



DCDC 2007-2008
Annual Progress Report

Decision Center for a Desert City
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Compiled by
Patricia Gober
Charles Redman
Bill Edwards
Nancy Jones
Michelle Rupp
Estella O'Hanlon
Annissa Olsen

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DCDC 2008
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Decision Center for a Desert City

Principal Investigators/Directors:

Patricia Gober
Charles Redman

Executive Committee:

Patricia Gober
Charles Redman
Robert Balling
Bob Bolin
William Edwards
Monica Elser
Grady Gammage
Craig Kirkwood
Margaret Nelson
Kerry Smith
Elizabeth Wentz
Dave White

Staff:

Bill Edwards
Nancy Jones
Michael Tschudi
Nick Gerbis
Estella O'Hanlon
Michelle Rupp
Annisca Olsen

Teams:

Climate Change and Urban Heat Island
Education and Outreach
Science and Policy
Modeling and Evaluation
Vulnerability
Water Demand and Decision Making



I. Introduction to DCDC

Arizona State University's Decision Center for a Desert City (DCDC) works to improve the effectiveness of policy analysis and water planning in the face of climate variability and change. These goals are more urgent now than when we first responded to the National Science Foundation's Decision Making Under Uncertainty (DMUU) Initiative in 2003. Climate forecasts (by DCDC and others) warn of potentially dire changes to the environmental systems that provide water to Phoenix and other cities of the Western United States, but water managers continue to resist incorporating climate forecasts and climate change scenarios into agency practices.

DCDC's original motivation—creating a timely interface between scientific understanding and human decision-making—remains the basis for our most important activities. Year 4 research activities included data collection and analysis, article submission, and the culmination of prior research projects in the form of refereed journal articles.

Activities:

The **climate research** team downscaled general circulation models and used Intergovernmental Panel on Climate Change scenarios to simulate runoff from upstream watersheds (Ellis et al. 2008). It analyzed drought determinants for the Colorado River Basin (Balling and Goodrich 2007), and quantified effects of the urban heat island on residential water use (Guhathakurta and Gober 2007). The team also estimated the effects of growth and housing construction on the urban heat island (Brazel et al. 2007), and established that urban water use is less sensitive to climate variability than previously thought because durable, inflexible irrigation systems dominate outdoor water use in the region (Balling and Gober 2007).

The critical links among climate, water, and growth continue to be a central focus of DCDC climate research. Our success in integrating urban water-balance and energy-balance models with diverse urban design options, allows us to better understand the sensitivity of residential water consumption to varying weather and climate conditions. It is also the basis for a collaborative project with geographers at Portland State University to integrate land-use planning into water-resource decision making as a potential adaptation to climate-induced water stress in the Western United States.

Decision-making research investigated decision makers' views of uncertainty and scientific information (White et al. 2008; Gober et al. in review) and determinants of water use at the household level (Wentz and Gober 2007). Ongoing studies include social-network analysis of scientists and water managers, interviews with water-resource decision makers to assess reactions to our water-simulation model (Wutich et al. in review), the effect of different uncertainty representations on water decision making, and psychological studies of tradeoffs made in residential water-consumption choices.

Vulnerability studies used a political-economy perspective to investigate how societal arrangements render some people and places disproportionately vulnerable to the threat of water shortage. This research is both qualitative and quantitative. Using qualitative analysis, DCDC scientists described the history of water management in Arizona and the failure of the water-policy community to respond to the challenges of rapid growth amidst climatic uncertainty (Hirt et al. in press). Other research included identifying the institutional forces that have generated water shortage conditions in Arizona's Central Highlands (Bolin et al. in press) and analyzing the way that Phoenix's cultural and environmental history have impeded climate adaptation strategies (Gober 2007; Gober in press).

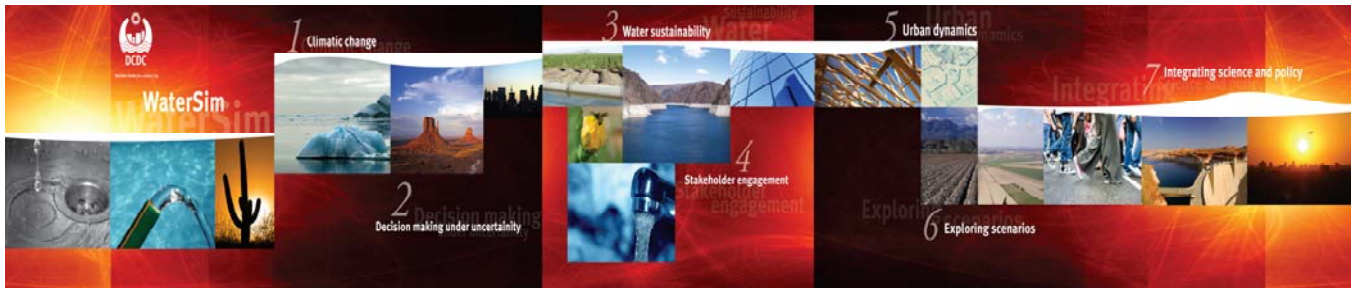
Quantitative studies used geographical information systems (GIS) to characterize the vulnerability of individual water providers based on their supply portfolios and projected growth conditions (Bolin et al. 2008 presentation at the Association of American Geographers meeting in Boston; Pompeii 2008 presentation at the American Association for the Advancement of Science meeting in Boston). Pompeii's poster, entitled "Water Privatization and Socially Constructed Scarcities: A Case Study in Phoenix, Arizona," won honorable mention in the Science and Society category at the AAAS meeting.

Methodological contributions center on the use of Bayesian Maximum Entropy (BME) to deal with uncertainty in a variety of water and climate modeling problems. In collaboration with other DCDC scientists, postdoctoral fellow Seung-Jae Lee produced a set of BME applications that are described in *Climate Research* (Brazel et al. 2007), *Water Resources Research* (Lee and Wentz 2008), the *Annals of the Association of American Geographers* (Lee et al. 2008), and *Geographical Analysis* (Lee et al. in review). This work demonstrates that BME can produce highly accurate spatiotemporal representations of environmental phenomena and is a useful tool for urban planners, water managers, and policy makers.

WaterSim integrates quantitative models representing water consumption and availability in Central Arizona under varying scenarios of population growth, climate change, individual behavior, and policy choices. Using a systems-dynamics framework built upon the software application *PowerSim*, WaterSim combines research results into a single, interactive tool with which users can explore plausible futures and evaluate strategies for avoiding unacceptable scenarios. WaterSim is shown in ASU's Decision Theater and disseminated to the public at <http://watersim.asu.edu>. The model was the basis for a front-page story about climate change and water-resource planning in the August 12, 2007, issue of *The Arizona Republic*, Arizona's largest-circulation newspaper.

WaterSim supports DCDC's relationships with local decision makers and serves as a basis for national and international scientific and policy engagement. It is not merely a static scientific product, but rather a dynamic tool that enables scientists and policymakers to collaborate—expanding knowledge, creating tools, and improving visualizations. Social scientists at DCDC gain new insights into developing and applying models through this co-production process.

During Year 4, DCDC scientists evaluated WaterSim using sensitivity analyses and history matching (Gober et al. in review). Work commenced to implement a GIS interface for WaterSim that will allow users to manipulate model inputs and outputs spatially. We are also in the process of building a more attractive and intuitive user interface for presentations in the Decision Theater.

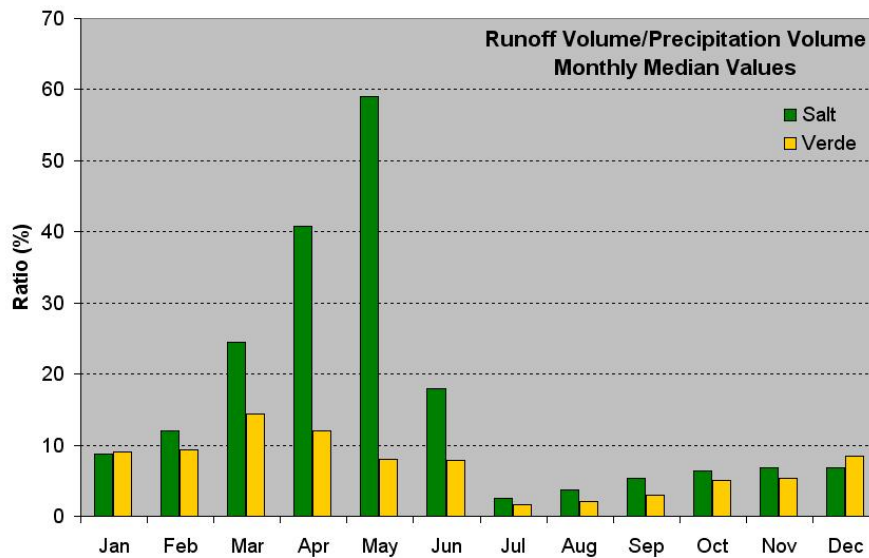


Year 4 Research Projects, listed with primary investigators, include:

Anthony Brazel, P.I. “Neighborhood Evapotranspiration Variation in the City of Phoenix: An Hourly, Seasonal, and Annual Evaluation using the Local-Scale Urban Meteorological Parameterization Scheme (LUMPS)” uses a neighborhood-scale meteorological model to investigate the relationship between heat storage and water loss and how it varies with different land-cover conditions. The project is a collaborative effort with the City of Phoenix Water Services Department. The City is interested in the “return on investment” of using water to reduce nighttime temperatures associated with the urban-heat-island effect.

