National Center for Earth-surface Dynamics

Strategic and Implementation Plan

Revision 2
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• PUBLIC VERSION •

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INTRODUCTION

Global Climate Models predict a change in precipitation in a watershed in California.

How will this affect key watershed properties like sediment yield and fish populations?

A stream restoration project team decides to create a series of natural-looking meander bends in an engineered stream.

Will the bends be stable over time?

Seismic reflection imaging reveals a large sinuous channel buried several hundred meters beneath the deep ocean floor.

Is it a good prospect for oil exploration?

What these questions have in common, apart from being highly relevant to society, is that addressing them requires a sophisticated, cross-disciplinary understanding of the dynamics of the Earth's surface (the "critical zone"), and in particular, of the channel systems that serve as its arterial network.

The National Center for Earth-surface Dynamics was created to provide this understanding.

NCED’s PURPOSE

NCED’s purpose is to catalyze development of an integrated, predictive science of the processes shaping the surface of the Earth, in order to transform management of ecosystems, resources, and land use.

NCED’s MISSION

NCED is a partnership of research and educational institutions, government agencies, and industry that pursues its goal of predictive Earth-surface science by integrating physical, biological, and social sciences. We achieve research synthesis by focusing on a fundamental component of the Earth-surface system – channel networks and their surroundings – that recurs in varying but fundamentally related forms across a wide range of environments and scales. We collaborate with applied partners to identify knowledge gaps and develop tools to forecast landscape evolution and guide landscape management, restore river systems, find and develop subsurface resources, and promote environmental awareness. NCED shares the excitement of landscape science with a diverse community, exchanging perspectives through partnering, nurturing, and interacting in formal and informal education settings.

NCED'S PRIMARY INITIATIVES

NCED activities are organized around six primary initiatives: three research initiatives (Integrated Projects or IPs), and three non-research initiatives.

1. ***Desktop Watersheds Integrated Project (DW)***

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

Goal: To discover and advance the fundamental relations needed to predict landscape evolution and to model the coupling of ecosystem, landscape, and land-use dynamics.

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

Science questions: (1) What is the topographic signature of tectonic, climatic, and other external influences on watersheds? (2) Where in the landscape do ecological regimes change, what factors cause these changes, and how would the locations of these ecological boundaries shift under altered climate, land use, or biological states? (3) How does the physical organization of the landscape provide a template for organization of the ecologic and channel-scale processes in the watershed? (4) Do biotic processes influence large-scale topographic form? (5) How predictable is landscape evolution, and what are the principal sources of uncertainty? (6) How can the driving equations of landscape evolution be scaled-up to large-scale, coarse-grained applications (such as entire mountain ranges)? (7) What are the long-term environmental consequences of various approaches to land use and how will use history influence future landscape evolution?

2 Stream Restoration Integrated Project (SR)

Motivation: The stream restoration project is motivated by the collision of social demand for stream restoration with a limited understanding of stream disturbance and restoration dynamics. The science basis for stream restoration is weak, the success of existing projects is poorly known, and the connection between research and practice is poorly developed. Progress requires a two-way collaboration between those developing new knowledge and those applying it.

Goal: To advance the science and practice of stream restoration by conducting and coordinating research and by working with agency and industry partners to identify information needs, develop improved tools, and transfer this knowledge into practice.

Approach: Together with agency and industry partners, we examine stream restoration practice, its scope, details, and missing links, so that we can define the most pressing research priorities and determine the best ways to get new information to those who use it. By combining expertise in biological, physical and social sciences with a research focus spanning the space and time scales needed to characterize stream disturbance, NCED is well placed to develop the integrated knowledge needed to improve the practice of stream restoration. By its position – affiliated with, but separate from both government and industry – NCED can define problems, propose solutions, and provide continuity and coordination without the constraints that can restrict those advocating, regulating and conducting restoration practice.

Science questions: (1) How can we determine resilient, dynamically stable channel cross section and planform characteristics in terms of imposed conditions (e.g., sediment and water supplies)? (2) What is the role of riparian vegetation in controlling stream morphology and the structure and function of the fluvial ecosystem? (3) How can we extend grain-scale understanding to the reach and network scale in order to better place restoration projects within their watershed context? (4) How can we estimate natural stream variability and incorporate variability and uncertainty in restoration design? (5) How can restoration objectives be more effectively identified, evaluated and incorporated in restoration design? (6) Is it feasible and/or desirable to determine the pre-anthropogenic state of a river, and would the pre-anthropogenic state represent a useful baseline for restoration?

