways to maintain group coherence and focus.

2. Better Communication among NCED Components

Connections between the scientists and both the formal and informal education components of NCED are being made. A good example was the exchange between the preparators of the source-to-sink sediment exhibit at the Science Museum of Minnesota (SMM) and the scientists at St. Anthony Falls Laboratory (SAFL).

The connection to the SMM could become the means to globalize the lessons learned from the formal education program. The science camps are a good idea that should be extended through the SMM and its connection to other science museums and centers. Can a traveling exhibit be developed?

Sustainability of the education programs. Sustained, repeated contact as students move through the grades is critical to insuring that more students from currently *underrepresented* minorities go on to college and enter the sciences. NCED has done well to determine where the gaps are in existing programs and then seeking to fill the gaps. In their renewal proposal, NCED will be required to

develop a long-term plan that will presumably describe how NCED and its programs, including the education programs, will be sustained after NSF funding ramps down or ends.

The Board feels that assessments and tracking will be key in generating the kind of support that could add to the education program in the near future and sustain it in the long term (post NSF funding). Measurement of the effectiveness of education programs is not often done. It is good that NCED is now consulting with the Education School at the University of Minnesota to develop assessments. NCED should take full advantage of the social scientists they are assembling later this same week to address the assessment and tracking issues, as well as cultural issues that were identified during this first year of the program (more about this later). Potential sources of funding are private foundations (Kellogg, Rockefeller, Mellon, MacArthur) and industries, particularly the oil companies that use geosciences and that are well aware of the short-comings of science education in the U.S. If these organizations were convinced that the programs work, by measures of success and by tracking of students who enroll in the NCED programs, they would more than likely contribute to an operating endowment to ensure that the programs continue and expand. The fact that the program is already supported by NSF makes it a very attractive candidate for leveraged support. An example of corporate interest in the education issue: Exxon-Mobil support of historically black colleges.

3. NCED and the Broader Scientific Community: Avoiding the Clique Syndrome

After experimenting with a small grants program and learning about its deficiencies, NCED is now developing a program ("Working Groups") that is likely to be much more effective in meeting NCED's mission and in engaging scientists from outside the NCED core group. They have carefully researched the NCEAS model (National Center for Ecological Analysis and Synthesis) and plan to bring Working Groups of approximately 12 scientists together with at least one NCED PI per group to address seven topics that relate directly to the NCED mission.

The Board feels that NCED has a good plan that is likely to succeed and looks forward to learning about the outcome at our next review meeting. Board members also noted that while it is beyond our competence and role to review all the proposals, individual Board members are willing to examine proposals and reviews of those proposals, in the Board member's area of expertise, and make recommendations to NCED leadership.

4. Adding PIs

In addition to the usual route of contact (personal networks, contact through reading papers and hearing presentations), the formation of the Working Groups (item 3) above affords an opportunity to "try out" a potential collaborator. Addition of PIs is likely to be required when NCED selects and begins work on its "depositional" field site (Wax Lake in the Mississippi River Delta was mentioned as a candidate).

Assessment and tracking of students through the NCED educational programs and on to college is a worthy research subject that could involve a new PI from the Social Sciences or education (see item 2 above).

NCED is to be complimented for developing procedures for replacing and adding PIs (Section VII.4 of their Strategic and Implementation Plan). They have a process for evolving PI participation.

5. Defining NCED's Role in River Restoration

Impacting river restoration is a natural consequence of pursuing NCED's larger goals and is therefore a good fit with their mission and activities.

Be sure to get in touch with the investigators (Margaret Palmer and David Allen) who are working on the NSF- and NCEAS-supported **National River Restoration Science Synthesis** (NRRSS), particularly those working on the Central US Large Rivers (CUSLR) Node, Upper Mississippi River Basin (UMSRB) Program.

NCED should think in terms of the thousands of restoration projects on rivers and streams throughout the U.S., in contrast to the high-visibility, multi-billion-dollar CALFED and Everglades projects, which tend to be mainly driven by water allocation issues. NCED could make a major contribution to the problem of naturalizing rivers and streams in settings where some control and regulation is required. Much of the theory and practice is inadequate in these situations. It is important to know where natural geomorphic processes can be restored and where they must be constrained to some degree. How to achieve this balance is both a scientific question and a question of social values. Also, the development of a "manual" is a good fit here. Restoration should also be a priority "Working Group" topic, and the Working Group would be a good way to get started.

6. Developing Effective Partner Relations

The first Partner meeting, with federal and Minnesota state agency personnel and engineering consulting companies, 14-15 October 2003, seems to have gone well. It was interesting that the agency people welcomed the opportunity to talk together about common issues, under the aegis of an objective, outside party. Tribal government representatives should be included. The experience seems to suggest a role for NCED as a broker, which bodes well for NCED's possible entry into areas, such as the Mississippi Delta, where contentious parties have been arguing over management of sediment and water for decades. NCED is not merely a broker, but also has a toolbox that would be helpful to all parties.

Already mentioned above (item 2) is a possible role for corporate partners and private foundations in sustaining and enhancing the education program.

7. Developing an Effective Social Science Program

and

9. Developing measures of Effectiveness in Applied Research and Societal Impact

1) Assessment of success and tracking of students has already been mentioned above, as a much-needed part of the NCED education component.

The social scientists who are meeting later this week are being asked to define a number of topics, including public perceptions of landscape and how it influences river management. Other topics could include:

2) impact of NCED on policy (e.g., management of dynamic landscapes, such as floodplains)

3) how to convey uncertainty about dynamic landscape processes and events to the public and to decision-makers (predictions about landscape processes are uncertain because of randomness and because of incomplete understanding of processes)

4) education and tracking of scientists who may go on to do multi-disciplinary and inter-disciplinary work

Other issues that Social Sciences might address are:

5) cultural issues in bringing *underrepresented* groups into science. Another issue is the clash of cultural values: a) the desire to have young people stay on reservations, rather than go out to the larger world; b) the practice of cooperative work on behalf of the group, rather than individual success in a competitive situation.

6) The former model (5b) is an example where the Native American culture may actually provide a guide to success in multi- and inter-disciplinary research, in contrast to the highly competitive and individualistic model that typifies much of science today. NCED itself could become an object of study in how to foster true interdisciplinary research.

7) Much cultural knowledge is in danger of being lost in the next few years, as there are fewer elders to pass this knowledge on to future generations. Some way needs to be found to ensure the survival of this knowledge, including knowledge about natural resources.

8. Positioning NCED for Renewal

Do all of the above! Also, despite the group's weariness with reworking the vision and mission statements, do make sure that both are things you can show progress on. Try to have a mission and goals you can actually make *measurable* progress on.

10. Administration

Several Board members noted that the share of the budget that goes to administration seemed large in proportion to the amount spent on other components, particularly research. In further discussions with the co-Directors, we learned that the other Science and Technology Centers spend equivalent amounts on administration, including activities such as the external reviews, that are required by NSF. Nevertheless, the Board encourages the co-Directors to exercise continuous vigilance in allocating and using funds.

Another concern is that the administrative burden from a complex project that requires interaction with many institutions and partners, other STCs, and NSF, may consume all of the co-Directors' time, taking good scientists away from the scientific interests that sustain and excite them and contribute to the project. Money spent on personnel who can relieve some of the administrative burden would be well spent.

11. EAB Schedule and Report to EAB

EAB members liked the suggestion that we meet in the Fall, in conjunction with the PIs' meeting. Those EAB members whose schedules allow the time would like to hear the PI presentations and have time to interact with the PIs. The official EAB meeting (day and a half) would best follow the PI meeting, so that at least some EAB members would have the advantage of hearing a complete exposition of science activities.

In the interest of streamlining administration, EAB recommends that each member of the Board receive a copy of the annual report prior to the EAB annual meeting. No additional progress report is necessary for the EAB.

Appendix D: Media and Publicity Materials

Media materials are on the following pages, and include:

1. Press information sheet for our first Press Day event
2. Article from the U of M Institute of Technology's Inventing Tomorrow magazine
3. Article from University of Minnesota's "UMN News" publication
4. Web version of Minnesota Public Radio story
5. Article from the U of M's student publication "Minnesota Daily"

Background Information: February 25, 2004 Press Day at the National Center for Earth-surface Dynamics

National Center for Earth-surface Dynamics (NCED)

NCED is a National Science Foundation (NSF) funded (with a generous match from the University of Minnesota) Science and Technology Center (STC). There are currently 11 STC's in the U.S. NCED is headquartered at the University of Minnesota's St. Anthony Falls Laboratory (SAFL) on Hennepin Island in the Mississippi River. NCED has research and education partners at the Science Museum of Minnesota, Fond du Lac Tribal and Community College, Massachusetts Institute of Technology, Princeton, University of California, Berkeley, and University of Wyoming. NCED received initial funding in August 2002 and is eligible for ten years of NSF funding. There are several NSF-funded centers and projects at the University of Minnesota, but NCED is the only STC.