Ann Kinzig and Bethany Cutts, co-P.I.s. “Implications of Spatially Heterogeneous Water Education and Educator Networks in a Desert City” maps the distribution of water conservation education efforts in metropolitan Phoenix and assesses whether public knowledge of water conditions differs between high- and low-water use areas.

Andrew Ellis and Robert Balling, Jr., co-P.I.s. “Past Patterns and Future Implications of Changes in Runoff/Precipitation Ratios on the Salt and Verde Watersheds” will produce a detailed spatial climatology of the runoff/precipitation ratio for the Salt and Verde watersheds and determine which portions of the watersheds are most highly associated with the overall runoff conditions. The research also investigates the role of elevation in affecting the ratio and the effectiveness of snowfall relative to rainfall in affecting the ratio a seasonal basis.

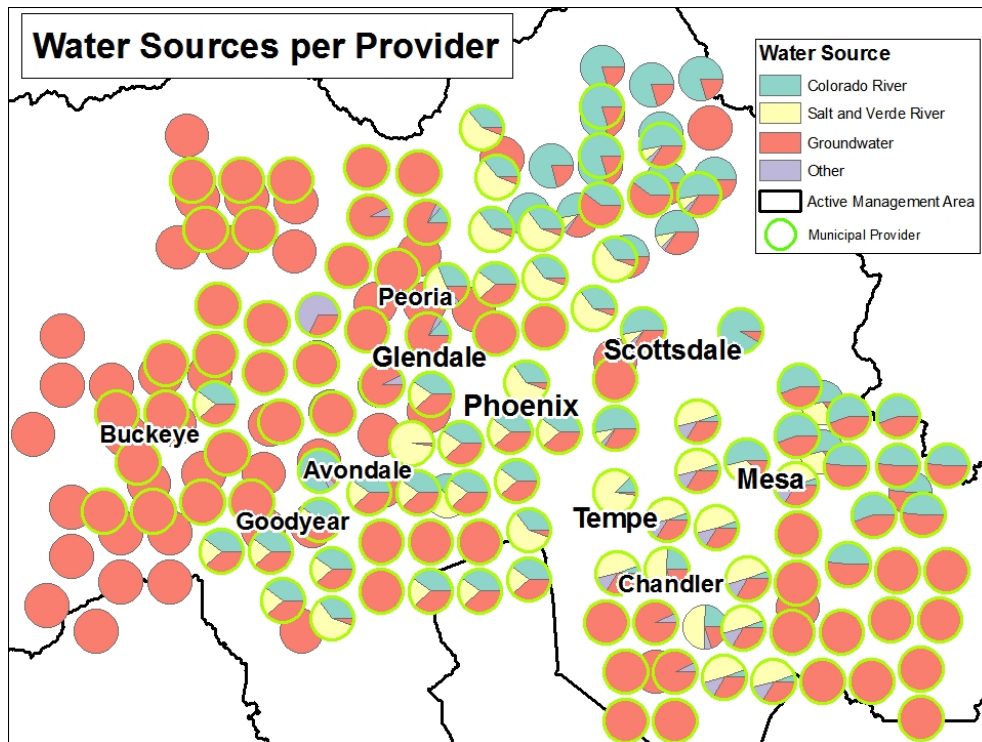


Craig Kirkwood, P.I. “Multi-objective Decision-analysis Framework for WaterSim” works to apply WaterSim to policy decisions. Researchers will use the framework to develop appropriate inputs for WaterSim and to improve post-processing of its outputs. The proposed multi-objective framework consists of three elements: (1) metrics or a set of quantitative measuring scales that provide a summary of decision-relevant WaterSim outputs, (2) scenarios that reflect fundamental uncertainty about the key variables affecting water availability, and (3) alternatives that capture policy choices for water-resource management. A central feature of (3) is that some policy alternatives create options for, or remove options from, future actions.

Amber Wutich, Beatrice Crona, and Paul Westerhoff, co-P.I.s. “Phoenix Ethnohydrology” is a follow-up study to the DCDC/LTER-funded Phoenix Area Social Survey II (PASS II), a survey of 40 neighborhoods conducted in Greater Phoenix in the summer of 2006. Based on respondents’ assessments of water quality in their neighborhoods in PASS II, the team selected a sub-sample of four neighborhoods for additional in-depth study, assessing resident’s ecological knowledge and perception of water quality, comparing perceptions of English- and Spanish-speakers, and correlating perceptions with the chemical content of drinking water.

L. Robin Keller, Craig W. Kirkwood, and Jay Simon, co-PIs. “Spatial Decision Research” continues previous efforts to develop and extend decision-focused spatial-evaluation metrics. By decision-focused, we mean that the metrics support decision making and policy creation that are based upon modeling results. By spatial, we mean that data are arranged spatially over a geographical region.

Bob Bolin and Kelli Larson, co-PIs. “Vulnerability to Water Shortage” developed a spatially explicit data set for analyzing place-specific vulnerabilities to water shortage. It ran a variety of climate-change, water-demand, and population-growth scenarios for communities in our area, with the ultimate goal of pinpointing where water stress will be first experienced and the socio-economic characteristics of the affected populations.



Dave White, P.I. “Decision Theater Experiments” continued interviews with water managers, probing their perceptions about the legitimacy, credibility, and saliency of WaterSim. We have now followed our panel through two waves of interviews and can assess its changing views of DCDC science and our simulation model.

Susan Ledlow and Ed Sadalla, co-PIs. “Residential Water Consumption Choices” identifies the tradeoffs people make between indoor and outdoor water use and across the range of specific indoor (showering, dishwasher, toilet flushing, etc.) and outdoor (landscaping, pools, car washing, etc.) uses. The goal is to investigate how choices of various uses varies with gender, income, and environmental attitudes.

John Sabo, P.I. “Bridging Perceptions of Local and Regional Water Supply in the Cadillac Desert.” Dr. Sabo, a faculty member in the ASU School of Life Sciences, has obtained NSF funding to revisit Marc Reisner’s apocalyptic thesis about the fate of agriculture and civilization in the western United States. DCDC will participate in a series of workshops dealing with the future of water supply and demand in the region. DCDC’s interest is in projecting future water-use patterns in major urban areas and in the agricultural sector. This project facilitates interaction with life scientists and enables DCDC to upscale its models and research from Phoenix to the Desert Southwest.

Education Activities:

The **Community of Undergraduate Research Scholars** continued as a year-long seminar in which students honed their research skills and discussed the multi-disciplinary context for their research endeavors. The seminar culminated with a poster session held in conjunction with a DCDC Water/Climate Briefing. The seminar included students from the Central Phoenix Long-Term Ecological Research Project (CAP LTER) and the Urban Ecology Integrated Graduate Education and Research Training (IGERT) project. DCDC students produced the following posters:

- Eva M. Wingren, Barrett Honors College. “Performance and Perception at a Science and Policy Boundary”
- John Wallace, School of Human Evolution and Social Change. “Pre-historic Land Use Across Perry Mesa, Central AZ”

The DCDC **Community of Graduate Scholars** continued as a required, year-long interdisciplinary seminar for all funded graduate students. Students developed a DCDC presentation that four of them presented, each to one of the other DMUU Centers. They also organized a DCDC-wide discussion series during the spring semester. Each of the three discussions attracted between 40 and 50 participants.

Panel 1: WaterSim: Facilitating Decision Making through Simulation Models (January 23, 2008)

- Tim Lant, DCDC and Decision Theater
- Kathy Jacobs, Arizona Water Institute and University of Arizona
- Clark Miller, Consortium for Science, Policy and Outcomes and Department of Political Science

Panel 2: Vulnerability to Water Scarcity (February 20, 2008)

- Bob Bolin, School of Human Evolution and Social Change
- Ann Kinzig, School of Life Sciences
- Dave White, School of Community Resources and Development

Panel 3: Water Policy: Are the Current Policies Adequate? (March 19, 2008)

- Judith Dworkin, Attorney-at-Law, Sacks Tierney
- Paul Hirt, Department of History
- Jim Holway, School of Sustainability

Monica Elser, DCDC education team co-leader, worked with two community college instructors and two high school Advanced Placement Human Geography teachers to develop lessons for geography courses using WaterSim. The team is readying the lessons for placement on the DCDC website. Both community college instructors will present professional papers about the project in Fall 2008 at regional geography conferences. The education team also developed a Webquest for the Southwest Water Information Project Atlas and presented it at a teacher workshop in Spring 2008.

The team tested classroom lessons about the urban heat island in Spring 2008 in a seventh-grade, after-school science program.

The education team conducted a Project Wet/DCDC Advanced Water Education Workshop on July 31 and August 1, 2007, attracting with 28 participants. The workshop, focusing on climate change and decision-making, was a collaborative effort with partners from the University of Arizona and the Maricopa County Extension Service. A similar program is planned for July 8 and 9, 2008 and will focus on water reuse and conservation.

