Proposal Addendum

Central Arizona–Phoenix Long-Term Ecological Research: Phase 2

This document addresses the concerns of the LTER renewal panel, which were in two parts: 1) an insufficiently developed social-science component (specifically, urban-planning theory) to our conceptual model for the urban socioecosystem; and 2) proposed research that appears diffuse in its lack of focus on key variables and controlling factors. We respond to these concerns by modifying our original proposal to incorporate a plan for building an inclusive yet unique *conceptual framework* for the CAP LTER that is founded on the idea that cities are complex, non-equilibrium, adaptive systems that respond by varying degrees to numerous internal and external driving forces, and is based in both social and ecological theory. We then will describe the mechanisms we will use to implement such new research as is relevant to and necessary for populating this conceptual framework. Our interdisciplinary team of ecologists, geoscientists, sociologists, environmental engineers, urban planners, anthropologists, archaeologists, geographers, environmental economists, and biomathematicians will develop the conceptual framework with input from and close interaction with several relevant groups at Arizona State University (ASU): a new Decision Center for a Desert City; the Consortium for the Study of Rapidly Urbanizing Regions and its Sustainable Technologies Program; two emerging schools: the School of Human and Social Change and the International School for Sustainable Futures; the new Consortium for Science, Policy and Outcomes; and planned Centers for Complex Social System Analysis and Environmental Economics Research. ASU is entering an era of rapid development and reorganization, much of it predicated on the concept of a university embedded within its urban community, and we will fully exploit these new entities to amplify the potential impact of the CAP LTER while remaining a project fundamentally based in ecological science.

After discussion with Henry Gholz and based upon a CAP LTER social scientist's detailed review of the social-scientist reviewer's critique, we interpret the panel recommendation to "submit an addendum to NSF that details a plan to develop a new conceptual framework that melds both the ecologically based framework with current theories in *urban planning*" (italics ours) to more broadly seek inclusion of recent urban social theory, rather than urban-planning theory. The researchers cited in the social scientist's critique are most assuredly not planners but rather those involved in research and theory on urban social dynamics and urban spatial forms, and theories under the general rubric of political ecology. We do not, however, plan to adopt one theory relevant to urban systems (such as planning theory or urbanism) to the exclusion of others (see below), and we already count among our participants individuals who work in many of these areas.

Background: Social Science in the CAP LTER

Although it was covered only briefly in our renewal proposal, the social-science component of CAP1 was significant and was solidly based in theories mentioned in the proposal review. For example, sociologist Bob Bolin's work in political ecology has employed contemporary urban social theory to analyze the sociospatial distributions of technological hazards in relation to disadvantaged populations (Bolin et al. 2002). That work, and related papers under review, develops an analysis of the ecology of environmental risk in Phoenix as shaped by successive economic regimes, including its early emergence as a postfordist (i.e., post Henry Ford) industrial center. The complex ways that the city's industrial ecology is historically bound up in class and race relations is also highlighted as part of a developing historical-geographical-environmental analysis.

In addition, CAP1 spawned several innovative social-monitoring projects that were the first of their kind in Phoenix and helped to forge new contacts with many social scientists that will continue to develop during CAP2. For example, the Phoenix Area Social Survey (PASS; led by sociologist Sharon Harlan) is an ongoing social survey to monitor people's environmental values, attitudes, and behaviors. Respondents are asked how concerned they are about air pollution, groundwater contamination, and water supply. Questions about landscaping preferences and attitudes about residential density and open space preservation provide a valuable baseline for investigating change over time in a rapidly urbanizing region. Significantly, we have received word that an extension of PASS will be funded (nearly $100K) from both general LTER and SBE supplements.

