UCI Water–PIRE

2014 NSF – PIRE

ANNUAL REPORT

Accomplishments

What are the major goals of the project?

Based on our proposal application, and working with our external evaluator (Dr. Lisa Kohne, SmartStart), the following major goals were identified for our project. No specific timeline was developed for each goal. Note that for the 2013 Annual Report we specified a total of 5 goals. After several workshops with project participants, we decided to combine two of the original goals (Goal 1--"Education" and Goal 5--"Workforce Development") into a single goal (Goal 2--"Education and Workforce Development"). This change does not reflect a change of project scope, but rather an attempt to streamline the evaluation of planned activities.

Goal 1: *Knowledge/Research/Discovery*. To increase knowledge and understanding of sustainable urban water systems, and in the process equip a new generation of engineers, natural, physical, and social scientists, policy makers, and educators with multi-disciplinary skills and sensitivities.

Goal 2: *Education and Workforce Development*. To (1) accelerate education and training in the area of urban water sustainability, and (2) diffuse knowledge about sustainability options to U.S. middle-school and high-school students, undergraduate STEM majors, graduate students, post-doctoral researchers, and practitioners. Through these educational activities we will contribute to the development of a workforce in urban sustainability science, engineering, and policy that will thrive in the face of transdisciplinary problems.

Goal 3: *Partnerships.* To improve urban water sustainability research and application through the establishment of new partnerships between university researchers, non-university researchers, and urban water managers.

Goal 4: *Institutional Capacity.* To increase the capacity of UCI's Henry Samueli School of Engineering (HSSoE) to lead research and educational exchange programs with other units on campus, other universities, non-university research programs, and international partners.

What was accomplished under these goals?

Major Activities:

Goal 1--Knowledge/Research/Discovery.

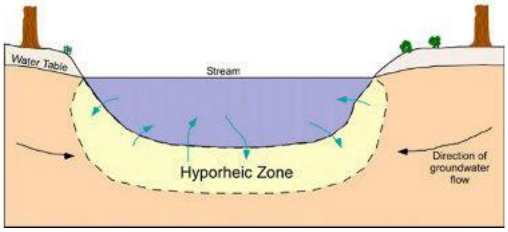
<u>Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams</u>

<u>Biofilter Ecology</u>. Ecological components of engineered systems are often overlooked. Collaborations between researchers from UCLA (R. Ambrose, B. Winfrey), UCSD/SIO (L. Levin, A. Mehring), and Monash University (A. Deletic, B. Hatt) are shedding light on the ecological structure and function of biofiltersand how they might be optimized using ecological principles.

**<u>Chemical Pollutant Removal in Natural Treatment Systems</u>.* Natural treatment systems remove pollutants from dry and wet weather urban runoff using natural, low-energy, ecological and physicochemical processes. In this effort a team of researchers from UCI (M. Rippy, S. Grant, W. Cooper, L. Weiden, E. Parker, D. Rosso, A. Robinson), UCLA (R. Ambrose, B. Winfrey), UCSD (L. Levin, A. Mehring), Monash University (Ana Deletic, David McCarthy, B. Hatt), and University of Queensland (Wolfgang Gernjak) are collaborating to better constrain the loading, fate, and transport of chemical contaminants in constructed wetlands and biofilters.

<u>Pathogen Removal in Natural Treatment Systems</u>. A significant barrier to the adoption of biofilter technology is the absence of agreed upon treatment credits for these systems. In this project a team of researchers from UCI (S. Jiang, E. Huang) and Monash University (A. Deletic and D. McCarthy) are quantifying the removal of human pathogens and viral and bacterial indicator organisms in biofilter columns.

<u>Multi-Physics Models and Measurements of Hyporheic Exchange</u>. The hyporheic zone is the sediment beneath and adjacent to a stream where surface water and groundwater mix. A team of researchers from UCI (S. Grant, M. Azizian, M. Rippy), University of Melbourne (M. Stewardson, A. McCluskey, E. Gee), and Monash University (P. Cook, A. Kessler) are developing multi- physics models for predicting, and experimental systems for measuring, contaminant removal in hyporheic zone treatment systems.



