

# ***C&EE Department Mission Statement: Engineering Sustainable Infrastructure for the Future***

*The one word on everyone's lips in the Capitol is a four-syllable noun that previously would have induced naps: infrastructure. It's the hot issue.<sup>1</sup>*

## **INTRODUCTION**

Many parts of the nation are suffering under the burden of decaying, strained public works systems<sup>2</sup>. This is particularly true across California – our highways and ports often are choked by the volume of people and goods moving through them; demands on our water quality and supply systems are moving steadily toward maximum capacity; hazardous wastes plague our environment while urban runoff threatens our coasts and ocean; communities and the structures within them (e.g., bridges, dams, levees and buildings) desperately need improved protection both from natural disasters (earthquakes, wildfires, and floods) and man-made hazards (terrorism). Moreover, over time demographic and economic growth patterns will exacerbate the impact of these disasters and hazards. California's population is expected to increase by as much as 30 percent over the next 20 years, from 37 million to 46 million people – the equivalent of adding three new cities the size of Los Angeles. Accompanying this population growth will be increased domestic and international commercial flows; domestic cargo volume is expected to increase by about 70 percent by 2025, while international trade is expected to at least double. The ports of Long Angeles and Long Beach alone anticipate a tripling of cargo volume by 2030. Accordingly, it should come as no surprise that the infrastructure investments of a half-century ago are straining to support modern population levels and commercial activities they were not designed to accommodate, and are sorely inadequate relative to the natural and man-made hazards they face. From this perspective, the American Society of Civil Engineers' assigning of an aggregate grade of "D" to the nation's infrastructure in its 2005 Report Card for America's Infrastructure comes as no surprise and requires action.<sup>3</sup>

Recently federal and state government agencies have focused increased attention on matters related to infrastructure remediation and improvement. At the federal level,

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<sup>1</sup> Skelton, George, "Lawmakers Must Deliver on Promise to Rebuild State," *Los Angeles Times*, 20 February 2006. (The "Capitol" refers to California's state capitol, Sacramento).

<sup>2</sup> For a fact sheet on the national infrastructure, go to [www.asce.org/reportcard/2005/page.cfm?id=145](http://www.asce.org/reportcard/2005/page.cfm?id=145). For a fact sheet on California's infrastructure, go to [www.asce.org/reportcard/2005/page.cfm?id=44](http://www.asce.org/reportcard/2005/page.cfm?id=44). For a fact sheet on Los Angeles County's infrastructure, go to [www.ascelasection.org/documents/report\\_cards/LA%20County%20Report%20Card.pdf](http://www.ascelasection.org/documents/report_cards/LA%20County%20Report%20Card.pdf).

<sup>3</sup> To see this report in both aggregate and disaggregated detail, go to [www.asce.org/reportcard/2005/index.cfm](http://www.asce.org/reportcard/2005/index.cfm). For a press release about the report, go to [www.asce.org/reportcard/2005/page.cfm?id=108](http://www.asce.org/reportcard/2005/page.cfm?id=108). The report evaluates 15 infrastructure categories. ASCE's analysis indicates that overall conditions have remained the same or worsened in 13 of those categories.

Senators George Voinovich, Thomas Carper and Hillary Clinton have introduced the National Infrastructure Improvement Act of 2006. If enacted, the legislation would mandate, among other things, the establishment of the *National Commission on the Infrastructure of the United States* “to ensure that the nation’s infrastructure meets current and future demands and facilitates economic growth.”<sup>4</sup> Closer to home, Governor Arnold Schwarzenegger’s \$222 billion, 10-year infrastructure-intensive ‘Strategic Growth Plan’ for California, unveiled in his State of the State speech in early 2006,<sup>5</sup> has heightened further the level of public awareness and discourse statewide. Elements of the infrastructure plan were brought before California’s voters in the November 2006 elections in the form of several public works bonds and passed by wide margins.<sup>6</sup> The resulting injection of money into the state economy (estimated at more than \$120 billion when expected federal, local and other funding sources are included) will finance hundreds of long-neglected projects relating to public transit, freeway upgrading, parkland expansion, housing, pollution control, flood control and various other water initiatives, and will constitute the state’s largest public construction effort in four decades. This represents a potential boon both to current civil and environmental engineering practitioners as well as those who will enter the workforce in the future – today’s civil and environmental engineering students.

The recent political and media emphasis on infrastructure is encouragingly and gratifyingly compatible with the long-standing, unifying research and instructional theme of the Department of Civil and Environmental Engineering: *engineering sustainable infrastructure for the future*. It is thus an opportune moment for us to specify the various aspects of this theme as they constitute the department’s mission.