3. Subsurface Architecture Integrated Project (SA)

Motivation: As channels evolve under conditions of net deposition, they produce subsurface sequences that control the flow and accumulation of oil, water, and gas. The extractability of these subsurface fluids depends sensitively on subtle variations in the distribution of porosity and permeability in the deposit. Thus improving our ability to predict these properties provides a significant avenue by which NCED research can benefit society. In addition, the SA project complements the other research IPs by providing integrated records of long-term mean and variability of sediment flux, biota, and channel geometry that can aid in establishing a baseline for studies of landscape sustainability and the effects of climate change.

Goal: To understand how channel dynamics in depositional systems control the porosity, permeability, geometry and connectivity of subsurface fluid conduits and reservoirs so as to improve the prediction of subsurface architecture at all scales and facilitate exploration for and management of subsurface resources.

Approach: The theme of the SA Integrated Project is “surface to subsurface”. Subsurface prediction entails understanding how surface channel properties, spatial patterns, and temporal evolution interact with net deposition to create the architecture of sedimentary deposits, and how these deposits are modified by subsequent erosion and biochemical alteration. The SA Integrated Project includes both fluvial and submarine channels, the latter both because of their fascinating similarity to fluvial channels and because they are extremely important but high-risk prospecting targets in the energy industry. Natural channel systems evolve slowly, so SA particularly emphasizes experimental research that in effect speeds up time, and complements field and theoretical studies.

Science questions: (1) What are the biasing and filtering properties of the sedimentary recording process? (2) What process similarities and differences underlie commonality in organizational structure of submarine and terrestrial channel systems? (3) How do preserved channel systems record tectonic, climatic, and sea-level signals? (4) How can understanding of channel processes on short time scales be upscaled for application on planetary time scales? (5) How do depositional and submarine channel networks self-organize? (6) How can stratigraphic information on natural variability and channel-system response to change be used to inform environmental management?

4. Education (ED)

Motivation: The familiarity and natural appeal of landscapes, and the methods of NCED’s integrative research approach, provide rich opportunities to excite students about science and encourage them to pursue careers in many areas of science and policy.

Goal: Bring Earth-surface dynamics to life for a broad spectrum of learners, in order to educate future leaders in NCED’s key mission areas of land, resource, and ecosystem management.

Approach: NCED uses the familiarity and natural appeal of landscapes to promote active learning about critical concepts: (1) that the Earth’s surface *is* “the environment” in which human, ecologic and physical dynamics are intimately interwoven; (2) that the Earth’s surface is naturally dynamic; and (3) that the landforms we see around us – whether from the ground, from the air, or via maps and 3D imagery – tell us about what the Earth’s surface is doing and how it has evolved.

At the graduate level, NCED engages students, across NCED institutions, in integrative research and unique center-based activities, such as video-conferenced seminars, joint advising, integrative seminars and short courses, center retreats, museum assistantships and internships with Partners. At the undergraduate level, NCED engages students within and outside NCED institutions in research experiences and infuses the methods, perspectives and results of NCED research into undergraduate coursework. At the K-12 level, NCED engages pre- and in- service teachers in research experiences and field-based institutes, develops teaching materials to supplement K-12 curriculum, brings experimental research to classrooms, and conducts environmental camps at middle- and high-school levels. NCED engages the public in NCED research through innovative museum experiences, such as outdoor parks and traveling exhibits, and media, such as films and television programs.

5. Knowledge Transfer (KT)

Motivation: NCED has a strong commitment to creating new insights and tools relevant to Earth-surface science. We have an equal commitment to communicating and disseminating these insights and tools to the practicing community and the public.

Goal: Create and maintain two-way communication and exchange among our applied science stakeholders, the broader research community, and NCED participants, in order to insure that NCED research is informed by societal needs and to insure that NCED results are disseminated.

Approach: NCED's knowledge transfer activities are integrated into the IPs and stem from our goals of informing NCED research and disseminating research findings and tools. To inform NCED research, we establish Science Partner Groups: appropriately selected practitioners committed to informing research and advancing practice. Through regular interaction with Science Partner Groups we establish avenues for open communication and exchange of research needs and new knowledge. Collaborations are through partner meetings, working groups, shared research (field and laboratory) experiences and workshops. Through our website we establish a repository of information, tools, data, images, and a platform for information exchange for the Earth-surface science community. We also have community impact through education and training programs. This includes workshops and short courses.

6. Diversity (DV)

Motivation: NCED's research mission is enriched by the inclusion of diverse voices. The environmental sciences have generally underperformed other areas of science and engineering in minority representation. For long-term success, efforts must be made to interest minority students in the sciences at an early age, and to sustain that interest over the course of their educational careers. To achieve this, NCED must itself be a model of a diverse research and learning community.