When the Big Backyard at the Science Museum of Minnesota opens in June, 2004, its interactive exhibits and Earth-surface Dynamics-themed nine-hole miniature golf course will introduce visitors to NCED science. NCED scientists and engineers played key roles in the development and prototyping of these exhibits.

NCED promotes landscape sustainability through research, education, and knowledge transfer. Researchers from the fields of civil engineering, ecology, geology, and hydrology work together to develop integrated models of the channel systems that shape the Earth's surface through time, in support of landscape restoration, environmental forecasting, and resource development.

St. Anthony Falls Laboratory

SAFL was built in 1938 with a Works Progress Administration grant, and is currently home to research groups from the Civil Engineering and the Geology and Geophysics Departments at the University of Minnesota. Utilizing the natural 50-foot drop from the top of St. Anthony Falls to the river surface below, up to 2200 gallons/second (300 cfs) of river water can be diverted through the building for experimental use. Experiments and studies at the lab range from water quality studies to river engineering, landscape and habitat restoration, and land-atmosphere interaction.

Elwha Dam model

In one such experiment, a vertically-distorted, scaled physical model (horizontal scale 1:310; vertical scale 1:81.7) of the Glines Canyon Dam and its reservoir (Lake Mills) in Washington State was designed by Chris Bromley, a PhD student in Geography at Nottingham University in the U.K., visiting SAFL, with funding ($35,000) from NCED's Visitor Program. Bromley also receives funding from the National Park Service. This dam is scheduled for removal in 2007.Removal of this dam (and its sister Elwha Dam) is unusual - and of particular interest to

NCED - because the primary motivation for removal is the restoration of natural habitat. More often, dams are removed to mitigate a potential hazard or to eliminate the cost, in maintenance or liability, of the dam.

The model will enable Bromley to collect experimental data on the effects of various strategies for removing the dam on the downstream release of the sediment currently stored in the dam's reservoir.

Some pertinent model facts and figures include:

- Planform length = 11 meters (36.1 feet)
- Planform width = 4.57 meters (15 feet)
- Model depth = 0.69 meters (2.25 feet)
- The dam is built of 21, 2.8 cm high (1.1 inch) wooden slats
- The discharge (flow rate) entering the model at its upstream end is 0.22 liters per second (0.008 cubic feet per second (cfs)), which scales to 1,749 cfs in the real Elwha River.
- The sediment mixture is composed of a mixture of sand and gravel, with particle diameters ranging from 0.01 mm to 9.5 mm (0.00039 inches to 0.37 inches)

Elwha River Dams—location, history, current issues

- The Elwha River flows northward across Washington State's Olympic Peninsula from Olympic National Park into the Strait of Juan de Fuca.
- The Elwha Dam is located 4.9 miles upstream from the mouth; the **Glines Canyon** dam is 8.5 miles further upstream.
    - Elwha Dam is a 108-foot high concrete gravity dam. Glines Canyon Dam is a 210-foot high concrete arch dam.
    - The Glines Canyon Dam began operation in 1926 to generate power for a paper mill
    - The Elwha Dam began operation in 1913
- Neither dam has fish passage facilities, which thus prevents 10 runs of native salmon and trout species from accessing over 70 miles of essentially pristine spawning habitat in the Elwha River and its tributaries upstream of Lake Mills.
- The fish population is important both culturally and economically to the Lower Elwha S'Klallam Tribe, whose reservation lands are located on the east side of the Elwha River at its mouth.
- Both the tribe and environmental groups successfully petitioned the federal government to purchase the two Elwha dams, study their environmental impact, and design a plan for restoring the fish habitat.
    - The Final Environmental Impact Statement of 1996 recommended removal of the dams and implementation of habitat restoration, at an estimated cost (now) of $135 million.

    - The dams were purchased by the Federal government in 2000
    - Dam removal and sediment management are expected to begin in 2007
- Unlike many reservoirs, which hold sediment full of pollutants from agricultural or urban run off, the 13.8 million cubic yards of sediment trapped behind the Glines Canyon Dam is derived from a pristine wilderness.
- But, even "clean" sediment can alter fish habitat as it washes downstream once the dams are removed—fine sediments can fatally injure the fish's gills and other organs, render their egg-laying grounds unusable, and reduce the populations of insects they eat.
- Coarse sediments can get trapped at various points in the river, causing flooding.

Dams in the United States

- The National Inventory of Dams lists 76,000 dams.
- Dams can be publicly or privately owned.
- Approximately 500 dams have been removed in the US, most of them within the past 15 years.
- 57 were scheduled for removal in 2003
- Dams are removed because:
    - they have exceeded their original design life (often 50 years) and may have become structurally unsound, especially if they were improperly maintained during that time
    - the capacity of the reservoir behind the dam has diminished as sediment has built up in the reservoir
    - The original purpose for the dam (irrigation, power generation, recreation) is no longer necessary or no longer justified by the cost, economically or environmentally, of the dam

Dams in Minnesota

- The National Inventory of Dams lists 910 dams in Minnesota
- Approximately 200 pose some hazard, according to the NID
- 298 were built before 1940
- The DNR Division of Waters administers Minnesota's Dam Safety Program and maintains Minnesota's component of the National Dam Inventory (NATDAM).
- The DNR provides a list of priority projects to the legislature every two years. One to two dam removals are normally included in the list, resulting in about one dam removal per year. This pace is expected to continue for at least 10 years, according to the DNR. (see http://www.amrivers.org/tableofcontents/appendixbmn.htm)

- According to American Rivers, nine dams have been removed in Minnesota; six since 1984
    - Removing the Sandstone Dam on the Kettle River opened 30 miles for fish migration; repairing and refurbishing it to provide hydropower would have cost over $1 million; removal cost $208,000.
    - The Welch Dam was removed from the Cannon River in 1994, restoring 12 miles of habitat for migrating fish.

Tal Flume—Can vegetation control a river?

Vegetation is ubiquitous and is transported and dispersed readily by wind and water; it will opportunistically colonize those areas of a river channel that are abandoned or exposed at low flows. Vegetation that is not removed in its immature stage will become stronger and increasingly resistant to erosion and removal by the flow. This has strong implications for river management and climate change. Human development of rivers often alters the natural flow regime and diminishes the high flows necessary to flush out the vegetation in its early stages. As a result, the vegetation colonizes large areas of the bed and becomes an active player in determining the shape ("morphology") of the river channel. The case is similar for periods of draught. Vegetation gone awry has profound impacts on stream habitat and is increasingly being recognized as a concern for future development projects. In addition, many previously altered systems are being investigated in search of ways to reverse the colonization that has occurred in order to reduce habitat loss.

University of Minnesota graduate student Michal Tal is investigating the role of vegetation along the river corridor through a series of controlled experiments. The main goal of the experiments is to better understand how vegetation interacts with the flow and the channel patterns that result from this interaction. In particular, Michal is researching how this "riparian" vegetation inhibits the tendencies of systems that are inherently braided – multiple channels that weave in and out of each other and wander freely back and forth across the river valley – by confining the flow to a well defined channel that migrates at a slower rate (meandering). Quantifying the role of vegetation in a river's behavior is fundamental to accurate modeling of rivers systems and will provide answers to as yet unanswered questions concerning stream dynamics. Michal's experiments will likely shed light on how management practices might lead to either an increase or decrease in the presence of vegetation and how in turn this will impact natural systems.