The social-science component of the North Desert Village (NDV) experiment, designed and coordinated by sociologist Scott Yabiku (hired in 2002) and cultural anthropologist David Casagrande (with internal ASU funding and participation from geographers Pat Gober and Elizabeth Wentz, sociologist Sharon Harlan, Grimm and Redman), examines landscape preferences and human behaviors before and after landscape treatments are put in place. This effort draws its conceptual focus from an interdisciplinary literature in individuals' landscape preferences and behavior (Daniel 2001; Kaltenborn and Bjerke 2002), a literature that suggests how people respond to different natural and human-altered landscapes; salient demographic, socioeconomic, and cultural characteristics that shape human interaction with their environments; and appropriate methods for measuring environmental values, landscape attitudes, and behaviors. We have a unique opportunity to examine human interaction with small-scale geographic environments—i.e., backyards and neighborhoods—that is experimentally based. We believe that small-scale behaviors such as water use and gardening have significant ecological consequences when aggregated across hundreds of thousands of households. The NDV project is our attempt to better understand small-scale behavior, the scale at which people make decisions about the urban environment, as a prelude for predicting landscape change through agent-based modeling.

Finally, in response to suggestions made in the midterm review of CAP1 we conducted an international search and were fortunate to hire a new biomathematician, J. Marty Anderies, whose research focuses upon ecological economics and the resilience of socionatural systems. Anderies, along with Kinzig and Redman, are members of the Resilience Alliance and bring that developing framework to CAP2 research, particularly concerning analyses of vulnerability and institutional responses to water shortage.

Background: Modeling and Model Integration in the CAP LTER

Conceptual frameworks represent the causal or logical structure of theory, the scaffolding from which hang other components of theory such as concepts, assumptions, hypotheses, facts, and confirmed generalizations (Pickett et al. 1994). Conceptual frameworks often incorporate models of several types—numerical models, simulation models, picture models, and conceptual models—and allow communication among the models and between models and data, and thus form the means of integrating disparate models. A modeling working group has been meeting in CAP LTER periodically for the past three years. This group assembled recently to consider the comments from reviewers of the renewal proposal. Because models are important to developing our conceptual framework but were not described in the proposal in any one section, we note here our work on several models that do include social drivers and then clarify our rationale for modeling and model integration.

Recently hired personnel will be contributing significantly to modeling efforts in CAP2, including Anderies, a meteorologist (Joe Zehnder), an urban planner with expertise in agent-based, urban-growth modeling (Subhrajit Guhathakurta), and an environmental engineer with expertise in urban sustainability (John Crittenden). Guhathakurta's work with UrbanSim, an open-source, agent-based community model, is in late stages of development, calibration, and validation for the Phoenix metro area (includes Maricopa County). This model uses 1990 as the base-year for simulation and the year 2000 as a significant point for validation of model results, and is running with input from ~65 data sets on demographics, economy, travel behavior, land ownership, location choice, development patterns, and others. A synthetic household table identifies every household in Phoenix by racial type, number of children, number of cars, income levels, etc., and each job is identified by type and location—making the model agent-based. This model is an example of one that can be used explore the effects of changes in driving variables (income distributions, job types, etc.) on urban growth patterns. Furthermore, UrbanSim is being employed to generate urban-metabolism metrics under different policy scenarios (Crittenden, Guhathakurta).

