DCDC 2004-2005
Annual Progress Report

Decision Center for a Desert City
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Compiled by
Patricia Gober
Charles Redman
Bill Edwards
Nancy Jones
Michelle Albrecht

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DCDC 2005
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Principal Investigators/Directors:
- Patricia Gober
- Charles Redman

Executive Committee:
- Patricia Gober
- Charles Redman
- James Buizer
- Bob Bolin
- William Edwards
- Grady Gammage
- Margaret Nelson
- Peter McCartney
- Tom Taylor

Staff:
- Bill Edwards
- Nancy Jones
- Michelle Albrecht
- Matt Kruger

Teams:
- Decision Science Team
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ASU ARIZONA STATE UNIVERSITY

DCDC 2005

I. Introduction to DCDC

The Decision Center for a Desert City (DCDC) investigates water decision making and management under increasing climatic uncertainty in the rapidly urbanizing desert of central Arizona. The region is beset by climatic uncertainty related to global warming, cycles of drought, flooding, other severe climate events endemic to the desert, and an intensifying and expanding urban heat island (UHI). The UHI effect alone has raised summer nighttime temperatures by 12 degrees F during the past 50 years. DCDC's long-term goals are to produce basic knowledge about the way individuals and their institutions respond to climate-induced water scarcity; to develop scenarios of the region's future based on population growth, land-use decisions, conservation practices, and climatic change; and to present scientific modeling and simulation in ASU's Decision Theater (DT), a new facility designed to visualize environmental processes and study decision making.

DCDC research is organized around three central research themes and asks the questions: *1) what are the sources of regional climate variation and change, and how do they influence water supply and demand?; 2) how do humans—operating as individuals, households, and communities—make decisions using this scarce resource?; and 3) what factors put individuals and communities at risk from climate-induced water scarcity?*

Climate Science

Climate science defines the uncertainty in and sets the limits for variability in the local and regional climate system that delivers water to a rapidly growing metropolitan region of 3.6 million in the Sonoran Desert. This research is organized around four research issues:

- Determinants of annual variation in temperature, rainfall, and drought conditions;
- Effects of global warming on temperature and precipitation;
- Potential interactions between climate change and variability; and
- Changes in magnitude and intensity of the UHI with rapid population growth and land-use change, and the effects of increasing temperatures on water demand.

Decision Science

Decision-making research explores human decisions about water use, including the markets that reconcile supply and demand, factors that influence household demand, and regional water and urban-growth policies. At scales ranging from regional and local to household and individual, research issues include:

- Urban growth and land-use decision making;
- Decisions of water managers and the environmental and economic values that underlie these decisions;
- Public attitudes about drought, water scarcity, growth, and conservation;
- Determinants of household and municipal water demand;
- Sensitivity of water demand to changes in price, media information, and climate variability; and
- Agent-based models of water decision making.

Vulnerability Analysis

Vulnerability analysis addresses the historical, political, and economic factors that place people and communities at risk of water shortage. This research activity will begin by studying scarcity in peri-urban communities—those most vulnerable to water shortages in times of drought—and then moving forward to detail the core of the metropolitan region.

- Identify the characteristics of people and places vulnerable to water shortage and increasing price—vulnerability mapping; and
- Effects of the UHI on outdoor water use—who pays the costs of increasing temperatures?

II. Highlights of Research Activities

In Year 1, DCDC supported research activities based upon its long-term mission of interdisciplinary, integrative, socially relevant investigations related to climate change and water management. High priority was assigned to proposed activities offering the following characteristics: intellectual merit and new knowledge production; relevance to decision making; likelihood of producing timely results; potential to leverage NSF funds with local support; suitability for visualization in the DT; and participation by community partners. Year 1 activities involved seven types of research projects: climate studies; urban heat island studies; public attitude surveys; decision research studies; GIS and agent-based modeling; baseline social vulnerability studies; and science and technology/boundary studies.

Climate Studies set the upper and lower limits of future water supply. Our initial climate studies have assembled historical information about temperature, precipitation, snow pack, and drought, and correlated these with large-scale climate anomalies such as El Niño Southern Oscillation (ENSO), Pacific Decadal Oscillation (PDO), Atlantic Decadal Oscillation (ADO), and sea-surface temperatures. Research focuses on determinants of climate variability and change in central Arizona and its watersheds, estimates of the upper and lower limits of temperature and precipitation, and development of credible scenarios of the region's climate future.