<u>Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.</u>

<u>GHG Fluxes from Sediments in Urban Wetlands</u>. Urban wetlands (including constructed wetlands, wastewater stabilization ponds, and golf courses) are known to emit the greenhouse gases carbon dioxide, methane, and nitrous oxide. In this effort, a team of researchers from UCSD (L. Levin, A. Mehring), and Monash University (P. Cook, V. Evrard) are conducting field measurements of greenhouse gas (GHG) emissions in urban wetlands in and around Melbourne, and relating the results to plant and animal communities present in these systems.

<u>Quantitative Microbial Risk Assessment</u>. Widespread adoption of rainwater and stormwater reuse may pose a public health risk. In this activity, researchers from UCI (S. Jiang, K.Y. Lim) and the University of Melbourne (A. Hamilton, K. Burry) are: (1) investigating the microbial risk associated with harvested rainwater for irrigation of household produce; (2) investigating the microbial risk associated with different modes of human exposure (toilet flushing, showering, and produce irrigation) to harvested stormwater; and (3) comparing quantified and perceived risks for stormwater reuse.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

Offsets for Water Management. Researchers from UCI (D. Feldman, J.D. Saphores, L. Stuvick, C. Patel), the Southern California Coastal Water Research Project (A. Sengupta, E. Stein), and the University of Melbourne/Center for Aquatic Pollutant Identification and Management (M. Arora, and V. Pettigrove) are investigating governance issues associated with development of innovative pollutant offset programs. The team is intensively studying an offset scheme being piloted at the Gisborne Recycled Water Plant in Jacksons Creek, a rural sub-catchment of the Maribyrnong River north of Melbourne.

Drought, Policy Evolution in Melbourne, and Comparisons to California. Researchers at UCI (D. Feldman, S. Grant, K. Low, A. AghaKouchak), University of Melbourne (A. Hamilton, K. Burry), and Monash (R. Brown) are investigating: (1) how policies instituted in response to the Millennium Drought (1995-2009) helped change water demand and supply options in Melbourne, (2) long-term impacts and implications of these policies on urban water use in the Melbourne metropolitan area; and (3) lessons from the Melbourne experience that might help ease water stress in California.

Layer 4: Watershed Scale Processes

Linking Low Impact Development and Flood Risk. Low Impact Development (LID) practices represent a highly distributed approach to reducing storm water runoff through urban drainage networks. As such, they have the potential to be used for flood risk management even though the majority were deployed to address the impacts of urbanization on urban water quality and ecology. In this effort a team of researchers from UC Irvine (B. Sanders, J. Schubert) and University of Melbourne (T. Fletcher and M. Burns) are working to couple storm water management models (USEPA SWMM) with two-dimensional flooding models (BreZo developed at UC Irvine) for predicting the impacts of LIDs on flood risk in urban catchments.

Linking Low Impact Development and Receiving Water Quality. Urban impacted estuaries frequently receive urban runoff inputs from distributed storm drain systems as well as riverine tributaries. Researchers from UCI (M. Rippy, S. Grant, B. Sanders, R. Stein, K. Davis), the Southern California Coastal Water Research Project (Karen McLaughlin), and the City of Newport Beach (John Kesseler, Jack Skinner) are exploring the water quality impacts of urban runoff from storm drains on bacteriological water quality at estuarine beaches.

Assessing Resilience of Water Resources to Climate Change. Reservoirs provide resilience against extreme climate events (e.g., floods and droughts) and are central to water resource management. In this effort a team of researchers from UCI (A. AghaKouchak, A. Mehran, S. Grant, J. Vrugt), University of Melbourne (M. Peel), and Melbourne Water (J. Ravalic) are working collectively to develop a modeling framework for assessing resilience to climatic change and extreme events.

Goal 2--Education and Workforce Development

In 2014 we continued to evolve the Undergraduate PIRE Program (UPP) Down Under. This year's cohort of 12 undergraduates hail from UCI, UCLA, and UCSD. They were selected from over sixty applicants, and bring to the program range of academic backgrounds, from environmental engineering to social ecology. The programming for this six-week event is detailed in the attached agenda and abstracts. Additional information on the UPP program can be found at the following URL: http://water-pire.uci.edu/uppdownunderabout/.

Goal 3--Partnerships.

The PIRE team: (1) was awarded a book contract to produce “The Water Sustainable City: Science, Policy and Practice” to be published by Edward Elgar Publishing, Ltd (UK) in 2015; (2) hosted a workshop at the California Stormwater Quality Association (CASQA) Annual Meeting; (3) hosted an all-hands-on-deck meeting at UCI; and (4) successfully applied for a special session on urban water sustainability at the Fall 2014 American Geophysical Union meeting to be held in San Francisco, California.