Websites

American Rivers' (a nonprofit organization) Dam Removal site:
http://www.amrivers.org/damremoval/default.htm

American Rivers' Questions about Dams:
http://www.amrivers.org/damremovaltoolkit/damquestions.htm

Association of State Dam Safety Officials: http://www.damsafety.org/

Chris Bromley: http://www.fsl.orst.edu/wpg/people/chris.htm

Elwha Klallam Tribe, Elwha River Restoration Project:
http://www.elwha.org/river.htm

Elwha Restoration Project Office, (826 E Front Street, Suite A
Port Angeles WA, 98362, Tel: (360) 565-1320):
http://www.nps.gov/olym/elwha/home.htm

Minnesota's Dam Safety Program:
http://www.dnr.state.mn.us/waters/surfacewater_section/damsafety/index.html

National Center for Earth-surface Dynamics: http://www.nced.umn.edu

National Inventory of Dams: http://crunch.tec.army.mil/nid/webpages/nid.cfm

United States Society on Dams: http://www.ussdams.org/

St. Anthony Falls Laboratory: http://www.safl.umn.edu

National Center for Earth-surface Dynamics: http://www.nced.umn.edu

UNIVERSITY OF MINNESOTA | SPRING 2003 | OF TECHNOLOGY

INVENTING TOMORROW

VISIONARY VENTURES

NSF funds bold new

INVENTING TOMORROW

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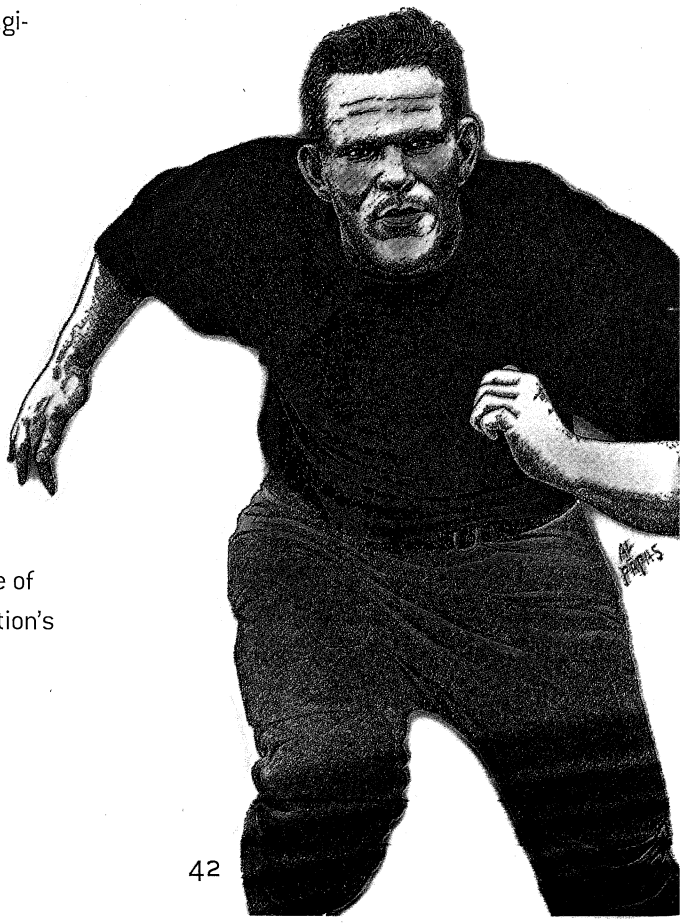
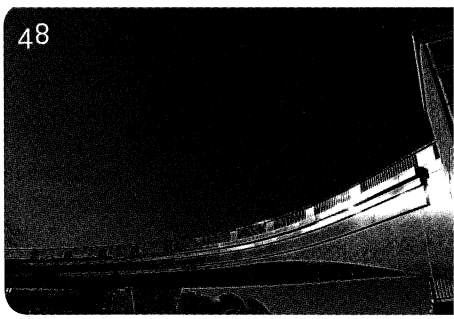




ON THE COVER: *Civil engineering professor Catherine French directs the Multi-Axial Subassemblage Testing laboratory, one of two new research efforts funded by major grants from the National Science Foundation.*

PHOTO BY JONATHAN CHAPMAN

NCED TEAM: Professors Chris Paola, Gary Parker, and Efi Foufoula-Georgiou

Two major NSF grants fund bold collaborations in earthquake engineering and surface process science

visionary ventures

THE EARTH SHUDDERS, AND A STACKED FREEWAY OVERPASS COLLAPSES onto the deck below, snapped in two like a broken chocolate bar. A docile river morphs into a roiling torrent that surges over its banks and engulfs everything in its path. Encrusted with frail shacks that house a teeming city's poorest residents, an entire hillside melts away in a giant mudslide, burying the occupants and their dreams of a better life. ■ The aftermath of a natural disaster evokes sympathy, relief money, volunteer assistance, and a sincere hope that something can be done to prevent or abate such catastrophes. Other crises—nascent, silent, unobtrusive—rarely disturb the consciousness of most people, for the problems and challenges of everyday life frequently trump long-term perspective. ■ Fortunately, a cadre of researchers around the world remains

BY MARGARET KAETER ■ PHOTOS BY JONATHAN CHAPMAN

MODEL BEHAVIOR: According to civil engineering professor Efi Foufoula-Georgiou, facilities like St. Anthony Falls Laboratory are becoming rare as researchers make greater use of models and simulations. Valuable as they are, however, computers and models won't make large-scale facilities obsolete, she says. "You can't understand everything with models and equations, so you need to test hypotheses under controlled conditions."

sity of Texas in Austin, who may submit a proposal to use the facility for studies of reinforced concrete.

"Everyone who uses this has agreed they will put the data into a repository," says Wood. "Therefore, if I'm developing analytical models, I can get this information, so I don't have to call 14 researchers and then find out that I can't read their computer files."

"These are expensive experiments with a lot of data," adds Deierlein. "The network allows us to archive and access data, so people around the world could benefit from one experiment. It's like archaeology—we want to be able to look at today's data in 20 years."

The MAST facility and its research data also will be available to investigators from disciplines other than engineering and geology. For example, it could be used in studies examining the economic and social impact of large-scale earthquakes.

Jerry Hajjar, associate professor of civil engineering, believes the University is the ideal spot for an earthquake laboratory. "Consulting firms in Minnesota increasingly are seeking national and international projects, which means they need engineers who know earthquake-resistant design," he says. "Also, we have a strong information technology component in the University's Digital Technology Center."

The facility's influence will extend far beyond Minnesota, attracting researchers from around the world—a prospect that Gulliver relishes. "Future research will be based on this model, so the MAST laboratory is a prime opportunity for the University to demonstrate leadership," he says.

NCED: WELLSPRING OF SURFACE PROCESS SCIENCE

For 65 years, researchers at the world-renowned SAFL have dedicated their efforts to solving major problems in hydraulic engineering and water resources.

Tucked away on a small island in the Mississippi River, just downstream from Minneapolis' historic St. Anthony Falls, the premier facility is the only laboratory in the world that can tap into a natural waterfall to provide virtually unlimited water flow for experiments in everything from river engineering to sediment formation.

Over the past two decades, SAFL has expanded its focus to include interdisciplinary research on water and its interaction with the environment. A modern computational network, field projects, and new labs in water quality and bioengineering complement SAFL's existing experimental facilities.

During this period, the number of large-scale facilities for experimental water-related research declined dramatically. Full-scale water flow research gave way to computerized models and equipment that requires minimal space. SAFL is now one of about a half-dozen U.S. laboratories that offer large-scale experimental facilities for engineering and geophysical fluid dynamics.

Valuable as they are, however, computers and models won't make large-scale facilities obsolete.

"You can't understand everything with models and equations, so you need to test hypotheses under controlled conditions," says Distinguished McKnight University Professor Efi Foufoula-Georgiou, SAFL director and NCED codirector. "Likewise, research efforts of that magnitude and scope are difficult to do with small grants."

In choosing SAFL as the center's lead institution, NSF recognized the laboratory's creativity and outstanding contributions to water-related research. NCED is the brainchild of SAFL faculty who envi-

sioned an interdisciplinary center where researchers could study the processes that change the earth's surface over time. That great idea generated an even better one.

"We realized we could be midwives for a new field that would not be civil [engineering], geology, or ecology but would be surface process science," says NCED co-director Chris Paola, professor of geology and geophysics.

To further develop the concept, SAFL faculty collaborated with colleagues at Massachusetts Institute of Technology, University of California-Berkeley, and Princeton University who will provide complementary areas of expertise and research facilities. The NCED team includes engineers, geologists, ecologists, biologists, chemists, oceanographers, environmental scientists, and experts from other fields.