Goal: Increase participation by underrepresented groups in NCED scientific disciplines until minority representation is continuously reflective of the US national population. This includes an immediate improvement in participation by members of all under-represented groups in NCED itself, and a specific focus on improvement in representation of Native Americans in NCED-related disciplines.

Approach: NCED actively pursues research collaborations with faculty from institutions with high minority enrollments, and particularly with Minority-Serving Institutions, to spread the excitement of NCED research beyond the boundaries of our institutions. NCED provides research experiences for underrepresented undergraduate students so that they can engage in field and laboratory experiments and gain the desire to be research scientists. NCED networks with local communities in order to immerse youths in science so that they can discover and gain necessary skills for pursuing careers in science, technology, engineering, and mathematics.

RESEARCH FOCUS AREAS

Research Focus Areas group investigators by common interests and skills. They inform each of our Integrated Projects and provide an important vehicle for the cross-disciplinary collaborations necessary for transformative advances:

1. Channel Network Dynamics and Scaling The spatial structure of landscapes provides an organizing template for many of the hydrologic, geomorphic, and ecologic processes that occur on them. This spatial organization, often manifested through self-similarity and scaling, provides one of NCED's major unifying themes. This Focus Area seeks to understand the space-time organization of channel networks, including morphology, hydrology, and ecology.

2. Channel and Floodplain Dynamics Channel and floodplain dynamics encompasses the local "unit processes" by which channels and their associated floodplains evolve, and as such forms the natural complement to the Channel Network Dynamics and Scaling group's focus on network-scale behavior and properties. This Focus Area works to understand the flux and morphodynamic laws governing channel and floodplain evolution.

3. Advanced Mathematical and Observational Methods The complexity of the surface environment – space and time scales spanning many orders of magnitude, strong nonlinearity, spontaneous pattern formation, and strong coupling between physical and biological processes – is a major reason why study of it has remained descriptive for so long. Transformation of surface process science requires infusion of advanced techniques in quantitative analysis and observation that can address these complexities. This Focus Area identifies and develops effective mathematical and observational techniques for analysis of channel systems, including localization, scaling, instability, and the coupling of physical and biological dynamics.

4. Ecogeomorphology The physical structure of the landscape provides an organizing template for life, influences habitat quality and diversity, and controls inputs, production, transformations and fluxes of materials, energy, and organisms. In turn, organisms shape the landscape through microbial weathering, mixing, dilation, and diffusion of soil, flow baffling, and the stabilization of bars, banks, and floodplains. This Focus Area investigates interactions of physical, biologic and biogeochemical processes in channels and floodplains.

5. Long-term Dynamics Planetary time and space scales are the arena in which slowly changing variables such as topographic long profile and overall sediment budget are determined; these in turn control channel evolution on shorter time scales. This Focus Area seeks to understand and model the behavior of channels and channel systems on planetary (geologic) time scales.

6. Human Dynamics The "fingerprint" of human influence extends across nearly all aspects of Earth-surface dynamics. Thus it is essential that we understand how humans make decisions that affect landscapes. This Focus Area integrates multicriteria decision analysis methods and economic valuation methods to develop a more comprehensive decision-making framework for landscape management.

RESEARCH ORGANIZATION AND EVOLUTION

NCED's Integrated Projects represent priority applications of our core channel-system research that are: (1) scientifically compelling, (2) broad and cross disciplinary, but also (3) focused enough to allow for measurable progress each year and major progress over several years, (4) societally relevant, and (5) integrative in terms of our core scientific expertise. In particular, all three IPs capitalize on NCED’s strength in combining field, laboratory, and theoretical approaches.

These Integrated Projects provide a natural means of establishing goal sets and work clusters that are intermediate in scale between the center’s overall mission and day-to-day research tasks. Thus they serve to maintain a clear “line of sight” between day-to-day research activities and the center’s overall mission. They provide natural pathways for synthesis across the six Research Focus Areas. Each Integrated Project is led by a project leader and steering committee who, together with NCED management, establish priorities and targets for work on the IP.

We expect the Integrated Projects to evolve in time. They will be continuously evaluated in terms of their scientific importance, societal relevance, and appropriateness for NCED. To insure that we remain open to new possibilities for growth, we will also initiate small research programs in areas that are possible targets for future work and/or high-risk but potentially high-return topics consistent with our mission but outside our current IP structure.

IMPLEMENTATION PLAN

NCED's three research Integrated Projects are organized around major application areas of our core science: the dynamics of channels and channel networks. This common scientific core across scales and environments is the primary vehicle for integration and synthesis of NCED research. It provides a network of pathways for cross-fertilization and the application of theoretical ideas, observational techniques, and research findings across apparently disparate fields. Thus the primary way we achieve center-scale research synthesis is by applying *common concepts and methods* across Integrated Projects. Our second approach to achieve synthesis is to insure that each IP can *incorporate and build on results* from the other IPs.