Goal 4: Institutional Capacity.

The PIRE team developed a K-12 outreach program in collaboration with a hydrology teacher at a local high school that serves a predominantly Hispanic community (The Academy in Santa Ana). That effort has spurred new collaborations between the Henry Samueli School of Engineering and a number of units on campus (e.g., in Biological Sciences). Videos and further documentation of this program can be accessed at the following URL: http://water-pire.uci.edu/outreach/outreach/.

Specific Objectives:

Goal 1--Knowledge/Research/Discovery.

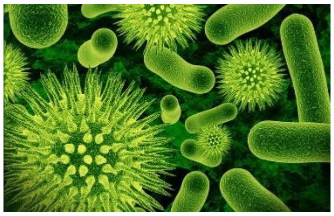
Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams

Biofilter Ecology: Lab Studies. A series of lab studies are being carried out at Monash University (biofilter column studies), UCLA (biofilter column studies), and UCSD/SIO (microcosm experiments) with the following objectives: (1) to assess the removal of TSS, NO3/NO2, NH4, PO4, TN, TP, and total Mn, Pb, Cu, and Zn; (2) to evaluate the effects of biomass harvesting on biofilter performance; (3) to assess the role of earthworms and millipedes in mobilizing Fe and P.

Biofilter Ecology: Field Studies. 35 biofilters ranging in age from <1 year old to 15 years old were sampled in Brisbane, Sydney, and Melbourne to characterize: (1) plant communities (species composition, root characteristics); (2) animal communities (invertebrate density, composition, diversity, and biomass); (3) drivers of soil invertebrate community composition and abundance, including C, N, and a suite of heavy metals.

Chemical Pollutant Removal in Natural Treatment Systems. Field and laboratory studies are being carried out at UCI, UCLA, UCSD, and Monash University to: (1) characterize pesticide abundance in stormwater runoff collected from 11 sites across 4 states in Australia from 2011 to 2014; (2) understand how nutrients and contaminants of emerging concern partition horizontally (inlet to outlet) and vertically (surface microlayer, bulk water, and pore water); (3) evaluate fluorescent spectroscopy for tracking sewage and toxic compounds; (4) determine the age distribution of carbon by 14C dating; (5) examine how the operational features of a biofilter (e.g., wetting/drying cycles) and plant and animal communities influence contaminant removal.

Pathogen Removal in Natural Treatment Systems. Laboratory studies are being conducted at UCI and Monash University to: (1) understand how pathogen removal efficiency is influenced by physical and biological characteristics of the pathogen (size, surface charge, structure and composition), filter media, and plant species; and (2) characterize the microbial water quality of urban runoff flowing through constructed wetlands in Melbourne and Southern California.



Multi-Physics Models and Measurements of Hyporheic Exchange. Modeling and experimental work is being carried out at UCI and University of Melbourne to: (1) develop predictive models for hyporheic zone treatment, including one for first-order pollutant removal in sediments and another for the set of biogeochemical reactions (aerobic respiration, ammonification, nitrification, denitrification) involved in nitrogen removal from streams; and (2) to design an experimental system ("flume-in-a-box") to quantify hyporheic zone treatment experimentally without running conventional flume tests (which generate large quantities of liquid/solid waste and consume significant energy).

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. The objective of this study is to measure greenhouse gas fluxes from different urban wetland types in and around Melbourne, and highlight the degree to which macroinvertebrates enhance greenhouse gas emissions.

Quantitative Microbial Risk Assessment. Modeling studies and surveys are being conducted at UCI and the University of Melbourne to: 1) quantify the microbial risk associated with different uses of water from various low-energy treatment options; 2) compare the risk outcomes from these water reuse activities with U.S. EPA drinking water standards; and 3) compare quantified risk with perceived risk.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

Offsets for Water Management. Policy studies are being undertaken at UCI, University of Melbourne, and Monash University to: 1) apply an integrated assessment scheme to management of water quality and quantity issues, changing land uses, and a range of water management options in the Jackson Creek Catchment; 2) modify and refine the integrated assessment by incorporating social, cultural, governance, and economic elements into its design; and, 3) to adapt the framework "proof of concept" in semi-arid climates. The model will build on efforts to evaluate trade-offs between nutrients and micro-pollutants caused by effluent discharge into Jackson Creek.

