CAP LTER 1997-2000

Central Arizona – Phoenix LTER
Land-Use Change and Ecological Processes in an
Urban Ecosystem of the Sonoran Desert
DEB- 9714833

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National Science Foundation
Site Review Team Visit

Cover: Survey 200 long-term monitoring project begins in spring 2000.
Photo by Tim Trimble, ASU

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I. INTRODUCTION TO CAP LTER

The CAP LTER project is a multifaceted study aimed at answering the question, “How does the pattern of development of the city alter ecological conditions of the city and its surrounding environment, and vice versa?” Central to answering this question is understanding how land-use change is driven by societal decisions, how these decisions alter ecological pattern and process, and how changes in ecological conditions further influence human decision making. Of the 24 sites funded under the nationwide LTER program, Phoenix and Baltimore are the only 2 established specifically to study urban ecosystems.

As we suggested in a recent article (Grimm et al. 2000), the rationale for the study of human-dominated systems is three-pronged. First, humans dominate Earth’s ecosystems; therefore, humans must be integrated into models for a complete understanding of ecological systems. Second, development of these more realistic models for ecological systems will lead to greater success in finding solutions to environmental problems. Third, although the study of ecological phenomena in urban environments is not a new area of science, the concept of city as ecosystem is relatively new for the field of ecology (Collins et al. 2000). Studying cities as ecosystems within new paradigms of ecosystem science will both raise the collective consciousness of ecologists about urban ecosystems and contribute to the further development of concepts that apply to all ecosystems.

Today, urbanization is a dominant demographic trend and an important component of land-transformation processes worldwide. By 2007, it is estimated that a majority of the world's population will live in cities for the first time in human history (Population Reference Bureau 2001). Urbanization interacts with global change in important ways and plays a central role in alteration of global biogeochemical cycles, changes in biodiversity due to habitat fragmentation and exotic species, and changes in land use and cover far beyond the city’s boundaries (Figure 1; Luck et al. in review).

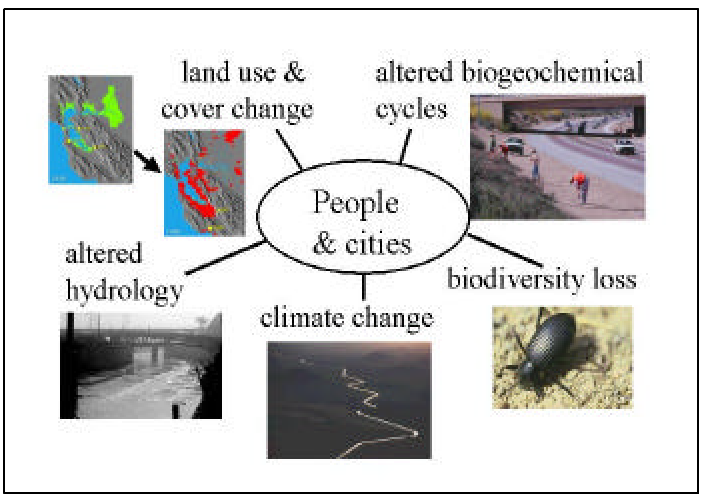


Figure 1. People and cities, by N. Grimm

The growing impact of urban areas is reason enough to study them. An even more compelling argument for understanding how cities work in an ecological sense is the fact that humans live in them and must depend on proper management to maintain an acceptable quality of life. To understand human actions and influences on ecosystems, it is essential to use approaches developed in the social, behavioral, and economic sciences. Acknowledging the central human component leads to an emphasis on new quantitative methods, new approaches to modeling, new ways to account for risk and value, the need to understand environmental justice, and the importance of working within a globally interacting network (Grossman 1993).

CAP LTER research began in spring 1998 with 28 initial projects that employed a variety of approaches to synthesize existing data and initiate new sampling. In Year 3, we began a long-term monitoring program, designed in light of the previous 2 years' research. Long-term experiments were established, and model development and synthesis of existing data continued. We invested extensive effort in developing a framework for conceptual integration of social-natural systems as applied to urban areas (Redman 1999; Grimm et al. 2000; Collins et al. 2000; Redman et al. in review) that built upon our earlier (proposal) ideas.

Altogether for the first 3 project years, about 100 faculty members, 75 graduate students, 25 undergraduate students, 60 K-12 teachers, and close to 100 community volunteers have been involved in some way in CAP LTER projects (Appendix B). CAP LTER participants have presented over 200 talks, papers, and posters to professional and community audiences and published 45 journal articles, book chapters, and reports (Appendix A). Ecology Explorers, our education outreach program, now involves 32 schools in 14 districts in its Schoolyard LTER efforts. In addition, over 20 community partners are substantively involved in the CAP LTER, such as Salt River Project, Maricopa Association of Governments, the United Stated Geological Survey, and Motorola. We are working with our community partners to define the issues and processes that shape this urban ecosystem and are useful for planning urban growth, especially in sensitive ecosystems.

CAP LTER is an important focal program for both social and natural scientific research at ASU. 29 grants totaling over $9M have involved CAP personnel as key participants or have built upon CAP resources (Appendix A), such as the University's new IGERT in urban ecology. A somewhat less tangible but nonetheless important contribution of the project is fostering interdisciplinary interaction. A monthly All Scientist Council meeting, open to all faculty members, students, and community partners, is regularly attended by 40-80 individuals. Every year we organize two events to encourage communication and integration among CAP LTER participants: a January "Poster Symposium" with a keynote speaker and a July "Summer Summit" workshop. Over 100 posters on CAP LTER studies have been presented at the three symposia, while 2 summer summits have focused on Human-Ecosystem Interactions and Interdisciplinary Projects.

CAP LTER scientists have been involved in cross-site and ILTER workshops and research, producing 9 publications based on cross-site activities. Workshops on human-ecosystem interaction hosted by Indiana University and ASU culminated in a funded Biocomplexity incubation proposal. CAP LTER personnel participated in the NSF-sponsored workshop, "Nature and Society" (Kinzig 2000) and in organizing the International Association of Landscape Ecology annual meeting to be held at ASU in April 2001. We hosted close to 20 seminar speakers and other visitors from LTER sites and other interdisciplinary programs (Table 1). Finally, CAP LTER participants attended the All Scientists' Meeting en force, contributing 13 posters and participating in 8 workshops.

Table 1. Visitors Hosted by CAP LTER

Greg Asner	Colorado, NWT
Robert Costanza	UMD, BES
Peter Groffman	IES, BES
J. Morgan Grove*	USFS, BES
Peter Kareiva*	NOAA
T. A. Steward Pickett*	IES, BES (3 times)
John Magnuson	Wisconsin, NTL
Emilio Moran*	Indiana University
Fred Rainey	Louisiana
Michael Rosenzweig	Arizona
William Schlesinger	Duke, JOR
Participants in January 2000 Human-Ecos Workshop	
Thomas Baerwald	NSF/BCS
William Burch	BES LTER
Steve Carpenter	NTL LTER
Terry Chapin	BCEF LTER
Ted Gragson	Coweeta LTER
Craig Harris	Kellog LTER
Peter Nowak	NTL LTER
Robert Waide	LTER Network
Sander van der Leeuw	Sorbonne
Grant Heiken	Los Alamos
Elinor Ostrom	Indiana University
Anthony de Souza	National Research Council
Thomas Wilbanks	Oak Ridge National Laboratory
Brent Yarnal	Penn State

*Also participated in January 2000 Workshop

II. HIGHLIGHTS OF RESEARCH ACTIVITIES

Research Strategy

Our strategy for establishing the CAP LTER research program was to begin with many, varied "initial projects" (see Web site for lists of projects). These included pilot projects to develop methods, data synthesis projects to analyze existing (often "mined") data, and short-term experiments. Researchers outlined work plans for initial projects as members of research teams, roughly following the LTER core areas but adding two areas focusing on human dimensions of ecological research. Based on the experience of the first 2 years, we determined the important variables to be monitored, sampling frequencies, and the temporal and spatial scales (in grain and extent) of monitoring. Our approach to long-term monitoring is 2-pronged: 1) Survey 200 - an extensive, expansive, multi-site (200 point) “snapshot” survey of ecological and social variables, conducted once every 5 years (Spring 2000, 2005, …); and 2) higher-resolution, detailed investigations in permanent plots and permanent aquatic monitoring sites. Several initial projects are complete and have evolved into elements of the core monitoring effort (urban water chemistry, primary production, organic matter storage and soil respiration, arthropod sampling).

We continue to acquire existing data to better understand the overall structure of the study area, define patch typology and long-term monitoring schemes, and construct initial materials budgets for the whole system. In fact, the almost overwhelming plethora of monitoring data in urban areas dictates a significant data-mining and synthesis effort for the foreseeable future. We also have continued to collect new data and develop models to be incorporated into the CAP hierarchical patch dynamics model (HDPM); leveraged funding (to CAP scientists J. Wu and D. Green) from the EPA to develop the model has strengthened this activity. Ultimately, spatial analyses of the Survey 200 data coupled with modeling will provide the broad context into which we will place more detailed studies.

Major early efforts in development of a conceptual basis for urban ecosystem research saw fruition during Year 3. In collaboration with BES scientists (Grimm et al. 2000) and as a result of a NCEAS workshop (Collins et al. 2000), we have set out a framework for the study of urban ecosystems, including key questions and the thorny issues of dealing with humans, in all their complexity, as parts of ecosystems (rather than as external disturbances). This fundamental work has continued through the cross-site efforts of social and natural scientists to forge a new kind of research agenda for LTER sites (Redman 1999; 2000 Tempe workshop on social-natural science integration; ASM workshops in social-natural science integration; cross-site proposals; Biocomplexity incubation grant, and many others). Another initial project describing urban growth patterns evolved into key contributions from CAP scientists to a major study of the patterns and implications of rapid urban-suburban growth in Phoenix, conducted for the Brookings Institution by ASU’s Morrison Institute for Public Policy. A list of CAP LTER projects and associated team members is provided as Appendix C.

Long-Term Monitoring

Geophysical Context and Patch Typology

For a research site as large (nearly 4000 km^2) and as heterogeneous as the central Arizona metropolitan area and surrounding desert, remote sensing approaches are essential to gain an adequate picture of patch structure and temporal change. We began by defining patch types according to land use, but have moved to a more sophisticated and realistic classification of land cover, thanks to the efforts of our remote sensing team. Most of the work described in this section has been carried out by ASU's Geological Remote Sensing Laboratory (GRSL).

The remote sensing team has produced data products that are currently being used for several ecological, biological, and geological research initiatives within the CAP LTER. The primary data product consists of land cover classifications for the Phoenix metropolitan region derived from Landsat Thematic Mapper (TM) data for 1985, 1990, 1993, and 1998

(Stefanov 2000; Stefanov et al. in review; http://elwood.la.asu.edu/ grsl/lter/land_cover_phx.html). These land cover classifications are immediately useful for patch dynamics modeling and provide baseline data for social science research (Figure 2). Other data products used in ongoing research include vegetation indices (both NDVI and SAVI) for the Phoenix metropolitan area for 1975, 1980, 1985, 1990, 1993, and 1998 derived from Landsat Multispectral Scanner and TM imagery. Vegetation index images for the study region provide information useful to understanding biomass and thence production, water use, carbon and nitrogen budgets, and geomorphic processes operating within urban parks (both neighborhood and desert remnant types) and undeveloped regions. Investigations of hillslope soil processes and piedmont geomorphology operating within the semiarid to arid regions of the CAP LTER site have incorporated high-resolution (3-20 m/pixel), airborne, remotely sensed data acquired as part of past and ongoing GRSL research programs (Robinson et al. 1998; Stefanov and Christensen 1999). In addition, airborne datasets with high spatial and spectral resolution (6-50 bands) available from GRSL (http://elwood.la.asu.edu/grsl/image.html) allow detailed spatial, biogeochemical, and mineralogical analysis of portions of the CAP LTER study area. Remote analyses of this order

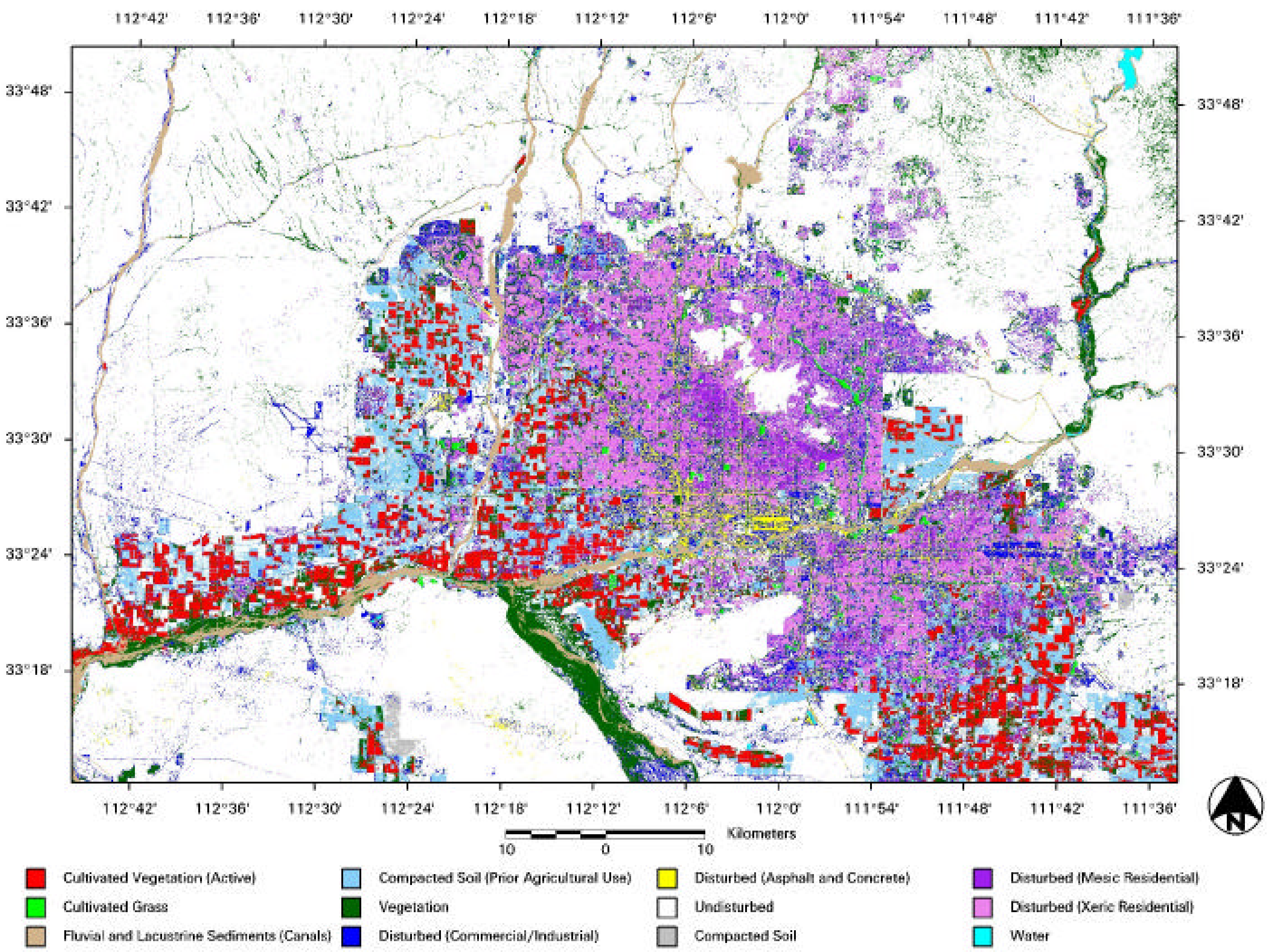


Figure 2. Land cover classification for the Phoenix metropolitan area produced using Landsat Thematic Mapper data and an expert system (Stefanov, et al. 2001).

are an integral part of currently funded (Wentz et al. 2001) and proposed CAP LTER research (Briggs et al. 2000).

The GRSL is also the seat of the ASTER Urban Environmental Monitoring (UEM) program (http://elwood.la.asu.edu/grsl/UEM/). The ASTER instrument, one of a suite of sensors on the orbiting Terra satellite, acquires surficial data from the visible through thermal infrared wavelength regions of the electromagnetic spectrum at resolutions ranging from 15-90 m/pixel (Abrams 2000). The UEM program will collect ASTER data over 100 global arid urban centers twice per year (day/night) over the projected 6-year life of the satellite (Ramsey et al. 1999). The classification techniques and results obtained from the study of the Phoenix metropolitan area are being applied to ASTER data and therefore have the potential to extend CAP LTER results to the global scale using data from other arid cities.

The research efforts described above have resulted in a much clearer picture of urban patch structure than was possible using land-use data alone. We have applied the classification to our 200 survey points (following section) to identify the patch type in which each point is located. In addition, ongoing and proposed research promises to position CAP LTER as a leader in quantitative remote biogeochemical analysis of urban ecological systems. Continued acquisition and analysis of both satellite- and airborne-based remotely sensed data, coupled with the Survey 200 program, presents a robust long-term monitoring approach useful at both the site and regional levels.

Survey 200: Interdisciplinary Long-Term Monitoring

The goal of the Survey 200 project is to quantify basic ecological characteristics of the CAP LTER study area and monitor long-term ecological trends over time and space. The data may also be used in a cross-site comparison with a similar survey being planned for the Baltimore Ecosystem Study. Using a dual-density, randomized, tessellation-stratified sampling design, 206 sample sites were selected within the CAP LTER area (Figure 3). A grid of 4-km x 4-km cells was superimposed on the study site with higher density of sites in the urban "core." Each GPS-located survey site consists of a 30m x 30m square plot centered on the randomized point. An initial pilot phase of sampling at 20 representative sites was undertaken in April/May 1999, during which the field protocols were tested and refined. The first full study was completed between mid-February and mid-May 2000, measuring: basic plot characteristics, documentary photos, observable landscape practices, vegetation cover, soil cores (to 30 cm depth), microbial activity, pollen, decomposition in litterbags and buried wood, arthropod diversity, and human activities. Bird species point counts and human-activity surveys are being conducted at 40 of the 204 sites on a monthly basis for a year.

The resulting field data have been entered into the CAP LTER database; all the main plot features (e.g., position of main land-cover types, individual trees and shrubs, sample locations) are fully geo-referenced. Laboratory analysis of soils, pollen, microbes and litter decomposition is ongoing. The data will soon be available for query and analysis by CAP researchers; data analysis and manuscripts reporting survey results are underway. Preliminary findings from the pilot survey of 20 sites carried out in early summer 1999 indicated a number of interesting trends. For example, the percentage of non-native plant species in residential yards appears to be higher in the Phoenix metropolitan area than in temperate

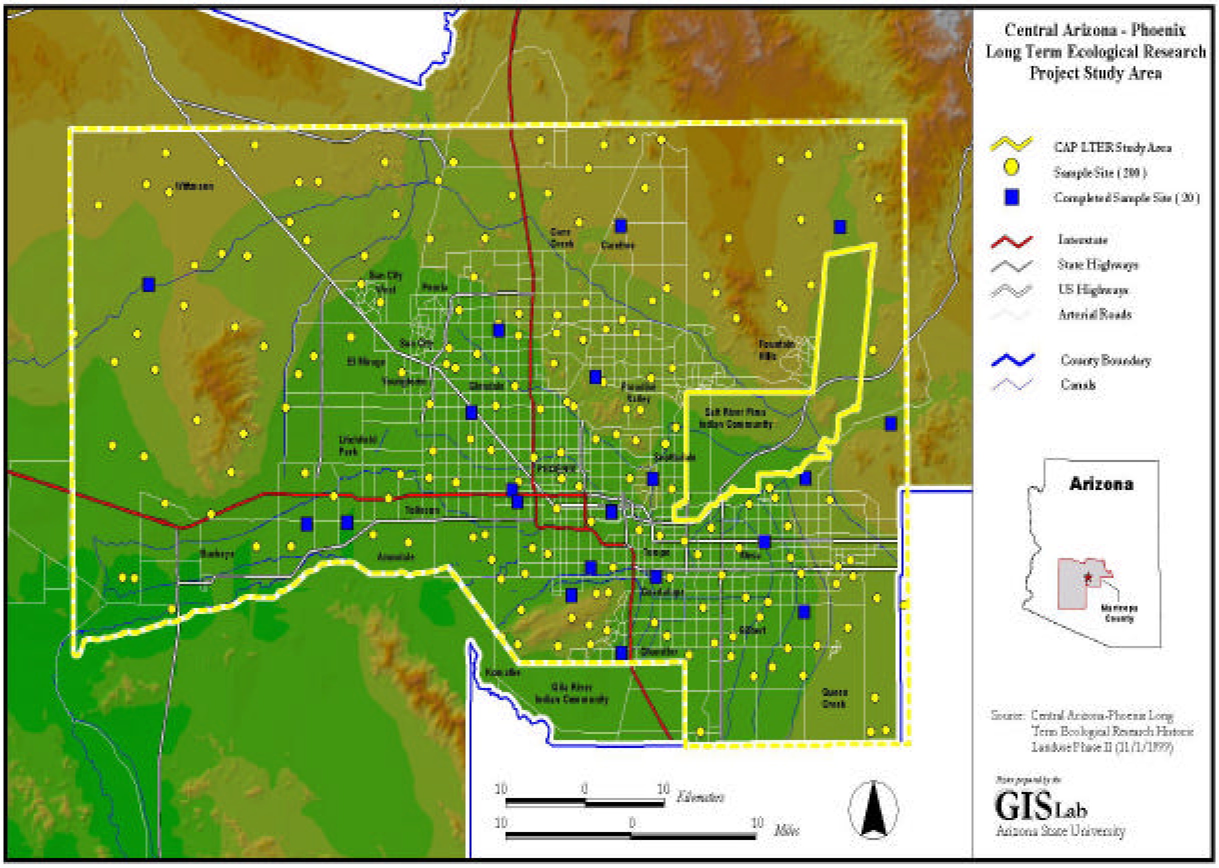


Figure 3. Map of the CAP LTER study area showing the 200 sites randomly selected for long-term monitoring of a range of ecological variables.

European cities. Shrub biomass per unit area in the desert exceeds that in residential yards, while tree biomass is higher in residential yards than in desert sites. Soil extractable NO_3-N varied by a factor of 500 in surface soils from the pilot plots, with highest concentration (up to 528.3 mgN/kg) in sites close to the urban center (particularly at unvegetated sites close to busy roads), low to moderate concentrations (5 – 50 mg/N/kg) in residential and agricultural sites and lowest concentrations (<10 mg/N/kg) in outlying desert sites.

Monitoring at Permanent Plots

Variables that change more rapidly than those assessed in the 200-point survey need to be monitored at greater frequency and at sites where public access can be restricted and experimental manipulations performed. Although this is an obvious caveat for most LTER sites, in a city it is no simple matter. We have identified several candidate sites and during Year 3 began to instrument them and take measurements. Most of our sites to date are on ASU property; we hope to expand this list to include other institutional and residential sites. Because of the tremendous variability seen among pilot sites, we must restrict intensive research efforts to just a few patch types: remnant desert, residential (turf lawn), and institutional. We describe research efforts at permanent plots in the sections below that deal with individual core research areas. However, all these efforts have been planned by a group with members representing all the disciplines involved in our study. In addition to permanent plots, other aspects of long-term monitoring focus on surface water chemistry and are described in the biogeochemical processes section.