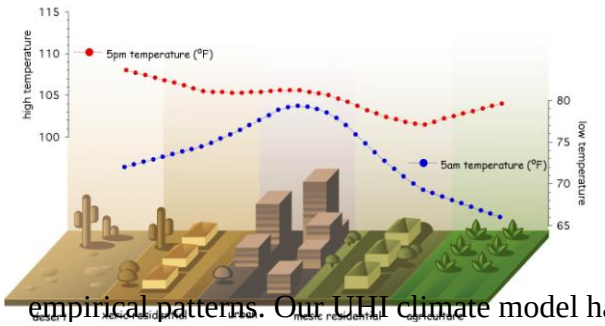

Figure 1. The UHI effect is greatest in urban areas during the night.

Urban heat island studies involve deterministic predictions of the magnitude and extent of the UHI under different land-use policies, landscaping practices, and water-conservation scenarios. Of particular scientific importance has been the effort to develop algorithms that allow specific climate prediction at the mesoscale and to test them against empirical patterns. Our UHI climate model has been joined with a planning model, UrbanSIM, ce and spatial configuration of growth. Next, the UHI nand and social vulnerability with an eye toward answering the questions: How do regional land-use decisions influence the urban climate and, in turn, how does a warmer regional climate affect landscaping decisions, water use, and social vulnerability?

Public attitude surveys reveal that individuals and water managers focus upon short-term drought more than long-term climate change and the UHI. Year 1 projects examine the human response to urban climate, both from expert and citizen perspectives. The overarching research question asks how public attitudes about urban climate respond to long- and short-term and large- and small-scale climate change.

Decision-research studies lay the groundwork for community interactions through structured studies of decisions that water managers make and the environmental and economic values that underlie these decisions. A multi-objective decision analysis will create a comprehensive catalog of concerns, identified by key stakeholders, for guiding water-resource policy in central Arizona.

GIS and Agent-based modeling enables DCDC' GIS and Decision Science teams to create innovative tools key to integrating models and building alternate scenarios. This collaboration has built a preliminary agent-based model of household water use and conservation, and they currently are constructing a prototype spatial environmental decision-support system.

Baseline social-vulnerability studies determine the sociological and organizational context for studies of community response to climate change and drought. Peri-urban communities north of Phoenix are highly vulnerable to water shortages because they rely almost exclusively upon a finite supply of groundwater and are growing rapidly. These communities are the canaries in the coal mine in terms of regional vulnerability. Systematic analysis of their evolution in response to water scarcity and their response to that scarcity suggests clues to the larger regional response to climate signals.

Figure 2. Areas most vulnerable to drought exist north of Phoenix.

Science and technology policy/boundary studies establish DCDC as a boundary organization, straddling the interface of science and policy. This research theme asks how basic research questions are defined, science is practiced and disseminated, interdisciplinary work is negotiated, success is rewarded, and the boundary between science and policy is bridged. DCDC participants are themselves subjects in an experiment about the nature of research questions, social relations, and collaborative research projects in a socially engaged, policy-relevant organization.

Decision Theater

In September 2005, ASU announced the establishment of the Decision Theater (DT), a 3-D, 270-degree immersive space designed to visualize environmental processes. Collaboration with DT was included in our original research proposal, but the DT was merely a concept at that time. As the University redirected resources to make the DT a reality and the opening was scheduled in May 2005, we accelerated research on the UHI and agent-based modeling, both topics that would be readily visualized.

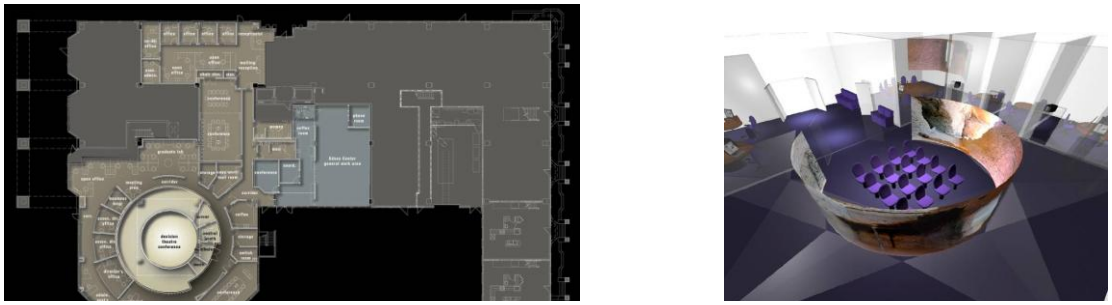

Figure 3. Architectural renderings of the Decision Theater space. The DT is located adjacent to DCDC offices.