Drought, Policy Evolution in Melbourne, and Comparisons to California. Policy studies are being conducted at UCI and University of Melbourne to: 1) understand the policy elements necessary for urban drought resiliency, as well as how various methods that may be adopted to alleviate drought impacts may be assessed and evaluated; 2) gauge how communities can be fortified against climate extremes by optimally selecting among various demand- and supply-side measures; 3) illuminate opportunities for, and impediments to, adoption of policies designed to deal with drought in urbanized regions in other geo-political settings (e.g., California).

Layer 4: Watershed Scale Processes

Linking Low Impact Development and Flood Risk. Numerical modeling studies are being undertaken at UCI and the University of Melbourne to (1) link together two complementary models (SWMM and BreZo) that model storm flows at different scales; (2) apply the linked models to a residential development in the Little Stringybark Creek catchment in southeast Australia; (3) characterize the flooding associated with 50 and 100 year storm events (the residential drainage system was designed for only 25 year events); and (4) evaluate whether, and to what extent, this poses a hazard that can be managed with LIDs deployed in the watershed.

Linking Low Impact Development and Receiving Water Quality. Field studies are being carried out at UCI to: (1) understand the relative importance of freshwater discharge from small storm drains and riverine tributaries on water quality at estuarine beaches; (2) to identify the mechanism of small drain stormwater discharge; (3) evaluate the importance of various estuarine processes (wind driven buoyant plume transport, turbulent diffusion, tidal advection) in controlling the fate and transport of stormwater released from small drains; 4) suggest management solutions for estuarine beaches that reflect dominant contaminant inputs (small drain – LID or riverine tributaries – TMDL).

Assessing Resilience of Water Resources to Climate Change. Data collection and modeling efforts are being carried out at UCI and the University Melbourne to: (1) examine how reservoir water levels in Melbourne and Southern California respond to different climate change scenarios; (2) explore how alternative water resources, such as stormwater harvesting and reuse, might improve community resilience to climate change; and (3) use a multi-scale global-local model to predict reservoir responses.

Goal 2--Education and Workforce Development

Objectives include: (1) to evolve the UPP Down Under Program (http://water-pire.uci.edu/uppdownunderabout/) including the development of a reciprocal program for Australian students, and (2) to liase with local high schools through the K-12 outreach program (http://water-pire.uci.edu/outreach/outreach/).

Goal 3--Partnerships.

Objectives include: (1) to develop a textbook on urban water sustainability (as promised in the proposal); (2) to run workshops and conference sessions; (3) to cultivate relationships with local organizations focused on water sustainability, including Tree People, Council for Watershed Health, Orange County Public Works, Southern California Association of Builders, Caltrans, RBF Consulting, City of Irvine, and UCI Sustainability Office.

Goal 4: Institutional Capacity.

A key objective has been to prepare proposals that support allied activities, such K-12 outreach and industrial applications of our PIRE related research.

Significant Results:

Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams

Biofilter Ecology: Lab Studies. Column studies are just beginning at Monash and UCLA. In the SIO microcosm study, earthworm mortality was extremely high in treatments containing ferrihydrite. P extraction results suggest that millipedes may affect the cycling of nutrients within biofilter soils, but that their effects may be partially dependent on key functional groups of microbes within the biofilter soil microbial community.

Biofilter Ecology: Field Studies. Root biomass and length were correlated with biofilter age, suggesting that biofilters may develop root traits associated with high pollutant removal over time. However, only one biofilter site contained the plant species identified to remove pollutants at the highest efficiency, *Carex appressa*. Heavy metal concentrations were positively correlated with biofilter age, and were significantly higher in surface sediment layers < 2 cm depth.

Chemical Pollutant Removal in Natural Treatment Systems. Field data provided the first evidence for surface microlayer formation and microlayer contaminant enrichment in natural treatment systems, and suggest that fluorescence spectroscopy may be useful for pollutant source tracking in these systems. PCA analysis on the pesticide data indicate (1) concentration patterns are site-specific (not State-specific) and (2) in some locations there is significant year-by-year variability. All pesticide concentrations are below public health standards and world-wide averages. Radioisotope analysis (14C/12C) suggests that older carbon accumulates in urban wetland sediments.