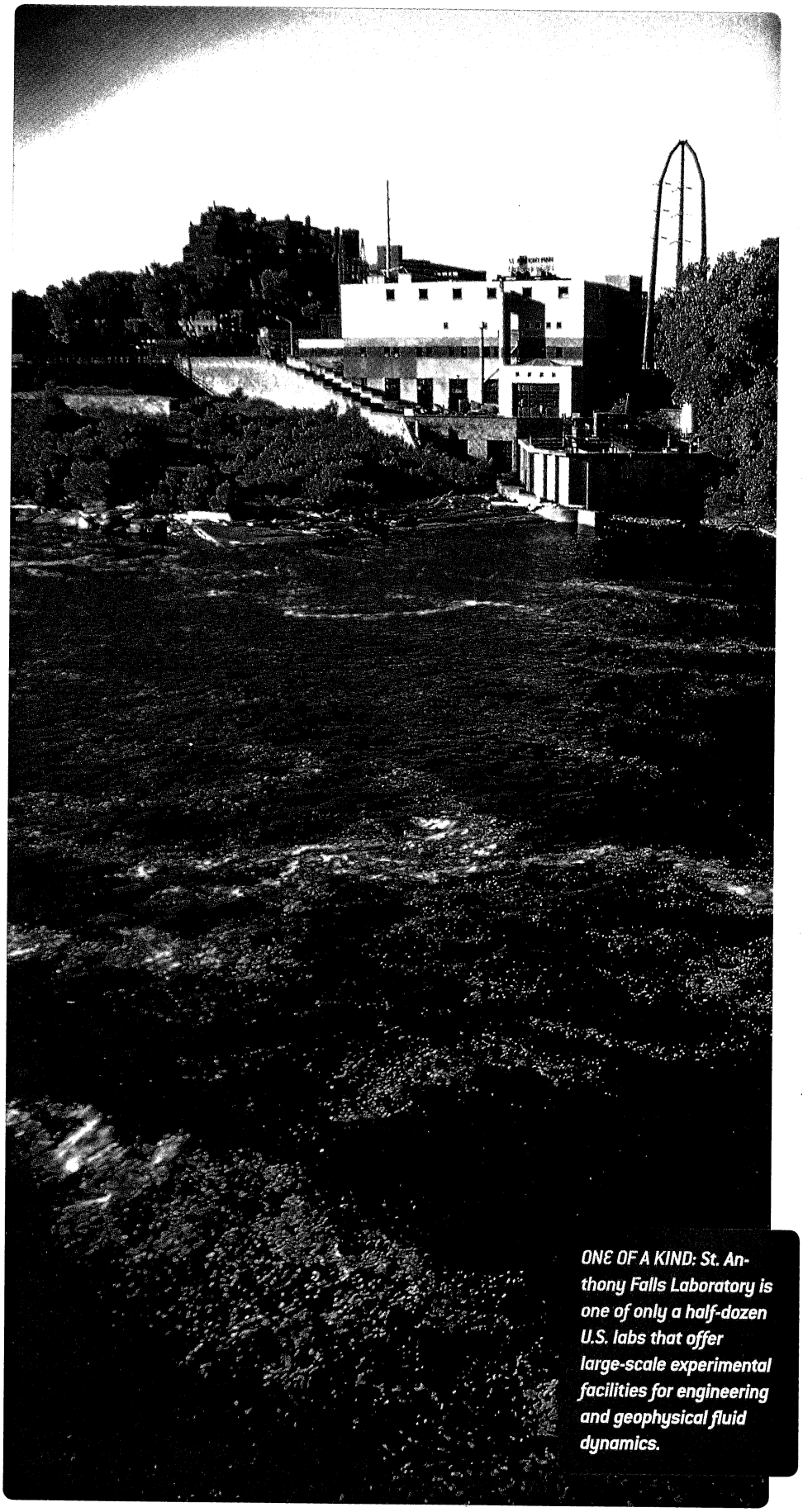
"Rachel Carson described sediments as 'a sort of epic poem of the earth,'" says Paola. "Unfortunately, this poem is written in a language we still can't always decipher. NCED will be a major step toward developing an integrated, predictive understanding of how our planet's surface works."

Four partner institutions—MIT, Princeton, UC-Berkeley, and Fond du Lac Tribal and Community College in Cloquet, Minnesota—received a total of $2.77 million, while the Science Museum of Minnesota received a $2.47 million grant, one of the largest awards in its history. The remainder of the award, $14.1 million, went to SAFL.

The University will give the center $3.2 million in cash over five years along with a $787,699 in-kind match. "This was a big vote of confidence in us by the University," says civil engineering professor Gary Parker, NCED director. "The cash allocation especially will allow us to do such things as fund minority research positions."

The one-time renewable NSF grant, combined with the University's contributions, will fund research in four major areas: landscapes and seascapes; basins; the effects of living things on the development of landscapes and stream channels; and integration of processes that change the shape of the earth's surface across environments and scales.

NCED researchers will study everything from sediment mechanics and erosion to braided rivers, rainfall, and climate



ONE OF A KIND: St. Anthony Falls Laboratory is one of only a half-dozen U.S. labs that offer large-scale experimental facilities for engineering and geophysical fluid dynamics.

change. Information gained from their work will aid responsible management of landscape resources, including forests, agricultural fields, and recreational areas, and wise development of resources like groundwater and hydrocarbons that are buried in sediments.

Human-induced changes—for example, population pressures on high-risk or environmentally fragile landscapes—are among the most pressing challenges. Population growth in the western and southwestern U.S. has created more developments in areas like Death Valley and the San Fernando Valley, former riverbeds that are prone to flash floods, mudslides, and landslides. Many of the world's developing and most populous nations are located in regions of high seismic activity.

"These are issues in terms of disaster, in terms of planning," says Parker.

"We have a small lab here [at] Northwestern … so I came to the University of Minnesota to use the large facilities," he says. "There are only six to eight labs of this size in the country."

NCED also will generate research opportunities for institutions that might not otherwise be able to fund studies, such as Fond du Lac Tribal and Community College.

"We always opened the lab to others, but now [they can submit] proposals. Now we

NCED will collaborate with the Science Museum of Minnesota to create an interactive Science Park on the river flats adjacent to the museum.
Content will be based on NCED research and will illustrate how water, air, and other forces sculpt the earth's surface.

affects erosion, sedimentation, vegetation, and other factors.

"This is multidisciplinary," says Foufoula-Georgiou. "We look at water, soil, vegetation, biology, biochemistry, and other areas to be able to quantify their interactions in time and space, so we can eventually build predictive models."

A portion of the NSF grant—$300,000—is reserved for a relatively small but noteworthy expenditure. NCED will seek recommendations from social scientists on

the St. Louis River—the largest U.S. tributary to Lake Superior—is among 43 sites identified by the U.S. and Canadian governments as Great Lakes Areas of Concern.

In most participating schools these activities are integrated into the science curriculum. As students strengthen their scientific skills, they're also helping communities identify and solve environmental problems. The data collected by the students are compiled, evaluated, and shared among all schools and with state and local communities in a variety of ways.

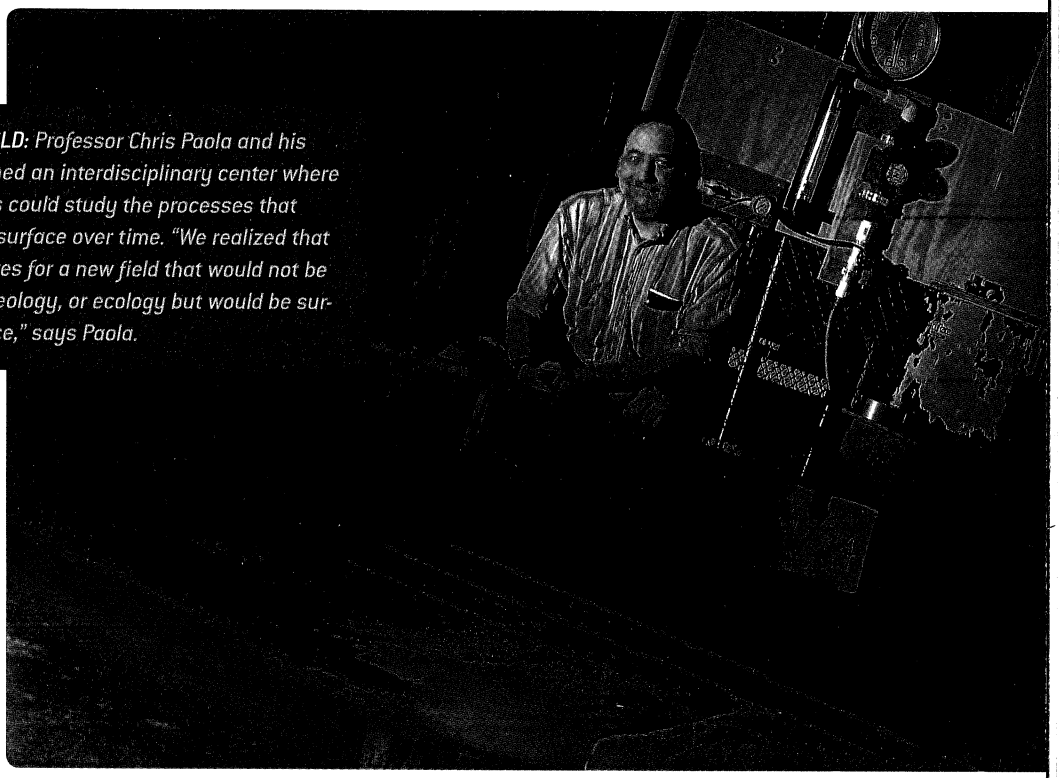
The Environmental Institute's wild-rice restoration project and a summer camp program offer other partnership opportunities.