Modeling

As with the Baltimore Ecosystem Study, we decided early on that a modeling approach that incorporates spatial heterogeneity at multiple scales, as well as temporal change in patch structure and interaction, was required to deal with the complex urban ecosystem. A hierarchical approach is important because the factors that govern urban ecosystem function occur at a variety of scales, so patches may be scaled up or down for different functional analyses. The patch dynamics approach focuses not only on the spatial pattern of heterogeneity at a given time, but also on how and why the pattern changes through time, and how that pattern affects ecological and social processes. Because cities are both expanding and changing within their boundaries, the dynamic aspect of this approach is crucial to complete understanding of urban ecological systems. The aim of our modeling effort is to develop a spatially explicit simulation model for the Phoenix metropolitan landscape that can be used to understand how land-use/cover change and ecological processes interact during urbanization.

The Hierarchical Patch Dynamics Modeling (HPDM) project serves as a synthesizing device and is crucial for integrating data obtained from individual projects. HPDM is composed of linked models at different spatial scales. At the local scale, patch models relate patch characteristics (e.g., size, shape, land cover, disturbance regime) to ecological and socioeconomic variables of interest. A family of ecosystem process models is being developed for different land-cover types. These models will provide information for constructing and parameterizing coarser-scale models. At the landscape level, we will build models for distinctive landscapes: natural vegetation dominated areas, suburban areas, and highly urbanized areas. These landscape models explicitly consider spatial heterogeneity and interactions among patches of different types. At the regional (CAP) scale, we are building a hierarchically structured, patch dynamic, spatially explicit simulation model (HPDM-CAP), which incorporates the interactions between landscape pattern and ecological and socioeconomic processes at different scales. To date we have completed the following components: 1) the hierarchical patch dynamics modeling platform, programmed in C, on which land-use change models and ecosystem models will be linked; 2) hierarchically structured land-use simulator for Phoenix; 3) series of landscape pattern analyses at different scales and comparison of the historical pattern of land-use change between Phoenix and Las Vegas areas, done in collaboration with visiting scholars; and 4) cellular automaton/Markovian simulation model of land-use change for the CAP area (Jenerette and Wu in press).

Our objectives and scope for next year are to develop the patch ecosystem models, revise and refine the land-use change model, and link the 2 types of models. To achieve long-term goals, the 3 tasks will be carried out interactively in a development-evaluation-development circle: 1) develop and evaluate a land-use change model for the Central Arizona – Phoenix area; 2) adapt and evaluate patch-level ecosystem process models appropriate for the CAP LTER project; 3) link patch ecosystem models with the land-use change model to construct a hierarchical patch dynamics model of Central Arizona – Phoenix (HPDM-CAP); and 4) evaluate HPDM-CAP. Our newly developed hierarchical land-use change simulator seems to produce more reliable land-use projections than the one we developed earlier, which was a single-scale CA model. The new model also allows political and administrative boundaries to be incorporated as constraints in the model.

Our research on pattern and scale analysis has generated much insight into the following questions in the context of CAP LTER: How does changing extent affect the results of different landscape metrics? How does changing grain size affect the results of different landscape metrics? How does changing the direction (or orientation) of analysis affect the results of different landscape metrics? How do the responses of landscape metrics to scale changes resemble or differ from each other across scales and across landscapes, and are these changes predictable? What does the scale-dependency of various landscape metrics entail and imply for landscape analysis?

Core Research Activities

Primary Production and Organic Matter

This set of projects concentrates on rates of net primary production associated with different land-use patches and how rates at larger scales depend on patch composition, location, and configuration. Measurements of net CO_2 exchange, biomass/biovolumes of selected plants, and soil respiration at residential, desert remnant, and agricultural sites are used to assess net aboveground primary production. Long-term experiments focusing on urban landscaping practices on water use have practical applications for urban ecosystem management.

Initial Projects:

In spring 1998, we began pilot projects using the same design and sites on both primary production and organic matter. The design consists of 6 treatments with 3 replicates each for a total of 18 field sites. The treatments are: 1) undisturbed Sonoran Desert; 2) agricultural field; 3) xeriscape residential yard developed from desert; 4) xeriscape residential yard developed from agricultural field; 5) mesiscape residential yard developed from desert; and 6) mesiscape residential yard developed from agricultural field. Measurements of micrometeorological parameters, plant growth, canopy cover, gas exchange, plant water relations, soil respiration, and residential irrigation patterns were made at frequencies ranging from continuous to quarterly, and were supplemented with greenhouse experiments on water use efficiency (WUE). We expected differences owing to patch type and patch history.

Agricultural sites generally had the highest carbon assimilation and transpiration fluxes, whereas remnant desert sites had the lowest (McDowell and Martin 1999). Residential xeriscapes and mesiscapes did not differ significantly in these parameters, but land-use history did affect fluxes. Surprisingly, water application volume was not related to residential yard design choice (xeriscape or mesiscape; Peterson et al. 1999). The greenhouse experiment showed that irrigation frequency affects plant growth, gas exchange, and WUE in some landscape plants (Stabler and Martin 2000). Frequency of irrigation did not affect total dry weight for Red Bird of Paradise, but frequently irrigated Blue Palo Verde had greater total shoot length and higher shoot and root dry weights than moderately or infrequently irrigated treatments. Preliminary data from microclimate transects indicate that patch type also affects temperature and dewpoint.

Long-Term Monitoring:

Year 3 marked the transition to the long-term monitoring phase for our primary productivity research. A permanent long-term monitoring plot was installed at the Desert Botanical Garden (DBG) to measure net primary productivity as affected by human activities and to obtain the measurements needed to establish allometric relationships for plants in human-managed landscapes. Long-term monitoring of urban water use also continues in residential sites established in the pilot phase.

Overall vegetation biomass for the CAP study area will ultimately be measurable using remotely sensed data. We are acquiring these data and developing datasets of vegetation indices, which are related to the amount of "greenness" (i.e., chlorophyll). The Soil-Adjusted Vegetation Index (SAVI; Heute 1985) is presumed to perform better than the Normalized Difference Vegetation Index (NDVI) for biomass estimation in areas of low vegetative cover. Preliminary analyses with these data focused on a transect from desert to urban land uses. SAVI may be superior to NDVI for the surrounding desert, but there was no difference between SAVI and NDVI in urbanized areas of the Phoenix region. Therefore, SAVI is recommended for use in arid urban systems as well as arid non-urban systems. SAVI was higher in urban than rural areas. Agriculture, desert, and residential had similar SAVI values, with agriculture the most variable (probably due to active vs. fallow fields); urban land-use types were noticeably lower. The mean and variability of all classes was highest in areas where agriculture dominated along the transect.

Long-Term Experiment and Interdisciplinary Projects:

A long-term experiment has been established at the DBG permanent plot site to test effects of plant density, species composition and combinations, and landscape irrigation on primary productivity and soil respiration. The experiment features 14 sub-plots of different yardscape plantings receiving variable watering regimes.

Several interdisciplinary projects have been initiated by the primary production team. In one project, surveys of homeowners were conducted to examine how socioeconomic factors and community ordinances influence vegetation patterns (landscape plant choices) in 4 diverse areas of greater Phoenix. Sampling protocols for this research were developed using the primary productivity pilot study sites, and surveys were developed with input from cultural geographers. Plant ecologists and climatologists collaborated on a second project that replicated research conducted in 1975-76 studying the effects of land use on microclimate along several commercial to rural land-use transects in the Phoenix metro area. An analysis of the data reveals an urban heat island in the Phoenix area that can be partitioned into 7 concentric zones of 6-km width from the urban core to the urban fringe.

Our data on urban landscaping practices and water use aids not only the monitoring effort but has practical applications for urban ecosystem management. Answers to several questions are being sought in this research: Is human land use a good predictor of annual net primary productivity of urban landscapes? How are variations in urban landscape microclimates related to urban land use, urban plant community structure, and landscape patch dynamics? At what spatial scales do landscape maintenance practices such as pruning affect within-patch vegetation density? Are the intensities and densities of spatial patterns of urban plant communities related to human preference? What is the spatial pattern of urban plant communities in relation to urban land-use typology? Do mechanistic linkages exist between socioeconomic factors, human landscape preferences, and the structure and composition of urban plant communities? What are the comparative relationships and linkages between above-ground and below-ground productivity in urban systems?

Populations and Communities

A wide range of individual studies in the realms of biology, botany, and zoology are contributing to our understanding of the processes and impacts of urbanization in an ecological framework, often working in uncharted territory. For example, there has been surprisingly little ecological research conducted on arthropods in urban environments (McIntyre 2000), yet fundamental information about how various facets of urbanization affect the diversity and distribution of ground arthropods may have important ramifications on ecosystem-level trophic dynamics, nutrient cycling, and other functions, given the diverse roles that arthropods play in ecosystems. Population/community research is focused on 5 groups: vascular plants, mycorrhizal fungi, arthropods, birds, and insect pollinators. We initiated pilot studies in 1998, taking advantage of existing datasets as well as the data-gathering potential of K-12 classes and the public (see Education and Outreach). Studies have been redesigned to meet long-term monitoring goals.

Initial Projects:

- *Creation of "The Phoenix Flora" database.* The Phoenix Flora is a database of vascular plant species with documented specimens for the CAP LTER area. The species listing includes: scientific names of all native or established alien taxa (species, subspecies, varieties, forms, cultivars) and where each taxon is known to grow according to quarters and specific locations; place names for the region; common names cross-referenced to families and scientific names for the layman; scientific and cultivar names of all taxa cultivated in the region; common names cross-referenced to families and scientific names; and a bibliography (http://lsvl.la.asu.edu/herbarium/herb13.htm).
- *Plant community survey.* This survey of desert plant communities in desert remnant patches repeats one completed 20 years ago. The survey shows how habitat fragmentation, caused by human alteration of the landscape, has affected plant communities of a formerly continuous expanse of native Sonoran Desert.

Woody species have now been surveyed in a total of 8 patches, using 100-m^2 quadrats arrayed along transects. Each transect samples a representative habitat type in a patch (e.g., south-facing slope). Summer herbs have now been sampled in a total of 6 patches; the other 2 patches had no significant summer herb growth. Analyses of vascular plants were performed by estimating species-area curves for spring and summer herbs and the woody species. Results indicate that the scale of environmental heterogeneity in these habitats is very small. This finding contrasts sharply with results from other biomes. Future analyses will include spatially explicit data on woody species within subsets of each study area, and a GIS database will be developed. More patches will be surveyed, and more spring and summer herbaceous data will be collected (rains permitting). We will explore how disturbance dynamics affect a patch's plant communities.

- *Arbuscular mycorrhizal (AM) fungal diversity*. A preliminary study was conducted to determine AM fungal diversity in residential landscaped areas ("yards") along a temporal transect (45 to 3 years since establishment). Methods were perfected, including soil sampling and trap culture, and this pilot study showed that richness was positively correlated with patch age (Stutz and Martin 1998).
- *Arthropod pitfall trapping.* We documented the abundance and distribution of ground arthropods in 6 different forms of urban land -use types (with 4 replicate sites each of: residential xeriscape, residential mesiscape, industrial/commercial property, agricultural field, urban desert-remnant parks, and desert parks on the urban fringe). Sampling involved pitfall trapping at each of our 24 study sites for 3 days once each month. Although taxonomic richness of arthropods was comparable among land-use types, community composition differed, with certain taxa being uniquely associated with each form of land use. Three taxa (springtails, ants, and mites) were extremely widespread and abundant, accounting for over 92% of individuals captured. When these 3 taxa were excluded from analysis differences were revealed in arthropod community composition with urban land use. Trophic dynamics also varied with land-use: predators, herbivores, and detritivores were most abundant in agricultural sites, while omnivores were equally abundant in all forms of land use. These community-level differences resulted from taxon-specific responses to habitat structure, which varied with land use. This initial project has continued as a long-term monitoring project.
- *Bruchid beetle study*. To better understand the impact of urbanization on an insect/plant interaction, we investigated causes of variation in population density between urban and natural desert sites in 3 species of bruchid beetles: *Mimosestes amicus*, *M. ulkei* and *Stator limbatus*, on the Blue Palo Verde, *Cercidium floridum* (Leguminoseae). Population densities of the 3 beetles varied between urban and desert sites (Figure 4), probably due to differences in preference for, and performance on, urban and desert pods. *S. limbatus*, which is highly polyphagous, had significantly higher densities in urban sites. *M. ulkei*, which feeds on seeds of only one native and one introduced species, had much higher densities in undisturbed desert sites, whereas *M. amicus*, which feeds on seeds of 5 native species, had higher egg densities in the urban sites. Further, water availability to the Palo Verde, which results in pods with more seeds and greater seed mass, affects *M. amicus* oviposition preference and offspring performance. The attack and survival rate of *Mimosestes* beetles is important because they may act as a keystone species and their presence may determine the structure of the whole community. Watering trees in urban environments may have effects that "cascade upwards" through several trophic levels, altering the entire community that depends on Palo Verde seedpods. This project has been a valuable resource for the Ecology Explorers program, and in turn, student participation has contributed data to the project.

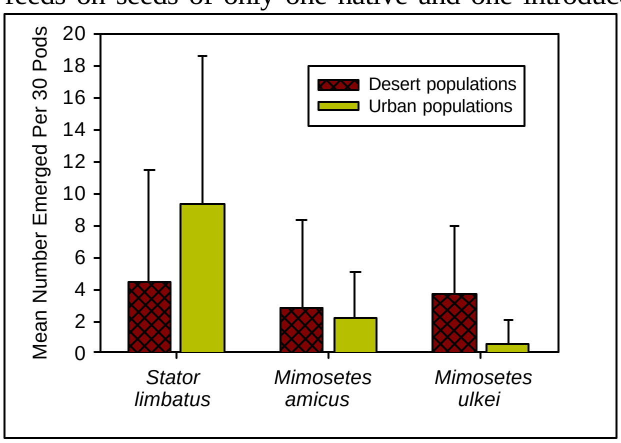


Figure 4. The mean number of 3 species of adult bruchid beetles that emerged from pods collected from 5 sites in the desert and 5 urban sites in the Phoenix metropolitan area.

- *Spatial variation in scorpion sting frequency*. Between 3000-4000 people report being stung by scorpions each year in the Phoenix area, but the frequency of stings is unevenly distributed across the metropolitan area. The number and geographic location of scorpion stings were reflected in the presence and abundance of some forms of urban land use. In particular, density of single-family homes and proximity to undeveloped open space were good predictors of the frequency of stings (McIntyre 1999).
- *Insect pollinator community structure*. We compared the richness and abundance of pollinator (Hymenoptera: Apoidea, i.e., bees) communities in 2 seasons among 4 urban land-use types (xeriscaped residential yards, mesiscaped residential yards, urban desert-remnant parks, and natural desert parks on the urban fringe). Both richness and abundance of bees were lower in residential areas than in desert areas, and desert areas on the fringe of the city possessed the highest diversity of all sites. Residential yards that used xeric landscaping were richer in bees than mesic (turf grass) yards. Although bee community structure was apparently unaffected by the number of local habitat features (native and exotic trees, shrubs, cacti, and herbaceous plants in addition to human-built structures), the types of habitat features do appear to influence the number and types of bees present in an area.
- *Bird counts*. In a pilot study, birds were counted along 30 line transects in 4 key habitats: older residential neighborhoods (8 sites), younger residential neighborhoods (8 sites), desert remnants (6 sites) and golf course (6 sites). Each site contained a 1-km-long transect and was sampled 3 times per month. About 180 species of birds have been recorded on transects, and we are analyzing seasonal trends and habitat associations from the 2-year dataset. The avifauna includes a number of non-native bird species (e.g., the Eurasian House Sparrow, the Great-Tailed Grackle) that specialize in urban habitats, or have become human commensals. At the same time, many native desert species (e.g., Cactus Wren, Abert's Towhee) also appear to be doing well in urban habitats. Other native species (e.g., Phainopepla, Black-Throated Sparrow), however, do not occur even in newer residential neighborhoods.
- *Physiological responses of birds to urbanization*. Our goal is to compare the physiological condition of native and non-native birds in different habitats to understand the impact of habitat modification on birds at the individual level. Captured birds are marked with numbered metal bands before releasing them, and morphology, body mass, fat reserves, status of molt, as well as the age, sex and reproductive status of each bird are measured. Blood samples are collected for assays of reproductive and stress hormones. These data should lead to a more comprehensive understanding of the mechanisms underlying the distribution and abundance of native and non-native bird species in different habitats.

Long-Term Monitoring:

- *Vascular plants*. Plants are monitored as part of the Survey 200 and at permanent plots.
- *AM fungi*. Arbuscular mycorrhizal diversity and root colonization are measured as part of Survey 200. Preliminary results indicate that, shortly after urban development (25 years), species richness of AM fungi is similar to that found in the adjacent Sonoran Desert. Because so little is known about AM fungi in urban ecosystems, our preliminary results are a unique contribution to the knowledge of this important group of organisms.
- *Arthropods*. The primary goal of the arthropod project is to monitor populations and communities of arthropods (insects and arachnids) within the context of the patch-mosaic model; i.e., to characterize arthropod assemblages as functions of land use and land cover so as to be able to predict patterns of arthropod diversity with future urban development. Preliminary data suggest arthropod community structure is affected by habitat structure and land use (see above). Because arthropods play key roles in nutrient cycling, organic matter decomposition, pollination, and soil aeration, spatial heterogeneity of arthropod communities in urban ecosystems therefore may affect ecosystem functioning.
- *Birds*. The goals of the bird project are to study changes in species diversity and population abundance and distribution over time and space as a result of urbanization. In August 2000 we changed the sampling method from line transects to point counts. In this method birds will be surveyed for 15 minutes at each point, 3 times in a season, 4 seasons per year. Locations were also changed from original sites to 40 points randomly selected from the Survey 200 sites, augmented by 10 additional riparian habitat sites chosen for their ecological importance and accessibility. Counting birds will allow us to directly relate bird densities to other environmental variables being monitored.

Long-Term Experiment:

A long-term experiment evaluating patch-specific variation in multiple trophic-level dynamics is currently being established. Questions addressed are: How similar are multi-trophic dynamics among different types of habitat patches in an urban ecosystem? How similar are patterns of plant damage, herbivore outbreaks, herbivore control by predators, and seasonal tropho-dynamics among habitat types? Using replicated, controlled cage experiments, we will manipulate the access of predators (initially, birds) to test for bottom-up or top-down control of tropho-dynamics in different habitat patches. We will establish bird-exclosures on shrubs and other vegetation at the LTER permanent sites, starting with the President's House (mesic residential) and the Desert Botanical Garden (desert remnant). By using the LTER permanent sites, we will link these experiments to other LTER core areas by quantifying changes in ecosystem function (e.g., productivity, P/R ratios, organic matter accumulation) as functions of trophic complexity and patch type.

Human Dimensions of Ecological Research

This research area poses the overarching question: What "natural" ecological and socioeconomic processes interact to generate spatial patterns and how do ecological consequences of development feed back upon future decisions? Research topics focus upon 1) historically defined processes (historic land-use, legacy and pioneer effects; 2) geographically defined processes (geography of the urban fringe and its effects on climate); 3) topically defined processes (environmental policy and risks); and 4) information system of human activities (local partner databases, census data). While various projects are organized under this heading, some projects by other teams are addressing questions about the human dimensions of ecological systems, and some projects within this group already have natural science elements. Our ultimate goal is to integrate social and natural science studies throughout our research.

The CAP LTER project has been at the forefront of efforts of social and natural scientists to forge a new kind of research agenda for LTER sites and, towards this goal, has coordinated workshops, presentations, incubation workshops, and cross-site activities. In January 2000, LTER scientists and colleagues from other large, interdisciplinary projects funded by NSF gathered in Tempe, AZ to discuss how to better integrate social and ecological research and to promote integrative research in the LTER network. The latest iteration in this process was presented at the LTER All Scientist Meeting in Snowbird, Utah in August, 2000.

Under the leadership of CAP LTER and BES personnel, these activities have produced a "white paper," a model for integration (Figure 5), and a Biocomplexity Incubation award from NSF. The model

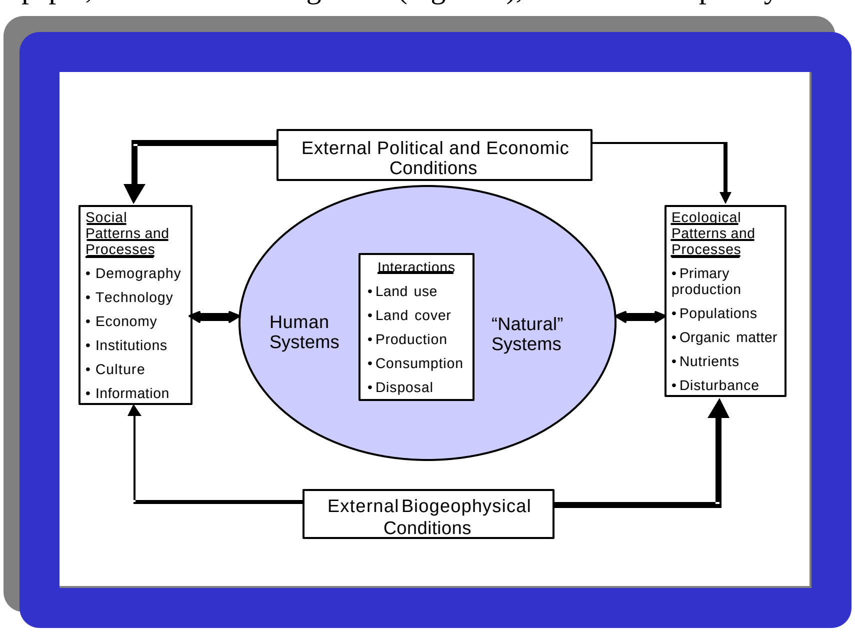


Figure 5. An integrated model of the human ecosystem. Disciplinary training encourages us to treat elements of human and ecological systems as distinct. In this model, urban LTERs emphasize interactions, the specific activities that mediate between the social and natural elements of the human ecosystem (Redman et al. in review).

and paper, *Human Dimensions of Ecological Change: Integrating Social Science into Long-Term Research* (Redman et al. in review), was developed from the Tempe workshop and presented and discussed at the LTER meeting in Snowbird. The intent of the paper is to provide a foundation and departure point for social scientists and biophysical scientists to consider collaboration for long-term research with particular emphasis on the LTER Network. It is also a recruitment call for more social scientists to become involved in ecological research. Putting words into action, a newly awarded Biocomplexity Incubation planning grant will allow CAP LTER and BES to pursue and foster 4-5 cross-site projects that will serve as models for integrating social science into LTER projects. In addition, CAP LTER has engaged in a range of comparative projects with BES and collaborated on numerous cross-site proposals.

Initial and Ongoing Projects:

- *Historic Land Use.* Because land-use change is a focal variable for CAP LTER, we initiated this project to set the baseline for how land use has changed in the study area. The project has been approached in two phases. In Phase I, we collected relatively coarse-resolution, time-series data about land-use development for the study area. GIS software and diverse data sources provided by the Maricopa Association of Governments and the Salt River Project were used to map the pattern of generalized desert, agricultural, recreational, and urban land uses for the approximate time periods: 1912, 1934, 1955, 1975, 1995 (Figure 6; Knowles-Yanez et al. 1998). Phase I data already have been used in spatial analyses and modeling of the CAP LTER regional landscape (see Modeling section, above).

  In Phase II, we are mapping land use by individual track for each of the cadastral square mile sections that include one of the 204 study sites (Survey 200) for the years 1934, 1949, 1961, 1970, 1980, 1990, and 1995. This historical perspective will enable us to compare patterns of future change to those of the past, when different social (and perhaps ecological) forcing functions were at work. Using this detailed information on temporal sequences of land-use change, we are currently defining alternate trajectories of change for each sector of the city and when they passed through analogous stages. Using these patterns, we hope to generate a more refined model for urban growth in our region and to identify pioneering activities that led to rapid change as well as factors that resisted urban growth and slowed the process.