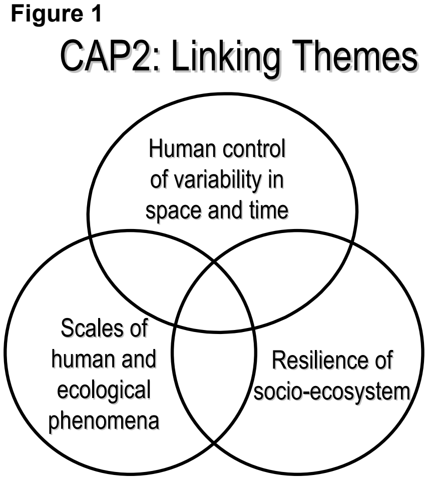
Given the potentially overwhelming number of models that can be envisioned for a complex system such as a city, the vision of a single, integrated, all-encompassing model is tempting. We suggest, however, that large-scale, integrated models are not scientifically sound in our context. The midterm site review team also echoed this belief when they suggested that we diversify our modeling efforts; in response, we assembled a modeling team to expand our modeling efforts. Model integration becomes problematic when physical models are coupled with biological and social models. Especially in the latter case, the causal relations between parameters are not well understood or may not exist; thus, they are impossible to parameterize. Processes in the extraordinarily complex urban system operate at multiple temporal and spatial scales. Given that social and ecological theory incorporate measures of uncertainty and other stochastic elements, propagating such uncertainties across multiple spatial and temporal scales can magnify them and jeopardize the credibility of the integrated model. Moreover, models should be developed to address specific questions, not developed for their own right. And finally, CAP LTER is not a short-term research project that is trying to solve a specific problem but rather a long-term program accumulating comparable data over decadal and longer time frames. Accordingly, we examine a complex socioecosystem with complex dynamics from MANY perspectives, and seek new and innovative ways to allow a diversity of approaches to be applied to generate an integrated understanding.

We propose to integrate our various modeling activities via "loose coupling" in which the output from one model serves to parameterize another model. For example, output from the UrbanSim model (Guhathakurta) can generate different scenarios for land use, which determine surface roughness parameters for a climate model (Tony Brazel, Susanne Grossman-Clarke, Zehnder). Similarly, UrbanSim can provide input data for spatially explicit, patch-specific ecosystem simulation of primary production using the patch aridland simulator (PALS), which is being modified for the Sonoran Desert and Phoenix human-managed landscapes (Jianguo Wu). We have already begun to make some progress on "loose coupling," through development of a hierarchical patch-dynamics framework (Wu and David 2002) and a distributed model platform (with leveraged funding from NSF-ITR; Peter McCartney). The reason "hard coupling," i.e., an integrated model, is not possible is because there is little or no feedback across scales. Individuals typically do not integrate climatic processes into their decisions about urban land use. As there is little theory available to link such processes, any attempt would be ad hoc. Simpler models and "non-integration" are in fact virtues of our approach rather than problems at this point in the evolution of our project. Development of our conceptual framework will therefore proceed with this caveat in mind, relying upon loose coupling and interfaces among diverse models rather than hard coupling or megamodels.

Developing a Socioecological Conceptual Framework

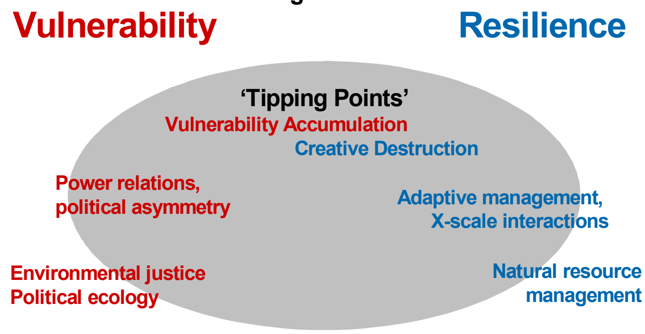
Although we have been working from a conceptual model of ecological change and ecological and social feedbacks centered on land use (see Fig. 1A in proposal), reevaluation of this conceptual model in preparing this Addendum has led us to a **concept of urban socioecosystems as complex, non-equilibrium, adaptive systems that are amenable to analysis using theory derived from widely ranging areas of ecology, physical sciences, industrial ecology, engineering, urban planning, ecological economics, political ecology, and other social sciences**. We aim to develop a framework that captures the salient elements of these theories without being subsumed by any one discipline. Hence, our framework will be inclusive yet unique. At a minimum, it will incorporate three new themes, mentioned but not elaborated upon in the proposal: 1) human control of variability in space and time; 2) scales of human and ecological phenomena; and 3) resilience of the socioecosystem (Fig. 1). The first theme recognizes that, although researchers have long been aware that human activities have profound effects on ecosystem structure and function (i.e., the ever-present focus on "impact"), less considered is deliberate and even inadvertent control of the *variability* of natural phenomena, which in turn can cascade through ecosystems and their components to create fundamentally distinct attributes. In focusing on *scale* of human and ecological phenomena, we can quantify both social and biophysical drivers that operate at different scales and ask how socioecosystems are integrated across these disparate scales, where the mismatches in scale may occur, and what problems these mismatches present for effective management of urban systems. Finally, the promise of integration between social science, engineering, and ecological perspectives is very real in analysis of the *resilience* of the socioecosystem. Resilience theory (Holling 1973; Gunderson and Holling 2002) has developed from ecological roots but is being applied increasingly to socioecosystems (e.g., Perrings 1998; Carpenter and Gunderson, 2001; Berkes et al. 2002; Redman and Kinzig 2003). Resilience is the ability of a system to absorb disturbance while retaining essentially the same structures, functions, and controls. Vulnerability is the extent to which part or parts of a socioecosystem are likely to experience harm from hazard exposure, either from external perturbations (acute) or stress from internal stressors (chronic) (Bolin 1998). Although different considerations underlie an assessments of vulnerability and resilience, both concepts are needed to understand the response of coupled human-natural ecosystems to stresses and disturbance and,