NSF also wants NCED to reach out to minority groups. "At issue to what we do is to manage landscapes, and that's important to Native American tribes," says Parker. "As a result we are developing an outreach program for junior colleges and high schools to show Native American students how their interest in the outdoors can relate to careers in science and technology."

NCED researchers also plan to offer short courses for engineers on such topics as submarine sedimentation and stratigraphy, erosion control, stream rehabilitation, and dam removal. Engineers from industry and government are also eligible for NCED research grants.

The largest and most visible NCED outreach project, however, will be its collaboration with the Science Museum of Minnesota, located in downtown St. Paul. Situated on a bluff with a spectacular view of the Mississippi River below, the museum—noted for its lively educational programming—is a natural fit for NCED.

The museum will create a series of interactive exhibits for a Science Park, to be built on a 1.2-acre section of the river flats adjacent to the museum. No specific exhibits for the outdoor park have been planned yet, but the content will be based on NCED research and will illustrate how water, air, and other forces sculpt the earth's surface. The park is scheduled to open in 2004.



BIRTH OF A NEW FIELD: *Professor Chris Paola and his colleagues envisioned an interdisciplinary center where diverse researchers could study the processes that change the earth's surface over time. "We realized that we could be midwives for a new field that would not be civil engineering, geology, or ecology but would be surface process science," says Paola.*

"I think a partnership between the lab and the science museum will create a very exciting outdoor experience for our visitors," says Carleen Pieper, the museum's communications director. "The science museum has always had a focus on environmental education. There are basic levels that most people understand—erosion, for example—but then there are more complicated things, like the effect of storm sewers on the environment. Forces that sculpt the landscape go beyond obvious things, like a stream that overruns its banks now and then. Our exhibits will show that landscapes are also affected by the decisions we make and how we plan for these occurrences."

The museum will expand its existing youth science center into the Science Park, where young people will serve as guides. Other plans include a summer institute for middle school teachers and the development of outreach programs for schools across the Upper Midwest.

WELCOMING THE UNEXPECTED

Both in concept and practice, the MAST and NCED initiatives will foment creativity. The ingredients are all there: a host of challenging problems, inventive minds, technical expertise, partnerships across disciplines and institutions, state-of-the-art technology, financial support, and an investment in education.

Unique in size and scope, the University's MAST system will expand large-scale testing capabilities nationally and internationally, and through NEES it will aid a sweeping effort to restructure earthquake engineering research in the U.S.

At NCED, an extraordinary scientific collaboration will oversee the genesis of a new superfield—surface process science—while the center's education and outreach partners serve the public through creative programs.

It's an exhilarating time for everyone involved, from program administrators and researchers to the wider scientific community and beyond. Perhaps most exciting of all is the prospect that MAST and NCED will generate significant advances that are virtually unimaginable today.

Parker summarizes their shared hopes for the future: "I'd like to see in 10 years some really important scientific developments, educational developments, and applications that we could not in any way have predicted."

Given the resources and talent committed to both ventures, it's going to be a dynamic decade. ■

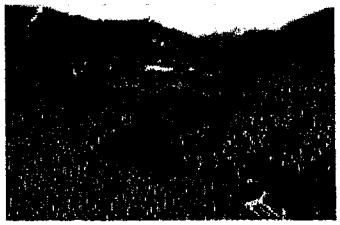
FOR MORE INFORMATION SEE WWW.CE.UMN.EDU

Saving salmon

U RESEARCHER HELPS BRING DOWN DAMS

By Deane Morrison

Thirty years ago the S'klamman tribe in Washington state began lobbying the federal government to remove two dams on the Elwha River, a river that starts in the Cascades and runs to the Pacific. Built in the first part of the 20th century, the dams provided electricity to a lumber mill, but devastated the rich native fish population, including cutthroat trout, char, steelhead, and Chinook salmon.



Two dams along the Olympic Peninsula's Elwha River--once one of the richest fish-producing rivers in the U.S.--will start coming down in 2007 with help from University researcher Chris Bromley.

Photo: National Park Service

Now the dams are coming down. But *how* to take them down is the tricky part. Remove a dam too fast and huge sediment deposits will wash downstream, smothering fish eggs and burying river-bottom ecosystems. Remove a dam too slowly and the costs pile up.

Enter Chris Bromley, a graduate student in geography at the University of Nottingham, England, now doing research at the University of Minnesota. Bromley came to the University because of the visitors' program at the National Center for Earth-surface Dynamics (NCED), a National Science Foundation Science and Technology Center that receives matching support from the University of Minnesota.

To find the optimal removal schedule, Bromley built a model of a Pacific Northwest river and dam, complete with sand and running water, at the U's St. Anthony Falls Laboratory, just downstream from Minneapolis's Stone Arch Bridge. The model replicates the Elwha River and its Glines Canyon Dam, one of the two dams scheduled for removal starting in 2007.

According to the National Park Service, removing both dams and allowing the ecosystem to restore itself would open up over 70 miles of largely pristine salmon habitat. In 30 years, the present population of about 4,000 native fish would rebound to nearly 400,000.

To learn more about the Elwha River restoration project, including history and photos, visit www.nps.gov/olym/elwha/home.htm.

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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

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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 Klamman tribe, says before the dams were built the tribe's culture and economy

were based on the fish taken from the Elwha.

The Klamman 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 Klammen 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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U researchers, students use model to study dam removal

By Jenna Ross
jross@mndaily.com

In the University's St. Anthony Falls Laboratory lies a 30-foot scale model of Washington's Elwha River. The mini river, built of wood, sand, concrete and Mississippi River water, flows to its dam as a laser inspects its surface.

Doctoral student Chris Bromley, who traveled from the United Kingdom's Nottingham University to create this river model, watched the process.

Bromley, with the help of University researchers and students, uses the model to research dam removal and its effects at the laboratory, part of the University's civil engineering, geology and geophysics departments.

Bromley came to the University last year as part of the St. Anthony Falls Laboratory's visitors program and said the laboratory has unique facilities he needs for his research.

"In the last few years, dam removal has become a huge issue in the United States," said Bromley, who received a $35,000 grant for his dam-removal research. "Taking down a dam is an intricate process, and with this model, we hope to find out the best way to perform this process."

The 200-foot-high Elwha Dam will be removed in 2007. American Indians and environmentalists call for its removal, hoping to re-establish the river's salmon population.

After researching the river at the University of Oregon, Bromley decided to do a dam removal model to mimic the proposed removal processes.

"Those people involved with the Elwha Dam removal are interested in my research, have been in touch and in some cases have come to the laboratory to see the model," Bromley said. "The results of my experiments will help them decide how to remove this dam."

> "In the last few years, dam removal has become a huge issue in the United States."
>
> **Chris Bromley**
> Nottingham University doctoral student

A scaled model replicates the processes seen in nature better than any computer simulation, Bromley said.

"And unlike most rectangular dam models, this is based on the river's topography," Bromley said. "I'm not aware of any other model like it."

After building the model, Bromley began removing the dam at different rates, watching the sediment and water flow change at each speed. A slow process is costly, while the high water flow from a quick process releases sediment built up by the dam.

"If you go too fast, the sediment released can overwhelm the system," Bromley said. "Oftentimes there is pollution attached to the sediment. When you release that sediment, you can also release that pollution."

Chris Paola, director for the laboratory, compared removing a dam to removing a tooth.

"If you do it too quickly, it's like tying the tooth to the string on the door handle and then slamming the door," Paola said. "It's painful. With the dam, we're trying to make the process as painless as possible."

University graduate Dianna Smith, who worked with Bromley to build the model, said she appreciated the project's realization.

"It's rewarding to be involved in taking an idea from concept to reality," she said.

University police crack down on illegal ticket scalping

By Koran Addo
kaddo@mndaily.com

University police increased their focus on illegal ticket scalping recently, making at least five arrests outside University sporting events in the past two weeks.

Police stepped up their efforts to stop ticket scalping at the request of event planners, University police Capt. Steve Johnson said.

Ticket scalpers have caused problems for years at the University, including obstructing traffic and harassing people as they go into different events, University officials said.

> "(Ticket scalpers) are very professional."
>
> **Capt. Steve Johnson**
> University Police Department

Despite the University Police Department's efforts to rotate different plain-clothes officers, Johnson said, catching ticket scalpers has proven to be a tricky endeavor.