II. Findings of Research Activities

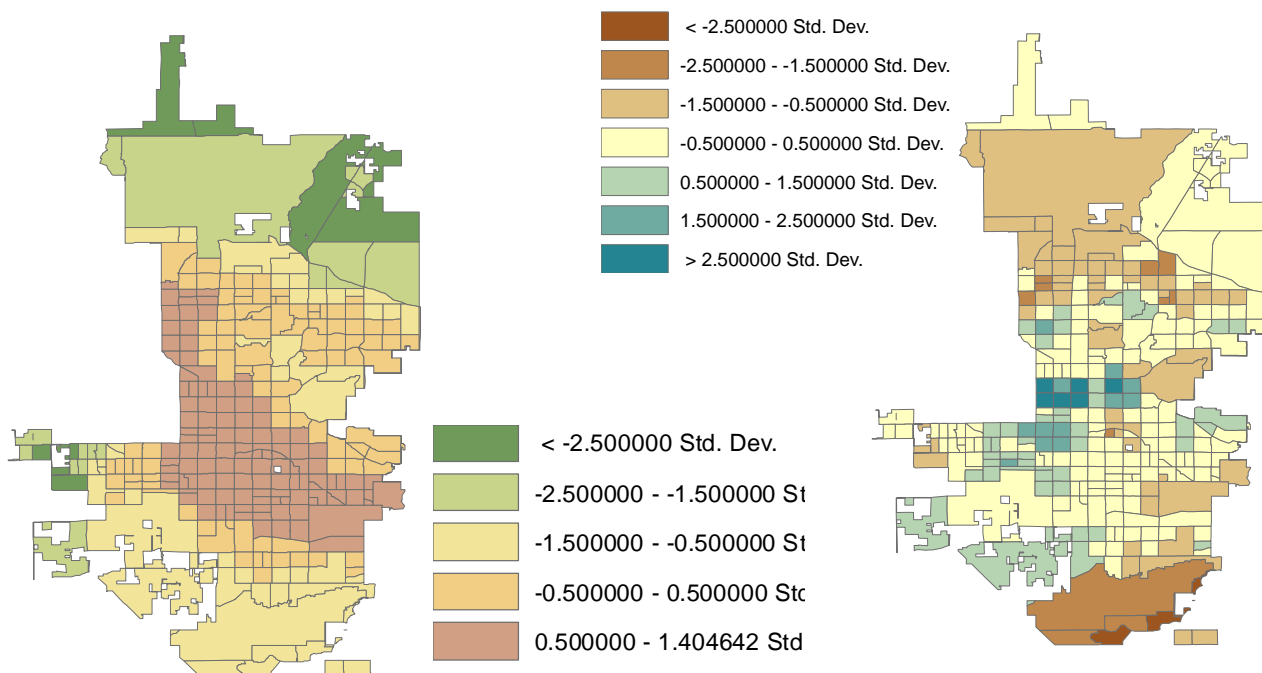
The Impact of Urban Heat Island on Residential Water Use in Phoenix Subhrajit Guhathakurta, Shawn Gaver, and Patricia Gober

Land-use and land-cover changes associated with rapid urbanization in the desert have raised summer nighttime temperatures in Phoenix by up to 12° F in the past 50 years. A team of interdisciplinary scientists at DCDC examined residential water records and found a relationship between rising temperatures and increased water demand. If the average nighttime temperature of 70° F were to increase by 1°, the typical household (presently using 16,000 gallons per month) would increase its monthly water use by 448 gallons. This work confirms the effect of environmental conditions on household-decision making and suggests that climate change poses an additional challenge for this arid region because it will increase water use. In addition, the research raises questions about smart-growth strategies that promote higher urban densities and compact cities, which may lead to an increasing heat-island effect and associated impacts on air quality and water use. It is imperative that plans for smart growth include strategies for mitigating heat-island effects, in order to achieve optimum environmental benefits.

Mean Nighttime Temperatures in
June 8, 1998 at 5:00AM

Mean Water Consumption by Single-
Family Units in June 1998

Derived from data provided by:
Joseph Zehnder and Susanne Grossman-Clark



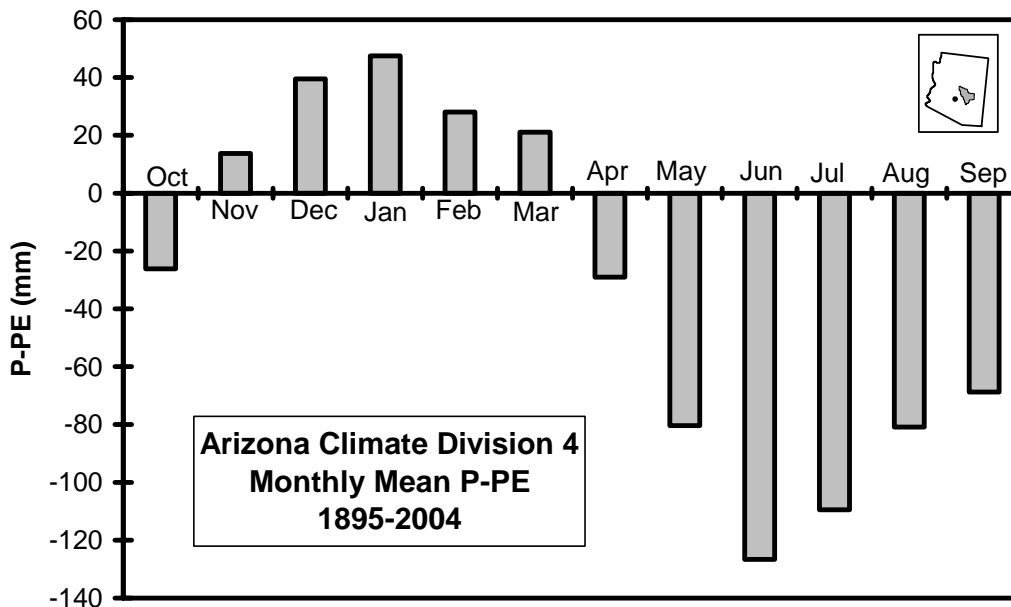
Factors Influencing Residential Water Consumption for the City of Phoenix Elizabeth Wentz and Patricia Gober

DCDC scientists studied how residential water demand in Phoenix varied from one location to another. They found that four factors influence the demand for water: household size, which reflects use for laundry, bathing, dish washing, and toilet flushing; the presence of an outdoor swimming pool; average lot size; and landscaping type (turf versus desert plants). Results can be used to estimate the effects of policies that limit pool construction, mandate smaller lot sizes, and provide incentives for residents to shift from water-hungry lawns to native desert plants for their outdoor landscaping. Understanding policy outcomes associated with new construction is particularly important in a rapidly urbanizing region where the current population of 3.7 million is expected to double in the next 40 years.



A Hydroclimatic Indexing Concept for Monitoring Drought Andrew Ellis, Gregg Garfin, and Robert Balling, Jr.

Standard drought indicators developed in the eastern and midwestern United States may not be applicable to western climate and water conditions. DCDC scientists partnered with scientists at the University of Arizona to develop a more appropriate drought index for the Colorado River Basin. They compared the resulting Hydroclimatic Index to more commonly known indices such as the Palmer Drought-Severity Index (PDSI) and the Standardized Precipitation Index (SPI) and found that the Hydroclimatic Index responded more quickly to short-term hydroclimatic changes than the PDSI and improved upon the capabilities of the SPI. This research is important because the Colorado River Basin is the source for about 30% of the Phoenix metropolitan area's water supply.

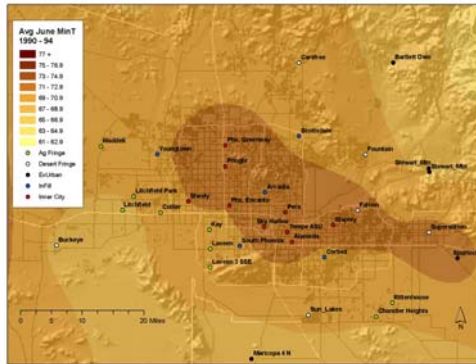


Mean monthly P (precipitation)-PE (potential evapotranspiration) values for Climate Division 4 in Arizona. On average, P-PE values are positive only during the period November through March, and it is likely that much of the surplus moisture in November recharges the soil following the summer season.

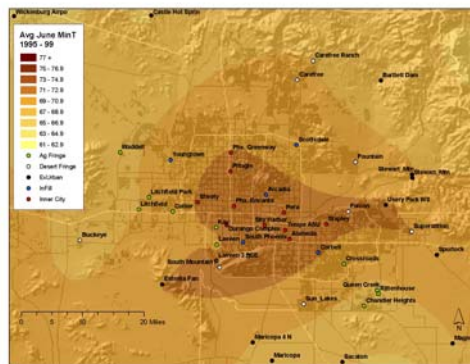
Spatial Expansion of Phoenix’s Urban Heat Island
Anthony Brazel, Brent Hedquist, Joseph Zehnder, and Patricia Gober

Rapid urbanization has warmed summer nighttime temperatures in Greater Phoenix, adversely affecting human comfort and health, energy and water consumption, and the region’s potential as a year-round tourist destination. Using a dense network of weather stations and detailed maps of new home construction, DCDC scientists discovered different regimes of local-area climate change between 1990 and 2004. The core of the city was hot at the start of the period, and remained hot throughout, while sites outside the urban center were cool and remained cool. The most dramatic changes in June nighttime lows occurred at the expanding urban fringe where previously cool, irrigated farmland was converted to new home developments; there were less dramatic changes in land where urban infill occurred. Results of the study will help potential home-buyers to gauge the effects of new land development on atmospheric conditions in their neighborhoods and enable policymakers to better understand the impacts of potential growth strategies.