- *Urban fringe morphology and climate.* The urban fringe project tracked the spatial distribution of the expanding urban fringe from 1990-1997. Likening the march of new residential development at the urban frontier to a "wave of advance," this research has updated a classic study of urban fringe morphology, but over a much shorter time frame and a much finer geographic scale (Gober et al. 1998). Findings show that the pattern of new development covers a surprisingly wide geographic area, especially at early stages of the growth cycle. As the growth cycle unfolds, new home construction takes place across a much narrower band of territory. Although Hans Blumenfeld's classic study of the urban

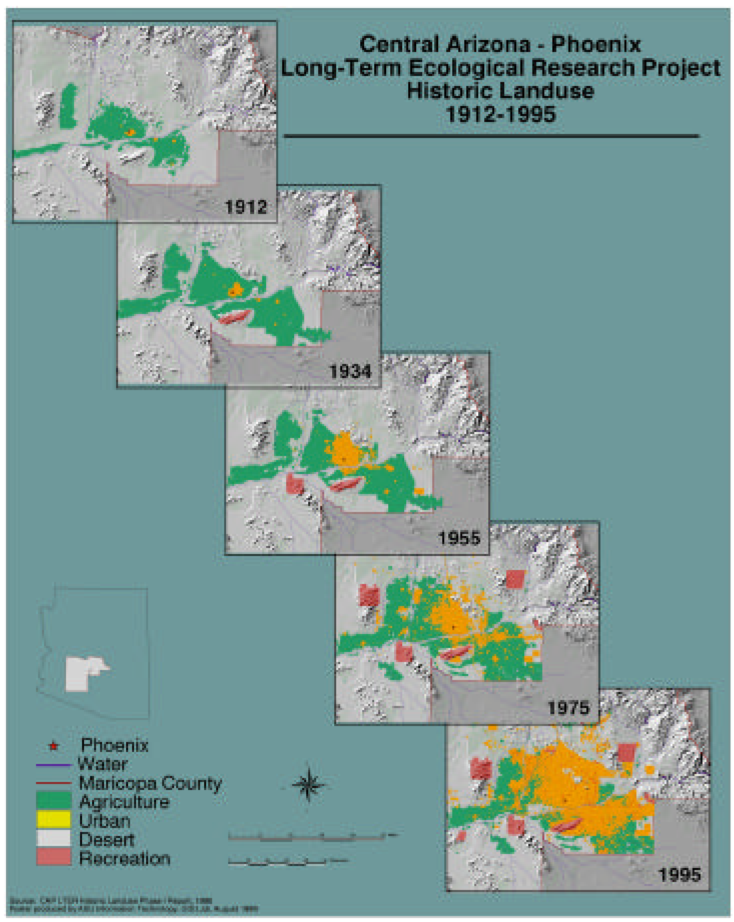


Figure 6. CAP LTER historic land use, 1912-1995.

fringe in Philadelphia showed that the crest of the wave of metropolitan expansion moved outward at the rate of one mile per decade during the first half of the 20th century, recent expansion in parts of contemporary Phoenix occur at a rate of *one mile per yea*r. The pace and distribution of new housing construction strongly relate to the pace and distribution of agricultural land turnover. There appears to be little or no lag, as much of the urban fringe literature suggests, from the time land is taken out of agriculture until it is used for housing and other urban purposes.

There is also a well-known "heat island" effect of urbanization. What is classified as "rural" (desert or farmland) determines the magnitude of the heat island in Phoenix—a "rural" desert is cooler at night whereas a "rural" agricultural landscape is warmer at night. During the day, there is an oasis effect evident in the city (the city is actually cooler than the rural desert). Time trends of urban effects in Baltimore and Phoenix are controlled by population growth rates in a non-linear manner over time (Brazel et al. 2000). Analysis of weather station data must be accompanied by land-cover and land-use analysis to unravel the local effects, after careful station history inspection to eliminate extremely local effects due to instruments, heights, changes in immediate surface, observation times for max/min temperatures, etc. (Brazel and Heisler 2000). The urban fringe represents a boundary of well-defined discontinuity in microclimate (Brazel et al. 1999) where heating (measured using remotely sensed data) is substantial (from 1985-present, >10°C in May). Finally, solar radiation receipt in and out of the metro area responds to the pollution dome over the city, with inner-city values 15% lower than outside values (Tomalty and Brazel 2000); UV-B radiation transects correlate (r^2 =0.7) with total incoming solar radiation variations.

- *Economic value of open space*. Land reserves or preserves have become increasingly important in urban environments, providing benefits to humans (as amenities) and to plants and animals (as habitats). This project provided empirical estimates of the economic value of open-space land. Because individual valuations underlie all market prices, we attempted to determine individuals' willingness to pay for the amenities associated with open-space areas through an analysis of the primary factors that determine land prices. The main problem that arose in undertaking such an investigation was determining the value of individual site characteristics, as these characteristics are not separately traded nor are they priced in explicit markets. Results indicated that open-space land has a positive and highly significant impact on the per acre price of residential parcels located near the McDowell Mountain Regional Park. That is, individuals living near this area are willing to pay a premium to do so.
- *Environmental risk study*. In this study we are mapping the geographic and social distributions of environmental hazards to learn how hazards are understood by those who live with them and to understand when and how people exposed to such hazards will organize and take action. The project is situated at the intersection of social and natural science, ethics and policy, and represents a new, integrative style of research. We have demonstrated that analyses relying solely on the presence of large-quantity generators or on the volume of toxic releases can be quite misleading. Instead, it is essential to account for the toxicity of releases (we used the Environmental Defense Fund's "toxic equivalency potential" weighting system, applied to EPA's Toxic Release Inventory data). Our most striking result, the comparison of weighted and unweighted releases, suggests that apparently clean new industry may harbor significant environmental hazards. The study location offers a valuable contrast to other studies of environmental equity, most of which are sited in the Northeast or South. In the Phoenix area, the presence of a TRI facility and the volume of emissions are strongly associated with measures of socioeconomic status and ethnicity at both the census tract and block levels. When the volume of emissions is weighted by a measure of their toxicity, however, the relationship becomes negligible. New forms of industry, such as computer chip manufacturers, often located in middle-class neighborhoods, are bringing toxic emissions to new areas and new populations, altering traditional patterns of environmental equity.
- *Gender and racial/ethnic inequality*. This project will measure the effects of changes in the location and types of employment opportunities on gender and racial/ethnic inequality in urban labor markets.
- *Dynamic political institutions and water policy*. Phoenix and other central Arizona cities have changed institutionally, and these changes have affected policy outcomes and thus our current environmental fabric. This project studies the relationship between institutional evolution and ecological policy outcomes.

Long-Term Monitoring and Cross-Site Comparison:

Long-term monitoring of social variables differs from that of ecological variables in that so many datasets are readily available and can be adapted for analyses of human dimensions of ecological change. We are utilizing census data, for example, in many projects; a partial list of datasets used by this team is provided in Table 2.

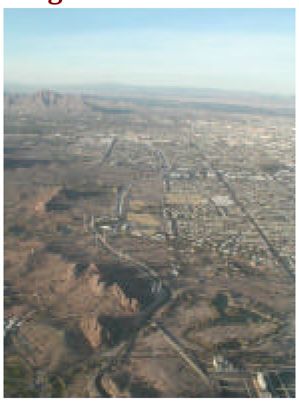
Table 2. Examples of Existing Datasets Relevant to CAP LTER "Human Dimensions" Projects

DATASET	SOURCE	EXAMPLES OF PROJECTS USING DATASET
Climate/weather	Municipal and state weather stations	Urban fringe
Demographic/census (decadal)	US Census Bureau	Environmental risk; Social area analysis
Employment data	Equal Employment Opportunity Commission (confidential)	Labor market dynamics
Environmental Hazard data: for Superfund, Treatment, Storage, and Disposal Facilities (TSDF), and Large Quantity Generator (LQG)	Right-to-Know Network	Environmental risk
Housing completions	Maricopa Association of Governments	Urban fringe
Housing market prices	Seidman Institute, ASU	Economic value of open space
Market data	Commercial service	Parks project
Mid-decade census, other demographic data	Maricopa Association of Governments	Environmental risk, labor market dynamics
Toxic Research Inventory (TRI)	Environmental Protection Agency	Environmental risk
Urban Infrastructure (water and sewer pipe length, volume, date of completion)	City of Phoenix	Urban infrastructure
Vegetation, infrared radiation	Remote sensing (CAP LTER/GRSL)	Social area analysis, urban fringe
Wage Data on industries and occupation	Bureau of Labor Statistics	Labor market dynamics

- *Labor market dynamics*. This analysis indicates that the largest occupational category in the Phoenix metropolitan area is office and clerical workers followed by professionals. Office and clerical jobs comprise the largest category of employment for women across all races, with women disproportionately employed in the service sector. Men's employment is more heterogeneous with respect to industry, with manufacturing and services the dominant sectors. Few studies have investigated how and why economic changes in the location and character of jobs are affecting gender, social class, and racial/ethnic equity. Our study will also compare economic restructuring and the spatial relocation of jobs over a 15-year period in the Phoenix and Baltimore Metropolitan Statistical Areas (MSAs).
- *Social area analysis*. This analysis uses census data and vegetation data to examine the relationship between socioeconomic status and vegetation patterns in the urban landscape at the neighborhood level. The question is: Do vegetation patterns differ with respect to socioeconomic status at the neighborhood level and, if so, how? Sociologists in the 1950s developed a methodology for social area indicators to examine the spatial heterogeneity of socioeconomic and demographic characteristics. Scientists from BES recently applied it to Baltimore to assess links with vegetation patterns; our study will analyze the socioeconomic/vegetation relationship in Phoenix and serve as a launching point for a cross-site project with BES.
- *Phoenix Area Social Survey (PASS)*. The main objective of PASS is to examine the reciprocal relationships, or interplay, between the social and natural environments in an urban ecosystem. To understand this complex process, we will conduct a longitudinal social survey of residents in the Phoenix-Mesa MSA. The survey will measure the social ties of individuals to their communities, values, and sentiments regarding communities, behaviors that affect the natural environment, and satisfaction with the area's quality of life. The community that people experience most directly is the neighborhood. Our central research questions ask how neighborhood social ties, values, and behaviors are connected with one another in ways that reflect willingness to act socially and politically with respect to the environment, and how changing environmental conditions, in turn, affect quality of life.

- *Urban parks*. The goal of the urban parks project is to understand the ecological and social roles that neighborhood parks play in an urban setting. Ecological processes in parks will be measured, and correlated to neighborhood socioeconomic status, use statistics, land-use history, and management strategies (facilities plus landscaping) in different neighborhood parks. Social perceptions of park value will be correlated to ecological processes, including biodiversity and measures of landscaping aesthetics. Standard parks can be found in many different cities, allowing for comparison of their social and ecological roles.

Biogeochemical Processes



This research area includes both aquatic and terrestrial elements of the urban landscape and has included projects at a range of scales, though much of our initial focus has been on whole ecosystem characterization. Data have been analyzed and synthesized for some initial projects, several others are completed (chemical and biological monitoring of urban lakes, a comprehensive nitrogen mass balance, and heavy metal analysis of lichens), a carbon balance project has begun, and monitoring of soil nutrient and carbon storage is underway. Long-term monitoring of surface water inputs and outputs of nutrients and major ions continues, as does dry and wet atmospheric deposition monitoring. We are interested in the transfer of materials from atmosphere to land to aquatic ecosystems and to groundwaters and, to that end, we have initiated sampling of storm events in collaboration with municipal and county agencies who are sampling floods and studies of aquatic nutrient cycling in a new urban watersheds project.

Initial projects:

- *Nitrogen mass balance*. A detailed nitrogen mass balance was constructed for the Central Arizona–Phoenix ecosystem using "mined" data, literature sources, sub-models of certain internal components, and preliminary CAP data. This detailed N mass balance (Figure 7) is apparently a first for an agro-urban ecosystem and is therefore a landmark effort. In particular, the influence of high nitrogen inputs and modified hydrology have been integrated into a conceptual model of nitrogen cycling in human-dominated ecosystems. A groundwater nitrogen mass balance is an important part of the whole-system

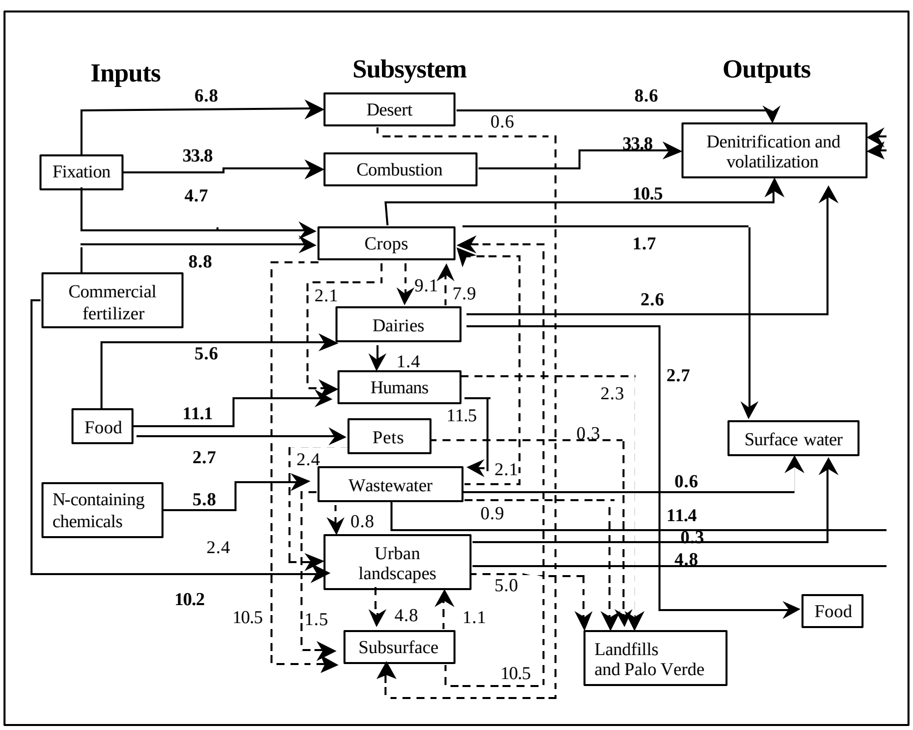


Figure 7. Diagram of nitrogen budget for the CAP ecosystem. All fluxes in 10^6 kg/y. Note that human mediated inputs constitute >90% (85/94) of inputs, whether deliberate (import of food, fuel, fertilizer) or inadvertent (fixation of N_2 during fossil fuel combustion) (Baker et al. in review).

nitrogen mass balance. This information can also be used to help guide more responsible use of commercial fertilizers by accounting for the use of high nitrate content groundwater for irrigation.

N input to the ecosystem was 94.1 x 10^6 kg/y, and total N output was 76.9 x 10^6 kg N/y, mostly as NO_x from combustion processes and N_2, N_20 and NO from denitrification. Riverine export was only 2.6 x 10^6 kg N yr^{-1}, < 3% of N input. Computed accumulation of N was 17.2 x 10^6 kg yr^{-1} (total input minus total output) or alternatively, 13.0 x 10^6 kg yr^{-1} (summing individual accumulation estimates). Key uncertainties include dry deposition of atmospheric N, soil processes, and denitrification rates. The N cycle of the CAP ecosystem is characterized by a dramatic (25-fold) elevation in N inputs compared to the surrounding desert, along with a significant increase in N accumulation. In contrast, N exports from the CAP ecosystem are elevated only 7-fold, because water management practices intended to conserve water also tend to promote N accumulation and volatilization, while reducing riverine N export.

- *Urban runoff.* This study addresses three main questions: 1) are nutrient (C, N) export rates and variability in nutrient export rates greater or less than those of the surrounding desert?; 2) how will nutrient export and its variability change with continued urbanization?; and 3) what are the "hot spots" of nutrient and contaminant storage and contribution to export in the city vs. the desert? We predict that temporal variability in exports will be less in urban than in desert watersheds, but suspect that spatial variability may be higher in cities relative to surrounding desert watersheds due to greater heterogeneity in storage of materials and in surface infiltration capacity. Since 1992 the USGS has been studying urban storm water runoff in the Phoenix area, in order to determine the physical, chemical and microbial characteristics of storm water from drainage basins with residential, industrial, and commercial land use. Results showed that the proportion of impervious surface is the single most important variable in predicting the export of nutrients from small urban watersheds. Hence, in the past year the main focus of CAP LTER research has been to determine the role of urban surfaces in the storage and transport of nutrients in the urban biogeochemical cycle. Surface loadings of major nutrients were measured on impervious asphalt parking lot surfaces embedded in different land uses (desert, industrial, commercial, residential). Parking lot surfaces were chosen as they contribute significantly to urban storm runoff. Just before the monsoon season, in summer 1998, a rainfall simulator was used to produce 5-minute rainfall events from which runoff was collected and chemically analyzed. Both nutrient and trace metal loadings (particularly of ammonium, nitrate, particulate C, and Zn) on asphalt parking lot surfaces varied considerably with site and pavement condition. Most striking were the results for dissolved nitrogen loadings on asphalt (average for nitrate was 151.3 mg/m^2) compared to desert soil (0.82 mg/m^2). Such enhanced N-deposition in the urban setting may be largely attributable to increased deposition from NO_x emitted from vehicle exhausts (see mass balance findings).
- *Urban watersheds project.* Our aims are to explore potential localized nutrient sinks in the urban landscape, and consequences of increased loading to aquatic ecosystems. Where in the landscape is N (and other elements) retained? This question is best answered using a hierarchical, patch-dynamics approach that incorporates both aquatic and terrestrial components of the landscape. Given the size and complexity of the study area, our initial focus on 1 or 2 smaller watersheds is warranted. In this research, we hope to integrate atmospheric deposition, storm water runoff, retention basin processes, hydrologic modeling, and aquatic biogeochemistry studies. To date, we have initiated or completed pilot projects on: 1) nutrient limitation in a highly modified urban stream-pond system; 2) spatial variation in nutrient concentrations in urban waterways; and 3) soil N cycling processes in retention (see "Disturbance" for further information on storm and flood sampling). Nutrient addition bioassay experiments in an urban stream revealed that phosphorus was limiting to algal growth during summer but not fall, in marked contrast to the N limitation characteristic of most regional streams (Grimm and Fisher 1986). These experimental results confirm predictions from sampling of waters that indicate a high N:P ratio in urban canals. Canals are the predominant lotic ecosystems in the CAP area, and their chemistry is strongly influenced by mixing of different source waters (canal water from the Salt, Verde, and Colorado Rivers, pumped groundwater, and irrigation return water). Initial measurements in neighborhood retention basins show a high potential for denitrification in these soils; we expect expanded measurements to show "hot spots" of denitrification in similar low-lying areas (recipient systems).

- *Urban limnology*. Numerous small lakes dot the metropolitan landscape and are nearly as ubiquitous as swimming pools and golf courses. These urban lakes were artificially created to serve recreational, aesthetic, and flood-control purposes. Monitoring has been infrequent and uncoordinated; although individual lakeowner associations have conducted some lake monitoring over the years, little effort has gone into synthesizing these data or systematically investigating the lakes chemically or biologically. The objectives of the study were to determine: 1) how the chemistry, primary productivity, and algal populations in the urban lakes are related to lake age, water source and other features; and 2) if the urban lakes represent sinks for nutrients and contaminants. To achieve the objectives of this study, 6 urban lakes varying in age and water source were sampled monthly or bimonthly for 2 years. We found that water source (effluent, groundwater, or surface (canal) water) was the more important factor explaining difference among lakes, with effluent lakes being hypereutrophic compared with meso- to eutrophic groundwater and canal lakes. Priority pollutants were not detected in lake water.
- *Lichens as indicators of changes in elemental deposition*. A study was conducted in 1998 and 1999 to determine whether trends in elemental deposition in Maricopa County are evident spatially and to a limited degree temporally (mid-1970s herbarium material compared to 1998 collections), based on an analysis of the lichen *Xanthoparmelia*. Patterns of trace metal deposition were assessed for a grid of 28 field sites from which samples of *Xanthoparmelia* were collected. Comprehensive elemental portfolios for digested lichen samples were compiled via inductively coupled plasma mass spectrometry (ICP-MS). Highly urbanized regions in Phoenix and copper mining and smelting regions had greater concentrations of Zn, Cu, Pb, and Cd. Concentrations of other elements were generally comparable to those reported for relatively unpolluted areas. Lead levels have fallen over the last 30 years by 71%, but Zn concentrations for some regions have increased by as much as 246%. The elemental fallout pattern was mapped for Zn, Cd, Co, Cr, Ni, Pb, Sb, and Cu, and the subsequent spatial analysis identified agriculture, mining, industrial activities, rock substrate and vehicular traffic as the major elemental sources in the county. An urban-rural gradient approach proved an unsatisfactory conceptual framework to explain the complex atmospheric fallout patterns in Maricopa County.

Long-term monitoring:

- *Long-term water monitoring*. The water monitoring project was established in February 1998 to measure the chemistry of surface waters upstream, downstream, and within the Phoenix metropolitan area. Its primary objective was to facilitate construction of nutrient budgets for surface waters and to look for changes in retention or export over time. Sites were established at 7 of the USGS's NAQWA program's river sites in the CAP study area (monitored from 1994-97) and have since been reduced to 5 sites sampled monthly or bimonthly. The objective of sampling at these sites is to capture high and low discharge periods in order to construct accurate flow-concentrations relationships to help with more accurate riverine flux calculations, rather than at regular intervals. Results of the long-term water monitoring project show that concentrations of nutrients, salts, dissolved organic carbon and suspended solids are consistently and markedly higher (by a factor of 1.5 to over 800, depending on constituent) at the sites downstream of the urban area compared to the upstream sites (Table 3). The only exception to this trend is seen in the proportion that dissolved organic nitrogen (DON) comprises of the total N pool, which decreases on passage through the urban system. At the input sites upstream of the urban area DON constitutes 70-90% of the total N pool, but less than 25% of that pool downstream of the city. Table 3 presents data for the latest 11-month sampling period (July 1999-May 2000) at 2 main input sites and the output integrator site downstream of the CAP urban ecosystem. The table includes average concentrations and associated standard errors (in parentheses) of several important chemical constituents.
- *Monitoring of atmospheric deposition*. The main goals of the atmospheric deposition research at CAP LTER are to: 1) develop a monitoring network to quantify the spatial variations in rates of atmospheric deposition for major nutrients and ions across the study area; 2) determine the role of atmospheric deposition in urban biogeochemical cycling; and 3) understand how inputs of nutrients and other materials via atmospheric deposition affects the function of other ecosystem processes such as primary productivity of native desert and introduced urban plant species. Existing monitoring of atmospheric deposition chemistry in the study area and surrounding region is limited. Therefore, monitoring of deposition of major nutrients and ions was initiated by installing a network of wet-dry bucket collectors

Table 3. Water Monitoring Project Data for the Latest 11-Month Sampling Period (July 1999-May 2000) at 2 Main Input Sites and the Output Integrator Site Downstream of the CAP Urban Ecosystem

CHEMICAL CONSTITUENT	INPUT SITES		OUTPUT SITE
	Salt River	Verde River	Gila River, Gillespie Dam
Nitrate-N (mg/L)	0.006 (0.002)	0.037 (0.029)	7.870 (0.316)
	n= 5	n= 4	n= 11
Ammonium-N (mg/L)	0.012 (0.001)	0.011 (0.004)	0.370 (0.068)
	n= 3	n= 4	n= 11
Phosphate-P (mg/L)	0.019 (0.003)	0.010 (0.004)	1.031 (0.149)
	n= 4	n= 4	n= 11
Dissolved Organic Carbon (mg/L)	2.8 (0.2)	2.0 (0.1)	4.9 (0.1)
	n= 5	n= 4	n= 10
Potassium (mg/L)	5.48 (0.2)	2.89 (0.2)	13.2 (0.4)
	n= 5	n= 3	n= 10
Sodium (mg/L)	194.3 (1.8)	35.0 (1.12)	624.6 (27.1)
	n= 5	n= 3	n= 9
Conductivity (uS)	1205 (34)	517 (23)	3726 (285)
	n= 5	n= 4	n= 8
Total Dissolved Solids (mg/L)	590 (7.5)	252 (7.6)	1671 (96)
	n= 5	n= 4	n= 5

(Aerochem Metrics, Inc Model 301) at 8 sites, from the urban center to agricultural areas and undisturbed desert beyond the urban fringe, between July and October 1999. Collectors were co-located with Arizona Department of Environmental Quality and Maricopa County Air Quality monitoring network sites, where concentrations of ozone, fine particulates (PM_{10} and $PM_{2.5}$) are monitored routinely (at sites 1-6), with additional monitoring of CO and NO_x concentrations at a smaller subset of the sites.