Interdisciplinary Activities

Critical to the success of an interdisciplinary research team is nurturing the intellectual and social basis for collaboration across traditional disciplines. During Year 1, considerable effort went into building teams and formulating problems. The original research proposal argued that different questions might be asked if we remained open to the possibility that ideas would emerge from interdisciplinary research teams working with community partners. To promote team building, we hosted nine Water/Climate Briefings involving researchers and community partners, held two meetings of team leaders, and on April 25, 2005 held a DCDC-wide retreat. Researchers from the Departments of Geography, Anthropology, Mathematics, Supply Chain Management, Philosophy, Planning, Civil and Environmental Engineering, and Family and Human Development; Schools of Community Resources and Development, Public Affairs, and Life Sciences; in addition to the Morrison Institute for Public Policy, the International Institute for Sustainability, and the Barrett Honors College actively participate in DCDC research and outreach. Some 21 faculty members, one outside scientist (L. Robin Keller from the University of California-Irvine), two academic associates, one postdoctoral student, 13 graduate students, and six undergraduate students have participated in Year 1 activities.

LIST OF DCDC RESEARCH PROJECTS

- *Simulating decisions of water use in uncertain times in the Southwestern US: An Agent-Based Model of strategies and population-level changes*. William G. Griffin, Shana K. Schmidt, and Brad Armendt.
- *Implications of urban-growth patterns for heat-island effects and water use*. Joseph A. Zehnder, Susanne Grossman-Clarke, and Subhrajit Guhathakurta.
- *The impact of the urban heat island (UHI) on water use: The case of Phoenix Metropolitan Area*. Subhrajit Guhathakurta, Patricia Gober, Joseph A. Zehnder, and Susanne Grossman-Clarke.
- *Analysis of drought determinants for the Colorado River Basin*. Robert C. Balling, Jr. and Gregory B. Goodrich.

- *Development of hydroclimatic drought indices for drought monitoring*. Robert C. Balling, Jr. and Andrew W. Ellis.
- *Development of GIS-based regional and urban climate-scale mapping for mesoscale and urban climate model verification and local climate component interpolation*. Joseph A. Zehnder, Susanne Grossman-Clarke, and Anthony J. Brazel.
- *Attitudinal study of DCDC participants and stakeholders*. Dave White, Elizabeth A. Corley, and Margaret White.
- *Decision research in water resource management: A multi-objective, multi-stakeholder analysis*. Craig W. Kirkwood and L. Robin Keller.
- *Modeling water markets*. John M. Anderies.
- *Water resources, climate change, and vulnerability in exurban communities.* Bob Bolin, Timothy Collins, and Yolanda Youngs.
- *Environmental spatial decision support systems for water policy and climatic uncertainty*. Elizabeth A. Wentz and Dave D. White.
- *Designing and implementing coupled modeling scenarios with a targeted 3-D visualization output*. Peter H. McCartney, William R. Griffin, Jim Holway, Anshuman Razdan, and Jeremy Rowe.
- *Development of DCDC data infrastructure*. Peter H. McCartney, Jana Hutchins, and Corrina Gries.

III. Highlights of Research Findings

Activities in the first eight months centered on (1) understanding and projecting the dimensions of the Urban Heat Island (UHI) and developing an agent-based model of water use─using the DT to visualize the results; (2) clarifying the boundary conditions associated with climatic uncertainty; and (3) acquiring the datasets that will support future research.

We investigated the spatial-temporal dimensions of the UHI, projected it to the Year 2040 using regional land-use projections, and displayed the findings in the DT. Results revealed that, under a business-as-usual model of urban growth, the UHI will expand in size but not grow in magnitude. When an alternative model of growth concentrated along the regional freeway system is fed into the UHI model, the spatial configuration of the heat island changes, with higher temperatures in corridors corresponding to the transportation system. Constructing these models has built the foundation for future development of alternative visions of the region=s future (growth boundaries, light-rail densification, open-space preservation, etc.), which will allow us to investigate effects on the UHI, water and electrical power use, and social vulnerability. This line of inquiry addresses human-natural coupled systems and explores the way different land-use policies influence urban temperature which, in turn, influences landscaping decisions, water use, and human comfort.

A second avenue of research developed an agent-based model of water use that integrates census data with city-supplied water-use data, and implements plausible agent-decision rules about water consumption, conservation, and media influence. At this initial stage of model development, we cross-referenced social and demographic data with water-use data to provide an

empirical basis for rule construction and consumer reaction to price changes. To date, a workable preliminary model has been produced and linked to MODFLOW, a model of underground pumping and recharge. Initial results suggest that substantial price increases are needed to influence household water use (including landscaping decisions) and that price sensitivity is a function of income.

DCDC's early climatic studies attempt to identify the determinants of drought conditions in the watersheds from which Greater Phoenix draws its water supply. In one study, currently under review in *Climate Change*, climatologist Robert Balling and graduate student Gregory Goodrich used a principal-components analysis to relate large, synoptic climatic conditions such as El Niño/Southern Oscillation, Pacific Decadal Oscillation, and Atlantic Multi-Decadal Oscillation to variations in the Palmer Hydrological Drought Index (PHDI) in the Colorado River Basin. That these predictors account for only 19% of the variance in PHDI confirms the substantial uncertainties in drought forecasting. Results of this study, along with output from numerical models throughout the world, warn of an increase in drought in the Colorado River Basin over the next decade.