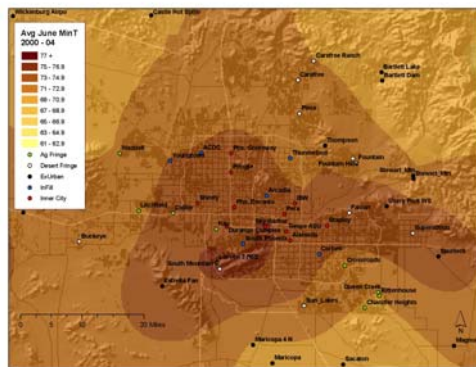
1990-1994



1995-1999



2000-2004



These maps show the spatial distribution of average June nighttime low temperatures in the Greater Phoenix region. Points represent climate stations in the region.

III. Research Findings: Training & Development

Undergraduate Education: In Year 4, Decision Center for a Desert City funded two undergraduate students to participate in the Community of Undergraduate Research Scholars (COURS) program. COURS is an interdisciplinary program, co-sponsored by the Barrett Honors College and the Global Institute of Sustainability (GIOS), and supervised by Barrett Honors College Associate Dean, Margaret C. Nelson. COURS integrates undergraduate students into ongoing research projects, provides an interdisciplinary environment that enhances cross-disciplinary communication and appreciation for the broader impacts of scientific work, and produces concrete research products.

All COURS students prepared research posters for presentation at a capstone event on April 30, 2008, featuring an outside speaker and widespread participation from DCDC faculty and community partners, and Central Arizona-Phoenix Long-Term Ecological Research (CAP LTER) and IGERT faculty.

DCDC student COURS poster presentations were “Peer Influence on Student Water Values,” by Allyn Knox and “Performance and Perception at a Science and Policy Boundary,” by Eva M. Wingren.



Graduate Education: To date, 32 graduate students from the Schools of Life Sciences, Social and Family Dynamics, Human Evolution and Social Change, Sustainability, Geographical Sciences, Earth and Space Exploration; the Departments of History, Geology, Environmental Design/Planning, Political Science, Computer Science and Engineering, Psychology, and Communications; and the Consortium for Science, Policy and Outcomes have participated in DCDC projects. We require research assistants to participate in a one-credit graduate seminar,

Community of Graduate Scholars, to facilitate collaboration among graduate students working on DCDC projects.

The Community of Graduate Scholars integrates graduate students into ongoing DCDC research projects, provides an interdisciplinary environment that enhances cross-disciplinary communication and appreciation for the broader impacts of scientific work, and produces concrete research products. Twelve DCDC graduate students participated in the CAP LTER 2008 poster symposium in January in Tempe. Their presentations were:

- “An Ethnohydrologic Evaluation of Water Quality in Phoenix, AZ,” Stacey Avent*, Amber Wutich, Beatrice Crona, Pat Gober, Mohan Seetharam, and Paul Westerhoff
- “Sensitivity of Residential Water Consumption to Variations in Weather and Climate: An Intra-Urban Analysis of Phoenix, Arizona,” Robert Balling, Pat Gober, and Nancy Jones
- “Is it Who You Know or What You Know? A First Examination of Water Information Distribution Across Organizational Networks,” Bethany Cutts*, Allyn Knox*, and Nickolas Moore*
- “Estimates of Outdoor Water Use in Phoenix Using LUMPS,” Jillian Elder*, Susanne Grossman-Clarke, Anthony Brazel, Hillary Butler*, and Paul Martin
- “A Scenario-Based Assessment of Future Groundwater Resources in the Phoenix Active Management Area,” Vanessa Escobar*
- “Focusing on Higher Quality Focus Groups,” Meredith Gartin*, Amber Wutich, Tim Lant, Dave White, Kelli Larson, Susan Ledlow, and Pat Gober
- “The Use of GIS as a Decision-Support Tool by Water Managers in Phoenix, Arizona,” Jason Howard*, Kelli Larson, Dave White, and Elizabeth Wentz
- “Spatial Extrapolation Mapping Based on Aggregated Data: Countywide Extrapolation of Phoenix Water Use Data,” Seung-Jae Lee and Elizabeth Wentz
- “Temporal Geographic Information System (TGIS) to Forecast Future Water Consumption in Phoenix, Arizona,” Seung-Jae Lee, Elizabeth Wentz, and Pat Gober
- “Water Resources, Climate Change, and Institutional Vulnerability: A Case Study of Phoenix, Arizona,” Brian Pompeii*
- “WaterSim as an Education Tool,” Michael Tschudi
- “Public Good or Commodity? Institutional Differences in Water Management Strategies and Conservation Outcomes in Tucson and Phoenix,” Kelly Turner*
- “Water Vulnerability on the Urban Periphery: The Case of Metropolitan Phoenix, Arizona,” Lilah Zautner*

*Graduate students



Two students presented posters at the American Association for the Advancement of Science (AAAS) meeting in February 2008 in Boston: "Water Resources, Climate Change and Institutional Vulnerability: A Case Study of Phoenix, Arizona," by Brian Pompeii, and "Water Vulnerability on the Urban Periphery: The Case of Metropolitan Phoenix, Arizona," by Lilah Zautner. Brian Pompeii won honorable mention in the Science and Society Division.



DCDC Posters at AAAS Meeting

Postdoctoral Fellows: DCDC funded two post-doctoral fellows during Year 4. They are Mohan Seetharam, a recent doctoral degree recipient from Clark University's Graduate School of Geography who specializes in GIS and vulnerability mapping, and Seung-Jae Lee, who received his doctoral degree from the Department of Environmental Sciences and Engineering at the University of North Carolina and specializes in environmental modeling, geostatistics, and data uncertainty.

DCDC also hosted Beatrice Crona, a postdoctoral fellow from the Stockholm Resilience Center; she was involved in a social-network study and in the ethno-hydrology project.

IV. Education and Outreach

Decision Center for a Desert City water/climate briefings are an important forum for interacting with community partners. Speakers in 2007-08 included partners in the water management community, a member of the Arizona State Senate, an independent film producer, and a University of California at Los Angeles scientist interested in climate change. These events drew a total of 499 participants.

September 5, 2007, “Groundwater Modeling and Multiple Scenario Analysis in the Prescott Active Management Area.” Daniel Timmons, a recent graduate from Northern Arizona University with a Master of Science degree in Environmental Science and Policy, used a groundwater model and scenario analysis to simulate the effects of continued population growth on groundwater supplies in the Prescott Active Management Area. Tom O’Halleran, Arizona State Senator from District 1, provided commentary and insights.

October 10, 2007, “The American Southwest: Are We Running Dry?” Jim Thebaut, writer, producer, and director, gave a preview of his new documentary film, “Running Dry,” and discussed an upcoming film project, The American Southwest: Are We Running Dry? Thebaut is a member of the International Documentary Association and has written, produced, and directed a series of films dealing with important social issues.

March 5, 2008, “The Colorado River, Climate Warming, and the Perfect Drought.” Glen McDonald, professor of geography at UCLA, used the paleoclimatic record to explore the potential impact of global warming on water in California. Results suggest that the 21st Century may be fraught with serious and prolonged water-management problems in Southern California and the Southwest.

April 2, 2008, “Challenges and Opportunities for Regional Water Planning: East Valley Water Forum Management Plan.” Teresa Makinen, Director of the East Valley Water Forum, and Doug Toy, who is involved in water planning for the City of Chandler, presented the East Valley Water Forum’s regional groundwater-management plan and discussed the need for a regional perspective in groundwater management and planning.

April 30, 2008, “Central Arizona Groundwater Replenishment District: Point and Counterpoint Discussion.” Robert Anderson, an attorney at Fennemore Craig, and Kathryn Sorensen, Administrative Services Director for the City of Mesa, debated state legislation that allows developers to use the Central Arizona Groundwater Replenishment District to fulfill their requirement for a 100-year assured water supply.

DCDC’s graduate students organized a series of three panel discussions dealing with the process of boundary science, vulnerability assessment, and water policy. A total of 199 university scientists and community partners participated in the discussion, which are described above in the Education Activities section.

DCDC also hosted a number of ad-hoc lectures over the course of the year:

March 31, 2008, "Situational Control of Pro-Anti Environmental Behavior," Dawn Hill, University of Arizona.

April 8, 2008, "Environmental Responsibility and Conservation Psychology," Melinda S. Merrick, Human Nature Research Laboratory, University of Illinois.

May 16, 2008, "Urban Climate Models and their Applications," Sue Grimmond, Environmental Monitoring and Modeling Group, Department of Geography, Kings College, London.

May 28, 2008, "Weathering the Waves: Climate Change, Livelihoods, and Politics in Tuvalu," Heather Lazrus, Environmental Anthropology, University of Washington.