Pathogen Removal in Natural Treatment Systems. In laboratory biofilter studies, human adenoviruses and MS2 exhibit similar patterns of treatment; namely, more virus removal occurs under dry (versus wet) conditions, and more removal occurs in columns with plants (versus no-plant controls). Removal is particularly significant (> 3-log10) in the biofilter planted with *Carex appressa*, a plant with an extensive root system. In wetland studies, a number of pathogens were detected (*Salmonella*, rotavirus and adenoviruses), although estimates of wetland removal efficiency require further analysis of samples using a digital PCR system.

Multi-Physics Models and Measurements of Hyporheic Exchange. Exact solutions were developed for pollutant removal in the hyporheic zone under steady and unsteady conditions. The solutions are premised on a canonical model for the flow of water through the hyporheic zone (the bedform pumping model developed by Elliott and Brooks), and provide new insights into the features of a stream most likely to control hyporheic zone treatment.

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. We observed significantly higher 15N and 13C (enrichment of both isotopes) in sediments and macroinvertebrates collected from the outlet of constructed wetlands (compared to the inlet), consistent with assimilation and drawdown of pools of CO_2 and dissolved inorganic nitrogen as they are transported through the wetland. We also observed significant enrichment in 13C with sediment depth. Our data indicate that neither chironomids nor oligochaetes derive a large portion of their diet from methanotrophs in golf course ponds or constructed stormwater wetlands, but this may not be the case at the Western Treatment Plant, where rates of C and N loading are likely substantially higher and redox conditions may favor methanogenesis.

Quantitative Microbial Risk Assessment. The infection risks associated with consuming home grown produce irrigated with harvested rooftop rainwater vary with the type of produce. Lettuce presents the highest risk, followed by tomato and cucumber. For stormwater harvesting, the risk assessment suggests that infection risks increase in the order: 1) toilet-flushing, 2) showering, and 3) food crop irrigation. Water managers and home owners in Australia ranked the same risks, from low to high: 1) toilet-flushing, 2) food crop irrigation, and 3) showering.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

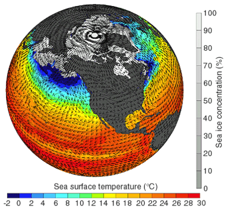
Offsets for Water Management. Western Water is exploring the use of water quality offsets and alternative regulatory compliance measures that allow wastewater agencies with exceptional needs to take cost-effective steps toward regulatory compliance. If approved, this measure would allow Western Water to continue discharging recycled water to Jacksons Creek through a trade-off between supporting environmental flows with treated effluent and micro-pollutants. Adaptive governance approaches are being pursued that are characterized by government collaboration with civil society groups, social learning through public participation, and experimentation leading to more flexible policy outcomes.

Drought, Policy Evolution in Melbourne, and Comparisons to California. During the Millennium Drought, water savings in Melbourne were primarily a result of curtailed environmental flows and government restrictions on urban water use. Creative public education programs may have caused a permanent reduction in per capita water consumption. Some drought impacts on agricultural communities were buffered by water market schemes that protected farmers in greatest need, helped finance modernization of irrigation infrastructure, and established water entitlements for the environment that protected critical habitat.

Layer 4: Watershed Scale Processes

Linking Low Impact Development and Flood Risk. The two flood models (SWMM and BreZo) were calibrated using available data in the Little Stringybark Creek watershed. Results indicate that (1) 100 year rainfall events will overwhelm the capacity of the existing drainage network at the local level and cause hazardous flood conditions, and (2) LID systems (distributed rain barrels) have the capacity to constrain peak flows to within the capacity of the local drainage network, and thus reduce flood risk.

Linking Low Impact Development and Receiving Water Quality. Our results suggest that small drains have a disproportionate impact on estuarine beach water quality for multiple reasons, including the nature of the drainage systems (location of drain outlets at mean tide line), low nearshore turbulence, and buoyancy effects associated with runoff plumes. Urban retrofits that minimize the volume of dry and wet weather runoff entering the local storm drain system appear to be the best option for improving beach water quality in urban- impacted enclosed beaches.



Assessing Resilience of Water Resources to Climate Change. The proposed nested modeling framework has been developed, and IPCC AR5 climate model projections are being used to quantify the potential impacts of climate change on droughts and water supply, and to assess resilience and vulnerability, in Southeast Australia and the Southwest U.S.