DCDC staff and participants acquired datasets from community partners that relate to a number of DCDC research areas. These datasets involve indicators of local and regional climate conditions, household water use, and public attitudes about water and conservation. Analysis of preliminary public opinion surveys shows that more than 80% of Phoenix-area residents realize that the region is experiencing drought conditions. Most, however, attribute the drought and water scarcity to short-term shortages in rainfall. Few make the connection to longer-term issues such as rapid population growth (13%), water policy (9%), global warming and climate change (5%), and landscaping practices (3%). The public perception of water scarcity is at odds with climate research that suggests that longer-term and larger-scale changes in the regional climate system lie ahead and with current thinking in vulnerability analysis that places less emphasis on the physical hazard itself (low rainfall) and more on the human institutions and social conditions (population growth and water policy) that place people and settlements at risk of harm from a particular environmental condition.

Findings from Educational Activities

Major findings of the COURS program, established under the research infrastructure of DCDC, CAP LTER, and the Urban Ecology IGERT, were that participating undergraduate students gained a deeper comprehension of their disciplines, a fuller understanding of the broader significance of their work, and an interdisciplinary perspective on research issues. These results are evidenced in a document COURS students presented to IIS faculty members and students at a panel discussion on interdisciplinary research training of graduate and undergraduate students. The report highlights five prerequisites for successful interdisciplinary education:

- Funded research for students during their interdisciplinary involvement;
- Mentors who support student research training;
- Commitment by students and faculty to the necessary time of meeting throughout the period of research (in the laboratory or field);
- Commitment by students and faculty to meet regularly as an interdisciplinary group; and
- Small student/teacher ratio.

IV. Education and Outreach

Education

Graduate Education
Thirteen graduate students from geography, political science, psychology, plant biology, microbiology, family science, and communications participated in Year 1 research projects.

Undergraduate Education
DCDC participated in the inaugural year of the Community of Undergraduate Research Scholars (COURS) program under the direction of Margaret S. Nelson, Associate Dean of the ASU Barrett Honors College. COURS is designed to improve the experience of undergraduate students and support the research teams of faculty, graduate students, and undergraduate students. It addresses a fundamental limitation for undergraduates often seen at large research universities: while offering rich and varied research opportunities, they can lack the kind of community of peer researchers that can be offered at small, private colleges. This program is structured to meet the special needs of undergraduates for 1) opportunities to build their professional and research identities, and 2) multidisciplinary contexts in which to recognize the broad scientific research community of which they are part.

The interdisciplinary COURS group met four times in fall 2004 and weekly in spring 2005. The program featured readings and discussion among students from a range of humanities, social sciences and science disciplines. Each student produced a research project and poster, and presented results at a joint meeting of DCDC, the Central Arizona–Phoenix Long-Term Ecological Research (CAP LTER) project, and ASU' Integrative Graduate Education and Research Training (IGERT) in Urban Ecology. DCDC supported one student in the academic year 2004-2005 and will fund four students in 2005-2006.

K-12 Education
DCDC partnered with the Lincoln Institute of Land Policy to host a land-use workshop with eight middle- and high-school teachers on March 1, 2005. Products of this workshop were activities dealing with long-term climate change in Phoenix, a GIS interface that enables students to explore factors related to the UHI, and a thermal-mapping activity. These activities will be incorporated into an Ecology Explorers Summer Internship for teachers from June 20 to July 1, 2005.

The Education Team surveyed water-education providers in the region. Results will be compiled in summer 2005. Based upon survey responses, DCDC will hold a one-day summit in December 2005 for water-education providers to garner feedback on possible lessons and modules derived from DCDC research, with a focus on decision making.

Outreach
The Decision Center for a Desert City bridges the gap between university-based research and public policy through its association with ASU's International Institute for Sustainability (IIS).

This institute brings together life, earth, and social scientists, engineers, and government and industry leaders to share knowledge and develop practical solutions to the environmental, economic, and social challenges of sustainable development, especially as they relate to urban areas. Several DCDC scientists conduct research through IIS, strengthening DCDC's ability to pursue collaborations among groups in the university, government, and industry, seeking novel solutions to problems of rapid urbanization. IIS also serves as the bridge to other relevant NSF-sponsored projects, especially the Central Arizona–Phoenix Long-Term Ecological Research project, and the cross-site Biocomplexity in the Environment project on Agrarian Landscapes in Transition.