Common research concepts and methods that link and energize the IPs include: recurring structures, such as tributary and distributary networks, incisional valleys, cyclic steps, and scour-lobe couplets; common processes such as channel meandering and braiding, bedform dynamics, channel-floodplain interaction, and avulsion; scaling and self-similarity; biological-physical coupling; self-organization and pattern formation; stochastic behavior and uncertainty; and humans as geomorphic agents. In many cases, experiments are particularly useful in clarifying the essential dynamics of these common processes. In addition, we seek ways in which IP results build on each other. Examples include: using desktop watersheds to provide the landscape context for stream restoration; integrating short-term dynamics from stream restoration and desktop watersheds to develop long-term flux laws for stratigraphic evolution; and using stratigraphic results to provide insight on long-term trends and variability that are useful in environmental management.

NCED's center structure adds value by promoting synergy and common themes among its education, knowledge transfer, diversity, and research activities. Our strategy for promoting synergy across all Center Initiatives is analogous to that for promoting synergy across our research: we seek common themes that cut across multiple Initiatives; and we seek ways that results from one Initiative can feed and energize other ones.

1. Desktop Watersheds (DW)

Implementation Approach:

We tackle the essential elements, listed below, needed to build Desktop Watersheds through theory building, modeling, experimentation, and fieldwork. Initial focus is on steep, relatively rapidly eroding landscapes, and, fieldwork is concentrated on the Angelo Coast Range Reserve (ACRR), in the Eel River basin, California. We will build from a static form of the Desktop Watersheds, in which fixed topography and steady state fluxes are used to estimate environmental properties, to a dynamic form in which solutes and sediment are routed from hillslopes through channel networks, and ecosystems respond to changing environmental conditions. Priority research areas for DW are:

1. Determine linkages between topographic signatures and local ecological and physical attributes. Simple measures of topography can be used to estimate ecologically significant attributes of landscapes and their rivers. Research priorities include: relationships between channel networks and biological productivity; improved methods for estimating bed material grain size in steep channels; methods to estimate channel dimensions and valley bottom width using airborne laser swath mapping data (ALSM); and ground-truth measurement via field surveys and experiments in the ACRR study site.

2. Link food webs and channel networks. The channel network organizes river and watershed biota and food webs. Research priorities include measuring and understanding linkages among sediments, nutrient cycling, and population dynamics; topographic controls on river and watershed organisms; biological linkages between channels and adjoining areas (floodplains, hillslopes); and controls exerted by channel network structure on local ecosystem properties.

3. Develop predictive models for channel incision into bedrock. Incision drives landscape evolution, and although significant progress has been made recently on incision theory, more work is needed, including: laboratory experiments to guide construction of a theory for bedrock incision by granular flows; developing a theory that accounts for fine scale abrasion, large-scale abrasion (block removal) and plucking; comparing processes with submarine canyon incision; and documenting river incision rates at the ACRR site using cosmogenic radionuclide dating.

4. Link dynamics of solutes, soil production and biota. Biotic processes strongly influence soil production (making particles available for transport to channels) and mediate geochemical reactions leading to solute losses. Priority research areas include: conducting field studies on microbial influences on soil water chemistry associated with long-term experiments simulating through artificial sprinkling possible effects of climate change; documenting the net solute losses from soil during transport from ridge crest to channel; and linking flux events (nutrients, particulates) with ecosystem response.

5. Understand controls on rate of landslide transport to channels. Prediction of rates of landslide transport to channels is of great practical and theoretical significance but we lack a quantitative theory for this. Research priorities here include: collaborating with the US Forest Service to build a 3-Dimensional shallow landslide model to estimate landslide size (and therefore volume); collaborating with colleagues outside of NCED to explore how to use airborne laser mapping data to document the topographic signature of deep seated landsliding on landscapes and how this can be used to infer landslide transport rates; and documenting river incision rate on the Eel River (which ultimately drives landslide rate).

6. Develop predictive sediment-routing models, including coarse sediment transport in shallow flows. Steep channels make up a large component of hilly and mountainous river networks, yet theory and observations that explain flow and sediment transport are lacking. Priority research areas include: building theory, conducting laboratory experiments and field studies on sediment transport in steep, shallow channelized flows; and developing sediment routing models that predict the effects of varying sediment supply on channel bed grain size.

7. Develop advanced numerical methods for feature extraction and upscaling transport laws. Even the highest-resolution topographic data available cannot resolve all the scales at which environmentally important processes occur. In addition, resolution may be limited by data availability or numerical modeling constraints. Thus an important effort within Desktop Watersheds is development of methods for identifying key morphologic elements (including human effects like roads) and for correctly averaging or parameterizing processes occurring below the resolution one is working with. A major element of our approach is to adapt methods from fields such as atmospheric sciences and hydrology where feature extraction and upscaling have been studied extensively.