Figure 1



ultimately, to their long-term sustainability. In the course of developing this addendum, we have brought together individuals who have already distinguished themselves with their perspectives on resilience theory (Kinzig) and vulnerability analysis (Bolin) to work on a new integration as tentatively portrayed in Figure 2.

Figure 2



Our plan for developing a new conceptual framework for CAP LTER is to hold a series of workshops involving, at a minimum, the individuals listed in Table 1. These workshops will build upon our current social- science work, including the spatial analysis of vulnerability underlying our environmental risk project and the social dynamics underpinnings of the PASS project, as well as incorporate the theoretical elements described above. Quarterly workshops will begin in fall 2004 and the process will culminate in a 2-3-day retreat in summer 2006 explicitly aimed at exposition and critique of the new conceptual framework. We do not intend, however, to work in isolation from other relevant, ongoing, and new efforts in urban environmental science both at ASU and elsewhere. We will invite individuals from our partner urban LTER and other groups focused on urban socioecosystems to participate in these workshops (Table 1).

Most importantly, we will work closely with the new Decision Center for a Desert City (DCDC), one of SBE's Decision Making Under Uncertainty Centers recently awarded to the CES/ASU (Gober, PI/PD). The DCDC examines water-management decisions in metropolitan Phoenix in the face of growing climatic uncertainty, including global climate change, interannual variability manifest in the current 6-year drought, and an intensifying and expanding urban heat island. The Decision Center is, at its core, a social-science project focused on human values, perceptions, behaviors, and decision-making. DCDC's initial projects include structured studies of decisions that water managers make and the economic and environmental values that underlie these decisions; collection of baseline information related to the establishment of DCDC as a boundary organization linking science and policy; GIS-based agent modeling of household water use under different conservation (and presumably landscape preference) scenarios; and social vulnerability studies of people and places at risk from climate uncertainty. We anticipate joint studies between DCDC and CAP2—in particular, studies related to the agent-based modeling and landscape scenarios, water-use trends and water-policy scenarios, and urban-design strategies to mitigate the urban heat island effect or flash-flood hazards.

Mechanisms to Identify New Research Initiatives

The functioning of complex urban socioecosystems cannot be understood without applying research methods that are fundamentally interdisciplinary in nature. The drivers of socioecosystem structure and function, which operate from both the social and biophysical realm at multiple scales, will affect various components of the urban socioecosystem in varying ways. Hence, we have proposed to investigate the structure, functioning, and resilience of the CAP urban ecosystem in five key interdisciplinary areas identified as constituting the most important system properties emerging from our research during CAP1. We call these Integrative Project Areas (IPAs), and they include: land-use and land-cover change (LULCC); climate-ecosystem interactions; water policy, use, and supply; fluxes of materials (and socioecosystem response); and human control of biodiversity.