Goal 2--Education and Workforce Development

The 2014 UPP is currently in progress, but the extensive stakeholder process used to develop this year's agenda has made it more inclusive and thoroughly multi-disciplinary, as reflected in the abstracts for the various presentations (see attachments).

Goal 3--Partnerships.

All of the objectives listed in the last section were achieved. These are described in more detail later in the annual report.

Goal 4: Institutional Capacity.

We are particularly proud of our pilot program with the The Academy High School in Santa Ana (http://water-pire.uci.edu/outreach/outreach/), as outlined later in this annual report.

Key Outcomes/Other Achievements:

Goal 1: Knowledge, Research & Discovery

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. Stable isotope data show evidence of significant C and N processing from inlet to outlet, and we observed a signature of nutrient assimilation within the invertebrate communities. GHG measurements are currently being conducted, and will be reported in the next annual report.

<u>*Quantitative Microbial Risk Assessment.*</u> The manuscript “Reevaluation of health risk standards for sustainable water practice through risk analysis of rooftop-harvested rainwater**”** has been published in a special issue of journal Water Research. A second manuscript describing a quantitative microbial risk assessment of stormwater harvesting will be submitted to Water Research in the next few weeks.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

<u>*Offsets for Water Management.*</u> Ecotoxicology analysis has established that micro-pollutants from agricultural production, such as pesticides, herbicides, and fertilizers, are the main stressors to Jacksons Creek, although other contaminants may also be present (e.g. estrogenic compounds). A manuscript describing our initial assessment of the offset scheme in Jacksons Creek was recently submitted to WIREs Water ("Governance issues in developing and implementing offsets for water management benefits: Strategic lessons from a new Australian undertaking.")

<u>*Drought, Policy Evolution in Melbourne, and Comparisons to California*</u>. During the Millennium Drought, Melbourne’s concerted public engagement process was critical for facilitating drought-adaptation. Among these efforts was a series of community visioning processes that helped establish a culture of public engagement regarding the identification, prioritization, and implementation of supply- and demand-side water management options (e.g., off-stream catchment, reducing household water use, incorporating plans for using low-quality treated water for non-potable needs, capturing stormwater runoff through bio-filtration, and reclaiming wastewater). By contrast, path-dependent water policies in California may inhibit adoption of comparable reforms. Impediments include fragmented authority for water management scattered among numerous jurisdictions and agencies, and institutional conservatism that discourages public engagement.

Layer 4: Watershed Scale Processes

<u>*Linking Low Impact Development and Flood Risk.*</u> A manuscript describing the SWMM/BreZo model and its application to flood risk management in catchments with significant distributed stormwater harvesting and reuse is under preparation by the UCI/University of Melbourne team. Future manuscripts will focus on how to distribute LIDs in a systematic way and develop incentive programs for LID adoption.

<u>*Linking Low Impact Development and Receiving Water Quality.*</u> Key outcomes include a manuscript describing the impacts of small drain discharge on local water quality at estuarine beaches submitted to the journal Environmental Science and Technology.

<u>*Assessing Resilience of Water Resources to Climate Change.*</u> A manuscript describing the modeling framework is under preparation.

Goal 2--Education and Workforce Development

The 2014 UPP is currently in progress, as described in more detail in the following two sections of the annual report.

Goal 3--Partnerships.

All of the objectives listed in the penultimate section were achieved.

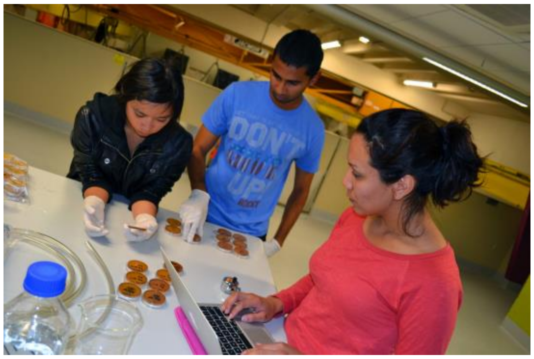
Goal 4: Institutional Capacity.

Proposals have been written to expand PIRE-related activities including K-12 outreach (CH2M Hill Foundation), agricultural applications of biofilter research (EPA STAR), an international conference in India (Indo-US Forum), and a UC Multicampus Research Programs and Initiatives Grant on urban water sustainability.