DCDC's WaterSim model was featured in a full-length story in the August 12, 2007, Sunday edition of the *Arizona Republic*. The article announced WaterSim's availability on the Web (<http://watersim.asu.edu/>) and discussed DCDC's work in climate, water, and decision science.

FROM THE FRONT PAGE

THE ARIZONA REPUBLIC

azcentral.com SUNDAY, AUGUST 12, 2007

Choosing a future for Arizona

IT'S 2030. We're in the 10th year of a sustained drought. Climate change shrinks rivers. We face a groundwater deficit of 8 trillion gallons, enough to create sinkholes and dry up aquifers. That's a scenario built by ASU's new WaterSim program. It's a grim picture, but the program offers choices ...

THE SCENARIOS		WHAT WE CAN DO
A sustained drought drains reservoirs and pushes the Colorado River system near collapse as millions of new people compete for the same short water supply.	DROUGHT 	Adding water is the key for Colorado River states, which propose lining canals and desalting runoff. Others say conservation is more sustainable, even in drought conditions.
Higher temperatures reduce runoff on the Salt and Verde rivers. Hotter weather increases demand by people and plants, further eroding supplies.	CLIMATE CHANGE 	Arizona has proposed plans to cut greenhouse gases with tougher rules on power plants and auto emissions. Changes would come slowly, leaving time to prepare.
Projected population in Maricopa County by 2030: 6.2 million, up from 3.8 million now. Conversion of farmland continues, shifting water supplies as demand climbs.	GROWTH 	With tight supplies, cities can adopt temporary drought restrictions or impose long-term rules that encourage fewer lawns and backyard pools.
Cities continue to meet all demands, tapping groundwater reserves as reservoirs drain. Sufficient water exists, but groundwater deficit grows.	WATER POLICY 	Residents would have to cut use by one-quarter or more to avoid serious aquifer damage. Some limits would need to be permanent to sustain supplies.

Public encouraged to play a role, one mouse click at a time

By **Shawn McKinnon** | THE ARIZONA REPUBLIC

Twelve years into one of the worst droughts on record, life remains pretty good in our little central Arizona oasis. No one has forced us to give up anything so far, not grass, not swimming pools, not the fake lakes that shimmer with real water.

We even managed to steal the "fastest growing" title from Nevada in the middle of this dry streak. But what if we had to do it again? What if the same drought strikes Phoenix 15 years from now? Some dry years, some emptying reservoirs, plus 3 million more thirsty people and the runoff-sapping effects of climate change. Could we still survive?

Arizona State University researchers asked that question, among scores of others like it, and built a sophisticated computer program called WaterSim to search for answers. The program uses existing models and data to produce water-use scenarios for urban Maricopa County. The designers acknowledge that they're not trying to predict the future. Instead, they hope the program will stimulate discussion about water-resource management and help end what they describe as paralysis in the debate over emerging issues such as climate change and sustainability.

See **WATERSIM** Page A8

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By Shawn McKinnon. Used with permission. Permission does not imply endorsement.

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Courtesy of Arizona State University's Global Institute of Sustainability, Decision Center for a Desert City, and Decision Theater, whose work is described here.

Presentations and Miscellaneous Activities

DCDC researchers regularly present DCDC research goals and results to community groups, students, and other local and international academic institutions.

On behalf of DCDC, Pat Gober made the following presentations in 2007-08:

July 14, 2007. "Urban Sustainability and the Future of Phoenix." Advanced Placement Conference, Las Vegas.

October 7, 2007. "Water, Climate, Growth, and the Future of Phoenix." Biltmore Kiwanis Club, Phoenix.

October 10, 2007. "Water! Where Will It Come From?" Scottsdale Area Association of Realtors, Scottsdale.

November 13, 2007. "Assessing Climate Change in Long-Term Water-Resource Planning." Annual Meeting of the American Water Resources Association, Albuquerque.

November 16, 2007. "WaterSim: An Integrated Model for Research and Decision Making." Colorado River Delta Research Coordination Network, Tucson.

November 26, 2007. "The Social Science of Climate Change." Climate Change: The Role of Higher Education in Arizona Conference, Tempe.

January 15, 2008. "The Inconvenient Truth about Phoenix." President's Community Enrichment Series, Desert Botanical Gardens, Phoenix.

February 16, 2008. "Desert Urbanization, Global Challenges." American Association for the Advancement of Science, Boston.

April 4, 2008. "Global Water Resources and Vulnerability from Climate Change and Population Growth." World Affairs Conference, Hilton Head.

Presentations

2008

Bolin, B., M. Seetharam, P. Gober, and B. Pompeii. 2008. "Water Resources, Climate Change, and Institutional Vulnerability: A Case Study of Phoenix, Arizona." Paper presented at the annual meeting of the Association of American Geographers, Boston, MA. April 18, 2008.

Brazel, A.J. 2008. "Benefits to Society of Urban Climate Research." Meeting of the Association of American Geographers, Boston, MA. April 18, 2008.

Chhetri, N. and U. Chong. 2008. "Soft-Path Solutions under Uncertainty: Multiple Stressor Analysis of Water Resources in the Lower Colorado River Basin." Paper presented at the annual meeting of the Association of American Geographers, Boston, MA. April 18, 2008.

Ellis, A.W. 2008. "Defining Drought Occurrence within the Colorado River Basin since the Late 19th Century." Annual meeting of the Association of American Geographers, Boston, MA. April 19, 2008.

Gammage, G. 2008. "State Trust Land Reform." McDowell-Sonoran Land Conservancy, Scottsdale, AZ. February 2008.

Gammage, G. 2008. "Will Phoenix Go the Way of the Hohokam?" Panel discussion hosted by *High Country News*. January 2008.

Gartin, M. 2008. "Being a 'Water-Buffalo': Political Discourse among Arizona's Water Policymakers." Paper presented at the 68th Annual Meeting for the Society for Applied Anthropology, Memphis, TN. March 27, 2008.

Gober, P. 2008. "Integrating Modeling for Water Resource Planning in Phoenix." Paper presented at the annual meeting of the Association of American Geographers, Boston, MA. April 18, 2008.

Gries, C., K. Jacobs, W.D. Otte, R. Vasquez, J. Abraham, R. Aguilar, J. McGill, S. Bhargav, and H. Nguyen. 2008. "The Arizona Hydrologic Information System." American Water Resources Association Spring Specialty Conference, San Mateo, CA. March 17, 2008.

Jacobs, K., J. Buizer, and D. Cash. 2008. "Making Short-Term Climate Forecasts Useful: Linking Science and Action." Invited Proceedings of the National Academy of Sciences Chapter, to be presented at a National Academy of Sciences Sackler Colloquium, Washington, D.C. April 2008.

Jacobs, K., L. Lebel, J. Buizer, L. Addams, P. Matson, E. McCullough, P. Garden, G. Saliba, and T. Finan. 2008. "Linking Knowledge with Action in the Pursuit of Sustainable Water Resources Management." Invited Proceedings of the National Academy of Sciences Chapter, National Academy of Sciences Sackler Colloquium, Washington, D.C. April 2008.

Killeen, P. 2008. "The Law of Affect." South American Psychological Association, Bogota, Colombia.

Killeen, P. 2008. "The Mother of All Discount Functions." Association for Psychological Science.

Lant, T. and V. Escobar. 2008. "Scenario-Based Modeling for Future Groundwater Management Planning." National Ground Water Association Groundwater Summit, Memphis, TN. March 31 - April 3, 2008.

Larson, K.L. 2008. "Sustaining Water Resources, or Maintaining the Status Quo?" Paper presented at the annual meeting of the Association of American Geographers, Boston MA. April 18, 2008.

Larson, K.L. 2008. "Environmental Perspectives as Sociocultural Elements of Water Resource Management: Case Studies of Portland, OR vs. Phoenix, AZ." Institute for Water and Watersheds, Oregon State University - Corvallis, OR. March 2008.

Larson, K.L. 2008. "Environmental Perspectives in the Phoenix Valley: Concern about Water Issues, Risk Perceptions, and Policy Preferences." Riparian Institute, Gilbert, AZ. February 2008.

Neff, M., B. Bolin, B. Cutts, K. Darby, E. Larson, T. Munoz-Erickson, and A. Wutich. 2008. "Does Truth Flow Like Water? The Role of Social Networks in the Flow of Scientific Understandings in a Water Management Controversy." Paper presented at the annual meeting of the Association of American Geographers, Boston, MA. April 15, 2008.

White, D.D., A. Wutich, T. Lant, and P. Gober. 2008. "Comparing Focus Group and Individual Responses on Sensitive Topics: A Study of Water Decision-Makers in a Desert City." Paper presented at the 14th International Symposium on Society and Resource Management, Burlington, VT. June 12, 2008.

Wingren, E., J. Parker, and B. Crona. 2008. "Performance and Perception at a Science and Policy Boundary." Pacific Sociology Association General Meeting, Portland, OR. April 10, 2008.

Zautner, L. 2008. "Water Vulnerability on the Urban Periphery: The Case of Metropolitan Phoenix, Arizona." Paper presented at the annual meeting of the Association of American Geographers, Boston, MA. April 18, 2008.

2007

Brazel, A.J. 2007. "Changing Urban Climate." Ninety-second Annual Meeting of the National Council for Geographic Education, Oklahoma City, OK. October 19, 2007.