Project plan:

	Project name	**Deliverables, Years 3-5**	**Links**
DW1	Exploit topographic signatures to estimate resource attributes	Digital terrain based tools for estimating channel morphology, bed grain size, and channel and valley width from ALSM data; measurement of influence of ACRR network structure on vegetation	SR1, SA1, SA6
DW2	Link food webs and channel networks	Determination of relations among bed sediment, nutrient uptake and key biotic populations at different network positions, isotope studies to map movements and energy sources of fish during their freshwater life histories; measurement of influence of ACRR network structure on vegetation	SR2-4, SA7
DW3	Develop predictive models for channel incision	Determine relation of wear of bedrock to inertial stresses in granular flows; experimental and field data on bedrock wearing rates; determine role of seepage erosion in bedrock channel head advance; theory of fluvial bedrock erosion that includes macroabrasion; initial application of bedrock erosion laws to submarine channel incision	SA5
DW4	Understand linkages among solutes, soil production and biota	Initial results on landscape controls on soil and riverine microbes and quantitative estimates of solute fluxes, ACRR site	SA10
DW5	Controls on rate of landslide transport to channels	Develop model for 3D shallow landslide failure and size; initial estimates of role of deep-seated landslides in sediment flux at ACRR	SA5
DW6	Sediment routing; coarse sediment transport in shallow flow	Sediment flux measurements from ACRR using radio tags; version 1 of a quantitative sediment routing scheme for ACRR	SR6-7
DW7	Numerical techniques for feature extraction and upscaling transport laws	Tested adaptation of large-eddy simulation methods from turbulence research to landscapes; initial wavelet based methods for feature extraction	SR4, SR6

2. Stream Restoration (SR)

Implementation Approach:

NCED combines physical, biological, and social sciences in an integrated approach to stream restoration. Better restoration science requires a better understanding of the physical and biological dynamics of stream systems; better identification and implementation of restoration priorities require a better understanding of the social drivers, tradeoffs, and constraints in restoration decision making. Priority research areas for SR are:

1. Collaborate with agency and industry partners to evaluate current practice, identify research needs, develop useful methods, and effectively disseminate this information. These collaborations begin with the NCED Stream Restoration Partners group, which includes agency, consulting, and academic partners and extends to allied organizations working on restoration.

2. Collaborate with researchers within and outside of NCED to develop a coordinated attack on the wide range of science needs for improved restoration practice. Focus initially on smaller streams, which account for much of the annual restoration expenditure but often do not have adequate scientific support. This coordination will occur through the Stream Restoration Partners group, working groups on focused topics, through the NCED visitors program, and other organized sessions at professional meetings.

3. Develop tools to improve evaluation of stream channels, design of restoration projects, and linkage between geomorphic design and ecological outcomes. These tools and their supporting material will be made available through short courses, certificate and degree programs, and disseminated through the NCED website.

4. Make better use of the many existing restoration "experiments" by developing tools to allow for more frequent and more effective evaluations of existing projects. These tools will focus in particular on better defining linkages between geomorphic design and ecological outcomes.

5. Develop techniques to place restoration actions in the larger spatial and temporal context of the watershed.

6. Understand and incorporate uncertainty, including both scientific uncertainty and stochastic processes, in restoration practice.

A large part of NCED's work in Stream Restoration involves training; this is discussed later in the Knowledge Transfer section.

Project plan:

	Project name	Deliverables, Years 3-5	Links
SR1	Predict trend & variability in bank stability, bed configuration & texture, planform & floodplain geometry	Prototype general channel cross section and planform predictor	DW1, SA1-2
SR2	Determine how physical channel attributes affect nutrient & contaminant dynamics	Initial field data on connection among sediment flux, nutrient cycling, and bioavailability of contaminants	DW2
SR3	Develop “fish equations” for predicting dynamics & diversity of fish populations in streams	Tested predictive equation from ACRR site	DW2
SR4	Bioengineering & bioremediation techniques to improve productivity, species diversity, channel-floodplain exchange, nutrient uptake, & contaminant management	Initial set of bioengineering training materials, stream restoration tools, & recommendations via website & stream restoration partners group	DW2
SR5	Dam Removal – predicting deposition & erosion of reservoir sediment, including impact on ecosystems	Predictive quantitative model for dam removal including valley evolution, sediment dispersal, and ecologically critical physical variables	SA3
SR6	Improve methods for reach and network scale routing of water and sediment	New methods for reach-averaged transport estimates incorporating sediment storage	DW6-7, SA4
SR7	Gravel dynamics (effect of sand and bars on gravel transport; gravel augmentation)	SAFL main-channel experiments on gravel dynamics; initial guidelines & recommendations available on website and shared with partners	DW6, SA1-2
SR8	Stream restoration objectives, tradeoffs, and decision-making under uncertainty	Initial measurements of public preference for restoration objectives and methods for improved decision-making incorporating uncertainty, multiple objectives, multiple projects available on website	SA2, SA9
SR9	Matching tools to goals: criteria for selecting modeling methods in restoration	Initial guidelines for use of highly developed predictive models vs. rational abbreviated methods	
SR10	Evaluate success of restoration methods on a management time scale	Working group in place on designing and demonstrating biological change over management and ecological time scales in stream restoration; NRRSS phase II evaluation project funded	
SR11	Place restoration in watershed context	Functioning initial version of Desktop Watersheds models (see DW)	DW