What opportunities for training and professional development has the project provided?

Goal 1--Knowledge/Research/Discovery.

Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams



Biofilter Ecology: Lab Studies. The column studies at Monash and UCLA are providing an opportunity for postdocs to learn new laboratory techniques and collaborate across all participating universities. Brandon Winfrey and Andrew Mehring are learning new techniques in the lab for measuring labeled nitrogen. The UCLA column study provides training in maintaining columns and water quality sampling for several students: Kelly Cheung (high school student in Los Angeles), Yareli Sanchez (doctoral student at UCLA), and Wei Wang (visiting doctoral student from Donghua University in China). The UCSD/SIO microcosm study provided research experience for Diana Kraikittikun, a UCSD undergraduate student.

Biofilter Ecology: Field Studies. One postdoc, Brandon Winfrey, surveyed vegetation and collected root samples in Melbourne. He learned how to use WinRhizo in Belinda Hatt's lab at Monash University. A portion of the invertebrate research was performed as a senior project by UCSD Environmental Systems Science major, Diana Kraikittikun; Diana is now participating in the UPP program in Australia. An additional female UCSD undergraduate student (Barbara Orelo) and one female Hispanic SIO technician (Jennifer Gonzalez) are involved in the project.

Chemical Pollutant Removal in Natural Treatment Systems. Several students and post-docs participated in field data collection, data analysis, manuscript generation, and model development. These include post-doctoral researcher M. Rippy, M.S. student A. Robinson, M.S. student L. Weiden, and undergraduate student A. Moussavi-Aghdam (note Ava was recently awarded a UCI Undergraduate Research Opportunity Program (UROP) fellowship to develop a model of nutrient and pathogen removal in biofilters under saturated and unsaturated conditions using the multi-physics finite element modeling platform COMSOL). Postdocs Andrew Mehring, Brandon Winfrey, and Megan Rippy will also learn how to use COMSOL.

Pathogen Removal in Natural Treatment Systems. A number of students participated in the pathogen survey, including a PIRE PhD student (Eric Huang), and 24 PIRE undergraduate students participating in the 2013 and 2014 UPP program. Edgar Gomez (an ethnic minority and member of the 2013 UPP cohort), will join the 2014 incoming class of Environmental Engineering M.S./Ph.D. students at UCI.

Multi-Physics Models and Measurements of Hyporheic Exchange. Several students participated in the development and write-up of the hyporheic exchange model, including a PIRE PhD student (Morvarid Azizian), and an undergraduate student (Ava Moussavi-Aghdam). An incoming PIRE PhD student (Emily Parker) will participate in hyporheic exchange modeling studies planned for next year. Emily was a member of the 2013 UPP cohort; she received the prestigious UCI Provost Doctoral Fellowship which provides $20,000 for the first year of her doctoral studies.

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. A PIRE post-doctoral researcher (A. Mehring) has led the design and implementation of this field project.

Quantitative Microbial Risk Assessment. A PIRE Ph.D. student (Keah-ying Lim) has been supported, and spent three months in Australia working with Professor Andrew Hamilton and Graduate Student Kristal Burry at the University of Melbourne.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

Offsets for Water Management. A PIRE PhD student in public policy and urban planning was involved in the development and write-up of the offsets work plan (Lindsey Stuvick).

Drought, Policy Evolution in Melbourne, and Comparisons to California. A PIRE PhD student in engineering (Kathleen Low) has been involved in the development and write-up of research results for this project.

Layer 4: Watershed Scale Processes

Linking Low Impact Development and Flood Risk. Post-doctoral researchers at UCI (J. Schubert) and U Melbourne (M. Burns) expanded their watershed modeling expertise and developed a better understanding of urban flood risk management. A two day workshop was held in Irvine in Spring of 2014 to make facilitate exchange of information and plan future activities. A UC Irvine undergraduate student (W Monsen) participated in the flood modeling workshop.

Linking Low Impact Development and Receiving Water Quality. In preparing the manuscript for this project, a post-doctoral researcher at UCI (M. Rippy) worked with an interdisciplinary team including field researchers (S. Grant at UCI, and K. McLaughlin at the Southern California Coastal Water Research Project), numerical modelers (PhD student R. Stein and co-PI B. Sanders), a water quality manager from the City of Newport Beach (J. Kappeler), and an M.D. who specializes in beach water quality issues (Dr. J. Skinner).