Figure 8. LTER deposition bucket collectors.

Data from the wet-dry bucket network will be used to determine the degree of broad-scale temporal and spatial variability in both wet and dry deposition across the study area (Figure 8). Although bucket collectors are considered adequate for collecting large particulate matter, they do not account for processes such as deposition by nitric acid, nor do they simulate real surface properties well. The magnitude of these effects can be evaluated by comparing dry bucket data with results obtained from a NOAA-operated dry deposition monitoring network site, where filter packs and inferential modeling are used to determine dry deposition of NO_3, NH_4, HNO_3 and SO_4 species. These data, along with the wet/dry bucket data will be supplemented by more comprehensive and accurate measurement of dry deposition during future years at a smaller number of sites. Annual wet and dry deposition of major nutrients (NO_3-N, NH_4-N, DOC and PO_4-P) for the first full year of sampling (2000) show the following patterns:

- no obvious enhancement of inorganic N (NO_3-N, NH_4-N) deposition at urban core versus desert sites;
- inorganic N deposition is largely in the form of ammonium (NH_4-N), predominantly as dry fall;
- DOC (dissolved organic carbon) deposition tends to be enhanced by a factor of x2-3 at urban compared to undeveloped desert sites;
- Phosphate-P (PO_4-P) is mainly deposited as dry fall and is enhanced by x3-10 times at urban & agricultural sites compared to undeveloped desert. More precise measurement of fine particulate NO_3-N, NH_4-N, and HNO_3 deposition planned for future studies can be expected to significantly increase overall rates of N-deposition to the system.

Geomorphology and Disturbance

Photo courtesy of Tempe Historical Museum

Photo by Wendy Bigler

Funding for additional studies in the realms of Geosciences and Engineering were provided via supplements during the first two years of CAP LTER. We chose to focus on building an understanding of the geomorphic template upon which the metropolis is expanding, including its rivers, a dominant feature of the landscape, and an engineering project (Tempe Town Lake) in the river channel.

- *Quaternary geomorphology*. Landscape development in the CAP LTER region defines the underlying spatial and temporal context for ecological studies. Landscape development over the last million years has determined the distribution of materials at the surface and in the shallow subsurface and has controlled the region's topographic form. Activity of the rivers that flow through the region dominates the area's recent geologic history. The Gila River (and its four tributaries that enter the Gila within in the study area) has existed as a major tributary of the Colorado River for the past 8-9 million years, and changes in surface transport rates and sediment supply in response to climatic variation drove an alternation of aggradation and entrenchment. We have made good progress in our efforts to apply the tool of cosmogenic dating to establish numerical ages for the incision and aggradation events (Robinson et al. 1999). We established GIS and remote sensing databases, important foundations for the multidisciplinary models central to the LTER project, created a bedrock geology map; and conducted a high-precision gravity survey of the western alluvial fan flank of the White Tank Mountains, which will determine the depth-to-bedrock profile and allow us to create a three-dimensional interface. This information will allow for the calculation of sediment flux to better determine the geologic history.
- *Century-scale channel change*. The main research questions addressed in this investigation of the Salt and Gila rivers are: What are the spatial and temporal components of change in the functional surfaces of the Salt River in the Phoenix metropolitan area, and what are the causes of these changes? Data from historical aerial photographs analyzed with a GIS show that large-scale regional flood events and local human activities have driven river channel change on the Salt River in the Phoenix metropolitan area. The photos above show the same view of Salt River in 1890 and just over 100 years later as Tempe Town Lake (Bigler 2001). Flood events have caused general changes in sinuosity of the low flow channel, but islands have remained remarkably consistent in location and size, while channel-side bars have waxed and waned. The most important determinant of local channel form and process is sand and gravel mining, which in some reaches occupies more than 70% of the active channel area. Using quantitative spatial analysis of imagery supplemented by field mapping, a probability of encountering low flow channels or other fluvial features was calculated for each location within the general channel area. The work was completed in 1999 and findings were published (Graf 2000).
- *Integrative investigations of a newly created lake*. The City of Tempe is undertaking a large ecological, hydrogeological experiment, the Rio Salado/Tempe Town Lake. A new urban lake was created in the dry (since 1938, except during floods) Salt River bed using collapsible, inflated rubber dams. The lake is over 3.2 km long, about 320 m wide, has a surface area of about 100 ha, and contains about 2500 acre-feet of water. The geological/ hydrogeological aspect of the study is to determine the effects of lake filling on local transient hydrological flow, to formulate an improved 4D-hydrogeological model of the area, and to provide subsurface geophysical control for geochemical and biological research at the lake. Microgravity

measurements before and after lake filling show that mean water-table elevations below Tempe Town Lake have stayed close to pre-lake levels, but water table surface curvature has increased significantly, possibly indicating unanticipated groundwater flow directions. We also have measured nutrient and other chemical concentrations in lake, inflow stream, and ground waters since initial filling, as well as algal populations, biomass, and zooplankton. We view this project as an excellent microcosm of the entire study area, because this "urban experiment" involves all components envisioned in our conceptual scheme of urban ecosystems: land-use change, change in ecological conditions, human feedbacks, and geophysical and societal constraints and drivers.

- *Historical investigations of disturbance.* Flash flooding characterizes Southwestern desert ecosystems, and urban areas are not immune to this disturbance. A graduate dissertation on the history of flooding in this desert metropolis, supported by CAP LTER, will provide a historical context for research on the effects of this disturbance. A project using remote sensing to identify fire-flood interaction and hazards (funded by NASA) adds further context. Finally, a preliminary eco-history of urban fire was completed during Years 1-2. Traditional urban fire history is narrowly humanistic and dominated by "big fire" disaster stories and institutional narratives centered on heroic firefighters. Our research effort centered on identifying the nature and location of quantitative and qualitative information that could be used in constructing an ecological history. The Sonoran Desert is not an easy ecosystem to study long-time fire activity using stratigraphic methods, due to limited charcoal and carbon deposition and the fact that the Phoenix area in particular has so disturbed most "natural" sites, the quantitative data to create not only a model but provide the variables necessary for a long-term comparative study, must be centered on human records. This effort involved statistics on physical fire obtained from local fire departments, county, state, federal, non-profit, and other agencies; data from various air quality studies revealing emissions from combustion events in the region; records from city clerks revealing budget priorities and other municipal dynamics; and maps, charts, aerial photographs, and general plans from urban, county and state planning departments, as well as non-profit museums and other repositories of information. The data compilation is complete and available through the CAP LTER archives and in a forthcoming book (Pyne in review).

III. EDUCATION AND OUTREACH

Environmental education and outreach activities are woven throughout CAP LTER. The CAP LTER project enhances the research and teaching skills of its participants, including undergraduate students, graduate students, postdoctoral students, faculty members, K-12 teachers and students, and high-school student interns. Our study of an arid ecosystem provides a powerful framework for training graduate students, nourishing cross-disciplinary projects, and contributing to the burgeoning field of urban ecology. We encourage ASU faculty members to draw upon project resources and incorporate urban ecological issues and data into their classrooms. Finally, we are committed to sharing what we learn with pre-college students and teachers, community organizations, governmental agencies, industry, and the general public in disseminating and sharing our findings.

K-12 Education

We reach out to the K-12 community through *Ecology Explorers*, a program that aims to:

- develop and implement a schoolyard ecology program where students collect data similar to CAP LTER data, enter results into our database, share data with other schools, and develop hypotheses and experiments to explain their findings;
- improve science literacy by exposing students and teachers to real research conducted by university-level scientists;
- enhance teachers' capabilities to design lessons and activities that use scientific inquiry and encourage interest in science;

- provide access to and promote the use of CAP LTER-generated materials and information;
- and encourage collaboration between CAP LTER researchers and the K-12 community.

Teachers and students from over 20 school districts participate in Ecology Explorer activities, including: 1) summer teacher internships; 2) scientist visits to classrooms; 3) data entry into our Ecology Explorers Web site; 4) poster sessions and regional science fairs; and 5) schoolyards as sites for gathering ecological data.

Three schoolyard supplements and additional corporate and foundation monies help support activities that promote scientific inquiry through schoolyard ecology. These activities engage students and teachers in “real” university-level science projects; enhance the use of technology in the classrooms via the Web site and databases; offer stimulating research experiences that enhance teaching; and provide an interface between the scientific community and schools to facilitate science standards reform. To date there has been student/teacher participation in plant survey, ground arthropod survey, bird survey, plant/insect interaction, and water sampling efforts. This coming year we expect to initiate the placement of urban ecology graduate fellows in K-12 classrooms through a new "Down to Earth Science" collaborative program in association with other science outreach programs at ASU.

The protocols developed during our summer teacher programs became the basis for the Ecology Explorer Web site (http://caplter.asu.edu/explorers). A database has been constructed for teachers and students to enter collected data on the Web. Follow-up activities with the teachers include biannual dinner meetings, as well as individual visits to classrooms by project personnel.

Through teacher evaluations and discussions, teachers have reported they have a better understanding of ecological research; students’ enthusiasm for the project exceeded expectations; students felt projects were important because of the ASU connection and were willing to put in extra effort to carry out the projects; more parents were involved than anticipated; and workshops/internships were valuable and enhanced their ability to teach science. Teachers have also reported that students’ math abilities improved as a result of participating in Ecology Explorers and that participating in poster presentations enhanced communication skills. Although the program has always been aligned with the Arizona State Science Standards, we have been working to align with other Arizona State Standards such as math, English, and social studies.

Each year, high-school students are mentored in lab and field research through SCENE (Southwest Center for Education and the Natural Environment), with day-to-day supervision provided by a graduate research associate, often involved in CAP LTER research. Our education personnel also work closely with the SCENE to implement other environmental education programs. Many teachers in SCENE’s Native Habitat Project use sampling protocols to monitor changes in schoolyard ecology as native habitats are developed at schools.

We work with a host of these educational partners, who serve on our K-12/Informal Science Education Advisory Team, to further enhance our Ecology Explorers program: the *Phoenix Zoo*, *Desert Botanical Garden*, and the *Arizona Historical Society Museum*, the *Maricopa County Parks and Recreation Department*, particularly *Usery Mountain Park*, and University groups involved in inquiry-based science education.

Community Partners

The most active of our federal partners has been the *USGS*, a main collaborator with the Historic Land-Use Team in Phase I of their study that involved capturing desert, agriculture, and urban land uses for the metropolitan area. Several USGS NAWQA sites are also participating in our long-term water-monitoring project, collaborating on studies of water quality and storm sampling. In the state realm, the *State Land Department* has been very helpful in allowing access to Arizona state land, and project scientists have collaborated with land department personnel on a study of insect communities on creosote bushes. Other agencies are helping with the historic land-use study (*Department of Water Resources*) and the atmospheric deposition study (*Department of Environmental Quality*). Representatives from various city agencies have served as information resources to CAP LTER personnel as well as partners in numerous grant proposals: The *City of Phoenix* has issued blanket permission for us to conduct fieldwork in the city's extensive park system, including at South Mountain Park. In addition, Phoenix is supplying water and sewer infrastructure information in the form of paper plats and electronic files to the urban fringe project. The *City of Scottsdale* has entered into an agreement with CAP LTER to conduct a nutrient limitation study at Indian Bend Wash, and the *City of Tempe* is a partner in our nitrogen balance study, particularly in allowing access to storm water retention basins and to non-retention areas for purposes of sampling soil and storm water.

Maricopa Association of Governments, consisting of the 24 incorporated cites and towns, 2 Indian communities, and Maricopa County, has been an integral partner, supporting the project by supplying GIS information and data and collaborating on investigations into growth planning, land-use projections, and open-space implementation. Rita Walton, MAG's policy and information manager, has worked with the Land-Use Change Team and co-authored a CAP LTER study on land consumption and absorption rates. We have also worked with the Flood Control District in projects involving storm hydrology and storm-water chemistry.

Motorola has been instrumental in helping us engage the K-12 community and beyond by: 1) funding an environmental education coordinator; 2) designing logos, exhibit displays, bookmarks, and other materials for Ecology Explorers; 3) working with project staff to design and produce our newsletter; and 4) contributing computers, as well as design, production, and printing costs of the newsletters and brochures. *Salt River Project*, a semipublic organization responsible for water management and supplying electrical energy to the region, has a long-term research and outreach relationship with CAP LTER. They have greatly facilitated the work of the Historic Land-Use Team and have contributed greatly to the nitrogen mass balance study and even provided a helicopter to reach several remote 200 Survey sample locations. The *Desert Botanical Garden* serves as one of our long-term sampling sites. A permanent, experimental plot was installed to measure net primary productivity as affected by human activities. Lastly, over 30 businesses/organizations/federal, state, regional, and local agencies entertain long-term monitoring of ecological variables on their sites. A list of our community partners is included in Appendix B.

Undergraduate and Graduate Education and Training

CAP LTER's university setting enhances the ability to conduct, communicate, and synthesize our research activities. Faculty members have expanded their courses to consider urban ecology and, in some cases, have designed new courses to accommodate CAP LTER research interests. For example, the Biology Department offered a seminar in urban ecology in the first and current year of the project, and last year the river channel change project contributed to the multidisciplinary education of 30 graduate students in botany, zoology, biology, agriculture, planning, geology, and geography by joining with a graduate course taught through the Geography Department.

In addition, graduate assistants gain exposure to interdisciplinary research, the importance of long-term datasets, metadata, and data archiving, as well as experience in database design and management, lab processing and analysis. The Goldwater Lab for Environmental Science has been expanded to accommodate CAP LTER's analytical needs and provide graduate student training on instruments housed in this facility. Data collected as part of the remote sensing lab's research programs is archived at the GRSL and is available to project researchers and graduate students.

Both NSF and ASU support over 20 graduate students a semester, each immersed in the research at hand and working together as a cohort for the project at large. Graduate students are currently drawn from a wide range of university programs and departments, including: anthropology, biology, curriculum and instruction, engineering, economics, geography, geological sciences, planning and landscape architecture, plant biology, and sociology. Graduate students serve as research associates and are trained in field-investigation techniques, data analysis, scientific writing, oral presentation, interdisciplinary interaction, GIS, and remote sensing. Students also receive exposure to the interactions of government agencies and the effects of large public works projects on public attitudes. Our successful grant proposal to the NSF's

IGERT program has added 8 IGERT Fellows and 13 IGERT Associates (many of the latter are CAP LTER RAs) to this active group of graduate students.

CAP LTER faculty members, postdoctoral associates, and senior graduate students have mentored 9 NSF-funded REU students who gained research training via summer projects integral to CAP LTER. Other undergraduate students have benefited by participating in data collection for the ground arthropod study, collections and curation activities, and courses that relate to the CAP LTER. Faculty members in geography, geological sciences, biology, and civil and environmental engineering have delivered additional training through graduate courses designed around CAP LTER activities. In many instances graduate students are full colleagues in the research activities, taking part in the framing, analysis, interpretation, presentation, and writing of results.

Postdoctoral Associates

Since the inception of the CAP LTER project, 11 postdoctoral associates have taken leadership roles in research and outreach activities. The project currently supports 8 postdocs, 4 of them full-time on CAP LTER. They interact with each other, participate in planning meetings with the co-project directors and project managers, work with faculty member participants and team leaders, collaborate with graduate students, and organize and coordinate the winter poster symposium and summer summit gatherings. They are integral to the research and field experience of CAP LTER and receive training in interdisciplinary collaboration, graduate student supervision, data analysis, and presentation techniques.

Dissemination of Research Projects and Results

In the 3 years of its existence, CAP LTER participants have presented 173 professional posters and presentations. In addition, we have reached out to over 100 community organizations and schools representing over 2,500 children. We publish a newsletter 3 times a year that is distributed to researchers, students, K-12 teachers, and community partners. The CAP LTER and individual projects have been the focus of articles in major scientific journals such as *BioScience*, *Science News*, and *American Scientist*, numerous newspaper articles, and the bird survey, ground arthropod, and bruchid beetle projects were featured in *Chain Reaction*, an ASU magazine for the K-12 community.

IV. Information Management

Resources

Computing activities at CAP LTER are carried out over a distributed network of resources. At the core is the CES Informatics Lab with over 200 gigabytes of storage and a dozen workstations. Additional resources for GIS and image processing are available in the ASU GIS Lab and the Geology Remote Sensing Lab. Data are archived in the CES Lab and protected via tape back up, redundant storage systems, and a security alarm system. A series of integrated databases were defined to serve as the core management system for CAP LTER. Its components include projects, personnel, bibliography, datasets, and calendar. Most of the information provided on the Web site is drawn dynamically from this database. Content for the metadata database follows the FGDC standard, with extensions based on current LTER practice.

Procedures

Data management procedures for CAP LTER projects tend to one of two trajectories: a relatively formalized one where the Lab staff are closely involved from the beginning of the project and another where the project researchers assume responsibility for their own data and work relatively independently of the lab until the data are submitted. Projects providing long-term monitoring or involving CES staff or post-docs typically belong to the first group, following the procedural model outlined in Figure 9.

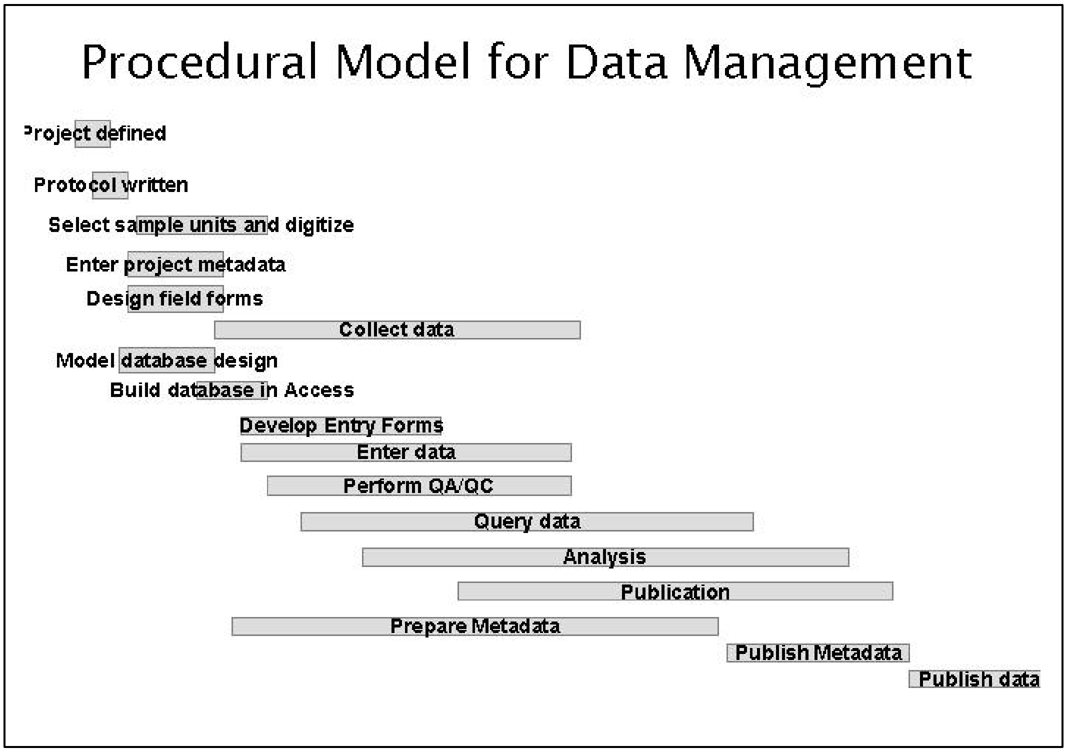


Figure 9. Procedural model for CAP LTER data management.

At the initiation of a new project, researchers are asked to decribe the project and any data product they expect to produce. They also turn in a detailed protocol for each dataset and samples of any field or lab entry forms. Each project also provides a GIS cover indicating its study area and/ or site sampling locations. The PIs meet with the Information Manager to discuss data management needs. For projects creating new primary data, a generalized schema of the database is modeled following the protocol and the entry. The databases are created and stored in secured project space on CES servers during the life of the project. Interfaces for data entry are developed with MS Access. While individual projects carry out their own data entry and analysis, CES staff provide support in designing queries to help researchers access their data.

Data for archiving are prioritized thus: *Primary* data consisting of original observations must be archived with complete metadata documentation. *Secondary* data that consists of transformations or other value-added treatments should be archived if the steps required to reproduce the same information would be considered unduly difficult or time consuming. *Acquired* data that was received unmodified from external sources is typically archived in its original form as a service to other CAP LTER researchers, but does not receive priority for extensive metadata development or maintenance unless it is clear that the originator is not assuming this responsibility. The CES Informatics Lab is the primary data archive. A limited set of data formats is used for archiving data according to the type of data. Restricting the number of formats supported allows for development of more standardized access tools and simplifies the process of forward migration to new versions or formats. For datasets that have been managed by the lab, there is little to be done to prepare data for archiving; datasets prepared elsewhere and turned in at the conclusion of the project require considerably more reformatting. The metadata catalog is directly updated by CES

Lab staff or staff from the GIS Lab or Remote Sensing Lab. Where possible, the lower-level (syntactic) categories of metadata are extracted from the data E/R models and loaded into the data catalog automatically. Input from researchers is required for higher level (semantic) information and poses a much greater challenge. Current practice is to extract what can be taken from the protocol and then arrange interviews with the PI/RA to get the appropriate information.

CAP LTER data are made available according to the terms set out in a data access policy that is published on the Web site. Internet publication is executed via a Web interface that supports searches of the dataset catalog. The metadata are currently returned as Web pages that may be interactively browsed. Access to online data is provided as a download link to the particular resource or, for certain data types, the interface will open the resource and provide the user with some means for online browsing and/or querying the data.

The CES Informatics Lab is active in the development of sophisticated database technology and applications. The award of a Biological Database and Informatics grant (McCartney et al. 1999) to develop new database tools has bolstered CES efforts in data management and use of existing data as components of our research projects. This 3-year project began in 2000 to develop advanced infrastructure for facilitating access to ASU's extensive environmental data resources for researchers, educators, and our partners in resource management. Another NSF project, funded through KDI (Razdan et al. 1999), seeks to develop a set of core technologies for recognizing and analyzing morphological features from 3-dimensional computer models. This approach is applied to research questions in six different disciplines. The CES Lab plays a role in developing the database for organizing storing and transmitting 3D data using XML.