Brazel, A.J. 2007. "Snow and Ice and Climate Change - Southwest and Global Perspectives." Second Annual Emeritus College Symposium on Environmental Changes: Science, Politics, and Culture, Tempe, AZ. November 3, 2007.

Brazel, A.J., S. Harlan, L. Prashad, W.L. Stefanov, D. Jenerette, L. Larsen, and N. Jones. 2007. "The Shaping of Neighborhood Microclimates." Ecological Society of America annual meeting, San Jose, CA. August 10, 2007.

Chhetri, N., L. Hiding, M. Neff, M. O Shea, A. Buttar, and U. Chong. 2007. "Multiple Realities: Stressor Analysis of Water Resources in Central Arizona." Paper presented at the conference on Connecting Science, Society and Development, University of Sussex, UK. September 18-20, 2007.

Ellis, A.W. 2007. "Instituting the Hydroclimatic Index in Monitoring Drought across the Colorado River Basin." Ninth Biennial Conference of Research on the Colorado Plateau, United States Geological Survey, Flagstaff, AZ. October 30, 2007.

Ellis, A.W. 2007. "Impacts of Potential Climate Change on Central Arizona Water Supply." Project WET Teachers Workshop, Global Institute of Sustainability, Arizona State University, Tempe, AZ.

Ellis, A.W. 2007. "Incorporating the Hydroclimatic Index in Drought Monitoring, Forecasting, and Scenario Building for the Colorado River Basin." Science and Technology Workshop, Bureau of Reclamation, Salt Lake City, UT.

Ellis, A.W. 2007. "Modeling the Impacts of Potential Climate Change on the Phoenix Water Supply." Guest lecture: BIO591/GPH591: Seminar in Ecological Climatology.

Gammage, G. 2007. "Proposition 207." Arizona Boards and Commissions Conference, Phoenix, AZ. December 2007.

Gammage, G. 2007. "Comparing Phoenix and Denver." Denver Leadership (including Mayor of Denver and Governor of Colorado). October 2007.

Gammage, G. 2007. "Arizona's Counties and the Future." County Supervisors' Association, Flagstaff, AZ. October 2007.

Gammage, G. 2007. "Growth and Water: Is Conservation Enough?" Panel discussion at the Colorado River Symposium, Santa Fe, NM. September 2007.

Gammage, G. 2007. "Arizona Home Rule." Arizona League of Cities and Towns Conference, Scottsdale, AZ. August 2007.

Gammage, G. 2007. "Recharge and Arizona Water Sustainability." Panel discussion at Southwest Hydrology Conference, Tucson, AZ. August 2007.

Gammage, G. 2007. "Superstition Vistas: The Future of Large Developments?" Technical session at the "Sustainable Water, Unlimited Growth, Quality of Life: Can We Have It All?" 2007 Regional Water Symposium, Tucson, AZ. August 31, 2007.

Groves, D., R. Lempert, P. Gober, and D. Yates. 2007. "Addressing Climate Change in Long-Term Water Resource Planning." Panel discussion presented at the American Water Resources Association's annual conference, Albuquerque, NM. November 13, 2007.

Guhathakurta, S. and P. Gober. 2007. "The Impact of Housing Characteristics and Surface Heat Islands on Water Use in Single-Family Residences: The Case of the Phoenix Metropolitan Area." Paper presented at the 54th Annual North American Meetings of the Regional Science Association International, Savannah, GA. November 9, 2007.

Harlan, S.L. 2007. "Household Water Consumption in an Arid City: Affluence, Affordance, and Attitudes." Presented at First Thursdays, Winslow | Orcutt Architects, Phoenix, AZ. December 6, 2007.

Harlan, S.L., S. Yabiku, L. Larsen, and A. Brazel. 2007. "Household Water Consumption in an Arid City: Affluence, Affordance, and Attitudes." Paper presented at the 102nd annual meeting of the American Sociological Association, New York, NY. August 11, 2007.

Holway, J. 2007. "Characterization of Arizona Energy/Water Issues." 2007 Regional Water Symposium "Sustainable Water, Unlimited Growth, Quality of Life: Can We Have it All?" Tucson, AZ. August 31, 2007.

Keller, L.R. and C. Kirkwood. 2007. "Preference Functions for Decisions with Geographically-Varying Attributes." INFORMS International Conference, Puerto Rico. July 10, 2007.

Larson, K.L. 2007. "Socio-Cultural Elements of Sustaining Water Resources: The Case of the Phoenix Oasis." School of Geographical Sciences, Arizona State University, Tempe, AZ. November 2007.

Redman, C.L. 2007. "Five Elements of a Sustainable Future." Emeritus College Symposium, Tempe, AZ. November 3, 2007.

Redman, C.L. 2007. "IGERT in Urban Ecology." Conference for Sustainability IGERT's, Fairbanks, AK. October 10-13, 2007.

Redman, C.L. 2007. "Sustainability." Leadership West Environment Issue Day, Tempe, AZ. May 3, 2007.

Schwartz, K. and M. Elser. 2007. "Using Survey Instruments to Design More Effective Workshops." Research Symposium at the North American Association for Environmental Education Annual Conference, Virginia Beach, VA. November 14, 2007.

White, D.D., A. Wutich, S. Ledlow, and P. Gober. 2007. "Credibility, Saliency, and Legitimacy of Boundary Objects for Water-Resource Decision Making: Assessing Stakeholder Response to DCDC WaterSim." Paper presented at the 13th International Symposium on Society and Resource Management, Park City, UT. June 17-21, 2007.

Wutich, A., T. Lant, M. Gartin, D. White, and K.L. Larson. 2007. "Getting Hard-to-Get Data: Are Group Interviews Really Better?" Paper presented at the annual meeting of the American Anthropological Association, Washington, D.C. November 29 - December 2, 2007.

V. Contributions

Human-Natural Coupled Systems: The Decision Center for a Desert City has produced a substantial body of urban environmental research that links the physical and human aspects of geography. DCDC—with its emphasis on climatic uncertainty, water resource management, and human vulnerability—has created opportunities for geographers to delve into new subfields and pose more complex societal questions. Examples of integrative work include: linking City of Phoenix water consumption with temperature and precipitation conditions (Balling and Gober 2007); assessing the sensitivity of different urban landscapes to climate conditions (Balling et al. under review); relating Phoenix’s urban heat island to residential growth patterns (Brazel et al. 2007); and correlating the urban-heat-island effect with residential water use (Guhathakurta and Gober 2008). An exemplar of this type of research is our project to relate individual perceptions of water quality to physical measures of odor, color, and taste, and then relate these in turn to the cultural understandings of water quality in Hispanic and Anglo neighborhoods.

Boundary Science: DCDC’s research, education, and outreach demonstrate a new form of science-policy engagement for geographers. The discipline of geography has, in the main, accepted Vannevar Bush’s linear model of science and society in which the social benefits of a scientific discovery appear many years after the discovery itself. According to this model, applied and basic science are separate activities. Applied geographers have been relegated to a secondary, derivative position in which they are perceived to use the ideas and methods of basic science for real-world problem solving. The unfortunate result of this false dichotomy is a disconnection between scientists and decision making. DCDC was founded to bridge this divide and to deploy the power of science for better water management decisions. DCDC provides an intellectual space for geographers to reconsider the boundary between science and policy, and to seek opportunities to fuse new-knowledge production with solutions to society’s most vexing problems.

Bayesian Maximum Entropy Modeling (BME): Postdoctoral fellow Seung-Jae Lee has engaged several DCDC geographers in writing a series of that use BME for spatial and temporal interpolation and extrapolation. Although the environmental modeling and assessment community has used BME as a means of managing uncertainty, it is not widely used in the geographical sciences. DCDC scientists have used BME stochastic methods to improve mapping accuracy of the urban heat island in Phoenix (Brazel et al. 2007; Lee et al. 2008), to extrapolate local-scale water consumption from cities where data are collected to outlying parts of the urban region (Lee and Wentz 2008), and to extrapolate water consumption data to future points in time (Lee, et al. under review).

Climate Modeling and Urban Design Options: DCDC’s interests in urban growth and climate have converged in analyses of the climate impacts of different urban design options. These projects take two forms. The first study builds upon studies of the sensitivity of different urban layouts to climate variability and change. The second involves linking urban water-balance and energy-balance models to analyze the water and temperature consequences of different urban design regimes. These

scenarios consider landscape treatments, building heights and densities, management of greenspace, and vegetated roof conversions.

Education: Monica Elser worked with two community college instructors and two high school Advanced Placement Human Geography teachers to develop lessons for geography courses centered on WaterSim. The group is preparing to put the materials on the DCDC Web site and the two community college instructors will present professional papers in the fall at regional conferences.

Contributions to other disciplines:

DCDC's mission as an interdisciplinary research center is to apply traditional disciplinary knowledge to solve the complex, practical problem of how to manage Central Arizona's water sustainably. The goal is not only to produce new disciplinary knowledge, but also to develop strategic connections among participating disciplines. WaterSim has provided opportunities for scientists from several disciplines to work on sub-models and then to negotiate with colleagues about how those models are joined.