Our current working hypothesis, developed and tested during CAP1, is that LULCC, and the various feedbacks such change generates, is a primary factor controlling rapidly urbanizing ecosystems such as Phoenix (hence was the central question during Phase 1). However, as our research progressed, it has become clear that climate-ecosystem interactions (e.g., the urban heat island effect) have become increasingly important as the city matures and that the CAP ecosystem will become more vulnerable to water-supply shortage and related issues over time. Similarly, we expect that fluxes of materials (e.g., as expressed in air quality issues, build up of N concentrations in groundwater supplies, toxic materials and heavy metals in soils) and the human impact on regional biodiversity will manifest more as drivers that modify system resilience from within, rather than driving large-scale system change. Hence our renewed and revised core research focuses in these five areas.

Although the main internal and external drivers of urban socioecosystems may be studied from disciplinary perspectives (e.g., water supply; macroeconomic “climate”; urban planning, zoning and land availability; institutional policies and local government politics; human perceptions), we contend that these drivers can best be understood when their impact is considered in our five interdisciplinary research areas, as so many patterns and processes are interrelated in urban ecosystems. Our key research tool in testing the resilience of the CAP ecosystem to changes in internal and external drivers of our system will be to develop and refine models addressing specific questions in each of the IPAs. When feasible, models from each of IPAs will be “loosely coupled” to explore interactions among different biophysical and social processes at larger scales. The Project Management Team and Leadership Council (see “Project Management” in proposal) will evaluate projects to be initiated, and new measurement variables to be added, in light of their potential contribution to our emerging conceptual framework.

Experience gained during CAP1 has given us insight into what factors make a successful new project, or when it is time to redesign, prune, or bring to an end one that we believe that has answered its original question. We have found that selection of new projects is best achieved by forming working groups of interdisciplinary scientists who meet regularly (e.g., weekly to monthly) for a limited period of time (typically 3-4 months) to crystallize the questions, choose the approaches and methods, and establish the basis for data analysis, synthesis, and paper writing. Meanwhile, smaller subgroups of the most involved researchers (and any relevant new hires that become involved) on the established projects, typically meet after 1, 3, or 6 years to evaluate how the project is doing and what, if anything, needs to be changed. Examples of this during CAP1 were: 1) an environmental risk group, which met biweekly for nearly two years to develop their research in the framework of political ecology; 2) a populations team responsible for work on ground arthropods (initial pilot work, which made a transition to long-term monitoring and for which sites are currently undergoing another round of refinements for Phase 2); and 3) the Atmospheric Deposition Program, for which the number of sites is now being reduced after 5 years’ of data collection, with improved deposition-measurement technology introduced at sites selected to correspond with new CAP2 research (fertilization experiment). This approach has served us well in the past and we will continue to use this process.

Literature Cited

Berkes F., J. Colding, and C. Folke, editors. 2002. *Navigating Social-Ecological Systems: Building Resilience for Complexity and Change*. Cambridge University Press, Cambridge.

Bolin, R., with L. Stanford. 1998. *The Northridge earthquake: vulnerability and disaster.* London: Routledge.

Bolin, B., A. Nelson, E.J. Hackett, K.D. Pijawka, C.S. Smith, D. Sicotte, E.K. Sadalla, E. Matranga, and M. O'Donnell. 2002. The ecology of technological risk in a Sunbelt city. *Environment and Planning A* 34:317-339.

Carpenter S.R., and L.H. Gunderson. 2001. Coping with collapse: Ecological and social dynamics in ecosystem management. *BioScience* 51:451-457.

Daniel, T. C. 2001. Whither scenic beauty? Visual landscape quality assessment in the 21st Century. *Landscape and Urban Planning* 54: 267-281.