3. Subsurface Architecture (SA)

Implementation Approach:

The Subsurface Architecture project applies NCED's integrated, predictive approach to understanding controls on the permeability and porosity structure of channel-related sedimentary deposits, taking advantage of current intensive interest in locating and developing subtle hydrocarbon traps. Many of these form in submarine channelized systems. The overall approach is to closely couple work on subaerial and submarine systems, adapting techniques from geomorphology, hydrology, and engineering to quantitative stratigraphic prediction, and in turn feeding back information on long-term trends and variability to environmental management. Priority research areas for SA are:

1. Using field and experimental data, test and refine existing hypotheses for how sedimentation rate, sea-level variation and other factors control the stacking of channels and related deposits in alluvial deposits.

2. Understand the comparative physics of terrestrial and submarine channels and channel networks, and specifically, seek to apply results from step 1 to submarine systems to catalyze rapid progress in understanding and predicting subsurface characteristics of submarine channel deposits.

3. Adapt methods and insights from analysis of subaerial tributary channel networks to subaerial distributary networks (mainly deltas) and to submarine networks of both types.

4. Develop a unified, predictive fluvial-submarine channel-architecture model that includes process-based understanding of channel geometry, the relative roles of critical common sedimentation elements (channels, lobes, floodplains), controls on channel shifting (gradual and abrupt), and external drivers such as sediment supply, subsidence, and sea level.

Project plan:

	Project name	Deliverables, Years 3-5	Links
SA1	Understand intra-channel processes controlling depositional geometry and reservoir quality	Initial channel-geometry models combining work in other IPs with experimental results targeting depositional units such as fans; initial models predicting depositional bias in channel preservation; first predictive model for processes controlling deposition of fine-grained sediment in active channels	DW1, SR1, SR7
SA2	Autogenic dynamics of channelized systems: quantifying the signature of variability in natural transport systems	Model(s) for distinguishing autogenic from external origin for parasequences; experimental data on autogenic variability in channel narrowing and widening, cutting and filling, and clustering	SR1, SR7, SR8
SA3	River system response to external forcing: changes in base level, sediment and water supply	Generalize existing 2D river-shoreline models to 3D; adapt dam-removal model for valley incision and filling in response to stratal response to base-level cycles	SR5
SA4	Upscaling in space and time: from human to planetary scales	Develop method(s) for applying turbulence analogies (in particular large-eddy simulation) to multi-scale surface evolution models	DW7, SR6
SA5	Comparative dynamics of submarine versus river channels	Provide synthesis analysis of similarities and differences in channel evolution in these two environments; initial application of modified Desktop Watershed tools to analysis of submarine channel networks	DW3, DW5
SA6	Statistics of depositional channel networks	Framework and initial results of statistical analysis of distributary channel networks including natural and experimental deltas	DW1-2
SA7	Channel–floodplain interactions	Adapt models of floodplain and channel-bank sedimentation from other IPs to depositional settings; adapt and develop model(s) describing growth and persistence of tie channels connecting floodplain lakes to main river channel	DW2
SA8	Steering of channels by active tectonics	Complete and analyze (with partners) two lab experiments defining control of relative rates of subsidence on steering river channels; analyze seismic data defining control of growing folds on positioning of submarine channels	
SA9	Channel mobility: avulsion and migration	Synthesis of existing laboratory and field data on controls on channel mobility	SR8
SA10	Microbial effects on porosity and permeability via microbially mediated cementation	Feasibility study of microbial cementation effects in experimental stratigraphy	DW4

4. Education (ED)

Implementation Approach:

NCED adopts a broadband approach to education, emphasizing informal as well as formal learners, and strong connections between its research and education programs. Key elements of our Education Initiative include:

1. Work intensively with the Science Museum of Minnesota and other science museums to develop engaging new methods for informal education centered on Earth-surface dynamics and environmental awareness.