DCDC's past and ongoing research projects include studies by economists of the price elasticity of local water demand, by psychologists of the trade-offs that people make between indoor and outdoor water use, by sociologists of the equity aspects of likely future water shortage, by historians of the environmental history of water conflicts and management, and by science and policy analysts of the evolving relationship between DCDC scientists and water decision makers. The results of these and other studies have appeared in a number of disciplinary and interdisciplinary journals, including the *Journal of Applied Econometrics*, *Journal of Public Economics*, *Environmental Hazards*, *Journal of the American Planning Association*, *Environmental History*, *Society and Natural Resources*, and *Research in Social Problems and Public Policy*.

Education and Outreach:

DCDC's formative years coincided with a fundamental restructuring of Arizona State University to augment transdisciplinary science and real-world problem solving. Hence, we were able to partner with other university programs to offer innovative learning programs to students. Margaret Nelson, Associate Dean of the Barrett Honors College, has for the past four years organized a three-credit Community of Undergraduate Research Scholars Program in conjunction with the Central Arizona-Phoenix Long-Term Ecological Research project and Urban Ecology IGERT. Students from the Research Experience for Undergraduates program have attended and presented posters at the American Association for the Advancement of Science (AAAS) meetings for each of the past three years, and we have sponsored a local poster symposium displaying their work. Held in conjunction with a DCDC Monthly Water-Climate Briefing, the annual poster symposium attracts students, their mentors, DCDC scientists, and water managers. It demonstrates the fusion of scientific discovery, transdisciplinary learning, and the search for real-world solutions.

In Years 3 and 4, we required DCDC graduate students to participate in a seminar to increase awareness of cross-DCDC activities and to institutionalize interdisciplinary research and learning. In Year 3, the students interacted with counterparts at other DMUU centers and organized a poster session at the 2007 AAAS meetings. In Year 4, our “DMUUsers” took to the road to visit the other centers and recruit students for cross-site collaborative projects. The aim of these activities is to build a grassroots, national network of interdisciplinary scientists who are interested in decision making under uncertainty and the link between science and solutions to societal problems.

DCDC co-hosted the Advanced Water and Climate Education Workshop, attended by 28 water educators and professionals, on July 31-August 1, 2007. The focus of the workshop was on climate change and its potential consequences for Central Arizona’s water supply. Speakers included: Michael Crimmins, Assistant Professor and Climate Science Extension Specialist from the University of Arizona; George Zaines, Assistant Professor and Extension Specialist in watershed, riparian, and rangeland management at UA; Andrew W. Ellis, Associate Professor of Geography at ASU and DCDC Climate Science team member; Tom Cooper, engineer in Intel’s water conservation program; Dave White, Assistant Professor of Community Resources and Development at ASU and DCDC Boundary Science team member; and Nancy Jones, DCDC Research Professional.

DCDC 2008 Annual Report – Appendix A
Partner Organizations and DCDC Participants

Partner Organizations

Salt River Project: (Ongoing) SRP delivers nearly one million acre-feet of water to a service area in central Arizona and operates an extensive water-delivery system that includes reservoirs, wells, canals, and irrigation laterals. SRP has provided a wide range of information to DCDC scientists, including hydrological data, public attitude surveys that reveal household perception of drought and responsiveness to conservation messages, reports of water duties (usage rates) associated with different land uses, water delivery data, and irrigation coverage. SRP climatologists and water managers are among the most regular participants at the DCDC Climate/Water Briefings and SRP representatives gave presentations and sparked discussion at two monthly Water/Climate Briefings. SRP also partnered with DCDC and University of Arizona's Water Resources Research Center on a summer 2006 workshop for teachers held at DCDC.

City of Phoenix: (Ongoing) DCDC collaborates closely with the City of Phoenix's Water Services Department, sharing the results of different but complementary water modeling efforts. In addition, the City has provided an immensely useful data set that includes municipal water use by different types of users across census tracts between 1990 and 2005. City representatives presented two DCDC monthly Water/Climate Briefings.

University of Arizona: (Ongoing) DCDC collaborates with three University of Arizona (UA) 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 efforts, investigating public perception of drought and water management. DCDC also partners with Climate Assessment for the Southwest (CLIMAS), part of UA's Institute for the Study of Planet Earth on climate research. DCDC and UA's Sustainability of semi-Arid Hydrology and Riparian Areas (SAHRA) are developing an online digital water-information system. SAHRA's experience with a broad spectrum of stakeholders (both public agencies and private organizations) enhances the relevancy of the project to decision makers.

Arizona Water Institute: (Ongoing) The Arizona Water Institute is a state-wide initiative to facilitate cross-university research about water resource management. Focus thus far is on developing the Arizona Hydrologic Information System.

Northern Arizona University: (2005-06) DCDC co-sponsored the Arizona Water Summit, held at NAU in August 2005, with the Center for Sustainable Environments. This event brought together the state, local, and tribal water management communities to discuss relevant science and policy issues related to water resource management.

East Valley Water Forum: (2004-05) The East Valley Water Forum consists of tribal, public, and private water agencies in the East Salt River Valley. They shared their groundwater-modeling output with DCDC so it could be integrated with agent-based models to produce visualizations for the Decision Theater.

Arizona Department of Water Resources: (2004-05) A DCDC-sponsored intern worked 20 hours per week at ADWR to retrieve data on the Phoenix area's water budget. The intern also developed metadata about how ADWR created the water budget.

INTEL: (2004-2005) The DCDC/Intel partnership pursued 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.

Lincoln Institute for Land Policy: (2004-05) 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.

Other Collaborators

Center for Science, Policy and Outcomes: (Ongoing) DCDC collaborates with ASU's Center for Science, Policy and Outcomes (CSPO), an internationally known organization involved in studying the linkages between science and technology and society. In fall 2006, CSPO convened a workshop of scientists actively studying water resource management in the Southwest with a goal of identifying the major stressors on the Phoenix metropolitan area water supply. Workshop results were used to help DCDC develop research priorities and to provide regional water managers with information regarding potential vulnerabilities. In spring and summer of 2007, CSPO will expand the geographic scope of their 2006 research. Specifically, CSPO will perform background research to identify key areas of uncertainty about water supply and assess the comprehensive picture of demand in the region to include the entire lower Colorado River Basin. They will produce a draft paper covering the current knowledge of stressors on this region's water supply and predictions about future changes. This paper will also create a ranking of stressors on the system.

Global Institute of Sustainability: (Ongoing) DCDC is administered by and closely collaborates with ASU's Global Institute of Sustainability (GIOS). GIOS serves as the bridge to other relevant NSF-sponsored projects, especially the Central Arizona Phoenix Long-Term Ecological Research (CAP LTER) project, the Urban Ecology Integrative Graduate Education and Research Training (IGERT) program, the cross-site Biocomplexity in the Environment project on Agrarian Landscapes in Transition, and the Sustainability Partnership Enterprise. As GIOS expands, international researchers are being asked to participate in its programs, including DCDC.

Decision Theater: (Ongoing) Founded simultaneously with DCDC, the Decision Theater at Arizona State University is a learning and decision space in which the latest understanding of complex social, economic, and natural processes and their interactions are visualized. DCDC works closely with DT to translate DCDC science and modeling into visualizations applicable for the general public and decision makers. DCDC's WaterSim is presented in the Decision Theater, and DT was used as the setting for a project to evaluate WaterSim as a decision support tool.

Central Arizona – Phoenix Long Term Ecological Research: (Ongoing) DCDC and the CAP LTER partnered in the design and implementation of the second round of the Phoenix Area Social Survey (PASS), a survey of 800 randomly selected Phoenix-area households. The survey asks respondents about their knowledge of, attitudes toward, and behaviors about a set of locally-relevant environmental issues, including urban sprawl, air quality, the urban heat island, and water scarcity. Results will allow DCDC researchers to test hypotheses about the interrelationships among environmental knowledge, attitudes and value systems, and ultimate behavior regarding water use and conservation practices. Closer collaboration between DCDC and CAP LTER, ASU's two large urban environmental research programs, offers the opportunity for integration of DCDC's inherently social science approach to urban modeling with CAP LTER's more ecological approach. A summer 2006 summit developed a research agenda to investigate human and ecological adaptations to future climate change. In 2007, DCDC and CAP LTER are expanding the PASS project to include GIOS scientists and public sector professionals.

University of California at Irvine Paul Merage School of Business: (Ongoing) Decision research at DCDC includes a partnership between L. Robin Keller (University of California at Irvine Paul Merage School of Business) and ASU faculty. The multi-objective decision analysis work performed in Year 1 is the foundation for developing decision-focused evaluation metrics for use with the models that are being developed within DCDC.

Community of Undergraduate Research Scholars: (Ongoing) ASU's Community of Undergraduate Research Scholars (COURS) provides opportunities for undergraduate students enrolled in the Barrett Honors College to contribute to DCDC research. In 2007, DCDC hosted the second annual COURS poster session, highlighting the interdisciplinary work of more than a dozen students. Faculty associated with DCDC, IGERT, the Southwest Consortium for Environmental Research and Policy (SCERP), CAP LTER and other NSF-funded projects oversaw the research presented.

Project Wet: (Ongoing) In 2006, DCDC partnered with University of Arizona's Project Wet and the Salt River Project to host a summer teacher training workshop, where 30 teachers from K-12 schools in the Phoenix Metropolitan area developed new learning materials based on local environmental issues such as water scarcity, water recycling, and the urban heat island. The new learning materials are based upon DCDC research, data sets, and outreach activities. A second "Advanced Water Educator's Workshop" is scheduled for July 2007.