"(Ticket scalpers) are very professional," he said. "They knew the officers well enough to identify (officers) by their name and badge numbers."

Johnson said University police will continue to track down ticket scalpers as long as they remain a problem on campus.

◆ At the University Police De-

WEEKLY CRIME REPORT

partment's request, the Department of Environmental Health and Safety responded to two calls this week after a chemical spill in Smith Hall was reported and a security monitor found a suspicious bottle of liquid in Moos Tower.

Craig Moody, Environmental Health and Safety Department director, said police often call the department to assist them when there is suspicion that a danger to the public might be present.

Both departments determined the public was in no immediate danger as a result of either incident.

◆ The University Police Department is interviewing the owner of a car whose occupants fled from police after an officer attempted to stop the vehicle for reckless driving. The case is still active and police have made no arrests.

◆ University police arrested six people after responding to several calls concerning the odor of marijuana in different Dinkytown apartment complexes this week.

Bell Museum is home to

Appendix E: Progress toward meeting Year 1 goals

Although we made significant progress in our research in Year 2, the refinement of our mission and consequent refocusing of our research means that most of the specific research goals set in Year 1 are no longer appropriate.

Here is a description of progress that we made toward goals that are still relevant (page numbers refer to last year's Annual Report):

Goal: develop a Social Science research component (p. 10): We made major progress toward this by holding a workshop on possible directions in Social Science in January. The workshop involved eight non-NCED participants and led to a series of practical recommendations that we are working to implement (see Appendix H for a list of attendees.).

Goal: develop an effective education evaluation program (p. 28): We have made progress on this by bringing in a University of Minnesota PhD candidate in Education Policy. Work with her is described in the Education section.

Goal: Pilot ESTREAM program (p. 29): We did this, with two ESTREAM teachers, and plans for more in Year 3.

Goal: expand educational program publicity (p. 29): We did this primarily through improvements to the website and more extensive contacts with local and national education communities.

Goal: improve graduate student participation (p. 65): We did this by involving graduate students in the October PI retreat and by encouraging graduate students to participate in the weekly videoconferences.

Goal: design and build Science Park outdoor exhibits with SMM (p. 36): This has been a very successful program. Details are described in the Education and Research sections, and the park itself is described in Appendix F.

Goal: Include Earthscapes related material for SMM YSC and school programs (p. 36): We accomplished this through regular meetings with SMM staff overseeing these programs.

Goal: Initiate relations with our environmental partners (p. 44, 56): We accomplished this by having our first Environmental Partners meeting in October. Since then we have worked with specific contacts established at that meeting to explore common research interests. Thus Year 2 is effectively the first year in which we have had a functioning Knowledge Transfer program.

Goal: Establish regular videoconferences as a tool for promoting collaboration within NCED (p. 45): We did this by finding a regular time and carrying out a full schedule of videoconferences.

Goal: Develop the NCED website as a tool for data archiving and access for the Center and the wider research community (p. 45): We initiated this successfully, starting with 7500 records of legacy river and sediment data loaded and made freely available to the research community.

Goal: Improve collaboration among NCED PIs (p. 65): Although there is still plenty of room for improvement, we believe we have made progress here (see the diagram under "Indicators", above). The primary techniques have been PI retreats, videoconferencing, the Angelo Coast Range Reserve field site, and ad-hoc visits by PIs to other NCED institutions.

Goal: Streamline PI record keeping (p. 65): Though we have made progress on this, and implemented a relatively streamlined interface for doing this via the NCED website, we still have some ways to go to get to the point where this becomes second nature. Compiling this year's annual report went more smoothly than last year's, and we hope to be further along by the time of next year's annual report.

Appendix F: The Big Back Yard

The Big Back Yard is NCED's interactive outdoor interpretation of erosion, transport and deposition, dynamically shaping Earth's surface from Source to Sink.

Overall description

The Big Back Yard is NCED's most public "face"; an interactive outdoor Earth-surface Dynamics experience. Its centerpiece is a miniature golf course, taking Golfers from Source to Sink. The golf course is surrounded by a series of related interactive exhibits, all placed within a carefully planned landscape, which reinforce NCED concepts. The Big Back Yard is part of a comprehensive "Earthscapes" Education program which includes the park, an annual summer Teacher Institute, a School Contact Program of assemblies, resources and classroom visits, and Youth Science Center after school and summer activities for teens (see Education section for full details of programs).

The Big Back Yard involves Science Museum of Minnesota visitors with NCED content in active, auditory and visual ways. Visitors choose to be Golfers, Players, and/or Observers. *Golfers* are issued clubs and golf balls, putting their way from Source to Sink. *Players* choose their own exploration through fairways, interactive exhibits, and interpreted landscape features. Viewing the park as a whole, *Observers* see global connections between groupings of exhibit activities—from Source erosion occurring in mountain streams to sediment being transported and deposited in short and long term Sinks.

At individual exhibits and golf holes, visual graphic panels explain processes demonstrated there. Golfers and Players immerse themselves in processes such as river braiding and meandering, sediment transport, runoff over permeable and impermeable surfaces and deltaic deposition. Running water and moving sediment throughout the BBY make erosion, transport and deposition tangible to multiple senses, while free verse introductions to golf holes encourage visitors to read aloud words describing these processes; the very language of NCED research comes alive in the BBY!

Goals:

1. Raise public awareness and understanding of Earth's changing and evolving surface;
2. Foster an appreciation among visitors of the complex interaction between humans and landscapes; and
3. Introduce audiences to the science of modeling the systems and processes that shape the Earth's surface.

Development

Development of the BBY was a major focus of NCED Research-Education Integration in Year 2. The intra-institutional design group included:

- NCED/FDLTCC: Andrew Wold;
- NCED/SMM: Patrick Hamilton, , Ken Kornack, Jim Roe, Peder Thompson;
- NCED/University of California, Berkeley: William Dietrich, Mary Power;

- NCED/SAFL: Karen Campbell, Jacques Finlay, Efi Foufoula-Georgiou, Sara Johnson, Michael Kelberer, Jeff Marr, Paul Morin, Chris Paola, Gary Parker, Vaughan Voller.

Exhibit developer Jim Roe took the group from high level brainstorming to detailed attention to images and text for interpretive graphics panels, while an infrastructure team, headed by Jeff Marr (NCED/SAFL) and Ken Kornak (NCED/SMM) led a parallel effort to conceive, prototype, and test golf holes and exhibits, including infrastructure details such as pump design and specification, appropriate sediment/water mixes, and flume design, one by one. This design work, along with prototype testing with children and adults, took place throughout the year, at NCED/SAFL and NCED/SMM. Having progressed together from ideas to sketches to models to outdoor construction and final proofing, we all look forward to celebrating when the Big Back Yard opens, June 26, 2004!

Individual exhibits and holes in the 9-hole regulation miniature golf course and the specific contributions of NCED researchers are described below in the order they appear to a visitor entering the Big Back Yard.

BBY Components

1. Entrance Lobby Mural

In a large lobby mural, cartoon characters Calvin and Hobbes welcome visitors to the park. The cartoon shows the two best friends staring at a small rivulet of water and exclaiming, "Look, some water running through the dirt. . . . I'd say our afternoon just got booked solid."

NCED research: This cartoon became a key inspiration for NCED scientists, staff, students and exhibit developers designing the park. SMM has purchased the rights to use it to engage the public with the dynamic roles of water and "dirt" in shaping Earth's surface.

2. Exhibit: 3-D Map of the World

This seven foot high 3-D image depicts Earth's continental and ocean floor surfaces, using data derived from satellite imagery. Nearby graphics panels feature enlarged images of specific surface features also visible at a smaller scale on the map, encouraging visitors to ask questions about the immense scale range of Earth's surface features and the visual record of surficial dynamics apparent in the distinctive patterns visible on the map. The key message is that erosive landscapes appear rough, while depositional ones are smooth.

NCED research: This map is one of many images developed within NCED for use in Education, Knowledge Transfer and Research.

3. Golf Hole 1: Source to Sink

Here, Golfers are introduced to the overarching concept that ties together all experiences in the Big Back Yard—Source-to-Sink. Near the tee, water flows down a model mountain range toward the pin at the other end of the fairway. Following the source-to-sink, Golfers tee off in the mountains (Source) and follow the flow of water and sediment down to the ocean (Sink), represented by a pool of water and a modeled delta.

NCED research: Golfers physically immerse themselves in the environment whose processes it is NCED's vision to more fully quantify and predict. The contrast between this "whole system" experience and the rest of the course reflects NCED's interplay of system-reach and unit-process research.