V. PROJECT MANAGEMENT

Considerable effort has gone into ensuring open lines of communication and achieving maximal input from the large number of participating core scientists (>50). Project Co-Directors Nancy Grimm and Charles Redman, together with an Executive Committee, establish and review policy, select postdoctoral associates, and allocate resources. To enhance communication among the various project participants, we have enlarged our Executive Committee to include scientists from a broader range of disciplines (Tony Brazel, Geography; John Briggs, Plant Biology; Stan Faeth, Biology; Pat Gober, Geography; Ed Hackett, Sociology; Milt Sommerfeld, Assoc Dean, College of Liberal Arts and Sciences and Plant Biology). The project managers (Diane Hope, Field; Brenda Shears, Administrative; Peter McCartney, Informatics, and Corinna Gries, Analytical Labs) serve as ex-officio members of the Executive Committee and are instrumental in the day-to-day operations of the project, supported by technical and administrative staff. Postdoctoral associates (Amy Nelson, Madhusudan Katti, David Lewis, Eyal Shochat, William Stefanov, and Wanli Wu) play major roles in the populations, human dimensions, biogeochemical, and modeling domains of the project and provide continuity in core CAP LTER research.

The Center for Environmental Studies provides the administrative infrastructure and houses most of CAP LTER personnel. Arizona State University, through the Office of the Vice Provost for Research, supports the activities of the Center for Environmental Studies (CES) and the CAP LTER. Center staff contribute substantially to the coordination and outreach efforts of the project (Lauren Kuby, special project coordination and new proposal development; Monica Elser, K-12 Ecology Explorers; Cindy Zisner, Webmaster; Linda Williams, financial and personnel tracking; Wayne Porter, network administration; Shirley Stapleton, meeting scheduling and coordination). The Center also provides the resources to host many interdisciplinary meeting and activities.

Monthly All Scientists Council meetings (open to all interested parties) provide opportunities for cross-disciplinary fertilization and information exchange through science- and results-based presentations. Attendance ranges from 40-80 people per meeting and includes faculty members, postdoctoral associates, graduate students, and community partners. The project directors meet monthly with the postdoctoral associates and project managers to discuss projects in which the postdocs are involved and to serve as a sounding board for their research activities and career development. Graduate students meet monthly at research-focused gatherings designed to facilitate interdisciplinary cross-fertilization.

Integrating the diverse activities of the CAP LTER relies on effective communication among participants. For example, the modeling component is an integrative activity that relies on data from both existing datasets and individual projects (obtained through appropriately designated and maintained databases), remote sensing, and GIS. An exciting integrative device that has developed as we have moved forward has been the formation of working groups. Groups can be organized by individuals or at the suggestion of the project directors or executive committee. They arise both out of particular needs or with the idea of exploring a potentially fruitful research area. For example, a working group was formed to brainstorm and work through the knotty problem of sampling during the pilot phase and the to design the 200-point survey. An atmospheric deposition group developed the monitoring scheme. And ongoing environmental risk, human-feedback, and carbon mass balance working groups are addressing project needs in these interesting and potentially integrative areas. In addition, very focused and sometimes discipline-specific working groups are created to address specific needs. A number of such groups are wrestling with issues related to the analysis of data collected from the Survey 200 data: soil carbon, vegetation/socio-demographic, birds, arthropods, native vegetation, and remote sensing/ground-truthing and calibration. A postdoctoral scholar, data technicians, and the GIS lab director collaborate on historic land use and environmental risk projects. The working group concept and the expanded Executive Committee have effectively replaced the original concept of a Management Leadership Council.

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Appendix A
CAP LTER Products

Presentations and Posters

Presentations at Regional, National, and International Conferences

2000

Anderson, S., and A. J. Brazel. 2000. A look at spatial and temporal climate change on the urban fringe. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Bolin, R. 2000. Environmental equity in a Sunbelt city. Presented at May 2000, *Urban Affairs Association*, Los Angeles, CA.

Brawley-Chesworth, A., and P. Westerhoff. 2000. Fate of MIB and Geosmin in surface water treatment plants. Presented at May 2000, *AWPCA Annual Conference*, Mesa, AZ.

Brazel, A. J., and G. M. Heisler. 2000. Some considerations in using climate data from existing weather stations or installing stations for research in Baltimore and Phoenix urban LTER sites. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Bruce, D., P. Westerhoff, M. Sommerfeld, L. Baker, M-L. Nguyen, H. Qiang, T. Dempster, and D. Lowry. 2000. Occurrence and potential causes of Geosmin and MIB in Arizona drinking waters. Presented at May 2000, *AWPCA Annual Conference*, Mesa, AZ.

Chambers, F. B., and A. J. Brazel. 2000. Heating and cooling in Colorado mining towns. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Compton, M., J. Hunter and M. Sommerfeld. 2000. Urban lakes - relationships between source water, lake age, water quality and biota. Presented at 14-15 April 2000 *44th Annual Meeting of the Arizona-Nevada Academy of Science*, University of Arizona, Tucson, AZ. *Journal of the Arizona-Nevada Academy of Science* (Proceedings Supplement) 35:46.

David, J., and J. Wu. 2000. A hierarchical patch dynamics modeling platform for modeling complex systems. Presented at 31 July-3 August 2000, *International Conference on Modeling Complex Systems*, Montreal, Canada.

Elser, M. M., and S. L. Williams. 2000. Urban ecology and urban schools: A model for encouraging long-term research with school children and teachers. Poster presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting*, Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts* p. 271.

Esparza, M, and P. Westerhoff. 2000. Characterization of soluble microbial products during full-scale wastewater treatment. Presented at May 2000, *AWPCA Annual Conference*, Mesa, AZ.

Fergason, K. C., Arrowsmith, J R., and Tyburczy, J. A. 2000. Changes of groundwater elevation associated with Tempe Town Lake. Presented at September 2000, *Arizona Hydrological Society Meeting*.

Fink, J. H., C. L. Redman, and N. B. Grimm. 2000. Expanding a long-term ecological research project into a national urban environmental laboratory. Presentation at special session on “Earth Sciences in the Cities.” (Abstract). *EOS, Transactions of the American Geophysical Union* 81:In press.

Grimm, N. B. 2000. Urban ecosystems as a frontier for the millennium: New challenges for aquatic ecologists. Presidential address, Presented at May 2000, *North American Benthological Society Annual Meeting.* Keystone, CO.

Grimm, N. B. 2000. Urban ecology and the challenge of integrating social and ecological sciences. April 2000, Plenary speaker, joint symposium of the *British Ecological Society* and the *Ecological Society of America*, *Ecology: Achievement and Challenge*, Orlando, FL.

Grimm, N. B., M. A. Luck, and G. D. Jenerette. 2000. Multiple-scale analyses of ecosystem function and human-ecological interaction in an urban setting, the central Arizona - Phoenix ecosystem. Presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting,* Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts,* p. 17.

Hope, D., J. Anderson, N. B. Grimm, and S. Boone. 2000. Atmospheric deposition in the Phoenix metropolitan area and its role in urban nutrient cycling. Poster presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting,* Snowbird, UT.

Hope, D., J. Anderson, N. B. Grimm, and S. Boone. 2000. Atmospheric deposition across the Central Arizona - Phoenix LTER site. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Hunter, J., M. Compton, D. Crowl, and M. Sommerfeld. 2000. Diatoms of Town Lake. Presented at 14-15 April 2000 *44th Annual Meeting of the Arizona-Nevada Academy of Science,* University of Arizona, Tucson, AZ. *Journal of the Arizona Nevada Academy of Science* (Proceedings Supplement) 35:11.

Jenerette, G., J. Wu, and N. B. Grimm. 2000. Nitrogen limitation and ecosystem self-organization: The effects of spatial heterogeneity. Paper presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting,* Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts,* p. 127.

Luck, M. A., G. D. Jenerette, J. Wu, and N. B. Grimm. 2000. Determining the size of urban landscapes: The urban funnel model and estimation of ecological footprint. Presented at 15-19 April 2000, *Annual Meeting of International Association for Landscape Ecology,* Fort Lauderdale, FL.

Martin, C. A., and L. B. Stabler. 2000. Plant gas exchange in urban and suburban landscapes. Poster presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting,* Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts* p. 308.

Martin, C. A., L. B. Stabler, and A. J. Brazel. 2000. Summer and winter patterns of air temperature and humidity under calm conditions in relation to urban land use. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

McCartney, P., I. Robertson, and G. Cowgill. 2000. Using metadata to address problems of data preservation and delivery: Examples from the Teotihuacan Data Archiving Project. Paper presented at 6 April 2000, *65th Annual Society of American Archaeology*, Philadelphia, PA.

Nelson, A., and S. Harlan. 2000. Labor market dynamics in a postindustrial city: A spatial and sectoral analysis of employment changes in the Phoenix MSA. Poster presented at 12-16 August 2000, *95th Annual Meeting of the American Sociological Association*, Washington, D.C.

Nguyen, M-L., and P. Westerhoff. 2000. Sources and transport of DOC/DBP precursors in the CAP and SRP canals. Poster presented at May 2000, *AWPCA Annual Conference*, Mesa, AZ.

Ramsey, M. S. 2000. Mapping the city landscape from space: The Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) Urban Environmental Monitoring Program. Presented at May 2000, invited *American Geophysical Union Annual Spring Meeting, (UO1: Earth Sciences in the Cities Special Session).*

Ramsey, M. S., and W. L. Stefanov. 2000. The Advanced Spaceborne Thermal Emission and Reflectance Radiometer (ASTER) Urban Environmental Monitoring Program: Local results using airborne MASTER data from Phoenix, AZ. Presented at November 2000, invited *ERIM 14th Applied Geol. Remote Sensing Conference (MASTER Special Session),* submitted for publication.

Rango, J. J. 2000. Patch isolation and priority effects and the structure of arthropod communities inhabiting creosote bush (*Larrea tridentata*) in central Arizona. Paper presented at the 6-10 August 2000, *Ecological Society of America 85th Annual Meeting*, Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts,* p. 182.

Robinson, S. E., and J. R. Arrowsmith. 2000. Alluvial fan depositional events identified by cosmogenic dating. Presented at 14-15 April 2000 *44th Annual Meeting of the Arizona-Nevada Academy of Science*, University of Arizona, Tucson, AZ.

Selover, N. J. 2000. Local climate effects of a large urban lake on Tempe, AZ. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Selover, N. J. 2000. Spatial variation in climate across the Phoenix, AZ, metropolitan area at various times scales. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Smith, C. S. 2000. Presentation at 3-6 May 2000, *Urban Affairs Association 30th Annual Meeting*, Los Angeles, CA.

Sollner, A., P. Westerhoff, and P. Fox. 2000. Membranes vs groundwater recharge: balancing water quality considerations. Presented at May 2000, *AWPCA Annual Conference*, Mesa, AZ.

Stabler, L. B., and C. A. Martin. 2000. Irrigation frequency affects growth and water use efficiency of two xeriphytic landscape plants. Presented at 23-26 July 2000, *97th International Conference of the American Society for Horticultural Science*, Orlando, FL.

Stabler, L. B., and C. A. Martin. 2000. Seasonal patterns of plant water status and gas exchange in two Sonoran Desert landscapes. Paper presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting*, Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts* p. 211.

Stabler, L. B., and C. A. Martin. 2000. Temporal and spatial patterns of temperature and CO_2 concentration in metropolitan Phoenix. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Tomalty, R. S., and A. J. Brazel. 2000. Urban influences on solar radiation in CAPLTER. Presented at 14-18 August 2000 *Third Symposium on the Urban Environment*, American Meteorological Society, University of California, Davis.

Wu, J. 2000. A landscape ecological approach to the study of urban systems. Presented at 15-19 April 2000, *Proceedings of the 15th Annual Symposium of US-International Association of Landscape Ecology*, Fort Lauderdale, FL., pp. 161.

Wu, J., and S. T. A. Pickett. 2000. New paradigms in urban ecology. Paper presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting*, Snowbird, UT.

Xu, Y., L. Baker, and P. Johnson. 2000. Groundwater nitrate accumulation in an arid agro-urban ecosystem, Phoenix, Arizona. Presented 30 May 2000, *American Geophysical Union Spring Meeting*, Washington, D.C.

Zhu, W., and N. B. Grimm. 2000. Carbon and nitrogen cycling in urban remnant patches: The effect of fossil fuel combustion. Poster presented at 6-10 August 2000, *Ecological Society of America 85th Annual Meeting*, Snowbird, UT. *Ecological Society of America 85th Annual Meeting Abstracts*, p. 362.

1999

Baker, L., D. Hope, Y. Xu, L. Lauver, and J. Edmonds. 1999. Nitrogen mass balance for the Central Arizona - Phoenix LTER ecosystem. Presented at August 1999, *Ecological Society of America Annual Meeting*, Spokane, WA.

Baker, L., and C. Redman. 1999. Environmental analysis of urban ecosystems. Presented at July-August 1999, *Research Frontiers Conference*, Association of Environmental Engineering and Sciences Professors, Penn State, PA.

Clark, K., and R. Ohmart. 1999. Avian responses to fragmenting habitat in an urban system. Presented at March-April 1999, *69th Annual Meeting of the Cooper Ornithological Society*, Portland, OR.

Clark, K., and R. Ohmart. 1999. Vertebrate species responses to fragmenting habitats in an urban system. Presented May 1999, *4th International Symposium on Urban Wildlife Conservation*, Tucson, AZ.

Damrel, D., D. Pinkava, and L. Landrum. 1999. The Phoenix flora data base. Revised edition. Best poster at *Arizona-Nevada Academy of Science* meeting, Flagstaff, AZ. *Journal of Arizona-Nevada Academy of Science* 24(Supple.):45-46.

Graf, W. L. 1999. The locational probability of the Salt River, Arizona. Presented at March 1999, *Association of American Geographers 95th Annual Meeting*, Honolulu, HI.

Grimm, N. B. 1999. Ecological investigations of a southwestern city: Preliminary findings from the Central Arizona - Phoenix Long-Term Ecological Research Project. Presented at November 1999, Invited speaker, *Annual Meeting of the Association of Ecosystem Research Centers*. Washington, D.C.

Grimm, N., L. J. Baker, and D. Hope. 1999. An ecosystem approach to understanding cities: Familiar foundations and uncharted frontiers. Presented at April 1999, Plenary speaker, *8th Cary Conference, Understanding Urban Ecosystems: A New Frontier for Science and Education*, Millbrook, NY.

Hostetler, M. E. 1999. The importance of multi-scale analyses in avian habitat selection studies in urban environments. Presented at March 1999, *69th Annual Meeting of the Cooper Ornithological Society*, Portland, OR.

Hostetler, M. E., and K. Knowles-Yánez. 1999. Land use, scale, and bird distributions in the Phoenix metropolitan area. Presented at May 1999, *4th International Symposium on Urban Wildlife Conservation*, Tucson, AZ.

Jenerette, G. D., and J. Wu. 1999. Dynamics of human-dominated land use change: Historical analysis and simluation of the Greater Phoenix region. Presented at 29 July-3 August 1999 the *5th World Congress on Landscape Ecology, International Association of Landscape Ecology*. Snowmass, CO.

Knowles-Yánez, K., C. Moritz, J. Fry, M. Bucchin, C. Redman, P. McCartney, and J. Maruffo. 1999. Historic land-use team: Phase I report on generalized land use. Presented at July 1999, *19th Annual User Conference*, Environmental Systems Research Institute, Inc., San Diego, CA.

Lauver, L. 1999. Nitrogen mass balance for municipal wastewater in the Phoenix - CAP LTER ecosystem. Grand prize winner, Student Environmental Engineering Essay Contest, American Society of Civil Engineers. Presented at July, *National American Society of Civil Engineers Conference.*

Luck, M., and J. Wu. 1999. Characterizing the landscape pattern of urbanization: An example from the Central Arizona - Phoenix urban LTER. Presented at 29 July-3 August 1999, presented at the *5th World Congress on Landscape Ecology, International Association of Landscape Ecology*. Snowmass, CO.

McIntyre, N. E. 1999. Influences of urban land use on the frequency of scorpion stings in the Phoenix, Arizona, metropolitan area. May 1999, *4th Annual International Symposium on Urban Wildlife Conservation*, Tucson, AZ.

McIntyre, N. E., J. Wu., and F. Steiner. 1999. Adopting a landscape ecology approach in the study of urban systems. Presented at August, *84th Annual Meeting of the Ecological Society of America*, Spokane, WA.

Peterson, K. A., L. B. McDowell, and C. A. Martin. 1999. Plant life form frequency, diversity, and irrigation application in urban residential landscapes. Presented at July, *96th Annual International Conference of the American Society of Horticulture Science*, Minneapolis, MN.

Ramsey, M. S., W. L. Stefanov, and P. R. Christensen. 1999. Monitoring world-wide urban land cover changes using ASTER: Preliminary results from the Phoenix, CAP LTER site. Presented at March, *13th Annual Applied Geologic Remote Sensing Conference*, Vancouver, British Columbia, Canada.

Robinson, S., J R. Arrowsmith, D. E. Granger, and F. M. Phillips. 1999. Using remote sensing and cosmogenic nuclides to determine spatial variability and timing of alluvial fan deposits. Presented at *Annual Meeting of the Geological Society of America*.

Vining, E. C., J. B. Gallaher, and T. A. Day. 1999. Effects of urban ground cover on microclimate and landscape plant performance. Presented at August, *84^{th} Annual Meeting of the Ecological Society of America*, Spokane, WA.

Wu, J. 1999. CAP LTER: Integrating ecological and socioeconomic patterns and processes. Presented at January, *Social Capital Modeling Workshop*, Indiana University.

Wu, J. 1999. New perspectives in landscape ecology. Presented at June, Inner Mongolia University.

Wu, J. 1999. Hierarchical patch dynamics and landscape ecology. Presented at June, *Second International Symposium on Moderal Ecology*, Beijing, People's Republic of China.

Wu, J. 1999. Effects of disturbance on metapopulation dynamics and species coexistence: When and how does space matter? Presented at 29 July-3 August 1999, *5^{th} World Congress on Landscape Ecology, International Association of Landscape Ecology*, Snowmass, CO.

Wu, J. 1999. Hierarchical modeling: A scaling ladder approach. Presented at 8-12 August 1999, *1999 Annual Meeting of the Ecological Society of America*. *Ecological Society of America.* Spokane, WA.

Wu, J., D. Jenerette, and M. Luck. 1999. A hierarchical patch dynamics approach to urban landscape ecology. Presented at the 8-12 August 1999, *Annual Meeting of the Ecological Society of America*, Spokane, WA. *Ecological Society of America Abstracts*, p. 215.

Wu, J., and J. F. Reynolds. 1999. Linking pattern and process using hierarchical patch dynamics modeling (HPDM). Presented at 29 July-3 August 1999, *5^{th} World Congress on Landscape Ecology, International Association of Landscape Ecology*, Snowmass, CO.

1998

Burns, E. K., P. Gober, and K. Knowles-Yánez. 1998. Rural-to-urban land conversion in Phoenix: The ecology of a city. Presented at 15-16 October 1998, *NSF Long-Term Ecological Research Coordinating Committee*, Madison, WI.

Burns, E. K., K. Knowles-Yánez and P. Gober. 1998. The changing urban fabric of the Phoenix metropolitan area: Focus on the urban fringe. Presented at 15-16 October 1998, *Arizona Planning Association Annual Conference*, Phoenix, AZ.

Edmonds, J. W., N. B. Grimm, P. Westerhoff, P., and S. G. Fisher. 1998. Spatial variation in organic matter quality in natural ecosystems: A determinant of microbial decomposition rates. Presented at June 1998, *Annual Meeting, North American Benthological Society*, Prince Edward Island.

Grimm, N. B., and C.L. Redman. 1998. Human and ecological sciences at the urban crossroads: central Arizona - Phoenix Long-Term Ecological Research. Presented August 1998, *Special LTER Session on Urban Ecosystems, Annual Meeting, Ecological Society of America*, Baltimore, MD.

Grove, J. M., C. L. Redman, S. T. A. Pickett, and N. B. Grimm. 1998. An hierarchical, patch dynamics approach to the long term study of urban ecological systems. Presented at May 1998, *Seventh International Symposium on Society and Resource Management: Culture, Environment, and Society*, Columbia, MO.

Hope, D., N. B. Grimm, and C. L. Redman. 1998. The Central Arizona-Phoenix (CAP) LTER: a new opportunity for urban ecological research. Presented August 1998, *Urban Ecosystems session, Annual Meeting, Ecological Society of America*, Baltimore, MD.

Hostetler, M. E. 1998. Scale and the design of urban landscapes for birds: A potential to integrate planning and design with the natural sciences. Contributed paper, 15-19 July 1998, f*or the Shire Conference: teaching ecology in landscape design and planning programs - from theory to practice.*

Knowles-Yánez, K., E. K. Burns, and P. Gober. 1998. Urban fringe morphology of metropolitan Phoenix. Presented at October, *Arizona Planning Association Annual Conference*, Flagstaff, AZ.

McIntyre, N. E. 1998. Arthropods in urban environments. Presented at December, *Hexapodium Symposium*, University of Arizona Insect Science, Tucson, AZ.

Moreau, J. M., G. E. Morrisey, and W. L. Graf. 1998. GIS analysis of channel changes in the upper rural reach of the Salt River. Presented at August, *Arizona Geographic Information Conference*, Phoenix, AZ.

Ramsey, M. S. 1998. Urban remote sensing analysis: The Phoenix LTER project. 22-26 June 1998, *15th ASTER Science Team Meeting*, Tokyo, Japan.

Redman, C. L. 1998. Humans as part of ecosystems. Presented at May 1998, *125th Anniversary Symposium, Yellowstone National Park*, Bozeman, MT.

Stutz, J. C., and C. A. Martin. 1998. Arbuscular mycorrhizal fungal diversity associated with ash trees in urban landscapes in Arizona. Presented at November, *American Phytopathological Society/ Entomological Society of America Joint Meeting*, Las Vegas, NV.

Wu, J. 1998. The hierarchical patch dynamics molding framework for the CAP LTER. Presented at December, *LTER Modeling Regionalization Workshop*, San Diego, CA.

Wu, J., and J. F. Reynolds. 1998. Developing models across multiple scales based on hierarchy theory. Presented at 13-17 July 1998, *International Conference on Complex Systems Modeling*, New Orleans, LA.

Wu, J., and O. L. Loucks. 1998. Hierarchical patch dynamics and scaling. Presented at 19-21 March 1998, the *International Workshop on Scaling & Modelling in Forestry: Applications in Remote Sensing & GIS*, Universite de Montreal.

LTER Symposia and Conferences

***CAP LTER Third Annual Poster Symposium*, January 19, 2001, Center for Environmental Studies, Arizona State University.**

Arrowsmith, J R., S. E. Robinson, K. Fergason, J. A. Tyburczy, S. D. Holloway, and S. E. Wood. CAPLTER geology and geophysics. (Overview poster)

Bagley, A. Projecting new growth using SAM-IM.

Berling-Wolff, S., and J. Wu. Simulating the urban growth pattern in the Phoenix metropolitan region: relating pattern to process.

Bigler, W. Before the river became a lake: Historical channel change in the Salt River, Tempe.