## RESEARCH MISSION

The Civil and Environmental Engineering Department enjoys a compelling, overarching sense of purpose and central focus, and recent initiatives described above have precipitated a renewal of the faculty’s sense of shared mission. We embrace a strongly

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<sup>4</sup> ASCE worked closely with Senator Voinovich and his staff to draft the legislation, formally introduced on 8 March 2006. For an official statement see <http://clinton.senate.gov/news/statement/details.cfm?id=252364&&>. For coverage and commentary from ASCE and the American Water Works Association, go to [www.asce.org/pressroom/news/grwk/event\\_release.cfm?uid=2559](http://www.asce.org/pressroom/news/grwk/event_release.cfm?uid=2559) and [www.awwa.org/Communications/news](http://www.awwa.org/Communications/news), respectively.

<sup>5</sup> For an elaboration of Schwarzenegger’s plan, go to [www.strategicgrowthplan.com/](http://www.strategicgrowthplan.com/). For the plan’s announcement, see Associated Press, “Transcript of Governor’s State of the State Speech,” *Los Angeles Times*, 6 January 2006. For information on California’s infrastructure needs and an overview of alternative proposals, refer to a briefing compiled by UC Berkeley’s Institute of Governmental Studies at [www.igs.berkeley.edu/library/htInfrastructureProposal.html](http://www.igs.berkeley.edu/library/htInfrastructureProposal.html). For further background, go to the California Infrastructure Coalition web site at <http://calinfrastructure.org/>.

<sup>6</sup> For pre-election coverage and analysis see Skelton, George, “Pitching Public Works Bonds Now a Team Sport,” *Los Angeles Times*, 28 August 2006; and Cannon, Lou, “Can We Be a 1<sup>st</sup>-Rate State with a 3<sup>rd</sup>-Rate Budget?” *Los Angeles Times*, 3 September 2006. Among the items appearing on the November ballot was Proposition 1B, a \$19.9 billion bond issue for transportation, Prop. 1E, containing \$4.1 billion in flood control bonds, and Prop. 84, an initiative to fund \$5.4 billion in various water projects. For post-election analysis see Rau, Jordan, “With Bonds Approved, the Line for Billions Forms,” *Los Angeles Times*, 9 November 2006.

held collective sensibility, organizing principle and resolve that we seek to elucidate below.

### *Apart....and Together*

The Civil and Environmental Engineering Department consists of four sub-disciplines, each of which – properly – investigates distinct areas of inquiry to one degree or another. **Environmental Engineering** traditionally concentrates on understanding the physical, chemical, and biological processes in environmental systems to protect the natural environment while meeting the demands of human activities. Typical areas of research include aquatic chemistry, water treatment, wastewater treatment, and contaminant fate, transport and remediation. **Geotechnical Engineering** is concerned with the behavior of earth systems, including all structures building on, in, or with the ground. Typical areas of study include soil material characterization, design of geo/structural systems (e.g., foundations, retaining structures, dams), and geo-related hazard characterization (earthquakes, landslides, expansive soils). **Hydrology and Water Resources Engineering** recognizes the heavy demands on existing water supplies in arid and semi-arid regions, created largely by the human-induced impact on the ecosystem. This motivates research designed to better understand and diagnose hydrologic fluxes, their spatial and temporal variability, and system responses to human perturbations in an effort to devise optimal methods for water resource planning and management. New research explores land surface modeling, hydrometeorology, and remote sensing and data assimilation. **Structural Engineering and Mechanics** incorporates the classic areas of structural mechanics, nonlinear analysis, structural dynamics, structural design, earthquake engineering, structural testing, and computational/solid mechanics as well as emerging areas such as meshfree methods, damage mechanics, and performance-based structural design. The corresponding research agenda includes examining the behavior of reinforced concrete structural elements and systems, analyzing homeland security design for structures, multiscale materials modeling, and generally pursuing optimum structural design.