4. Golf Hole 2: Erosional Landscapes

This hole requires golfers to putt up a hill and around a corner in order to send their ball down, unpredictably, into a modeled drainage basin. Graphics for this hole point out that as water and sediment move downhill, they organize into bigger and fewer channels and that these erosional patterns can be found all over the world in very small and very large examples.

*NCED research:***:** The design and experience of this hole were directly informed by modeling done in Focus Area 1: Channel Network Dynamics and Scaling.

5. Exhibit: Erosion Fast Forward

This stand-alone model demonstrates processes that create erosional networks. A fine mist of water sprayed on a bed of sand reveals evolving patterns of erosion, transport, and deposition. Three identical models operate side-by-side; as networks emerge in one, another may be ending its cycle, assuring that visitors always see a variety of stages of this dynamic process.

NCED research: This exhibit is derived from physical and computational model studies conducted as part of Focus Area 1: Channel Network Dynamics and Scaling, in particular physical models developed at NCED/SAFL and NCED/Berkeley.

6. Exhibit: Erosion Recorder

This free-standing model shows erosion, transportation, and deposition of sediment. It is a clear-sided flume, filled with about four inches of black and white sediment, which may be lifted on one end or the other to provide a slope. A water source at the high end sprays onto the sediment, initiating erosion. When the eroding water and sediment mix enters an ocean-like pool of water at the low end of the flume, the water slows, depositing the sediment in visible layers. By manipulating the water level at the low "ocean" end of the flume, visitors can change the patterns of deposition into the ocean pool within seconds. When erosion is complete, the model automatically tilts to reverse the flow of water and sediment and begin the process over again.

NCED research: This exhibit actively engages visitors in the modeling process used in Focus Area: Long Term Dynamics. It is based primarily on NCED's unique eXperimental EarthScapes facility.

7. Exhibit: Braided River

A water and sediment mixture flows continuously from a single source at the top of a slight incline. As the mixture flows down the incline it creates a pattern of braided channels, constantly changing and migrating, from one side of the tank to the other. Visitors playing in this activity are encouraged to dig their own riverbeds, mound up levees, and construct dams to see what happens to obstructed sediment as water keeps flowing.

NCED research: This exhibit was prototyped and intensively tested at SAFL in Year 2. Braided rivers are a major research interest in NCED, involving PIs in all five Focus Areas. Example projects include scaling in braided rivers, autogenic variability, and vegetation effects.

8: Golf Hole 3: Hydraulic Jump

Water flowing across a natural or dammed spillway forms a thin sheet across the breadth of the spillway as it descends. When the shallow, rapidly moving water enters a deep pool and narrowing channel, the flow suddenly jumps in depth forming a visible ridge of turbulent water called a hydraulic jump. Golfers try to golf across the thin, fast-moving water. If they putt too softly, the ball

will be washed into a gutter by the stream. If they hit it too hard, the ball will splash through the stream and overshoot the hole. Putting into the jump can even return the ball to the golfer!

NCED research: This hole actively involves the Golfer in a classic aspect of river mechanics and dam design that can have important implications for aquatic habitats and human river use. The design is based in part on numerous hydraulic jump experiments at SAFL.

9. Golf Hole 4: Local Watershed

Golfers tee-off through a large storm-sewer grate as if they were at the point where a city's drainage system empties into a river. The challenge is to track the source of pollutants back through a surprising complex of tunnels and gutters to a front yard. Storm-sewer design is a classic topic in hydraulic engineering. Golfers experience the ways in which an engineered runoff system can affect water delivery to river channels.

NCED research: Golfers experience a key human aspect of flux into a channel system, a developing focus of NCED research.

10. Golf Hole 5: Draining the Fields

This fairway is a small-scale farm field. From the tee, golfers are asked to aim for a set of drains installed in low areas of the miniature farm field. Any one of the drains will carry the golf ball a short distance underground, delivering it into an open choice point. On the second putt, Golfers will assess two options (pins) and choose to golf either to the river or to an upland pond. Golfers will attempt to improve their score by choosing the upland pond.

NCED research: This hole involves the Golfer in a common local land use practice and its impact on channel systems; previous projects by NCED researchers provided background information.

11. Golf Hole 6: Hard Surface Runoff

In urban landscapes, rainwater runoff quickly makes it way to lakes and rivers because so much of the landscape has been covered with impervious surfaces, such as pavement and shingled roofs. This fairway has a split personality, one part representing a wetland, the other a street and gutter. Golfers aim for a matrix of closely spaced holes representing a pervious surface, like a lawn or wooded area. If the golfer putts over the matrix slowly, the ball passes through one of the holes and slowly meanders its way through a green, stylized swamp to a green near the hole. If the golfer overshoots the matrix, then the ball speeds down a gutter and away from the pin.

NCED research: Previous projects by NCED researchers provided background on runoff in urban landscapes. The Golfer experiences the basic effect of impervious cover on speeding the runoff of water to stream channels.

12. Landscape feature: Rain Garden

At the lowest points in the Big Back Yard are a series of rain gardens designed to catch drainage from the entire park and allow it to seep slowly into the ground. The main rain garden provides the key component in an exhibit about nonpoint-source pollution. Visitors are asked to consider the Big Back Yard as a microcosm of the city in which they live, with areas of impervious surfaces—including the roof of Science House—and potential pollutants such as organic matter. And, as happens in cities and suburbs, rainwater washes across every surface of the park into drains. In this exhibit, those drains are part of a watershed that drains into the rain gardens.

NCED research: Visitors are introduced to a landscape management practice, closely related to one of NCED's goals: landscape sustainability. Over time, food webs will emerge in the areas; these will be used in Earthscapes Education programs to teach concepts related to Focus Area 4: Ecogeomorphology.

13. Golf Hole 7: Meandering River

Golfers approaching this hole have two options before them—one wet, one dry. Either way, they navigate the hazards of a meandering river. In the channel, water and sediment flow through a shallow channel (about 18 inches wide) that loops and bends down the length of the fairway. Golfers choosing not to risk the hazards of the water can golf across the flood-plain topography next to the meander.

NCED research: NCED PIs have developed much of the basic theory of river meandering. River meandering continues to be a major NCED Research focus, especially in Focus Area 2.

14. Golf Hole 8: River Engineering

This fairway is loosely modeled on a section of the Mississippi River at St. Anthony Falls. To the Golfer, it looks like an emptied river showing many of the ways that the river has been engineered. The Golfer's challenge is to putt upstream, engaging in several of the hazards created by the lock-and-dam complex and the concrete apron of the falls. The object is to reach the pin located in the pool above the dam.

NCED research: The Golfer experiences a highly engineered river channel and gains an appreciation for human impacts on channel systems, a major focus of NCED's River Restoration Initiative.

15. Exhibit: Dam Removal

This is a closed-system, free-standing flume, in which visitors see how sediment fills a reservoir behind a dam. By releasing water either through the dam or through an underground pipe, visitors flush the reservoir.

NCED research: Visitors experience engineered impacts on river channels, especially those related to dams. The exhibit was informed by NCED's ongoing dam removal research.

16. Golf Hole 9: Gulf of Mexico

The last hole of the golf course consists of a putt into the Gulf of Mexico. Golfers take a simple shot in the direction of a pool of water representing the Mississippi delta complex and the Gulf of Mexico.

NCED research: Delta processes are a key component of Focus Areas 1, 2 and 5. This hole also reinforces the overall BBY message (and NCED concept) of a "Source to Sink" understanding of Earth-surface dynamics.