Bolin, B., A. Nelson, E. Hackett, D. Pijawka, M. O'Donnell, S. Smith, D. Sicotte, and E. Sadalla. South Phoenix assessment of community and environment.

Brazel, A. J., C. A. Martin, D. Hope, A. Ellis, G. Heisler, L. Baker, S. Anderson, N. Selover, L. Stabler, R. Tomalty, and J. Blair. CAP LTER climate. (Overview poster)

Bruce, C., and D. Worley. Tracking growth in the Valley of the Sun residential completions (1990-1999).

Cousins, J. R., and J. C. Stutz. Trap cultures reveal higher species richness of arbuscular mycorrhizal fungi in comparison to soil samples in the Phoenix metropolitan area.

David, J. L., and J. Wu. Developing a hierarchical patch dynamics modeling platform.

Elser, M. M., and C. Saltz. Ecology Explorers: K-12 student contributions to the CAP LTER project. (Overview poster)

Fergason, K., R. Arrowsmith, and J. Tyburczy. Investigation of changes in groundwater elevation associated with Tempe Town Lake.

Fry, J., L. Nogue, C. Patterson, and C. S. Smith. Historic Land Use Phase II.

Grimm, N. B., L. A. Baker, D. Hope, W. Zhu, J. Anderson, A. Coppola, J. Edmonds, S. Grossman-Clarke, G. D. Jenerette, A. P. Kinzig, J. Klopatek, D. B. Lewis, M. A. Luck, M. Sommerfeld, P. Westerhoff, J. Wu, and Y. Xu. Biogeochemical processes in an urban ecosystem, metropolitan Phoenix, Arizona. (Overview)

Harlan, S., A. Nelson, E. Hackett, A. Kirby, B. Bolin, D. Pijawka, T. Rex, and D. Hope. Phoenix area social survey: Long-term monitoring of social interaction, and environmental change in urban neighborhoods.

Hope, D., S. Grossman-Clarke, W. Stefanov, and P. Hyde. Modeling nitrogen dry deposition inputs to the CAP LTER urban ecosystem.

Hope, D., C. Gries, W. Zhu, S. Carroll, A. Nelson, L. Stabler, C. L. Redman, N. B. Grimm, and A. Kinzig. Application of integrated inventory to the study of urban ecosystem: An extensive 200-site field survey of the Central Arizona-Phoenix LTER. (Overview poster)

Hope, D., N. B. Grimm, J. Anderson, and M. Clary. Atmospheric deposition of major nutrients across an urban-desert gradient in central Arizona.

Jenerette, D., K. Gade, N. Grimm, D. Hope, M. Luck, W. Marussich, and J. Roach. The ecological footprint workshop: Creating an ecological and social sciences interface.

Jenerette, G. D., M. A. Luck, J. Wu, N. B. Grimm, D. Hope, and W. Zhu. Spatial patterns of soil organic matter in central Arizona.

Katti, M. and E. Shochat. Phoenix Or Tucson - Does landscape determine where Abert's Towhees choose to live?

Krutz, G., and G. Woodall. Dynamic political institutions and water policy in Central Arizona-Phoenix.

Martin, C., T. Day, J. Briggs, J. Stutz, and M. Sommerfeld. Primary productivity at the CAP LTER.

Marussich, W. A., J. MacHeffner, W. F. Fagan, and S. H. Faeth. Urban ecology: Population and community patterns. (Overview poster)

McCartney, P. Ecological informatics at CAP LTER. (Overview poster)

Nelson, A., B. Bolin, E. Hackett, D. Pijawka, E. Sadalla, D. Sicotte, D. Brewer, and E. Matranga. The ecology of risk in a Sunbelt city: A multi-hazard analysis.

Nelson, A., and S. Harlan. Labor market dynamics in a postindustrial city: A spatial and sectoral analysis of employment changes in the Phoenix MSA.

Putnam, C. Cactus Wren condos: Does urbanization affect the characteristics of Cactus Wren roost nests?

Putnam, F. ADWR groundwater model.

Rango, J., M. Tseng, and E. Shochat. 200 point survey: Vegetative arthropod community structure.

Rango, J., E. Shochat, M. Tseng, W. Fagan, and S. Faeth. Ground arthropod community composition in a heterogeneous urban environment.

Redman, C. L., and P. Gober. Human dimension of CAP LTER research. (Overview poster)

Roach, W. J., A. Coppola, and N. B. Grimm. Nutrient dynamics in arid urban fluvial systems: Canals and streams.

Shochat, E., and M. Katti. Bird species diversity in the greater Phoenix area.

Sicotte, D. Political and legal controversies over hazardous industrial waste in three central Arizona communities.

Stabler, L. B., C. A. Martin, and J. C. Stutz. Potential effects of mycorrhizal associations on urban tree carbon storage potential.

Stiles, A., and S. M. Scheiner. Analysis of desert vegetation data from the 200 sites survey.

Warren, P., and A. Kinzig. Ecological and social factors predicting avian diversity in urban parks.

Whitcomb, S. A., J. C. Stutz, and C. A. Martin. Spatial patterns of belowground respiration and related soil parameters in a simulated xeric urban landscape.

Wu, J., J. L. David, G. D. Jenerette, M. Luck, and S. Berling-Wolff. Modeling land use change and ecosystem processes of the Phoenix metropolitan landscape. (Overview poster)

Zschau, T., S. Getty, C. Gries, and T. H. Nash III. Spatial and temporal variation of elemental deposition in Maricopa County, Arizona.

LTER All Scientists Meeting 2-4 August 2000, *Long-Term Ecological Research: Unifying Principles and Global Applications*, Snowbird, UT.

Baker, K. S., B. Benson, J. Brunt, N. Gardiner, D. L. Henshaw, E. Melendez, J. Porter, P. McCartney, and D. Steigerwald. 2000. LTER information management: Paradigm shift or paradigm stretch? Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 400.

Baker, L. 2000. Ecosystem-level nutrient dynamics: Cross-comparisons. Workshop.

Bolin, R., E. Matranga, E. Hackett, E. Sadalla, D. Pijawka, D. Brewer, and D. Sicotte. 2000. Environmental equity in a Sunbelt city. *Ecological Society of America 85th Annual Meeting Abstracts* p. 370.

Bolin, R., E. Matranga, A. Nelson, E. Hackett, D. Pijawka, D. Brewer, and D. Sicotte. 2000. The ecology of risk in a Sunbelt city: A multi-hazard spatial analysis. Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 375.

Edmonds, J. 2000. Strategies for the integration of social and biological sciences. Workshop.

Elser, M. M., S. Bestelmeyer, and R. Boone. 2000. Models for linking schoolyard ecology with LTER sites: What has worked and what hasn't. Workshop.

Foster, D., N. Brokaw, B. McDowell, C. Redman, J. Thompson, and R. Waide. 2000. Importance of past and current human and natural disturbance in ecosystems. Workshop.

Grimm, N., L. Band, and D. Childers. 2000. Human modifications of hydrologic cycles: Effects on nutrient dynamics at local and regional scales. Workshop.

Grimm, N. B., and C. L. Redman. 2000. Central Arizona - Phoenix LTER: Initial studies in a southwestern urban ecosystem. Poster..

Harlan, S., A. Nelson, E. Hackett, R. Bolin, A. Kirby, and D. Pijawka. 2000. Phoenix area social survey. Poster *Ecological Society of America 85th Annual Meeting Abstracts,* p. 375.

Hope, D., J. Anderson, N. B. Grimm, and S. Boone. 2000. Atmospheric deposition across the Central Arizona - Phoenix LTER ecosystem: Some preliminary findings. Poster.

McCartney, P. 2000. The LTER network information system and beyond. Workshop.

Melack, J., T. Dunne, and N. Grimm. 2000. Development of coupled hydrological-biogeochemical models of materials transport at the landscape scale. Workshop.

Nelson, A., E. Matranga, B. Bolin, E. Hackett, D. Brewer, D. Pijawka, D. Sicotte, and E. Sadalla. 2000. The distribution of technological hazards in the greater Southwest, 1991 to 1996. Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 376.

Parmenter, B., S. Gage, S. Faeth, and N. McIntrye. 2000. Arthropod studies in the LTER network: Current assessments, cross-site activities, and future directions. Workshop.

Peterson, K. A., and C. A. Martin. 2000. Effects of planned residential community covenant codes and restrictions on vegetation structure. Poster. *Ecological Society of America 85th Annual Meeting Abstracts*, p. 392.

Rango, J., N. McIntyre, W. Fagan, and S. Faeth. 2000. Ground arthropod structure in a heterogeneous urban community. Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 373.

Redman, C. 2000. Human ecology and the LTER approach: Potential cooperation with social, behavioral, and economic scientists. Plenary presentation.

Redman, C., and M. Grove. 2000. A framework for integrating core social science areas for the LTER network and opportunities for cross-site comparisons. Workshop.

Roach, W. J., A. Coppola, and N. Grimm. 2000. Nutrient dynamics in arid urban fluvial systems: Canals and streams. Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 384.

Sicotte, D. 2000. Environmental justice struggles in central Arizona. Poster. *Ecological Society of America 85th Annual Meeting Abstracts,* p. 389.

Stabler, L. B., C. A. Martin, K. Peterson, and J. Blank. 2000. Effect of urban land use on vegetation cover and microclimate. Poster. *Ecological Society of America 85th Annual Meeting Abstracts* p. 373.

Stefanov, W. L., M. S. Ramsey, and P. R. Christensen. 2000. Monitoring urban land cover change: An expert system approach to land cover classification of the Phoenix metropolitan area. Poster. *Ecological Society of America 85^th^ Annual Meeting Abstracts* p. 387-388.

Wu, J. 2000. Hierachy and scaling. Presented as part of scaling from site to region workshop (organized by D. Peters and D. Foster).

***CAP LTER Second Annual Poster Symposium*, 19 January 2000, Center for Environmental Studies, Arizona State University, Tempe.**

Blair, J. M., M. J. Taylor, and A. Brazel. 2000. Urban climate change: Defining the magnitude of islands and oases.

Bolin, R., E. Hackett, D. Pijawka, E. Sadalla, D. Brewer, E. Matranga, and D. Sicotte. 2000. Environmental equity in a Sunbelt city.

Clark, K. B., G. D. Jenerette, and J. J. Rango. 2000. Heterogeneous urban landscape structural effects on desert remnant bird species assemblages in Phoenix, Arizona.

Compton, M., J. Hunter, and M. Sommerfeld. 2000. Urban lakes – relationships between source water, lake age, water chemistry, and biota.

Cousins, J. R., and J. C. Stutz. 2000. Arbuscular mycorrhizal fungal species composition, richness, and abundance in the Phoenix metropolitan area.

Edmonds, J., D. Hope, and N. Grimm. 2000. Spatial and temporal trends in surface waters moving through the Phoenix metropolitan area.

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Swanson, S. J. 1999. Predicting biomass in the Phoenix Basin: integrating time series and spatial analysis of environmental data.

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Wu, J., and D. G. Jenerette. 1999. Simulating the spatial and temporal dynamics of urban landscapes: model structure and preliminary results.

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Zhu, W., D. Hope, and C. Gries. 1999. Studying urban patches in broad spatial and long-term temporal scales: A case example from Phoenix metropolitans.

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Theses and Dissertations

In Progress

Anderson, S. Synthesizing spatio-temporal data for detecting and analyzing geographic change: A case study on urban change (Ph.D., Geography, E. Wentz).

Applegarth, M. Pediment controls in the Sonoran Desert (Ph.D., Geography, R. Dorn).

Bigler, W. Environmental History of the Salt River, Phoenix (Ph.D. Geography, W. Graf).

Clark, K. Vertebrate species composition of desert islands in Phoenix (M.S., Biology, R. D. Ohmart).

Damrel, D. A horticultural flora of the ASU Arboretum (M.S., Plant Biology, D. J. Pinkava).

Edmonds, J. W. Understanding linkages between dissolved organic carbon quality and microbial and ecosystem processes in Sonoran Desert riparian-stream ecosystems" (Ph.D., Biology, N. B. Grimm).

Fergason, K. Microgravity monitoring of Tempe Town Lake hydrogeology (M. S., Geology, J R. Arrowsmith and J. Tyburczy).

Goettl, A.C. What limits primary production in Indian Bend Wash? (M.S. Biology, N. B. Grimm).

Holloway, S. Proterozoic and Quaternary geology of Union Hills, Arizona (M.S., Geology, J R. Arrowsmith).

Honker, A. A river sometimes runs through it: a history of Salt River flooding and Phoenix.(Ph.D., History, P. Iverson and S. Pyne).

Jenerette, G.D. Scale dependence of terrestrial nitrogen storage (Ph.D., Biology, J. Wu and N. B. Grimm).

Luck, M. A. A landscape analysis of the spatial patterns of human-ecological interactions (M.S. Biology, J. Wu and N. B. Grimm).

Oleksyszyn, M. Native-exotic vegetation interactions in abandoned agricultural fields (M.S., Plant Biology, J. C. Stromberg).

Peterson, K. A. Assessing impacts of socioeconomic factors and residential community ordinances on new urban landscape vegetation patterns (M.S., Plant Biology, C. A. Martin).

Riley, S. Decay of the convective boundary layer in a stratified atmosphere (M.S., Mechanical and Aerospace Engineering, H. J. S. Fernando).

Roach, W. J. Nutrient dynamics in arid urban fluvial systems: How changes in hydrology and channel morphology impact nutrient retention (Ph.D., Biology, N. B. Grimm).

Roberge, M. Desert urban hydrology: Human encroachment onto hillslope and channel systems (Ph.D., Geography, R. Dorn).

Robinson, S. E. Understanding Quaternary landscape development in the Phoenix area using remote sensing and cosmogenic dating (Ph.D., Geology, J R. Arrowsmith and P. R. Christensen).

Sicotte, D. Political and legal controversies in central Arizona communities facing possible contamination with hazardous industrial waste (Ph.D., Sociology, E. J. Hackett).

Stabler, L. B. The urban forest and microclimate: Interactive and feedback effects on CO_2 and water cycling (M.S., Plant Biology, C. A. Martin).

Stiles, A. Influence of urbanization on vascular plant species diversity within desert remnant patches (Ph.D., Plant Biology, S. Scheiner).

Stuart, G. Surface and subsurface pollen records of the Phoenix area (Ph.D., Anthropology, J. Schoenwetter).

Vining, E. Plant-microclimate interactions (M.S., Plant Biology, T. Day).

Whitcomb, Sean A. Belowground spatial patterns and dispersal of arbuscular mycorrhizal fungi in an arid urban environment (M.S., Plant Biology, J. C. Stutz).

Xu, Y. A spatial model of N cycling within the Phoenix metropolitan ecosystem (Ph.D.,Civil and Environmental Engineering, P. Johnson and L. Baker).

Completed

Compton, M. A. 2000. A comparative study of desert urban lakes receiving well, canal, and effluent source waters. 137 p. (M.S., Plant Biology, M. Sommerfeld).

McPherson, N. 1999. Fate of 50 years of fertilizer N application sin the Phoenix ecosystem (M.S., Civil and Environmental Engineering, L. Baker).

Stefanov, W. L. 2000. Investigation of hillslope processes and land cover change using remote sensing and laboratory spectroscopy (Ph.D., Geology, P. R. Christensen).

Zschau, T. 1999. Effects of a copper smelter on desert vegetation: A retrospective after 26 years (M.S., Plant Biology, T. H. Nash).

Books, Book Chapters, and Conference Proceedings

In Press

Grimm, N. B., L. J. Baker, and D. Hope. In press. An ecosystem approach to understanding cities: Familiar foundations and uncharted frontiers. In *Understanding urban ecosystems: A new frontier for science and education*, A. R. Berkowitz, K. S. Hollweg, and C. H. Nilon, eds. Springer-Verlag, New York, NY.

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Brazel, A. J., A. Anderson, and N. Selover. 1999. Microclimate and housing waves along the urban fringe, In *Proceedings Biometeorology and Urban Climatology at the Turn of the Millennium*, Int. Congress of Biometeorology & Int. Conference on Urban Climatology, 8-12 Nov. Sydney, AU (Preprint Paper on CD ROM).

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Reynolds, J., and J. Wu. 1999. Do landscape structural and functional units exist? Pp. 273-296 in *Integrating hydrology, ecosystem dynamics, and biogeochemistry in complex landscapes*, edited by J. D. Tenhunen and P. Kabat. John Wiley, Chichester.

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Gober, P. E., E. K. Burns, K. Knowles-Yánez, and J. James. 1998. Rural-to-urban land conversion in metropolitan Phoenix. Pp. 40-45 in *Arizona policy choices*, J. S. Hall, N. J. Cayer, and N. Welch, eds. Morrison Institute for Public Policy, Arizona State University, Tempe.

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Grimm, N. B. 1997. Opportunities and challenges in urban ecological research. November, Pp. 90-96 in *Proceedings of the International LTER Network Conference*, Taipei, Taiwan.

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In Press

Bolin, B., E. Matranga, E. J. Hackett, E. K. Sadalla, K. D. Pijawka, D. Brewer, and D. Sicotte. In press. Environmental equity in a Sunbelt city: The spatial distribution of toxic hazards in Phoenix, Arizona. *Environmental Hazards*.

Fagan, W. F., E. Meir, S. Carroll, and J. Wu. In press. The ecology of urban landscapes: Modeling housing starts as a density-dependent colonization process. *Landscape Ecology*.

Graf, W. L. In press. The fluvial imperative: Connecting science and policy for America's rivers. *Annals of the Association of American Geographers*.

Hope, D., S, Palmer, M. F. Billett, and J. J. C. Dawson. In press. Carbon dioxide and methane evasion from a temperate peatland stream. *Limnology and Oceanography*.

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In Review

Baker, L. A., Y. Xu, L. Lauver, D. Hope, and J. Edmonds. Nitrogen balance for the Central Arizona-Phoenix ecosystem. Submitted to *Ecosystems*.

*Dawson, J. J. C., M. F. Billett, and D. Hope. In review. Diurnal variations in the carbon chemistry of two acidic upland streams in NE Scotland. *Freshwater Biology*.

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*CAP LTER fully supported Field Project Manager Dr. Diane Hope during the time she wrote these articles.

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Christensen, P. R., J. Bandfield, V. E. Hamilton, D. Howard, M. Lane, J. Piatek, S. W. Ruff, and W. L. Stefanov. 2000. A thermal emission spectral library of rock-forming minerals. *Journal of Geophysical Research* 105:9,735-9,739.

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Grimm, N. B., J. M. Grove, S. T. A. Pickett, and C. L. Redman. 2000. Integrated approaches to long-term studies of urban ecological systems. *BioScience* 70:571-584.

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Lauver, L., and L. Baker. 2000. Wastewater reuse: Implications for nitrogen export and retention in the Phoenix ecosystem. *Water Research* 34:2734-2760.

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Westerhoff, P., and D. Anning. 2000. Concentrations and characteristics of organic carbon in surface water in Arizona: Influence of urbanization. *Journal of Hydrology* 236:202-222.

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Zipperer, W. C., J. Wu, R. V. Pouyat, and S. T. A. Pickett. 2000. The application of ecological principles to urban and urbanizing landscapes. *Ecological Applications* 10(3):685-688.

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Aitkenhead, J., D. Hope, and M. F. Billett. 1999. The relationship between dissolved organic carbon in streamwater and soil organic carbon pools at different spatial scales. *Hydrological Processes* 13(8):1289-1302.

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Wu, J. 1999. Hierarchy and scaling: Extrapolating information along a scaling ladder. *Canadian Journal of Remote Sensing* 25(4):367-380.

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Stutz, J., and C. A. Martin. 1998. Arbuscular mycorrhizal fungal diversity associated with ash trees in urban landscapes in Arizona. *Phytopathology* 88:586.

Wu, J. 1998. Scaling-up: From cell to landscape (book review). *Ecological Engineering* 10(4): 369-371.

Reports

Submitted

Robinson, S. E., and Arrowsmith, J R. Submitted. Quaternary mapping of a desert piedmont using NS001 and TIMS remote sensing datasets. Open File Report 2000-xx, Arizona Geological Survey, Tucson, Arizona, 10 pp. and 4 plates.

Community Outreach Presentations and Miscellaneous Activities

2000

Bolin, R. 2000. Environmental equity in a Sunbelt city. April, presented in the Colloquium Series, Sociology Department, Arizona State University, Tempe, AZ.

Bolin, R. 2000. Environmental equity in a Sunbelt city. April, presented to the Science and Technology Studies Department, Rensselaer Polytechnic Institute, Troy, NY.

Fink, J. 2000. Project Phoenix 2100: Building a national urban environmental research agenda. Ecosystem Engineering Seminar presented 23 August 2000, Environmental Fluid Dynamics Program, Arizona State University, Tempe, AZ.

Nash III, T. H. 2000. Effects of copper smelter on desert vegetation: A retrospective after 26 years. Seminar presented January 2000, Department of Biogeochemistry, Max Planck Institute for Chemistry, Mainz, Germany.

1999

Gober, P. 1999. LTER and the potential for integrating social and natural science research. Paper presented 24 September 1999 to the Department of Geography, University of Toledo, Toledo, OH.

Gober, P. 1999. LTER and the potential for integrating social and natural science research. Paper presented 5 November 1999 to the Department of Geography, University of South Carolina, Columbia, SC.

Hope, D. 1999. Studying urban ecosystems: the Central Arizona-Phoenix Long Term Ecological Research project. September 1999, Seminar at Department of Biology, University of New Mexico, Albuquerque.

Hostetler, M. E. 1999. Notes from an urban ecologist: The CAP LTER project in Phoenix, AZ. February, presented to Grand Canyon University, Phoenix, AZ.

Hostetler, M. E. 1999. CAP LTER avian study in Phoenix, Arizona. March, presented to Maricopa Audubon Society, Phoenix, AZ.

Hostetler, M. E. 1999. How birds respond to urban growth and habitat fragmentation. March, presented to Arizona Aviculturist Society Monthly Meeting, Phoenix, AZ.

Hostetler, M. E. 1999. CAP LTER avian study in Phoenix, Arizona. April, presented to Birders Anonymous, Sun City West, AZ.

Shears, B. L. 1999. Potential collaborative research with the CAP LTER. January, presented to Rocky Mountain Station Management Team Meeting, U.S. Forest Service, Fort Collins, CO.

Stefanov, W. L. 1999. Using remote sensing to define patch typology. Guest lecture for the Arizona Geographic Alliance, Tempe, AZ.

1998

Knowles-Yánez, K., and E. K. Burns. 1998. The changing urban fringe. October, Arizona Planning Association, Phoenix, AZ.

Lindauer, P., and M. Elser. 1998. K-12 teachers and students involved in Central Arizona - Phoenix Long-Term Ecological Research. October, Arizona Sciences Teachers Association Conference, Mesa, AZ.

Redman, C. 1998. Students, teachers, and environmental science in the coming decade. Keynote presentation at the Arizona Science Teachers Association Conference, Mesa, AZ.

Redman, C., and B. McDowell. 1998. Urban ecology: interdisciplinary science for a sustainable future. November, Arizona State University's 60th Anniversary Celebration of Graduate Education, Tempe, AZ.

Community Outreach Publications, News Articles About CAP LTER, and Other Non-Standard Publications

2000

Boudreau, D. 2000. Going buggin'. *Chain Reaction* 2:18-20.

Boudreau, D. 2000. Phoenix: A city for the birds. *Chain Reaction* 2:21-22.

Boudreau, D. 2000. Numbers tell the story...sometimes. *Chain Reaction* 2:24-25.

Campbell, G. 2000. CAP-LTER takes research study to city streets. *ASU Insight* January 14, 2000.