Without question, *we consider this quartet of diverse research programs to be absolutely vital to our core research mission and educational mandate*, and seek to cultivate an academic environment conducive to the pursuit of the faculty's sub-disciplinary endeavors. However, diverse research is by no means divergent research. Accordingly, the C&EE Department faculty actively engage in synergistic collaborations that cross both sub-disciplinary and departmental boundaries. Prominent examples include Prof. Eric Hoek's involvement with the UCLA Water Technology Research (WaTeR) Center and Prof. John Wallace and Prof. Jonathan Stewart's participation in the Network for Earthquake Engineering Simulation (NEES) project.<sup>7</sup> Other campus units involved in various projects include Atmospheric Science, Molecular Biology, Environmental Health Science, Chemical Engineering, Policy Studies, Geography, Statistics, Earth and Space Science, Applied Mathematics, Electrical Engineering, Computer Science, and the Institute of the Environment. Beyond UCLA, the faculty

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<sup>7</sup> Go to [www.watercenter.ucla.edu](http://www.watercenter.ucla.edu) and [www.nees.ucla.edu](http://www.nees.ucla.edu), respectively. Other examples are provided below (pages 5-8) in elaborating upon the department vision.

work with private industry, government agencies, and national laboratories. Research partnerships in emerging cross-disciplinary fields such as earthquake engineering, environmental biotechnology, and integrated water supply and waste management *by definition* require an expansive pooling of intellectual capital and expertise. Fortunately, our faculty are situated at the nexus of a series of exciting disciplinary connecting points, and will be instrumental in achieving the engineering innovations of the future. The importance of our department's deliberate posturing in this regard cannot be overstated, for we believe that an increasingly integrated perspective related to impacts on our atmosphere (air), hydrosphere (water), geosphere (soils), biosphere (biota) and anthrosphere (humans) is essential to – if not constitutive of – a vision focused on engineering for a more sustainable regional, state and national infrastructure.

### *The Vision*

We seek to leverage and extend our sub-disciplinary strengths and apply them within a multi-disciplinary context to solve societal problems related to our guiding theme: *engineering sustainable infrastructure for the future*. It is under this rubric that we aspire to educate future engineering leaders, most of whom will work in multi-disciplinary environments to address a host of 21<sup>st</sup> century challenges. The theme contains key, inter-related elements. With an infrastructure-based vision motivating our teaching and research enterprise, *we first and foremost have conceptualized and oriented our activity at the macro level to broaden and deepen fundamental knowledge of the inter-relationships among the built environment, natural systems and human activities in all fields*. From this encompassing directive flows, on a more practical level, specific research and educational themes, which include:

- **Characterization and mitigation** of natural and man-made hazards;
- **Development and application** of new engineering materials and systems and other technological innovations to **optimize performance** of infrastructure as well as **safeguard and economize** the infrastructure-society relationship;
- **Improvement** of the reliability, performance, and disaster-resistance of water supplies, treatment processes, and distribution systems; and
- **Promotion** of performance-based earthquake engineering as a new paradigm for analysis and design of disaster-resistant infrastructure.

This agenda establishes a comfortable balance. The first two themes reflect department-wide imperatives, while the second two themes focus on the more tailored interests of binary sub-discipline combinations (Environmental Engineering and Hydrology and Water Resources Engineering in one, Geotechnical Engineering and Structural Engineering and Mechanics in the other) – and their respective outside collaborators.

Though a complete accounting would be prohibitive in length, a brief look at selected examples drawn from current C&EE research programs will help place this thematic agenda in its proper context and bring it to life.

*Southern California's population is situated within an active geologic zone, and as the population progressively encroaches into surrounding wildlands it becomes exposed to both natural and man-made hazards. C&EE faculty are engaged actively in characterizing and mitigating hazards in order to improve regional safety, but with perhaps global benefits. Two examples illustrate what this means.*

The southern California region experiences periodic and severe wildfires at the ever-expanding urban-wildland interface. C&EE faculty, in conjunction with the National Weather Service (NWS) and the United States Geologic Survey, are investigating the physical and chemical response of burned watersheds in order to improve the prediction of post-fire floods and debris flows and mitigate damage to downstream communities. They also are working with the NWS to improve operational flood forecasting models through incorporation of remote sensing technologies and optimization techniques. The research focuses on improving day-to-day operations of river and flood stage warnings as well as longer term probabilistic forecasts of stream flow. It also addresses the transport and biogeochemical cycling of toxic trace elements, including *Hg* and *As*, and the persistence of pathogenic organisms in environmental biofilms. For example, in 2006 a C&EE team in collaboration with the UCLA Center for Embedded Networked Sensing deployed a wireless sensor network to characterize the effects of irrigation on arsenic mobilization in a Bangladeshi aquifer.