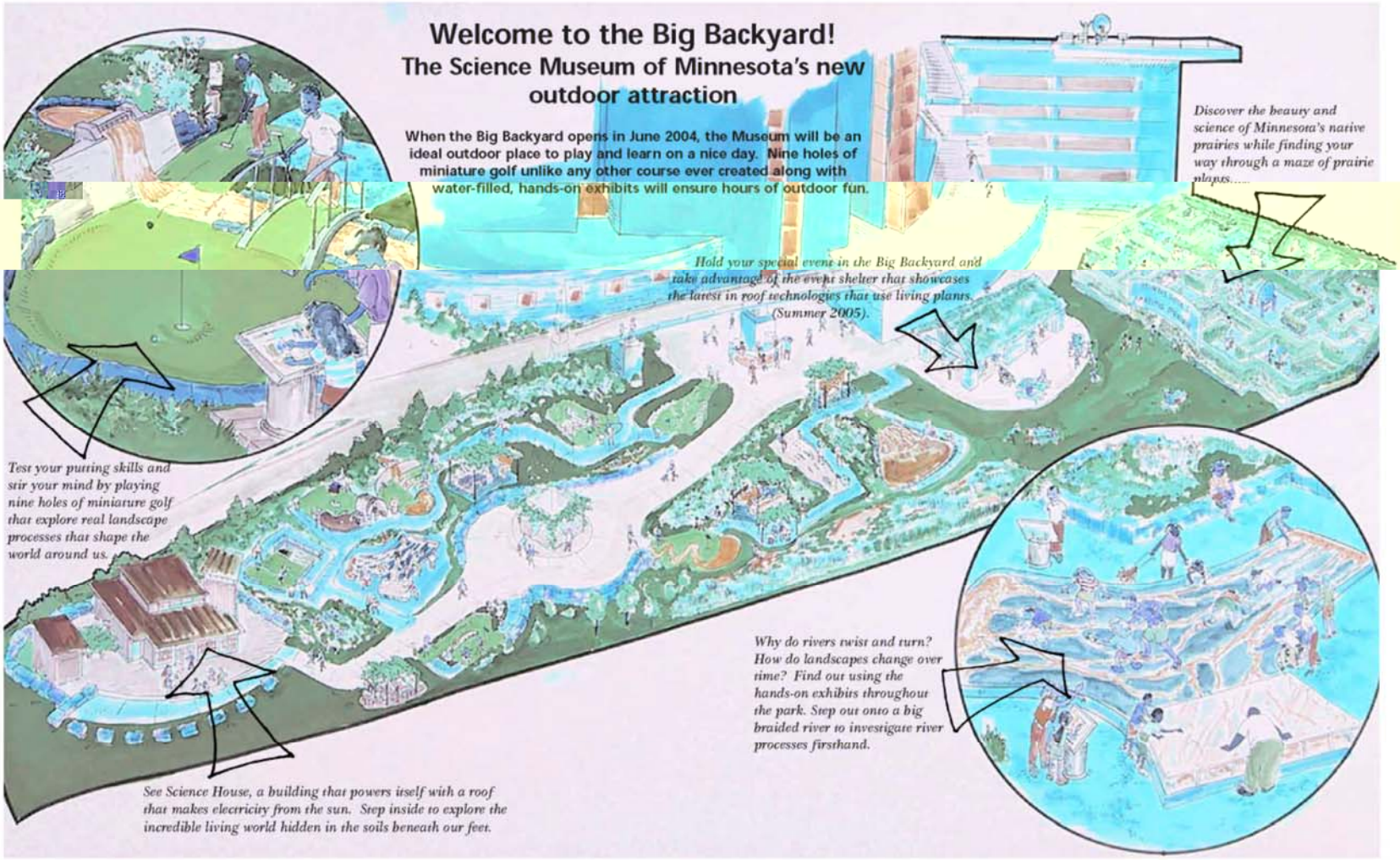
17: Exhibit: Turbidity current

In a glass-sided flume, visitors recreate the submarine process known as turbidity current. Choosing between two different sediment charges (one small, one large) they release a sediment flow into the flume. The action of the sediment and water is clearly visible, as this process creates similar patterns regardless of scale. At regular intervals (every 10 releases or so) the tank automatically flushes the sediment into a holding tank, preparing it for another round of experiments.

NCED research: Visitors experience submarine expressions of erosion, transport and deposition, gaining an understanding that these processes shape Earth's surface below the ocean's surface, as well as on continents. The exhibit is closely modeled on flume studies conducted by NCED PIs in Focus Areas 2 and 5.

18. Science House

This 1,000 square-foot building is designed to model alternative strategies for energy production and use. It also provides a facility in which to develop and implement programs around the themes and content of the Big Back Yard. NCED/SMM Graduate Museum Assistants are developing interpretive materials, activities, and specifications for instrumentation to use in exploring the BBY. NCED/SMM Earthscapes programming (especially Youth Science Center and Teacher Institutes) will make intense and regular use of this educational laboratory and meeting space facility.


Welcome to the Big Backyard!
The Science Museum of Minnesota's new outdoor attraction
When the Big Backyard opens in June 2004, the Museum will be an ideal outdoor place to play and learn on a nice day. Nine holes of miniature golf unlike any other course ever created along with water-filled, hands-on exhibits will ensure hours of outdoor fun.
Discover the beauty and science of Minnesota's native prairies while finding your way through a maze of prairie plants.....
Hold your special event in the Big Backyard and take advantage of the event shelter that showcases the latest in roof technologies that use living plants. (Summer 2005).
Test your putting skills and stir your mind by playing nine holes of miniature golf that explore real landscape processes that shape the world around us.
Why do rivers twist and turn? How do landscapes change over time? Find out using the hands-on exhibits throughout the park. Step out onto a big braided river to investigate river processes firsthand.
See Science House, a building that powers itself with a roof that makes electricity from the sun. Step inside to explore the incredible living world hidden in the soils beneath our feet.

Appendix G: 2003 Partners Meeting

Description:

The first annual NCED Environmental Partners Meeting lasted for two days and involved representatives from 20 Partner organizations along with 14 NCED participants. Each agency gave a brief presentation outlining its current efforts in Earth-surface dynamics and ideas for collaborating with NCED.

Meeting Goals:

1. To identify fundamental **science questions** at the intersection of the interests of NCED, its Partners, and society; and
2. To determine the most effective **means of collaborating** between NCED and its Partners.

Meeting Synopsis:

Science Questions:

The group identified two broad research areas in which we have common interests: river restoration and reservoir sediment management. Several potential field sites exist for both research areas. Existing and planned NCED research includes connections to both themes; meeting presentations and discussions confirmed their relevance to Partner interests. Both research areas also provide opportunities to address the sociological issue of perceptions and applications of science in resource management.

Means of collaborating

Collaborating with Partners:

Several means of ongoing collaboration were proposed during the meeting. The group agreed that an annual all-Partners meeting, scheduled to coincide with NCED's NSF site visit, will be valuable. Future annual meetings might focus on a particular research topic.

Other collaboration suggestions included:

1. Research-focus meetings: 1-3 day events, focused on single topic, model or data set or exchange of these, involving a subset of partner and NCED researchers;
2. Visitor, field site, and facilities exchanges among NCED and Partners could be coordinated by NCED; and
3. NCED can also play a vital role by facilitating information exchange among Partners.

Collaborating with the wider community:

Partners expressed particular enthusiasm for NCED's proposed Working Group program. Other proposals included:

1. NCED sponsorship of sessions at professional conferences and participation or organization of international conferences; and
2. NCED could investigate establishing ties to U.S. Geological Survey Cooperative Research Units on university campuses.

Collaborating with tribal communities:

Partners shared potential resources and expressed the need for education and training of Native students to serve in agency positions that deal with land and resource management on and around tribal lands.

Collaborating on data archiving and analysis:

Data archiving: In addition to NCED-generated data, many ideas for hosting additional data sets or using data to generate or refine models and techniques were proposed. USGS and USFS have data sets that complement data NCED is generating. These data sets might be hosted by or linked to NCED's archive.

Data analysis: Though most agencies are mandated to use internally generated models, there was consensus on the need to develop better algorithms for key processes that could form a 'common core' that each agency could adapt to its own model structure and applications. In addition, several partner representatives expressed enthusiasm for cross-agency work comparing algorithms and implementations.

Appendix H: Social Science Workshop

The Social Science Workshop was held January 14-16, 2004 to discuss and explore possible social science dimensions to NCED's research, and to garner recommendations on how best to incorporate these dimensions.

The main recommendation of the panel, which we have adopted, was to focus our social science efforts on our River Restoration Initiative. This will allow us to apply our available social science resources to the area where we can have the greatest impact. In addition, we will mainly be concerned with two sub-areas of social science: policy/decision-making in river restoration projects, and the environmental economics of river restoration.

Beginning in summer 2004, we will turn this general mission into a set of concrete plans, and take steps to add one or more Principal Investigators from the social sciences to direct our efforts.

Workshop attendees:

Attendee	Affiliation
John Adams	Geography, University of Minnesota
Thomas Baerwald	Division of Behavioral and Cognitive Sciences, NSF
Matt Kondolf	Landscape, Architecture and Environmental Engineering, University of California, Berkeley
Richard Lane	Earth Science Division, NSF
Diana Rhoten	Social Science Research Council
Richard Sparks	Director, Illinois Water Resources Center
Gary Woodard	SAHRA (STC), University of Arizona
David Zilberman	Agriculture and Resource Economics, University of California, Berkeley
Chris Paola	NCED Director
Vaughan Voller	NCED co-Director
Karen Campbell	NCED Higher Education Knowledge Transfer Director
Diana Dalbotten	NCED Diversity and K-12 Education Director
Rochelle Storfer	NCED Deputy Director of Administration
Pat Hamilton	NCED PI
Mary Power	NCED PI
Greg Wilkerson	NCED PI