Hathaway, J. 2000. Urban ecology project brings real science to K-12, gets research assistance in the bargain. *ASU College of Liberal Arts and Sciences News* Spring 2000.

Hathaway, J. 2000. IGERT program gives scientists training to tackle big questions. *Center for Environmental Studies Newsletter* 3(2):1.

Ingley, K. 2000. Desert plants don't mean water savings, study hints. *The Arizona Republic* January 20, 2000:A1, A22.

Kuby, L., ed. 2000. CAP LTER 200-point survey begins in spring! *Center for Environmental Studies Newsletter* 3(1):1.

Kuby, L., ed. 2000. Spotlights: Tim Craig's Research on bruchid beetle populations with Valley schools. *Center for Environmental Studies Newsletter* 3(1):2.

Martin, C. 2000. Spotlights: On Research: The CAP ecosystem: An urban forest in the Sonoran Desert. *Center for Environmental Studies Newsletter* 3(2):2.

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Redman, C. L. 2000. From the director's desk: Charles L. Redman. *Center for Environmental Studies Newsletter* 3(1):1.

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Webster, G. 2000. Helping out with ASU project doesn't bug E. Valley students. *East Valley Tribune* May 10, 2000.

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Grants Awarded

2000

"16th Annual Symposium of the International Association of Landscape Ecology," ($1,500). U.S. Chapter Arizona Commission on the Arts. L. Musacchio, PI.

"A Hierarchical Patch Dynamics Approach to Regional Modeling and Scaling," U.S. EPA, 1/1/2000-1/1/2003. J. Wu and D. Green, PIs.

"Ecology Explorers Summer Teacher Internship," ($25,000). Arizona Community Foundation.

"Faculty Grant-In Aid Award," 2000-2001, graduate student support. S. Harlan, PI.

"Identification of Urban Particulate Source Regions Using Remote Sensing: Classification of Landsat ETM Data for the Nogales, AZ Area," ($31,554). Southwest Center for Environmental Research and Policy, 2000-2001. P. Christensen, PI; W. Stefanov, M. Ramsey Co-PIs.

"Integrative Graduate Education and Research Training in Urban Ecology," ($2,698,494), National Science Foundation, IGERT, 2000-2005. S. Fisher, C. Redman, W. Graf, N. Grimm, E. Hackett, Co-PIs.

"Landscape Change at the Urban Fringe: Interactions Between Geology, Ecology, and Culture in Phoenix," ($3,000). Mini-Plus Grants for Interdisciplinary Team Research, Herberger Center for Design Excellence, Arizona State University. L. Musacchio, J R. Arrowsmith, and S. Robinson, Co-PIs.

Two CAP LTER Supplements: "LTER Schoolyard Supplement," ($15,000); "CAP LTER REU Supplement" ($15,000). National Science Foundation. C. Redman and N. Grimm, Co-PIs.

1999

Five CAP LTER Supplements: "CAP LTER Schoolyard Ecology Supplement" ($15,000); "CAP LTER Collections Supplement" ($50,000); "CAP LTER General Supplement" ($35,000); "CAP LTER REU Supplement" ($15,000); "Connectivity Supplement" ($149,239), Long-Term Studies Program, National Science Foundation, 1998-1999, N. Grimm and C. Redman, Co-PIs.

"Dynamics of an Urban Carbon Dioxide Dome" ($498,367). NSF Urban Initiatives Program, 1999-2002. R. Balling, PI/PD, P. Day, H.J. Fernando, P. Gober, T.Hogan, J. Klopatek, E. Wentz, Co-PIs.

"Long-Term Monitoring of Phoenix Forest Ecosystem/CAP LTER" $10,000). U.S. Department of the Interior, Forest Service, 1998-1999. N. Grimm and C. Redman, PIs

"Long-Term Monitoring of Phoenix Forest Ecosystem/CAP LTER" ($10,000). US. Department of the Interior, Forest Service, 1998-1999. N. Grimm and C. Redman, PIs.

"Observing Patterns of Prokaryotic Diversity along Land Use Gradients of the CAP LTER" ($394,440). National Science Foundation, Microbial Observatories, 1999-2003. F. Rainey, PI.

"Biological Stoichiometry from Genes to Ecosystems" ($2,842,162). National Science Foundation, Integrated Research Challenge in Environmental Biology, 1999-2002. J. Elser, W. Fagan and J. Harrison, PIs.

"Management of Nitrate-Contaminated Groundwater in the SRP Service Area" ($42,000). 1999-2001. L. Baker (PI) with P. Johnson and Ying Zu (Co-PIs).

"Assessing Impacts of Residential Community Ordinances on New Urban Landscape Vegetation Patterns" ($5,000). International Society of Arboriculture, 1999-2001. C. Martin and K. Peterson, PIs.

"Do Mycorrhizal Associations Enhance Urban Forest Carbon Sink Potential?" ($4,250). International Society of Arboriculture, 1999-2001. C. Martin, L. McDowell, and J. Stutz, PIs.

"Multi-Spectral Remote Sensing of Brush Fire Scars in Arid Urban Regions: Analysis of Future Fire and Flooding Hazards" ($325,170). NASA, Office of Earth Science, 1999-2002. M. Ramsey and J Arrowsmith, PIs.

“A Hierarchical Patch Dynamics Approach to Regional Modeling and Scaling” ($629,540). U.S. Environmental Protection Agency, STAR Grants for Research, 1999-2002. J. Wu and D. Green, PIs.

“Networking our Research Legacy,” ($720,000). NSF/BDI. 1999-2002. P. McCartney, C. Redman, C. Gries

1998

ASU Executive on Loan to City of Phoenix, 1998-1999, through the ASU Office of the President. E.K. Burns.

Summer 1998 Undergraduate Research funding for Lisa Lauver, senior in Civil and Environmental Engineering, through the WISE program in the College of Engineering and Applied Sciences. NSF Women in Science and Engineering Program. E.K. Burns and L.A. Baker.

Four Supplements to CAP LTER: “CAP LTER Schoolyard Ecology Supplement” ($15,000); “CAP LTER Curation Supplement” ($50,000); “CAP LTER General Supplement” ($50,00); “CAP LTER REU Supplement” ($15,000). Long Term Studies Program, National Science Foundation, 1998-1999. N. Grimm and C. Redman, PIs.

“Scientist/Teacher Partnerships for the Environment” ($50,000 cash; $50,000 in kind (equipment and services)). Funded by Motorola Corporation.

Datasets, 1997-2000

PROJECT	DATASET	ACCESS	ONLINE	CLASS	CORE AREA
Aquatic Core Monitoring (Continuation of NAWQA)	Aquatic Core Monitoring Dataset	public	in prep	primary	Nutrients
Assessing Biodiversity of Arbuscular Mycorrhizal Fungi	Fungi Dataset		in prep	primary	Populations
Atmospheric Deposition	Atmostpheric deposition study	public		primary	Nutrients
Bird Survey with Data Synthesis	Bird transect survey dataset	public	in prep	primary	Populations
Century-scale Channel Change	Channel Change Dataset	public	in prep	primary	Geosciences
Comparison Among Residential Patch Transition Types; Before-After	Residential Patch Types Dataset		in prep	primary	Primary Production
Ecological and Economical Benefits of Tree Cluster Design in Urban Parks	Urban parks bird survey	public		primary	Primary Production
Ecology Explorers	Ecology Explorers Arthropod survey	public	1999	primary	K-12
Ecology Explorers	Ecology Explorers Bird survey	public	1998	primary	DB/Remote Sensing/GIS
Ecology Explorers	Ecology Explorers Bruchid Beetle study	public	1998	primary	DB/Remote Sensing/GIS
Establish pilot GIS database	Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Administrative Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Arizona Boundary	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	City Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Lunch Areas	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Maricopa County Boundary	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Photo 1993 locations	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Photo 1996 locations	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Planning boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Pnlfcd Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Project Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Quadrangle Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Sht_bnd Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Supervisory Boundaries	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Agricultural areas	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hospitals	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Industrial areas	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Landfill areas	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	MAG Landuse classification	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Cultural	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Cultural	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Population	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Solid waste disposal	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Structural	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	FP FCD Floods	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	FEMA	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hazardous zones	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	RM FCD	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	RM FEMA	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	SPWBLN1	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Spwbln2	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	floods - Spwbln2	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods - Spwzn2	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods - Swe_fcd	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods - Swe_fema	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods Spwbln3	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Thalweg position	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Floods - Xs_fcd	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Elevation points	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Elevation index	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Ele_ln	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso10-93	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso12-78	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso1-93	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso2-100	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso24-10	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso24-2	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso24-25	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso24-50	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso2-78	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso2-80	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso2-93	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso6_10	restricted	1999	acquired	DB/Remote Sensing/GIS

PROJECT	DATASET	ACCESS	ONLINE	CLASS	CORE AREA
Establish pilot GIS database	iso6_100	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso6_2	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso6_25	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso6_5	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso6-72	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso7-92	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso8-54	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	iso8-63	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Natenv	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	ls24-100	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Obser_gg	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Rainfall GG	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Repeater	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Soil	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Vegetation	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Assr. Book	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Centroid	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Parcels	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	State Land	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	DR INQ	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Drntocln	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Drtocpt	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hydrology	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hydrology MP	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Lakes	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Watershed	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Envrntr	restricted	1999	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	30 Minute Digital Elevation Model		1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	1:250000 scale Digital Elevation Model of CAP LTER study area		1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Statewide coverage of Indian reservation land in Arizona	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Geologic Faults		1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Geologic formations in Arizona	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Bureau of Mines Minerals Availablity System (MAS) data set	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Spring locations in Arizona	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Major soils and some minor soils groups	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Point locations of various cities and towns	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Township and range grid lines	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Incorporated city boundaries	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	U.S. Congressional Districts	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Individual county and an appended statewide coverage	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Arizona Actual Vegetation, 1993	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Arizona's natural vegetation	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hydrologic unit code areas	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Interstate highways	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Irrigated lands in Arizona in the early 1960's	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Lakes in Arizona	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Public Land Survey system data (Township, Range and Section), land Ownership and county	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Point data for the Census landmarks	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Arizona's natural vegetation	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	7.5 minute quadrangle boundaries	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Riparian vegetation associated with perennial waters	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	School Districts	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Hydrography consisting of linear features, i.e. streams	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	Wilderness Areas	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	State boundary coverage	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	USGS Digital Raster Graphics	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	USGS Digital Orthophoto Quarter Quads	public	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	ctract - census tract information	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	exlu95 - 1995 existing land use map	restricted	1998	acquired	DB/Remote Sensing/GIS

PROJECT	DATASET	ACCESS	ONLINE	CLASS	CORE AREA
Establish pilot GIS database	dsrtsp	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	dvlp - development	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	edist - education districts	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	genplan - general land use plan	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	magstrt - MAG Street layer	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	marblock	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	emp - employment demographics	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	exlu90 - 1990 existing land use map	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	mpa96	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	pinblock	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	raz96	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	rez98q2 - 1998 reservation layer	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	rez96q2 - 1996 reservation layer	restricted	1998	acquired	DB/Remote Sensing/GIS
Establish pilot GIS database	rez97q2 - 1997 Reservation layer	restricted	1998	acquired	DB/Remote Sensing/GIS
Gender and Racial/Ethnic Inequality in Postindustrial Urban Labor Markets: A Spatial and Sectoral Analysis of Employment Changes	Labor Market summary data	public		secondary	Land Use Changes
Gender and Racial/Ethnic Inequality in Postindustrial Urban Labor Markets: A Spatial and Sectoral Analysis of Employment Changes	Census Data 1980	restricted		acquired	Land Use Changes
Historic Records of Climate in Valley	Climate Change dataset	public	in prep	secondary	Geosciences
Historic Records of Climate in Valley	Monthly climate data for phoenix and wickenburg	public		secondary	Geosciences
Historical Land Use Database	Landuse in Phoenix, Phase 2	public	in prep	secondary	Land Use Changes
Historical Land Use Database	Land use change in Phoenix: Phase I	public	1999	secondary	Land Use Changes
Hohokam Canals and Multi-Use Facilities	Hohokam Canals Cover	public	1998	secondary	DB/Remote Sensing/GIS
Lichen Resurvey with Heavy Metal Analysis	Lichens Resurvey Dataset		in prep	primary	Nutrients
Multi-Temporal Remote-Sensing Data Acquisition for CAP LTER Land Cover/Land Use Monitoring and Modeling	Landsat TM data	restricted	1998	acquired	Geosciences
Nutrients and Data Synthesis, Mass Balance	Dairy farm locations	public	in prep	secondary	Nutrients
Nutrients and Data Synthesis, Mass Balance	Arizona wells water quality database	Restricted	in prep	acquired	Nutrients
Nutrients and Data Synthesis, Mass Balance	Wastewater reuse, recharge, and discharge	restricted	1998	acquired	Nutrients
Pilot Arthropod Sampling	Arthropod monitoring data	public	in prep	primary	Populations
Plant Species Richness Patterns in the CAP LTER Area	Phoenix flora database	public	in prep	secondary	Populations
Plant Survey of Current Vegetation	Desert plant Survey Dataset		in prep	primary	Populations
Point Count Bird Censusing	Bird survey point count	public		primary	Populations
Quaternary Geomorphology Study and Data Synthesis	Quaternary Geomorphology Dataset	public	in prep	primary	Geosciences
Scorpions in Urban Environments	Scorpion	public	in prep	primary	Populations
Survey 200	Survey 200 monitoring dataset	public		primary	Populations
The Effects of Urbanization on Reproduction in Birds	Bird physiology study	public		primary	Populations
Urban Fringe Morphology	Urban Fringe Morphology Dataset		in prep	secondary	Land Use Changes
Urban Lakes: Recipient Systems for Nutrients and Contaminants	Urban Lakes Dataset		in prep	primary	Nutrients
Using Remote Sensing to Define Patch Typology	Land cover classification of the CAP LTER Study area	public	in prep	secondary	DB/Remote Sensing/GIS
Vertebrate Species Composition of Remnant Desert Islands within Urban Phoenix	Vertebrate species survey of desert remnants	public	in prep	primary	Populations

APPENDIX B
PARTICIPANTS

Principal Investigators/Project Directors

Nancy B Grimm, Biology	1997-present	Charles L Redman, Center Env Studies	1997-present

CoPrincipal Investigator(s)

Stuart G Fisher, Biology	1997-present	Stanley H Faeth, Biology	1997-present
Jianguo Wu, Life Sciences ASU W	1997-present	William F Fagan, Biology	1997-present
Alfredo G de los Santos, Maricopa Comm Colleges	1997-present	Patricia Gober, Geography	1997-present
		Jeffrey M Klopatek, Plant Biology	1997-present
Steve S Carroll, Biology	1997-present	Thomas H Nash III, Plant Biology	1997-present
Lawrence A Baker, Civil/Env Eng	1997-present	Michael B Ormiston, Economics	1997-2000
Elizabeth K Burns, Geography	1997-present	K David Pijawka, Plng/Lndscpe Des	1997-present
Phillip R Christensen, Geology	1997-present	Milton R Sommerfeld, CLAS/Plant Bio	1997-present
Thomas A Day, Plant Biology	1997-present	Frederick A Staley, Curr/Instruction	1997-present

CoPIs, Geoscience/Engineering Supplement, 1997-1999

Ramon Arrowsmith, Geology	1997-present	Sandra L Houston, Civil/Env Eng	1997-present
William L Graf, Geography	1997-2000	Frederick R Steiner, Plng/Lnds Arch	1997-present

Senior Personnel: Managers

Corinna Gries, Analytical Lab Mgr.	2000-present	Peter H McCartney, Info Mgr, CES	1997-present
Diane Hope, Field Project Mgr, CES/Bio	1997-present	Brenda L Shears, Admin Proj Mgr, CES	1997-present

Senior Personnel: Core Scientists

James R Anderson, Mech/Aero Eng	1997-present	Michael Kuby, Geography	1997-1999
Robert C Balling, Geography	1997-present	Leslie R Landrum, Plant Biology	1998-present
C. Michael Barton, Anthropology	1997-present	Theresa A Markow, Plant Biology	1997-1998
Neil S Berman, Chem/Mat Eng	1997-present	Chris A. Martin, Plant Biology	1997-present
Robert Bolin, Sociology	1999-present	James W. Mayer, Ctr for Solid State Sci	1998-1999
Ward W Brady, Resrce Mgmt, ASU E	1997-1999	Rob Melnick, Morrisson Institute	1997-present
Anthony J Brazel, Geography	1997-present	Laura R Musacchio, Plng/Lnds Arch	1999-present
John M Briggs, Plant Biology	1999-present	Michael Musheno, Center for Urban Inq	1997-1999
Timothy P Craig, Life Sciences, ASU W	1997-present	Margaret C Nelson, Anthropology	1998-present
Lisa C. DeLorenzo, Public Affairs	1999-2000	Robert D Ohmart, Biology	1997-present
Pierre Deviche, Biology	2000-present	David L Pearson, Biology	1997-present
Ronald I Dorn, Geography	1997-present	Donald J Pinkava, Plant Biology	1997-present
Michael E Douglas, Biology	1998-present	Stephen J Pyne, Biology	1998-present
James F Eder, Anthropology	1997-1999	B.L. Ramakrishna, Plant Biology/CSSS	1999-present
James J Elser, Biology	1997-present	Michael Ramsey, Geology	1997-present
Joseph M. Ewan, Plng/Lnds Arch	1999-present	Glen E Rice, Anthropology	1997-present
Patricia L Fall, Geography	1997-present	Edward K Sadalla, Psychology	1998-present
H J S Fernando, Mech/Aero Eng	1997-present	Samuel M Scheiner, Life Sci, ASU W	1997-present
Peter Fox, Civil & Environmental Engr	1997-1999	Arleyn W Simon , Anthropology	1997-present
Jana Fry, GIS Lab	1997-present	Andrew T. Smith, Biology	1998-1999
Douglas M Green, Resrce Mgmt, ASU E	1997-present	Katherine A Spielmann, Anthropology	1997-present
Corinna Gries, Plant Biology	1997-present	Juliet C Stromberg, Plant Biology	1997-present
Edward J Hackett, Sociology	1998-present	Edward Stump, Geological Sciences	1997-1998
Sharon Harlan, Sociology	1999-present	Jean C Stutz, Plant Biology	1998-present
Timothy D Hogan, Economics	1997-present	Stanley R Szarek, Plant Biology	1998-present
Paul C Johnson, Civil/Env Eng	1997-present	Elizabeth A Wentz, Geography	1997-present
Mary R Kihl , CAED/Herberger Ctr	1997-present	Paul C Westerhoff, Civil/Env Eng	1997-present
Bradley Kincaid, Mesa Comm College	1997-1998	Susan Wyckoff, Physics & Astr/ACEPT	1997-present
Ann P. Kinzig, Biology	1999-present	James A Tyburczy, Geology	1998-present
Carol C Klopatek, Microbiology	1997-1999	Sander van der Leeuw, Sorbonne, Paris	1999-present
Glen S. Krutz, Political Science	1999-present	Rita Walton, Maricopa Assn of Govts	1997-present

Postdoctoral Research Associates

Suzanne Grossman-Clarke, Mech/Aero Eng /CES	2000-present	Amy L Nelson, CES	1999-present
Mark Hostetler, CES/Biology	1997-1999	Eyal Shochat, CES/Biology	2000-present
Madhusudan V Katti, CES/Biology	2000-present	William Stefanov	2000-present
Kimberley Knowles-Yanez, CES	1997-1999	Paige Warren, Biology	2000-present
David B Lewis, CES/Biology	2000-present	Russell Watkins, CES	1999-2000
Nancy E McIntyre, CES/Biology	1997-2000	Wanli Wu, CES/Biology	2001-present
Markus Naegeli, Biology	1998-1999	Weixing X Zhu, CES/Biology	1999-2000

Other Collaborators

Dave Anning, USGS	1998-present	Charles Kazilek, Life Sciences Vis Lab	1999-present
Barbara Backes, Life Sciences Vis Lab	1999-present	John Keane, Salt River Project	1997-present
Laural Casler, Life Sciences Vis Lab	2000-present	Robert Minckley, Auburn University	1999-2000
Ken Fossum, USGS	1998-present	Fred Rainey, Louisiana State University	
Steve Getty, University of New Mexico	1998-1999		

Research Technical Personnel

Michael Baker, P/T Aide/Birder, CES	1998-2000	Alejandria Mejia, Plant Biology/Herbrm	1998-2000
Damon Bradbury, Tech, CES	1998-1999	Michael Myers, Research Spec, CES	1998-2000
Amalya Budet de Jesus, P/T Tech, CES	2000-2000	Theodore Oliver, Comp Dbse Spec, CES	1997-1999
Adam Burdick, Biology	1998-1999	Sandra Palais, Seidman Res Inst, ASU	1997-present
Michael Clary, Tech, CES	2000-present	Wayne Porter, Com Datbse Spec, CES	2000-present
Roy Erickson 2000-present	2000-present	Seth Paine, P/T Research Tech, CES	2000-present
Tracy Flores, Tech, CES	2000-present	Sarah Quinlivan	2000-present
Kaberi Ka Gupta, CES, Data Entry	2000-present	Beverly Rambo, P/T Aide; Birder, CES	1998-present
Shero Holland, Tech, CES	1998-2000	Tom Rex, Seidman Res Inst, ASU	1997-present
Thomas Hulen, P/T Aide/Birder, CES	1998-1999	Stephen Rosales, Com Datbse Spec, CES	1999-2000
Meryl Klein, P/T Tech/Birder, CES	1998-1998	Melissa Rossow, Plant Biology/ Herbrm	1999-1999
Cathy D Kochert, Research Spec, Bio	1999-present	C. Scott Smith, IT GIS Lab	1998-present
Kelly Lazewski, Tech, CES	Spring 2000	Diana Stuart, Res. Aide, CES	1999-present
Jomarie Lemmer, P/T Birder, CES	1999-2000	Maggie Tseng, Research Spec, Bio/CES	1997-present
Matthew Luck, GIS Research Spec, CES	2000-present	Jaqueline Walters, Research Spec, CES	1997-2000

Public Outreach Personnel

Monica Elser, Education Liaison, CES	1998-present	Peggy Lindauer, Education Liaison, CES	1997-1998
Lauren Kuby, Community Liaison, CES	1998-present	Charlene Saltz, Env Edu. Coor, CES	2000-present
Kathryn Kyle, Exec Admin, SCENE	1997-present	Susan Williams, Education Liaison, CES	1999-2000

Office Personnel

Shirley A. Stapleton, CES	1997-present	Cindy D Zisner, CES	1997-present
Linda K Williams, CES	1997-present	Kathleen A Stinchfield, CES/Biology	1997-present

Graduate Research Associates

Sharolyn Anderson, Geography	1999-2000	Kenneth Fergason, Geology	1999-2000
Stephen Ammerman, History	1998-1999	Wei Gao, Geography	Spring 1998
Todd D Becker, Economics	1998-1999	Aisha M Goettl, Biology	2000-present
Sheryl Berling-Wolff, Plant Biology	2000-present	Root Gorelick, Economics/Biology	1999-2000
JoAnne Blank, Plant Biology	2000-present	Dennis C Gosser, Anthropology	1998-1999
Karen E Blevins, Geography	1998-1999	Dennis Hale, Curr/Instruction	1997-1998
Debbie A Brewer, Geography	1999-2000	Stephen D Holloway, Geology	1997-1998
Kevin B Clark, Biology	1998-1999	Andrew M Honker	1999-2000
Mark A Compton, Plant Biology	1998-2000	Justin S Hoppman, Plng /Lndscp Arch	1998-2000
Jamaica Cousins, Plant Biology	1999-2000	Jeffrey James, Geography	Spring 1998
Dixie Z Damrel, Plant Biology	1998-1999	G Darrel Jenerette, ASU W Life Sci	1998-present
Lisa Dent, Biology	Summer 1998	Michael LaBianca, Sociology	Summer 2000
Dean Dobberfuhl, Geology	1998-1999	Hongyu Liu, Life Sciences, ASUW	Fall 1997
Jennifer W Edmonds, Biology	1998-present	Matthew A Luck, Biology	1998-2000