ASU President's Office: (2006-08) DCDC and other university constituents, under the guidance of the Office of the University President, partnered with the Arizona Republic to create the Metropolitan Phoenix Indicators Project, a set of data presented in an impartial manner to illuminate the current state of the economic, social and cultural life of our region.

Other ASU research and academic units: (Ongoing) DCDC regularly co-sponsors lectures and symposia with other ASU research and academic units. These events bring together individuals from industry and multiple academic disciplines to explore and discuss topics such as robust decision making, historic perspectives of water in societies, visualization in environmental policy, and climate change in human-dominated systems.

Community Partners-Personnel Exchanges

City of Tempe: (Ongoing) City of Tempe supplies household-water-use data for DCDC analysis. Under DCDC's auspices and supervision, the Tempe Water Utilities Department sponsored an internship in 2006-07. The student investigated the potential water savings under various landscape water conservation scenarios.

City of Mesa: (2006-07) Under DCDC auspices and supervision, the City of Mesa Utilities Department sponsored an internship for an undergraduate student. The intern worked with a water resource specialists in the Resources Division of the Utilities Department. The intern assisted in research focused on scenario assessment for Mesa's long-term groundwater management plan.

DCDC Participants

Principal Investigators/Project Directors

Patricia Gober, School of Geographical Sciences

Charles L. Redman, Global Institute of Sustainability

Co-Principal Investigators

Bob Bolin, School of Human Evolution and Social Change

Grady Gammage, Jr., Morrison Institute for Public Policy

Thomas Taylor, Mathematics and Statistics

Senior Personnel: Manager

Bill Edwards, Executive Administrator

Senior Personnel: Core Scientists

John Anderies, School of Life Sciences

Brad Armendt, Philosophy

Richard Aspinall, School of Geographical Sciences

Robert Balling, School of Geographical Sciences

Anthony Brazel, School of Geographical Sciences

David Casagrande, Global Institute of Sustainability

Elizabeth Corley, School of Public Affairs

Andrew Ellis, School of Geographical Sciences

Monica Elser, Global Institute of Sustainability

Gregg Garfin, Institute for the Study of Planet Earth, University of Arizona

William Griffin, Family & Human Development

Corinna Gries, Global Institute of Sustainability

Suzanne Grossman-Clarke, Global Institute of Sustainability

Subhrajit Guhathakurta, School of Planning

Ed Hackett, School of Human Evolution and Social Change

Sharon Harlan, School of Human Evolution and Social Change

James Holway, Global Institute of Sustainability

Jana Hutchins, Institute for Social Science Research

Kathy Jacobs, SAHRA, University of Arizona; AWI

Donald Keefer, Supply Chain Management

L. Robin Keller, University of California-Irvine Graduate School of Management

Peter Killeen, Psychology

Ann Kinzig, School of Life Sciences

Craig Kirkwood, Supply Chain Management

Michael Kuby, School of Geographical Sciences

Tim Lant, Global Institute of Sustainability/Mathematics

Kelli Larson, School of Geographical Sciences/Global Institute of Sustainability

Peter McCartney, Global Institute of Sustainability

Margaret Nelson, Barrett Honors College

Joan McGregor, Philosophy
Rob Melnick, Global Institute of Sustainability/Morrison Institute for Public Policy
Ray Quay, City of Phoenix
Anshuman Razdan, Partnership for Research in Spatial Modeling
Jeremy Rowe, Information Technology
Charlene Saltz, University of Arizona
Daniel Sarewitz, School of Life Sciences
Kerry Smith, W.P Carey School of Business; Economics
Barbara Trapido-Lurie, School of Geographical Sciences
Elizabeth Wentz, School of Geographical Sciences
Dave White, School of Community Resources and Development
William Verdini, College of Extended Education
Joseph Zehnder, Geography

Postdoctoral Research Associates

Timothy Collins, School of Geographical Sciences
Seung-Jae Lee, School of Public Health
Mohan Seetharam, Decision Center for a Desert City

Other Collaborators

Rimjhim Aggarwal, School of Sustainability
James Buizer, Office of Sustainability Initiatives
Netra Chhetri, Consortium for Science, Policy & Outcomes
John Crittenden, Civil & Environmental Engineering
Beatrice Crona, School of Human Evolution and Social Change
Michael Crow, President Arizona State University
Rob Edsall, School of Geographical Sciences
Priscilla Greenwood, Department of Mathematics
Paul Hirt, Department of History
Susan Ledlow, Global Institute of Sustainability
Chris Lukinbeal, School of Geographical Sciences
Chris Martin, Department of Applied Biological Sciences
James Middleton, College of Education
Soe Myint, School of Geographical Sciences
John Parker, Barrett Honors College
Ed Sadalla, Department of Psychology
Nancy Selover, School of Geographical Sciences
Paul Torrens, School of Geographical Sciences
Paul Westerhoff, Civil & Environmental Engineering
Amber Wutich, School of Human Evolution and Social Change

Research Technical Personnel

Steven Brautigan, Decision Theater
Aashish Chaudhary, Decision Theater
Charlie Collins, Decision Theater
Deirdre Hahn, Decision Theater
Dustin Hampton, Decision Theater
Jiuxiang Hu, Decision Theater
Shea Lemar, Information Technology
Wayne Porter, Global Institute of Sustainability
Robin Schroeder, Global Institute of Sustainability
Michael Zoldak, Institute for Social Science Research

Public Outreach Personnel

Nancy Jones, Decision Center for a Desert City

Research Support Personnel

Michelle Schwartz, Decision Center for a Desert City
Karen Gronberg, Global Institute of Sustainability
Nikol Grant, Global Institute of Sustainability
Linda Newsom, Decision Center for a Desert City
Estella O'Hanlon, Decision Center for a Desert City
Lauren Kuby, Global Institute of Sustainability
Michael Tschudi, Decision Center for a Desert City

Graduate Research Associate

Srushti Abhyankar, Department of Computer Science and Engineering
Stacey Avent, School of Human Evolution and Social Change
Suresh Ayyalsamy, Family and Human Development
Neil Barton, School of Geographical Sciences
Jagadeesh Chirumamilla, School of Geographical Sciences
Erin Comparri, School of Geographical Sciences
Bethany Cutts, School of Life Sciences
Stephanie Deitrick, School of Geographical Sciences
Jillian Elder, School of Geographical Sciences
Vanessa Escobar, Geology
Meredith Gartin, School of Human Evolution and Social Change
Chris Graham, School of Geographical Sciences
Anne Gustafson, History
Shannon Gysberg, School of Geographical Sciences
Zeenat Hasan, School of Human Evolution and Social Change
Brent Hedquist, School of Geographical Sciences
Vasudha Lathey, Environmental Design/Planning
Kim Michel, School of Life Sciences

Mark Neff, School of Life Sciences
Darren Ruddell, School of Geographical Sciences
Megan O'Shea, School Of Earth & Space Exploration; School of Geographical Sciences
Jamie Patterson, School of Geographical Sciences
Brian Pompeii, School of Geographical Sciences
Shana Schmidt, Family and Human Development
Clea Senneville, School of Sustainability
Cheryl Sexton, Family and Human Development
Clarie Smith, School of Human Evolution and Social Change
Subramanian Swaminathan, School of Geographical Sciences
Margaret White, School of Life Sciences
Yolanda Youngs, School of Geographical Sciences
Lilah Zautner, School of Geographical Sciences
Kelly Turner, School of Geographical Sciences

Other Grads

Jessica Block, Geology
Hoi Cheung, College of Design
Kade Hutchinson, Geology (Decision Theater)
Steve Swanson, School of Human Evolution and Social Change

Community of Undergraduate Research Scholars (COURS)

Malaya Fletcher, Global Institute of Sustainability
Peter Howe, School of Geographical Sciences
Allyn Knox, Biology
Matt Kruger, Political Science
Nicholas Moore, School of Geographical Sciences
Arianne Peterson, School of Human Evolution and Social Change
Melanie Tluczek, School of Human Evolution and Social Change
Eva Wingren, School of Human Evolution and Social Change

Other Undergrads

Lubinka Andonoska, Public Administration
Hillary Butler, Plant Biology
Avneet Buttar, Computer Information Systems
Laura Hand, Public Administration
Brian Keegan, Business
Andrew Knochel, Urban Planning
Adam McDaniel, Global Institute of Sustainability
Eric Moore, Department of Finance
Caroline Newcombe, Civil Engineering

Annissa Olsen, School of Global Studies
Michelle Rupp, Political Science
Rosanne Servis, English
Uven Chong, Mechanical Engineering

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
Kerry Schwartz, Water Resources Research Center

Organizational Partners (outside ASU)

Salt River Project
City of Phoenix
East Valley Water Forum
Arizona Department of Water Resources
Intel
University of Arizona
Lincoln Institute for Land Policy
Arizona Water Institute
City of Tempe
City of Mesa
Arizona Town Hall

Other collaborations

ASU President's Office
American Indian Policy Center
Central Arizona–Phoenix Long Term Ecological Project (CAP LTER)
Arizona Town Hall