2. Enhance the education of NCED student participants by providing unique opportunities and an extended, cross-disciplinary peer and mentor network.

3. Adapt research tools such as 3D visualization, wireless sensors, and laboratory experiments to provide novel K16 educational tools.

4. Develop a new, practice-oriented program in Stream Restoration that will help advance training in restoration as well as attract a broader student population into NCED areas, including students who are not intent on research careers.

5. Design programs to engage science teachers in NCED research in ways that allow them to bring this knowledge to their students in practical ways, and share the products of this work via the NCED website.

Project plan:

	Project name	**Deliverables, Years 3-5**	**Links**
ED1	Bring surface dynamics to informal education with the Science Museum of Minnesota	Big Back Yard (BBY) exhibits fully functioning, at least one new component added, and functioning Youth Science Center –NCED docent program for Big Back Yard; BBY visitor target of 150,000 reached or surpassed; initial NCED components of Water Planet and Science on a Sphere developed; 3D film outline developed with SMM	all
ED2	Provide unique center-based experience for graduate students	Strong graduate student participation in cross-disciplinary research & seminars, Grad Student Council, videoconferences, NCED retreats, site visits, partner research, internships; thriving Grad Museum Assistantship program;	all
ED3	Stream Restoration certificate program	Functioning certificate program in Stream Restoration	SR, DV
ED4	NCED enhancements to undergraduate education	Non-NCED participation in summer research surpasses 20 total (shared with Diversity); at least 3 NCED-inspired undergrad courses developed and taught; NCED research-based course materials available on web with documented use	all
ED5	K-12 teacher development	Functioning ESTREAM and Earthscapes Summer Institute summer teacher programs, with commensurate participation in Earthscapes School Residencies; materials developed through above programs made available for broad use over the web, and promoted at local and national conferences	all
ED6	Visualization tools to enhance Earth-science education	Research-grade 3D surface visualization and anaglyph map tools widely and successfully used in K16 education	DW, SA, KT

5. Knowledge Transfer

Implementation Approach:

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

1. Establish regular communication between NCED and Science Partner Groups for each IP area.

2. Develop website content for each IP including recent research products (articles, data, technologies, software), links, and future directions.

3. Conduct application-oriented short courses and workshops both at NCED facilities and at other meetings.

4. Provide opportunity for collaborative research between NCED and non-NCED researchers within each IP through joint research, the Working Groups program, the Faculty to Faculty program, and the Visitor Program.

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

5. Develop a Stream Restoration Newsletter that highlights issues important to the stream restoration community.

6. Produce a stream restoration “toolbox” containing helpful numerical models, equations, and information derived directly from NCED research efforts.

7. Support the development of education and training programs in stream restoration.

Project Plans (divided by IP):

	Project name	Deliverables, Years 3-5	Links
Desktop Watersheds			
KT1	Desktop Watershed Partner Group	Identify and formally adopt partners into the DW Partner Group; hold initial meeting	DW
KT2	Make components of the Desktop Watershed available to practitioners and the public	Initial results available through website and publication, including DTW web portal on NCED site	DW, ED
KT3	Collaborative DW research with non-NCED researchers	DW working group established, 1-2 Visitors' Program participants complete DW projects	DW
Stream Restoration			
KT4	NCED Stream Restoration Partner Group	Annual SRPG meetings with report; Subgroup activities, including Training, Evaluation Team, and Field Meetings	SR
KT5	Stream Restoration website	Website has comprehensive inventory of training opportunities and compiles training materials following the open courseware model; NCED SR data and results; newsletter & enhancements; at least 10 tested NCED Stream Restoration tools for free download	SR, ED
KT6	Stream Restoration Newsletter	Quarterly Stream Restoration Networker; Circulate to agencies and research institutions involved in stream restoration	SR, ED
KT7	Stream restoration "toolbox" containing useful numerical models, equations, and guidance for practitioners	At least 10 tested NCED Stream Restoration tools for free download, with guidelines governing access and usage of tools, and supporting documentation available online	SR, ED
KT8	Education and training programs in stream restoration	Establish certificate program in Stream Restoration at the University of Minnesota, with collaboration from PIs at other NCED institutions; develop and present new training courses in stream restoration	SR, ED
Subsurface Architecture			
KT9	Establish regular communication between NCED and Subsurface Architecture Partner Group	Annual meetings with SA Partner group	SA
KT10	Develop website content for Subsurface Architecture goals, current progress, and future direction	Experimental stratigraphy results freely available online	SA, ED
KT11	Conduct short courses and workshops	Two industrial short courses per year in quantitative sedimentology and stratigraphy	SA, ED

6. Diversity

Implementation Approach:

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

1. Use a vigorous Undergraduate Summer Internship Program to bring upper-level students from underrepresented groups to NCED facilities for a summer to do research on NCED topics.