Terrorist attacks on civilian and government facilities in the U.S. and elsewhere highlight the need to enhance the physical security of civil infrastructure such as power plants, dams, gas and oil transmission lines, highway crossings, bridges and airports. A major imperative in this difficult undertaking is determining the mechanical response of structures from 'extreme events' such as accidental and intentional explosions, impacts by high velocity projectiles, ramming, as well as severe earthquakes. Acquiring this capability is essential for developing viable, economical design and retrofitting strategies as well as assessing the vulnerability and dominant failure modes of existing and new structures. C&EE faculty are working on the development of high-fidelity (i.e., accurate and robust) computational tools to determine the mechanical response of structures to such extreme events

*The public demands that the operation, maintenance, rehabilitation, and expansion of the regional, state, and national infrastructure proceed with minimal disruption of citizens' lives. As a result, we are vigorously pursuing the innovative solutions required both to improve the performance and minimize the environmental impact of existing systems, as well as reduce construction delays and project costs for new systems. Our goal is to help reduce the gap between future needs and present capabilities through technological innovations designed to safeguard, improve, and economize infrastructure and society.*

C&EE faculty are developing, testing, characterizing, simulating, designing, optimizing, and implementing advanced structural materials to improve the stability, fouling resistance, application range, and overall efficiency of advanced water purification technologies; as well as to enhance the strength, fracture resistance, ductility, energy dissipation, durability, and serviceability of advanced new structural materials. Research in such materials includes investigation of carbon nanotubes, nanoparticles, fibrous and particulate composites, nanocomposites, nanosensors, metals and alloys, fiber reinforced concrete, fracture-resistant materials, fouling-resistant materials, polymers, zeolites, dendrimers, and biomaterials (biopolymers, enzymes, DNA, bones). Key applications in the area of advanced structural materials focus on structural health monitoring, multi-hazard resistant infrastructures, optimal material systems and structures, and advanced transportation systems. Key applications in the area of advanced water purification materials are the formation and testing of low energy and fouling-resistant reverse osmosis membranes for the production of water from saline sources (desalination) as well as the design and field testing of novel chemical and biological sensors to improve the timeliness and accuracy of water quality monitoring.

For example, in the area of water quality engineering, C&EE faculty are immersed in the research, development, optimization, and implementation of ground-breaking technologies for sensing, treatment and remediation applications. One project, in collaboration with researchers from Chemical Engineering and the California Nanosystems Institute, includes the creation and deployment of low energy, fouling resistant nano-composite reverse osmosis membranes for desalination and water purification. Another project, in collaboration with Electrical Engineering faculty as part of the Networked Infomechanical Systems project, is developing a near-real time sensor for detecting *enterocci* bacteria in recreational water. In terms of water resources engineering, embedded networked sensors in soil in conjunction with advanced data assimilation methods are being used to characterize the infiltration and transport of treated wastewater for use in irrigation. Three dimensional fields consisting of moisture, temperature, and nitrate concentrations can be estimated by optimally combining the sensor data with numerical models of the transport phenomena.

*In water-scarce regions like the western United States, upgrading the reliability, performance, and disaster resistance of water supplies, treatment processes, and distribution systems is a critical area of research.*

C&EE faculty are amongst the leaders in better assessing water stores and fluxes in the hydrologic cycle and improving reliability of the water supply system via optimization methods. In collaboration with UCLA's Center for Embedded Network Sensors, ongoing work combines remote sensing and hydrologic modeling in an effort to obtain real-time estimates of snowpack in mountainous watersheds for significant lead-time forecasting of water supply and spring snowmelt. New remotely sensed estimates of evaporation are being implemented in both operational flood forecasting models and agricultural applications for optimizing irrigation. Advanced optimization models also are being developed and employed for more efficient operations of large-scale hydropower and

water supply systems, such as the California Central Valley Project and the Metropolitan Water District of Southern California.

In terms of water quality, department researchers are developing methods geared toward providing early warning of changes in raw and treated water quality as well as identifying more robust and flexible treatment processes. For example, our faculty are developing new hybrid electrochemical membrane systems in order to create adaptive water purification processes that will help treatment plants deal with variable raw water quality using a single unit operation. In addition, land-use classification via remote sensing is being employed to improve estimates of non-point source pollution and stormwater flow from urban areas.

Faculty members also are taking a lead role in understanding the seismic vulnerability of California's endangered levee system. The research involves ascertaining the vulnerability of earthen levees to breaches from earthquakes through both full-scale field testing of and fundamental, laboratory-based studies of the cyclic behavior of the organic peats underlying many levees.

*Recent earthquakes, such as those effecting Northridge and Kobe, Japan, have exposed the seismic vulnerability of our infrastructure. The design and retrofit of our civil infrastructure must respond to a variety of performance criteria that have significance for owners and other stakeholders (post-earthquake downtime, amortized annual monetary loss, fatalities, etc.).*

Unfortunately it has become apparent that conventional engineering analysis methods are unsatisfying in that they typically describe performance of systems in traditional engineering terms (collapse, permanent deformations, etc.) in a deterministic way. Performance-based earthquake engineering (PBEE), by contrast, seeks to yield meaningful performance predictions within a fully probabilistic framework, so that seismic hazards can be contextualized with other hazards that can influence decision makers (flood, financial solvency, terrorism, etc.).