Gunderson L.H., and C.S. Holling, editors. 2002. *Panarchy: Understanding Transformations in Human and Natural Systems*. Island Press, Washington, DC.

Holling, C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecology and Systematics* 4:1-23.

Kaltenborn, B. P., and Bjerke, T. 2002. Associations between environmental value orientations and landscape preferences. *Landscape and Urban Planning* 59(1): 1-11.

Perrings, C.A. 1998. Resilience in the dynamics of economy-environment systems. *Environmental and Resource Economics* 11(3-4):503-520.

Pickett, S.T., J. Kolasa, and C.G. Jones. 1994. *Ecological understanding*. Academic Press, San Diego.

Redman, C. L., and A. P. Kinzig. 2003. Resilience of past landscapes: resilience theory, society, and the longue durée. Conservation Ecology 7:14.

Waddell, P., A. Borning, M. Noth, N. Freier, M. Becke, and G. Ulfarsson. 2003. Microsimulation of urban development and location choices: Design and implementation of UrbanSim. *Networks and Spatial Economics* 3 (1): 43-67.

Wu, J., and J.L. David. 2002. A spatially explicit hierarchical approach to modeling complex ecological systems: theory and applications. *Ecological Modelling* 153:7-26.

Table 1. Partial list of potential participants in workshops to develop a conceptual framework for understanding long-term change and resilience of urban socioecosystems.

Name (unit)*	**Role in CAP LTER+**	**Contributions to conceptual framework development**
Nancy Grimm (SoLS: EEES)	Project Director	Ecosystem ecologist, biogeochemist; developed initial land-use-based conceptual model
Charles Redman (CES, Anthropology)	Project Co-Director	Archaeologist with expertise in human-environment interactions and legacy research; Co-Director of DCDC, Director of AgTrans, CSRUR
Braden Allenby (CEE)	new	Industrial ecology expertise
J. Marty Anderies (SoLS: HD)	Co-PI	Biomathematician, expertise in ecological economics, resilience
Bob Bolin (Sociology)	Co-PI	Expertise in political ecology, environmental risk analysis, vulnerability analysis
John Briggs (SoLS: EEES)	Co-PI	Landscape ecology, disturbance, biodiversity, plant ecology
John Crittenden (CEE)	Senior Person	Sustainability and engineering; industrial ecology; Director of CSRUR Sustainable Technologies Program
Patricia Gober (Geography)	Senior Person	Director of DCDC, expertise in human migration patterns
Subhrajit Guhathakurta (PLA)	Senior Person	Developing UrbanSim for Phoenix, agent-based, urban growth models
Sharon Harlan (Sociology)	Co-PI	Social dynamics, human response to environment
Diane Hope (CES)	Co-PI and Field Project Manager	Ecologist, knowledgeable about all CAP LTER field projects
Ann P. Kinzig (SoLS:HD)	Co-PI	Ecologist, science and policy, resilience analysis
Chris Martin (ASU East)	Co-PI	Urban horticulture, primary production, water use in urban landscapes
Sander van der Leeuw (Anthropology)	new	Archaeology; human-environment interactions; Director of School of Human and Social Change, planning Center for Complex Social Systems Analysis (with SoLS)
Jianguo Wu (SoLS: EEES)	Co-PI	Landscape ecologist, ecosystem simulation modeler; developed hierarchical patch dynamics platform for modeling, landscape metrics for Phoenix
Scott Yabiku (Sociology)	Senior Person	Human-environment interactions; developed social component of suburban landscape experiment
Joe Zehnder (Geography)	Senior Person	Climate modeling, meteorology

* CEE- Civil and Environmental Engineering; CES- Center for Environmental Studies; EEES- Ecology, Evolution & Environmental Science; HD- Human Dimensions of Biology; PLA- Planning & Landscape Architecture; SoLS- School of Life Sciences

+ new – individuals not previously associated with CAP LTER