2. Develop a *Faculty-to-Faculty* program to build research ties to faculty from schools with large minority enrollments, particularly Minority Serving Institutions. Identify faculty at MSIs who work in NCED research areas and bring faculty with their students to NCED as visiting researchers, to participate in conferences and workshops, and to speak at seminar series.

3. Work with and support efforts by NCED participating institutions, STC partners, and other broader efforts to recruit and fund students from underrepresented groups into NCED-related graduate research.

4. Use the NCED certificate program in Stream Restoration to provide an additional gateway to NCED graduate programs.

5. Increase the number of potential future recruits by collaborating with local communities, including the Fond du Lac Reservation, to provide Native American youth science enrichment and immersion programs including seasonal camps and after-school activities.

6. Use the Youth Science Center at the Science Museum of Minnesota, especially the Big Back Yard Park Crew, to team underrepresented youths with faculty and graduate student mentors from NCED and create NCED-based hands-on activities.

Project plan:

	Project name	Deliverables, Years 3-5	Links
DV1	Faculty-to-Faculty: building durable connections to Minority-Serving Institutions	3 new faculty introduced to NCED research in Years 3-5 through visits or participation in conference or workshop, including multiple visits to NCED facilities; new collaborations, and recruiting visits by NCED faculty	all
DV2	Direct recruiting of under-represented students to NCED graduate and postdoc program	Bring percentage of graduate students from underrepresented groups to approximately 10% of total graduate students and postdocs by end of year 5 including participation in the SR certificate progam	all
DV3	Undergraduate Summer Internship Program	Ongoing participation of 5 undergraduate students each summer, with consistent recruitment of USIP students to NCED graduate program and the majority of USIP students going to graduate school.	all
DV4	Gidakiimanaaniwigamig (Our Earth Lodge) and Ando-giikendaasowin (Seek To Know) science camp programs	90 students per year participate in the two camps and programs in Years 3, 4, 5; documented improvement in grades and test scores for students in both programs; majority of participants attend college, with substantial fraction majoring in science, math, engineering or technology	DW, SR, ED
DV5	Earthscapes in the SMM Youth Science Center (YSS)	Substantial participation by minority students in YSC park crew and other activities	all

APPENDIX A – Key of Acronyms and Abbreviations

List of Principal Investigators

Initials	Principal Investigator	Institution
JB	Jill Banfield	University of California - Berkeley
KC	Karen Campbell	University of Minnesota - Twin Cities
DD	Diana Dalbotten	University of Minnesota - Twin Cities
BD	Bill Dietrich	University of California - Berkeley
JF	Jacques Finlay	University of Minnesota - Twin Cities
NF	Nick Flores	University of Colorado - Boulder
EF	Efi Foufoula	University of Minnesota - Twin Cities
PH	Pat Hamilton	Science Museum of Minnesota
BH	Ben Hobbs	Johns Hopkins University
MH	Miki Hondzo	University of Minnesota - Twin Cities
MK	Michael Kelberer	University of Minnesota - Twin Cities
JM	Jeff Marr	University of Minnesota - Twin Cities
DM	David Mohrig	Massachusetts Institute of Technology
CP	Chris Paola	University of Minnesota - Twin Cities
GP	Gary Parker	University of Illinois - Urbana
LP	Lesley Perg	University of Minnesota - Twin Cities
FPA	Fernando Porté-Agel	University of Minnesota - Twin Cities
MP	Mary Power	University of California - Berkeley
IRI	Ignacio Rodriguez-Iturbe	Princeton University
VV	Vaughan Voller	University of Minnesota - Twin Cities
PW	Peter Wilcock	Johns Hopkins University
GW	Gregory Wilkerson	University of Illinois - Urbana
AW	Andy Wold	Fond du Lac Tribal and Community College

List of Acronyms and Abbreviations

ACRR Angelo Coast Range Reserve
ALSM Airborne Laser Swath Mapping
BBY Big Back Yard
DTW Desktop Watersheds
DV Diversity
DW Desktop Watersheds Integrated Project
ED Education
IP Integrated Project
KT Knowledge Transfer
NCED National Center for Earth-surface Dynamics
NSF National Science Foundation
PI Principal Investigator
SA Subsurface Architecture Integrated Project
SR Stream Restoration Integrated Project
SRPG Stream Restoration Partner Group
US United States
USIP Undergraduate Summer Internship Program
YSS Science Museum of Minnesota Youth Science Center