Meeting the goals of PBEE requires not only good physical understanding of the processes to be modeled, but also of the uncertainty associated with those models and the parameters they utilize. C&EE faculty, in conjunction with researchers in the Earth and Space Science and Public Policy Departments, are in the midst of devising models and generating the fundamental data needed for delivering key aspects of PBEE, from material characterization (soils, concrete, composites, etc.), probabilistic characterization of earthquake ground motions, full-scale field and scale model (laboratory) testing of systems to gain insight into mechanisms controlling performance (soil-foundation-structure interaction, wall-frame systems), development of advanced materials, and numerical simulation of structures and other systems. Department researchers also are playing key roles both domestically and internationally in both expanding and utilizing our knowledge through service on critical policy-establishing committees for earthquake engineering practice.

A representative example of this research is a project, conducted in collaboration with C&EE faculty from across the U.S. as well as experts in public policy, which is addressing the collapse risk of vulnerable non-ductile reinforced concrete structures. The project is utilizing new concepts in ground motion hazard characterization, sophisticated concrete and soil-foundation element testing, and simulation tools to evaluate the vulnerability of various classes of buildings. Those models in turn are used to forecast the collapse risk of buildings across the Los Angeles urban region in the event of a large earthquake. Mitigation strategies for the most at-risk classes of structures also are being investigated to reduce this hazard, for which there are significant life safety implications.

## FACULTY RECRUITMENT

The C&EE Department seeks to aggressively hire tenure-track faculty candidates who share the integrated approach, articulated above, to the civil and environmental engineering disciplines, and who aspire to complement our strengths and expand our capabilities in a unified effort aimed at *engineering sustainable infrastructure for the future*. We feel confident that prospective faculty members will be attracted to and stimulated by the department’s cohesive sense of purpose and vision.

<b>Rank</b>	<b>FTE</b>	<b>Percentage</b>
Professor	7	46.6%
Associate professor	1	6.8%
Assistant professor	7	46.6%
<b>Total</b>	15	100%
Female Faculty	3	20%

The table to the left shows the number and distribution of ladder faculty in the department. Our roster of 15 FTE is three below the target goal of 18. Reaching our target FTE with strategic hires

is essential to further elevate our national ranking, which has steadily improved in recent years.

The table reveals a healthy distribution in rank and gender – our female faculty ratio is 20 percent, the highest in UCLA’s Henry Samueli School of Engineering and Applied Science. Because of the department’s high percentage of non-tenured faculty (assistant professors), current recruiting efforts are directed toward securing a senior position (full professor) with a proven track record. We are interested especially in those whose areas of research include advanced materials, environmental biotechnology, and sensor technology. In the area of advanced materials we desire someone pursuing revolutionary breakthroughs in infrastructure enhancement, encompassing areas such as mechanics and design of micro/nano structured materials for engineering structures, smart/active materials for failure- and performance-based assessment of systems subjected to extreme conditions, constitutive characterization of new construction nanomaterials, and analysis of material microstructures and their connection to nano-, meso-, and macro-scale structural behavior. In the area of environmental biotechnology we seek someone whose work encompasses all aspects of biological methods and applications for characterizing engineered and natural systems, treatment/reclamation of impaired waters and wastewater, and remediation of contaminated sites. Finally, we are interested in individuals with expertise in genetic/molecular techniques that can be applied to the

development of chemical and biological sensors and/or alternative/renewable energy in combination with applications to conventional aspects of the biological treatment of water, soil, and air. The advanced sensor field and viable candidates working within it recognize the critical relevance of health monitoring and sensor network applications to infrastructure and environmental systems, particularly as they relate to protection from extreme events. Accordingly, we are attracted to those who are developing sensor technology applicable to **1)** optimal networking and data collection in the field, **2)** infrastructure subjected to natural and other hazards, and **3)** monitoring environmental contamination and geochemical processes.

Each of the three areas mentioned above requires multi-disciplinary collaboration between the hired faculty member and other department faculty, as well as specialists in disciplines such as bioengineering, materials science, computer science, electrical engineering, nanotechnology, earth and space science, and others. The ability to identify key confluences in research interests and exploit them through effective research partnerships is essential if new faculty are to contribute to the challenge of *engineering sustainable infrastructure for the future*.