The Climate Science and Decision Science teams supplied research output for the first visualizations of the Decision Theater (DT) at ASU. The DT is a state-of-the-art facility presenting immersive, 3-D visualizations of complex multivariate relationships based on actual environmental data and modeling results, linking researchers, policy makers, and resource managers. The Decision Science Team provided agent-based modeling output that, when coupled with groundwater modeling supplied from the East Valley Water Forum, presents a comprehensive visualization of the impact of population growth and land-use change on the region's aquifers. In addition, output from the urban heat island research was joined with land-use models to evaluate the historic and future impacts of land-use change upon the regional temperatures.

The Sustainability Partnership Enterprise (SPE), another branch of IIS, spans the boundaries between researchers, educators, policy makers, and practitioners. SPE assists policy makers, resource managers, and industry leaders in planning and responding to the challenges of urban growth, environmental protection, resource management, and social and economic development. DCDC works with SPE to engage policy makers on water-management and climate issues.

In March, DCDC joined the Sustainable Materials and Renewable Technologies (SMART) program at ASU to host a conference on sustainable-engineering approaches to water management. SMART evaluates existing and emerging technologies for buildings, roads, and surfaces in urban regions.

L. Robin Keller (University of California at Irvine Graduate School of Management) is a member of the Decision Research Working Group working to ensure that decision research is fully integrated into the design and application of decision-science tools and decision-support tools, and to provide decision-research advice on these activities. To date, Keller and Craig Kirkwood (ASU) are working on a multi-objective decision analysis to create a comprehensive catalog of concerns identified by key stakeholders. This catalog will be used to focus discussion and promote constructive interaction for water-resource policy in central Arizona.

Community Partners-Collaborative Research

Salt River Project
SRP delivers nearly 1 million acre-feet of water to a service area in central Arizona as well as operates an extensive water-delivery system that includes reservoirs, wells, canals, and irrigation laterals. SRP provides survey data that scientists on the Decision Science and the Science and

Technology Policy/Boundary Organization teams will analyze. Representatives from SRP gave presentations and sparked discussion at two monthly Water/Climate Briefings.

East Valley Water Forum
EVWF consists of tribal, public, and private water agencies in the East Salt River Valley. They are sharing their groundwater-modeling output with the Decision Science team so it can be integrated with agent-based models to produce visualization for Decision Theater (DT).

City of Phoenix
The City of Phoenix supplies household-water-use data for DCDC analysis. The assistant director of the city's water services department is also part of the management team creating the Greater Phoenix Water Atlas and Information System. Phoenix representatives gave presentations on municipal water-management at two DCDC monthly Water/Climate Briefings.

Arizona Department of Water Resources
A DCDC-sponsored intern works 20 hours per week at ADWR to retrieve data on the region's water budget. The intern also developed metadata about how ADWR created the water budget. The GIScience and Decision Science teams work with ADWR representatives on modeling output (MODFLOW), which is being integrated with agent-based modeling from the Decision Science Team.

Intel
The DCDC/Intel partnership are investigating three areas of mutual interest: 1) sharing expertise and technology through education, training, seminars, and the Decision Theater; 2) working with industrial-sector water users to promote conservation measures and voluntary goals before mandatory water requirements take shape; and 3) researching the policy and technology driving water management.

University of Arizona
DCDC collaborates with three University of Arizona research centers dedicated partly or wholly to water and climate research. Researchers from the Arizona Water Resources Research Center (WRRC) participate in the Science and Technology Policy/Boundary Organization team investigating public perception of drought and water management. DCDC also partners with Climate Assessment for the Southwest (CLIMAS), part of U of A's Institute for the Study of Planet Earth. Their mission—to improve the region's ability to respond to climatic events and climate change—complements DCDC's goal of managing the uncertainty associated with drought, climate variability, and global climate change. DCDC and the U of A's Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) will initiate a digital water-information system. SAHRA's experience with a broad spectrum of stakeholders (both public agencies and private organizations) will enhance the relevancy of the project to decision makers.

Lincoln Institute for Land Policy
DCDC partnered with the Lincoln Institute for Land Policy on a land-use workshop that developed three K-12 education modules: (1) long-term climate change in Phoenix, (2) GIS interfaces to explore the urban heat island, and (3) a thermal-mapping activity.