Joaquin Maruffo	1998
Wendy A Marussich, Plant Biology	1999-present
Eric S Matranga, Geography	1999-2000
Nicole McPherson, Civil/Env Eng	1998-1999
Cherie Moritz, Plant Biology/GIS	Fall 1998
Erin Vining Mueller, Plant Biology	1998-1999
Leslie Nogue, Anthropology	2000-present
Michelle M Oleksyszyn, Plant Biology	1998-1999
Alanna E Ossa, Anthropology	1998-1999
Gemma Paulo, Economics	Spring 1998
Kathleen A Peterson, Plant Biology	1999-2000
Jessamy Rango, Biology	1998-present
Eva C Reid, Geography-GIS Lab	1999-2000
Martin Roberge, Geography	1998-1999
Sarah Robinson, Geological Sciences	1998-present
Michael Rogers, Curr/Instruction	1998-1999
Bruce Ryan, Plant Biology	Summer 1999
Samuel Schmieding, History	1998-1999
Diane M Sicotte, Sociology	1998-present
Curtis Sommer, Anthropology	1999-2000
Kim Sonderegger, Anthropology	1998
L Brooke McDowell Stabler, Plant Bio	1998-present
William L Stefanov, Geology	1998-2000
Arthur Stiles, Plant Biology	1998-present
Glenn Stuart, Anthropology	1999-present
Anne Sumner, Curr/Instruction	1999-2000
Steven J Swanson, Anthropology	1998-1999
Wendy Thomas, Geography	Spring 1998
Niccole Villa, Geography	1998-1999
Gretchen Walters, Plant Biology	1998-1999
E Christian Wells, Anthropology	1998-1999
Jill Welter, Biology	Summer 1998
Sean Whitcomb, Plant Biology	2000-presnet
Gina Serignese Woodall, Political Science	1999-present
Steven Wood, Geological Sciences	1998-1998
Ying Xu, Civil/Env Eng	1998-present
Angel Zambrano, Plant Biology	1998-1999
Toralf Zschau, Plant Biology	1998-1999

Other Grads

Jeremy Buegge, Plant Bio, Eco Exp	1999
Jenny Draevich, Biology, Eco Exp	1998
John Frich, Biology, Eco Exp	1998
Elena Ortiz-Barney, Plant Bio, Eco Exp	2000-present

Research Experience for Undergrads (REU*)*

Joanne C Blank, ASU	Summer 1999
Shawn A Boone	Summer 1999
Andy H Chan	Summer 1998
Noah D Dillard, Kalamazoo College	Summer 2000
Christopher Farley	Summer 1998
Matthew de la Pena Mattozzi, Harvey Mudd College	Summer 2000
Christopher Putnam, ASU	Fall 2000
Erik J Wenninger	Summer 1998
Selena L Wightman	Summer 1999

Other Undergrads

Christopher Anto	1998-1999
Juan Beltran, Bird data entry	Summer 2000
Robert Brant, Biology	1999-2000
Matt Bucchin, GIS Lab	Fall 1998
Crystal Brillhart, Biology	2000-present
JoAnne Blank, Plant Biology	1998-1999
George Cadiente, Geological Sciences	Summer 1999
Natalie Case, Hughs BREU; urban lakes	Spring 1999
Richard Cassalata, Biology	2000-present
Linda Drummond, Plant Biology	1998-1999
Esther Ellsworth, Bio/Society, Eco Exp	1999-present
Kevin Fantozzi, Life Sci, ASU W	1998-1999
Susan Farley, Biology	2000-present
Travis Fears, IT/Ecology Exp Web site	1998-1999
Ayoola Folarin	1998-1999
Jennifer Folsom, IT/Eco Exp Web site	1998-1999
John Frich, Biology	1999-present
Cyd Hamilton, Biology	1998
Marc Hinze, Biology	1998-1999
Moe Moe Htun, Bird data entry	1998-1999
Jennifer Hunter, Hughs, urban lakes	1999
Lisa Lauver, Civil/Env Eng	1998-1999
Christian Lawrence, Biology; arthropods	1999-1999
Katie LeBlanc, Anthro, CES office supp	1997-1999
Brian Lutz, Bio/Society, Ecology Exp	1999-present
Anita Maestos, Biology	2000-present
Lisa C McKelvy, Biology; arthropods	1998-present
Cathryn Meegan, pollen tech; Anthro	Summer 2000
Randi Mendoza, Biology, Eco Exp	1999
Robert Mitchell, Biology	Spring 1998
Ellen Morrisson, St. Olaf College, MN	January 2001
Mary Nowicki, Biology	2000-present
Tracy Osborn, Civil/Env Eng	1998-1998
Chris Patterson, GIS Lab	2000-present
Christopher Putnam	2000-present
Barbara Schmidt, Plant Bio	Summer 2000
Brian Sherman, IT, Eco Exp	Spring 1998
Chris Sommers, IT/Eco Exp Web site	1998-1999
Maria Tcherepova, Plant Biology	Summer 2000
Lisa Thompson, CES, office	1998-present
Brian Tong, Birder data entry	1999-2000
Sean Walker, Biology; arthropods	1998-1999
Jennifer Zachary, Biology	1999-2000

High School Students

Sambo Dul, SCENE research intern	1999	Natalys Ter-Grigoryan, SCENE res intern	1999
Juan Gomez, Tempe HS	2000		

Pre-College Teachers

Robert Atwood, Meyer Elementary	1999-2000	Sharon Langston, Monte Vista Elem	1999-2000
Renee Bachman, W.T. Machan Elem	1999-2000	Karen Lee-Price, Moon Mntn School	2000
Joyce Baldwin, Sacaton Middle School	1998-2000	Jim Little, Rhodes Jr. HS	2000
Jim Barnette, Zedo Ishikawa Elementary	1999-2000	Marjorie McKenzie	
Paula Beacom, Lowell Elementary	1999-2000	Jim Manley, Stevenson Elementary	1998-2000
Chuck Bell, Deer Valley HS	1999-2000	Mary Martine, Kiva Elementary	2000
Wendy Blasdell, Mountain View HS	1999-2000	Vickie Massey, Mendoza Elementary	1998-2000
Dave Boomgaard, Brimhall Jr. HS	1998-2000	Stephanie Mihalic, Greenway Mid School	2000
Carole Boling, W.T. Machan Elementary	1999-2000	Birgit Musheno, Desert Vista HS	1999-2000
Scott Bowling, Discovery Elementary	1998-2000	Donna Palladino, Copper Canyon Elem	2000
Sharlene Cardona, Falcon Hill Elem	1999-2000	Gary Patterson, Skyline HS	1999-2000
Dave Carpentar, Meyer Elementary	1999-2000	Kathleen Pelley, Evans Elementary	1998-2000
Meg Davis, McKemy Middle School	1998-2000	Trish Peters, Pueblo Elementary	1999-2000
Joelle Don de Ville, St. Mary's HS	1998-2000	Kris Rademacher, Desert Vista High School	1998-1999
Ed Eberle, Dobson HS	1998-1999	Nancy Ragle, McKemy Middle School	2000
Vickie Eberle, Sunridge Learning Center	1998-1999	Lisa Randall, Stevenson Elementary	1998-2000
Ann English, Desert Eagle HS	1999-2000	Linda Sargent, Mountain View HS	2000
Michelle Fink, Meyer Elementary	1998-2000	Darlene Sitzler, Eisenhower Elementary	1998-2000
Ann Flagg, EDU Prize	1999-2000	Mike Sliskovich, Supai Middle School	2000
Gerry Foster, Mesquite HS	1999-2000	Susan Soroka, McKemy Middle School	2000
Scott Greenhalgh, Tempe Union HS	1999-2000	Kara Steiner, Mendoza Elementary	2000
Janet Henderson, Deer Valley Mid Schl	1999-2000	Joyce Sterret, Trevor Browne HS	1998-2000
Susie Huffaker, Meyer Elementary	1999-2000	Toby Tucker, Fountain Hills HS	1998-1999
Tad Int-Hout, Desert Harbot Elementary	1999-2000	Michelle Volk, Kyrene Aprende Mid Schl	1999-2000
Sue Johnson, The Family School	1999-2000	John Wallace, Mountain View High School	1998-2000
Teresa Krause, Mendoza Elementary	1998-2000	Kimberly Wilson, Kyrene Pueblo Mid Schl	2000
Larry Langstaff, Hendrix Jr. HS	1999-2000	Susan Wiseman, Arthur M. Hamilton Schl	2000

Volunteer Participants

Michelle Bagley, Bird Survey
Genine Baker, Bird Survey
Mike Baker, Bird Survey
Lois Bansberg, Bird Survey
Richard Bansber, Bird Survey
Barbara Barnes, Bird Survey
Millie Billotta, Bird Survey
Terry Brodner, Bird Survey
Joshua Burns, Bird Survey
Adam Burdick, Bird Survey
Eleanor Campbell
Evie Chadbourn, Bird Survey
Marty Chew, Bird Survey
Tillie Chew, Bird Survey
Marti Cizek, Bird Survey
JoAnn Dalcin, Bird Survey
Newilda DeFrance, Bird Survey
John Delventhal, Bird Survey
Bix DeMaree, Bird Survey
Cliff Drowley, Bird Survey
Mildred Eade, Bird Survey
Vicki Eberle, Bird Survey
Amy Elsnic, Vertebrate Species Project
Herbert Fibel, Bird Survey
Dwayne Fink, Bird Survey
Anne Fischer, Bird Survey
Craig Fischer, Bird Survey
Dick Foegel, Bird Survey
Lori Ford, Bird Survey
Jim Forrest, Bird Survey
Jeanne Frieden, Bird Survey
Thomas Gaskill, Bird Survey
Alison Grinder, Bird Survey
George Hansen, Bird Survey
Elizabeth Hatcher, Bird Survey
Helen Haukland, Bird Survey
Meg Hendrick, Bird Survey
Ted Henricks, Bird Survey
Jan Hilton, Bird Survey
William Karl, Urban Lakes Study
Mark Malone, Bird Survey
Charlotte Mars, Bird Survey
Cathy Merrill, Bird Survey
Nettie Meyers, Bird Survey
Grace Miller, Bird Survey
Sandra Mobley, Bird Survey
Carolyn Modeen, Bird Survey
Pete Moulten, Bird Survey

Roy Muehlberger, Bird Survey
Andrea Nesbitt, Bird Survey
Laurie Nessel, Bird Survey
John Nichol, Bird Survey
Maxime Parent, Bird Survey
Tom Partel, Bird Survey
Bill Peterson, Bird Survey
Stella Peterson, Bird Survey
Joan Powers, Bird Survey
Timothy Price, Bird Survey
Peg Purcell, Bird Survey
Beverly Rambo, Bird Survey
Jennie Rambo, Bird Survey
Linda Rawles, Bird Survey
Nancy Reed, Bird Survey
Diane Rhodes, Bird Survey
Steve Rissing, Bird Survey
Pat Roberston, Bird Survey
Arlene Scheuer, Bird Survey
Terry Schulte, Bird Survey
Linda Scharf, Bird Survey
Beverly Shaver, Bird Survey
Norm Shrout, Bird Survey
Jim Sommers, Bird Survey
Andree Tarby, Bird Survey
Lorraine Thompson, Bird Survey
Walter Thurber, Bird Survey
Juanita Valentyne, Bird Survey
Anita Van Auken, Bird Survey
Susie Vaught, Bird Survey
Cindy West, Bird Survey
Alice Williams, Bird Survey
Penny Wilson, Bird Survey
Marika Witenko, Bird Survey
Keith Yett, Bird Survey

Community Partners

Arizona Department of Water Resources
Arizona Department of Environmental Quality
Arizona Geographic Alliance
Arizona Historical Society Museum
Arizona Public Service
Arizona School Services through Education Technology, ASU
Arizona Science Center
Arizona State Land Dept
Arizona Tribal Coalition, UT-CO-AZ-NM-Rural Systemic Initiative
Arizona Collaborative for Excellence in Preparation of Teachers (ACEPT), ASU
City of Phoenix
City of Scottsdale
City of Tempe
Creighton School District
Deer Valley High School District
Desert Botanical Garden
Flood Control District of Maricopa County
Fountain Hills High School District
Gila River Community Schools
Gilbert High School District
Glendale School District
Maricopa Association of Governments
Maricopa Community Colleges Motorola
Maricopa County Parks and Recreation Department
Mesa Public Schools
Mesa Systemic Initiative
Office of Research Publications, ASU
Office of Youth Preparation, ASU
Peoria Unified School District
Phoenix Elementary School District
Phoenix Union High School District
Pueblo Grande Museum
Salt River Pima-Maricopa Indian Community
Salt River Project
Southwest Center for Education and the Natural Environment
St. Mary's High School
Tempe Elementary School District
Tempe Union High School District

The Phoenix Zoo
Tonto National Forest
U.S. Dept. of Agriculture
U.S. Forest Service
U.S. Geological Survey

The following businesses/organizations/agencies have given the CAP LTER project permission to conduct long-term monitoring of ecological variables on their sites:

Arizona Department of Environmental Quality
Arizona Public Service
Arizona Department of Transportation
Arizona State Land Department
Arizona State Parks
City of Phoenix
City of Chandler
City of Scottsdale
City of Tempe
Desert Botanical Garden
Duncan Family Farms
Flood Control District of Maricopa County
Honeywell
Insight Enterprises
Intel
Maricopa County Department of Environmental Services
Maricopa County Parks and Recreation Department
Morrison Brothers Ranch
Rogers Brothers Farms
Salt River Project
Sonoma Farms, Inc.
Tempe Union High School District
Tonto National Forest
Town of Fountain Hills
US Forest Service
US Geological Survey
Valley Lutheran Hospital
Dobson Ranch Homeowners Association
Dawn Lake Homeowners Association
Las Brisas Homeowners Association
Val Vista Lakes Community Association
Ocotillo Homeowner Association

APPENDIX C
CAP LTER PROJECTS, 1997-2000

No	Team	Title	Project Type	Participants*	Start Date	Status
		*Lead PI listed first, student research associates in parentheses (), techs/field assts. in brackets [], *italics* indicate former participants in ongoing projects				
1	DB	Establish pilot GIS database	Data synthesis	Fry, McCartney, Wu, Wentz (Gao, Maruffo, Swanson, Wells)	Fall 97	Completed
2	DB	Using Remote Sensing to Define Patch Typology	Long term	*Ramsey*, Christensen, Hope, Burns, Wu, Gober, Stefanov	Fall 97	Ongoing
3	LU	Urban Fringe Morphology	One time	Burns, Gober, Walton, Knowles-Yanez (James, Blevins)	Spring 98	Completed
4	DB	Modeling: Initial Structure and Work on GIS	Data synthesis	Wu (Luck)	Spring 98	Ongoing
5	GE	Century-scale Channel Change	One time	Graf (Roberge)	Spring 98	Completed
6	GE	Quaternary Geomorphology Study and Data Synthesis	One time	Arrowsmith (Robinson, Wood, Holloway)	Spring 98	Completed
7	NU	Nutrients and Data Synthesis, Mass Balance	Data synthesis	Hope, Baker, McCartney (Ying, Lauver, McPherson)	Spring 98	Completed
8	NU	Aquatic Core Monitoring (Continuation of NAWQA)	Long term	Hope, Grimm, Baker (Edmonds, Goettl)	Fall 97	Ongoing
9	NU	Lichen Resurvey with Heavy Metal Analysis	Repeat experiment	Gries, Nash, Getty (Zschau, Zambrano)	Spring 98	Completed
10	PO	Pilot Arthropod Sampling	Long term	Faeth, Fagan, McIntyre, Shochat, (Rango) [Tseng, McKelvy, Stuart]	Spring 98	Completed
11	PO	Plant Survey of Current Vegetation	Data synthesis	Scheiner (Stiles)	Spring 98	Ongoing
12	PO	Bird Survey with Data Synthesis	Data synthesis	*Hostetler*, Katti, Shochat, *Pearson*, *Ohmart*, Deviche [Stuart, Rambo, Hulen, Lemmer, Bachman]	Spring 98	Ongoing
13	ED	Ecology Explorers	Long Term	Staley, *Lindauer*, Elser, *Williams*, Kyle, (*Hale, Rogers*, *Sumners*)	Fall 97	Ongoing
14	OM	Comparison Among Residential Patch Transition Types; Before-After	One time	Martin, Brazel, Burns (Stabler, Peterson, Blank)	Spring 98	Completed
15	DI	General Model of Urban Fire Ecology	One time	Pyne (Schmieding, Ammerman)	Summer 98	Completed
16	GE	Historic Records of Climate in Valley	One time	*Balling*	Spring 98	Not conducted
17	LU	Hohokam Canals as Multi-Use Facilities	One time	Spielmann, Rice (*Sonderegger*)	Spring 98	Pending
18	HU	Economic Analysis, Open Space	One time	Hogan, Ormiston (Becker)	Spring 98	Completed
19	LU	Historical Land Use Database	Long term	Redman, *Knowles-Yanez*, Fry, McCartney, Keane (*Moritz,* Reid, Hoppman) [Smith]	Summer 98	Ongoing
20	GE	Multi-Temporal Remote-Sensing Data Acquisition for CAP LTER Land Cover/Land Use Monitoring and Modeling	Data synthesis	Ramsey, Wu, Burns, (Stefanov)	Summer 98	Completed
21	PP	Above and Below Ground Estimates of Urban Plant Biomass	Repeat experiment	Klopatek, Klopatek	Summer 98	Not conducted
22	PO	Assessing Biodiversity of Arbuscular Mycorrhizal Fungi	Repeat experiment	Stutz, Martin (Cousins)	Summer 98	Ongoing
23	PO	Vertebrate Species Composition of Remnant Desert Islands within Urban Phoenix	One time	Ohmart, Clark	Summer 98	Completed
24	NU	Urban Lakes: Recipient Systems for Nutrients and Contaminants	Long term	Sommerfeld (Compton, Hunter, Case) [Holland, Myers, Bradbury, Walters, Karl]	Summer 98	Completed
25	PO	Scorpions in Urban Environments	One time	McIntyre	Fall 98	Completed
26	PO	Effects of Urban Horticulture on Insect Pollinator Community Structure	One time	*Hostetler*/McIntyre [sample collection: Compton, Hope, Stabler, *Naegeli*, Rango, Rissing, Stefanov, Stiles, Walters, Wells, Williams, *Zhu*, Bradbury, Holland, Meyers; taxonomic id, Minckley]	Fall 98	Completed
27	PO	Survey 200	Long term	Redman, Grimm, Hope, Gries, Carroll, *Zhu*, McCartney (Stabler, Stiles) [Rosales, Myers, Clary, Lemmer, Budet de Jesus, Paine, Tseng, Walters, Kochert] other: Martin, Green, Scheiner, Brazel, McIntyre, Faeth, Nelson, Burns, Katti, Shochat, Stuart, Rainey	Spring 99	Ongoing
28	NU	Urban Storm Runoff		Hope, *Naegeli*, Grimm	Spring 99	Completed
29	LU	Are Microclimates Sustainable on the Urban Periphery of Phoenix, Arizona?	One time	Brazel (Anderson)	Fall 98	Ongoing
30	GE	Decade-Scale Change by Channel Eng: The Rio Salado (Tempe Town Lake) Project--Hydrogeologic component	One time	Arrowsmith, Tyburczy (Fergason)	Fall 98	Completed
31	NU	Atmospheric Deposition	Long term	Hope, Grimm, Anderson [Clary, Paine, *Holland, Bradbury*] (*Boone*)	Fall 98	Ongoing

32	HU	Environmental Risk	Long term	Bolin, Hackett, Pijawka, Sadalla, van der Leeuw, Nelson (Brewer, Mtranga, Sicotte)	Fall 98	Ongoing
33	PO	Backyard Bird Survey	Long term	*Hostetler*, Katti, Shochat, *Pearsom. Ohmart*, Deviche [Stuart, Rambo, Hulen, Lemmer, Bachman]	Spring 98	Ongoing
34	PO	Point Count Bird Censusing	Long term	*Hostetler*, Katti, Shochat, *Pearsom. Ohmart*, Deviche [Stuart, Rambo, Hulen, Lemmer, Bachman]	Summer 98	Ongoing
35	NU	Canal Study	One time	Grimm, Hope (Roach)	Summer 99	Completed
36	PO	Bruchid Beetle Study	Long term	Craig (Wallace)	Spring 98	Ongoing
37	LU	Spatial/Temporal Change of Climate/Air Quality in Relation to Urban Fringe Development	One time	Brazel, (Selover, Vose)	Summer 99	Ongoing
38	GE	Prediction Model of the Presence of Bedrock Pediments vs. Alluvial Slopes	One time	(Applegarth) Dorn, Brazel	Spring 00	Ongoing
39	LU	Urban Fringe Infrastructure Morphology	One time	Burns, Nelson (Sun)	Spring 00	Ongoing
40	HU	A River Used to Run Through It: Water Use and Flooding in Phoenix	One time	Honker	Spring 00	Ongoing
41	HU	Phoenix Area Social Survey	Long term	Harlan, Nelson, Hackett, Sadalla, Bolin, Pijawka, Hogan, Rex, Kirby	Spring 00	Ongoing
42	LU	Gender and Racial/Ethnic Inequality in Postindustrial Urban Labor Markets: A Spatial and Sectoral Analysis of Employment Changes	One time	Nelson, Harlan (Sicotte, LaBianca)	Spring 00	Ongoing
43	HU	Dynamic Political Institutions and Water Policy in Central Arizona - Phoenix	One time	Krutz (Serignese)	Summer 00	Ongoing
44	NU	Nutrient Transport and Retention in Urban Watersheds	Long-term	Grimm, Hope, *Zhu,* Lewis (Roach, Jennerette, Goettl, Dillard, Zachary)	Spring 2000	Ongoing
45	HU	Social Area Analysis	One time	Nelson, Martin	Summer 00	Ongoing
46	PO	The Effects of Urbanization on Reproduction in Birds	One time	Katti, Deviche	Summer 00	Ongoing
47	PO	Plant Species Richness Patterns in the CAP LTER Area (initially part of project 11)	Data synthesis	Pinkava, Landrum, (Damrel)	Spring 98	Completed
48	PP	Effects of Urban Ground Cover on Microclimate and Landscape Plant Performance (initially part of project 14)	One time	Day, (Vining Mueller)	Spring 98	Completed
49	LU	Land Use Effects on Temperature and Humidity along a Urban-Rural Transect Gradient (initially part of project 14)	One time	Martin, Brazel (Stabler)	Summer 98	Completed
50	OM	Soil CO_2 Flux and Enzyme Activity Under Two Patch Type Conversions (initially part of project 14)	One time	(Oleksyszyn) Green	Spring 98	Completed
51	PP	Landscape Water Use Efficiency (initially part of project 14)	One time	Stabler, Martin	Spring 98	Completed
52	HU	Urban Parks	Long term	Kinzig, Martin, Warren, Katti, Shochat, (Blank)	Fall 2000	Ongoing