Outreach Activities

To further our goal of bridging academic research and community practice, DCDC hosts monthly Water/Climate Briefings that allow participants (academics and practitioners) to share research and current practices related to decision making. The aim is to broaden the understanding of decision-making processes in the field of water-resource management. To date, there have been nine briefings with attendance figures ranging from 33 to 70. Participation from non-ASU practitioners increased over time as the community learned of this opportunity. Community partners suggested (and headlined) many of the featured presentations:

- *Water Resource Planning Strategies*, presented July 12, 2004, by the City of Phoenix. This first briefing featured City of Phoenix representatives, who provided in-depth background on their water-resource planning process.
- *Arizona=s Water Management Framework and Current Challenges*, presented September 1, 2004, by the Arizona Department of Water Resources, the City of Mesa, and the City of Peoria.
- *An Update from the DCDC Climate Science Team*, presented on October 6, 2004, by Robert Balling and Joseph Zehnder, who introduced the uncertainties of climatic conditions that impact our region=s water supply.
- *SRP Water Supplies and Growth on the Salt and Verde Watersheds*, presented December 1, 2004, by John Hetrick from the Salt River Project, who detailed impacts on urban Phoenix's water supply from growth on the Salt and Verde Watersheds.
- *Gila River Indian Community Water Settlement*, presented February 9, 2005, by Ron Lewis, General Counsel for the Gila River Indian Community. Lewis provided background on the history and outcome of federal legislation that settled a decades-old dispute about water allocations to tribal lands in Arizona, including an explanation of historic and future irrigation on the tribal land.
- *Public Perceptions of Drought in Arizona*, presented March 2, 2005, by the Salt River Project, the City of Phoenix, and *The Arizona Republic*. These partners presented results of public-attitude surveys and examined how these attitudes impact water decision making.
- *Managing Arizona=s Water*, presented April 6, 2005, by Tim Henley of the Arizona Water Banking Authority, who introduced practices and impacts of water management on the lower basin of the Colorado River.
- *Water and Climate Research at the University of Arizona: Presentations and Panel Discussion*, presented May 11, 2005, by researchers from the University of Arizona=s five water research centers. Directors presented highlights of their research and identified potential opportunities for partnerships between the U of A and ASU.

In keeping with DCDC=s position at the boundary of science and policy and given our mission of providing useful climate and water information to local and regional decision makers, we will create a printed Water Atlas and Electronic Water Information System. We will develop these products in collaboration with community and academic partners who will link us to relevant datasets, suggest the information to include, and provide vital financial support for our efforts.

The printed Water Atlas will illustrate our regional climate and water context, tell the story of the development of central Arizona's water-delivery system, describe the basics of regional water

supply and demand, and raise the specter of increasing uncertainty due to global climate change, droughts, floods, and the urban heat island effect. The Electronic Water Information System will contain dynamic water and climate information that is continually updated, archived, visualized, and animated.

Dissemination of Research Projects and Results
Co-Directors Gober and Redman presented DCDC research goals and results to several community groups and state and local agencies (City of Tempe, East Valley Water Forum, University of Arizona, CLIMAS, Arizona Governor's Water Forum, and the Sustainable Materials and research Technologies program). The first issue of DCDC's semiannual newsletter was created to outline the vision, mission and research taking place on the project. More than 500 copies were distributed to participants, community partners, ASU academic departments and students. A Web site (http://dcdc.asu.edu) was created and is being consistently updated to detail specifics of the project and provide materials from presentations, meetings, and briefings.

Community Outreach Presentations and Miscellaneous Activities
Gober, P. and T. Gallier. Arizona's drought and Tempe's plans for dealing with it. Presented at October 26, 2004, Let's Talk Tempe, Tempe, AZ.

Redman, C.L. DCDC: Building a boundary organization to improve decision making under uncertainty. Presented at October 26, 2004, East Valley Water Forum Quarterly Meeting, Chandler, AZ.

Gober, P. and C.L. Redman. DCDC: Building a boundary organization to improve decision making under uncertainty. Guest lecture presented at November 22, 2004, Climate Assessment for the Southwest (CLIMAS) at the University of Arizona, Tucson, AZ.

Redman, C.L., E. Livingston, and A. Horne. Future sources of water to meet Arizona's growing needs. Panel discussion presented at January 7, 2005, Governor's Water Forum, Phoenix, AZ.

Gober, P., C.L. Redman, W.C. Edwards, and N. Jones. Investigating human decision making under climatic uncertainty. Poster presented at January 19, 2005, 7th Annual CAP LTER Poster Symposium, Tempe, AZ.

Gober, P., C.L. Redman, B.S. Shears, L. Kuby, J. Zehnder, and S. Grossman-Clarke: The International Institute for Sustainability and The Decision Center for a Desert City: Research with a purpose. Poster presented February 3, 2005, at the annual meeting of the National Council for Science and the Environment, Washington, DC.

Redman, C.L. Building a boundary organization to improve decision making under uncertainty. Presented at March 9, 2005, SMART conference on re-thinking urban water: A sustainable engineering approach, Phoenix, AZ.

Gober, P. and C.L. Redman. DCDC: Building a boundary organization to improve decision making under uncertainty. Presented at March 10, 2005, University of Arizona/Arizona State University collaboration meeting, Casa Grande, AZ.

Gober, P. Decision Center for a Desert City. Presented at March 17, 2005, Valley Forward, Land Use Subcommittee meeting, Phoenix, AZ.

Publications and Products

In Press

Collins, T. Households, forests, and fire hazard vulnerability in the American West: A case study of a California community. *Environmental Hazards: Human and Policy Dimensions, Global Environmental Change.*

Grossman-Clarke, S., Zehnder, J.A., Stefanov, W.L., Liu Y. and M.A. Zoldak. Urban modifications in a mesoscale meteorological model and the effects on near surface variables in an arid metropolitan region. *Journal of Applied Meteorology*.

Submitted
Balling, R.C., Jr., and G.B. Goodrich. Analysis of drought determinants for the Colorado River Basin. *Climatic Change*.

Publications in Preparation
Ellis, A.W., G Goodrich, and J.A. Skindlov. An ensemble method for forecasting seasonal precipitation: Winter variability on Arizona watersheds.

Books in Press
Gober, P. *Metropolitan Phoenix: Place Making and Community Building in the Desert*. University of Pennsylvania Press, Philadelphia, PA.

Dissertation in Progress
Collins, T. People, Forests and residential fire-hazard vulnerability in Arizona's White Mountains. (Ph.D., Geography, K. McHugh, advisor).

Presentations at Regional, National and International Conferences

Gober, P. Multidisiplinarity in Geography: What does the future hold? Paper presented April 2005, *Annual meetings of the Association of American Geographers*, Denver, Colorado.

Griffin, W.A., S.K. Schmidt, and B. Armendt. Simulating decisions of water use in uncertain times in the Southwestern US: An ABM of strategies and population level actions. Paper presented June 26-28, 2005, *North American Association for Computational Social and Organizational Science*. Notre Dame, Indiana.

Forthcoming Presentations
Keller, L.R., C. Kirkwood, and N. Jones. Decision research in water resources management: A Multi-objective, multi-stakeholder analysis. To be presented November 2005, *The Institute for Operations Research and the Management Sciences (INFORMS)*.

Zehnder, J. Implications of urban growth patterns for heat island effects and water use. To be presented February 16-20, 2006, *Annual Meeting of the American Association for the Advancement of Science*, St. Louis, MO. Submitted.

McCartney, P. Coupling agent-based models of decision making to groundwater resources via MODFLOW. To be presented February 16-20, 2006, *Annual Meeting of the American Association for the Advancement of Science*, St. Louis, MO. Submitted.

White, D. Citizen and expert perspectives on water management and sustainability in Arizona. To be presented February 16-20, 2006, *Annual Meeting of the American Association for the Advancement of Science*, St. Louis, MO. Submitted.

Shangraw, R.F. Arizona State University's Decision Theater. To be presented February 16-20, 2006, *Annual Meeting of the American Association for the Advancement of Science*, St. Louis, MO. Submitted.

V. Contributions

DCDC is, at its core, an interdisciplinary enterprise concerned with the human response to climate change, risk and uncertainty, vulnerability and resilience at a range of scales from the household to the community and region. Although some of our contributions will be made inside traditional disciplines, DCDC=s added value is in its capacity to ask new questions and to fuse traditional ways of studying human decision making and the urban environment. Examples of these fusions are below:

$ Agent-based modelers have introduced empirical results of public-opinion surveys into decision rules about how agents respond to price changes and conservation practices. They have also used GIS to study how changes in the price of water will influence the landscape of water demand. This work has married the ideas of sociologists and psychologists with geographers and planners to produce more robust models of agent behavior in the face of resource scarcity, public policy, and media influence.

$ Although climatologists could use the MM5 regional heat island model exclusively to study the physical properties of and spatial and temporal dimensions of the urban heat island, they are creating new insights by linking the MM5 to planning, economic, and vulnerability models. In particular, DCDC has joined the MM5 climate forecast model to different outputs from UrbanSIM, a land-use model based upon alternative visions of the future, and future simulations will be linked to water markets and social vulnerability.

$ We will integrate information yielded from focus groups and qualitative studies into preliminary environmental spatial decision support systems. The integration of quantitative and qualitative studies is at the forefront of intellectual and methodological challenges in the social sciences.

$ Links between climate science and vulnerability science occur as scientists examine uncertainties associated with the upper and lower limits of temperature and precipitation, and social scientists analyze how humans as individuals and social organisms react to these uncertainties.

Contributions to Human Resource Development

DCDC provides a framework for training graduate students, nourishing interdisciplinary projects and contributing to the fields of geography, decision research, vulnerability analysis, and agent-based modeling. Our project is also committed to engaging undergraduate students and K-12 teachers, community organizations, government agencies, and the general public in our interdisciplinary investigation of climate change and human decision making. Graduate students are drawn from a wide range of disciplines, including geography, psychology, political science, family science, communications, plant biology, and microbiology.

Contributions to Resources for Research and Education

DCDC=s setting within a large public institution enhances its ability to leverage research and outreach programs for educational benefit. To date, 13 graduate students have been engaged in DCDC research programs. DCDC is a founding partner and collaborator in the university=s new Community of Undergraduate Research Scholars (COURS) Program. Preparation of the DCDC proposal provided the initial impetus for this innovative program, which integrates undergraduate students into research.

DCDC=s close collaboration with the Decision Theater (DT) offers myriad opportunities to link research and education. The DT is both a setting to view visualizations but also a laboratory for studying and engaging decision makers. We anticipate examining the way research and educational infrastructure melds together in the DT.

Contributions beyond Science and Engineering

DCDC's core mission is to produce the scientific understanding and support tools that will lead to better water decision making and a more sustainable future for Phoenix, the fastest-growing large metropolitan area in the United States. Results and modeling products can be adapted to other regions experiencing rapid growth, water scarcity, and climatic uncertainty.

DCDC 2005 Annual Report – Appendix A
Participants 2004-2005

Principal Investigators/Project Directors
Patricia Gober, Geography
Charles L. Redman, International Institute for Sustainability

Co-Principal Investigators
Bob Bolin, Anthrolpology
Grady Gammage, Jr., Morrison Institute for Public Policy
Thomas Taylor, Mathematics and Statistics

Senior Personnel: Managers
Bill Edwards, Admin Proj Mngr

Senior Personnel: Core Scientists
William Griffin, Family & Human Development
Peter McCartney, International Institute for Sustainability
Joseph Zehnder, Geography
Robert Balling, Geography
Andrew Ellis, Geography
Dave White, School of Community Resources and Development
Elizabeth Corley, School of Public Affairs
Elizabeth Wentz, Geography
Margaret Nelson, Barrett Honors College
Anthony Brazel, Geography
Monica Elser, International Institute for Sustainability
Corinna Gries, International Institute for Sustainability
Suzanne Grossman-Clarke, International Institute for Sustainability
Subhrajit Guhathakurta, School of Planning
Sharon Harlan, Anthropology
L. Robin Keller, UC-Irvine Graduate School of Management
Ann Kinzig, School of Life Sciences
Craig Kirkwood, Supply Chain Management
Anshuman Razdan, Partnership for Research in Spatial Modeling
Jeremy Rowe, Information Technology
Charlene Saltz, International Institute for Sustainability
John Anderies, School of Life Sciences
Brad Armendt, Philosophy
Gregg Garfin, CLIMAS, University of Arizona
Kathy Jacobs, SAHRA, University of Arizona
James Holway, International Institute for Sustainability
Richard Aspinall, Geography
Robert Edsall, Geography
Ed Hackett, Anthropology
Peter Killeen, Psychology
Michael Kuby, Geography
Joan McGregor, Philosophy
Rob Melnick, Morrison Institute for Public Policy
William Verdini, College of Extended Education
Donald Keefer, Supply Chain Management

Postdoctoral Research Associates
Timothy Collins, DCDC
David Casagrande, IIS

Other Collaborators
Chris Lukinbeal, Geography
James Buizer, Office of Sustainability Initiatives
John Crittenden, Civil & Environmental Engineering
Michael Crow, President
Daniel Sarewitz, School of Life Sciences

Research Technical Personnel
Jana Hutchins, International Institute for Sustainability
Shea Lemar, Information Technology
Barbara Trapido-Lurie
Michael Zoldack, International Institute for Sustainability

Public Outreach Personnel
Nancy Jones, Communications Mgr

Research Support Personnel
Michelle Albrecht
Karen Gronberg

Graduate Research Associates
Stephanie Deitrick, Geography
Suresh Ayyalsamy, Family and Human Development
Erin Comparri, International Institute for Sustainability
Shannon Gysberg, Geography
Brent Hedquist, Geopgraphy
Shana Schmidt, Family and Human Development
Jagadeesh Chiruma, International Institute for Sustainability
Bethany Cutts, School of Life Sciences
Chris Graham, Geography
Kim Michel, School of Life Sciences
Cheryl Sexton, Family and Human Development
Subramanian Swaminathan, Geography
Margaret White, School of Life Sciences
Yolanda Youngs, Geography

Other Grads

Community of Undergraduate Research Scholars (COURS)
Matt Kruger
Malaya Fletcher

Other Undergrads
Adam McDaniel, International Institute for Sustainability

Community Partners
Michael Ellegood, Maricopa Flood Control District
Mitchell Haws, Bureau of Reclamation
John Hetrick, Salt River Project
Ray Quay, City of Phoenix
Dallas Reigle, Salt River Project

Salt River Project
City of Phoenix
East Valley Water Forum

Arizona Department of Water Resources
Intel
University of Arizona
Lincoln Institute for Land Policy