Assessing Resilience of Water Resources to Climate Change. A PIRE PhD student (Ali Mehran) participated in the development and write-up of the model.

Goal 2--Education and Workforce Development

Many large cities around the world face the triple hit of limited freshwater resources, increased climate variabiltiy, and rapid population growth associated with urbanization of the human population. These changes come at a time when engineers, in particular, are ill prepared to design and build civil infrastructure responsive to the challenges that lie ahead. We hope to "evolve" this traditional mindset through new course offerings, the writing of a multi-disciplinary textbook on urban water sustainability ("The Water Sustainable City: Science, Policy, and Practice" to be published by Edward Elgar Publishing, Ltd (UK) in 2015), engagement of undergraduates in interdisciplinary research programs in the U.S. and Australia, the implementation of a field "bootcamp" for top undergraduate environmental engineering and science majors at UCI, UCLA, and UCSD, and active engagement of K-12 teachers and students.

Goal 3--Partnerships.

Through our industrial and educational partners, we are: (1) supporting K-12 teacher participation in sustainability field research; (2) enhancing undergraduate training in urban water sustainability science and engineering; (3) expanding the global participation and cultural awareness of students at all levels; (4) exposing students to a variety of career options in urban water sustainability, including academia (through participation of university faculty, post-doctoral scholars, Ph.D. students, and undergraduate students), engineering consultancy (through the involvement of professional organizations such as the California Stormwater Quality Association, CASQA) and government (through the involvement of SCCWRP, OC Public Works, Melbourne Water, and the City of Irvine); and (5) generating K-12 lesson plans that fulfill the Next Generation Science Standards.

Goal 4: Institutional Capacity.

Key staff in the Henry Samueli School of Engineering have gained significant experience in shepherding large bi-national research projects, including the organization of visas and plane flights, and other logistical issues associated with research abroad experiences.

How have the results been disseminated to communities of interest?

Goal 1--Knowledge/Research/Discovery.

Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams

Biofilter Ecology: Lab Studies. Data collected from these studies will form the basis of several manuscripts on the effects of biomass harvest on pollutant removal (Monash), effects of oligochaetes on pollutant removal (Monash, UCLA, UCSD), effects of plant species and oligochaetes on hydraulic conductivity (Monash, UCLA, UCSD), and effects of plant species on pollutant removal (Monash, UCLA).

American
Ecological
Engineering
Society

Biofilter Ecology: Field Studies. Post-doctoral researcher B. Winfrey reported on the root structure results to the American Ecological Engineering Society during the 14th Annual meeting in Charleston, SC in June 2014. UCSD Undergraduate D.Kraikittikun presented a poster entitled “Community Analysis of Australian Biofilters” at the 2014 Environmental Systems Symposium in San Diego, CA in May 2014.

Chemical Pollutant Removal in Natural Treatment Systems. M. Rippy led the preparation of the Environmental Science and Technology manuscript describing the surface microlayer results, and presented her analysis at the May 2014 Urban Streams Conference in Portland, OR.

Pathogen Removal in Natural Treatment Systems. S. Jiang gave a presentation at Back Bay Science Center Science (Newport Beach, CA) science education evening program for the local community on microbial pathogens in urban stormwater and their management. Several manuscripts are being prepared and will be submitted in the next year.

Multi-Physics Models and Measurements of Hyporheic Exchange. S. Grant and M. Azizian presented a poster on one of the hyporheic zone treatment models at the February 2014 Ocean Sciences Meeting in Honolulu, and delivered an oral presentation at the May 2014 Urban Streams Conference in Portland, OR. A manuscript was prepared and submitted to the journal Environmental Science and Technology. As noted above, the manuscript was returned with a request for minor revisions.

Environmental
Science & Technology

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. Dissemination of results will occur in the coming year.

Quantitative Microbial Risk Assessment. In addition to the two manuscripts, a poster presentation was presented at the 18th Annual Water Reuse and Desalination Conference to share the results of the study with industrial leaders and engineering practitioners: Lim, K., Hamilton, A. and Jiang, S. "Quantitative Microbial Risk Assessment of Sustainable Urban Stormwater Harvesting Practices".

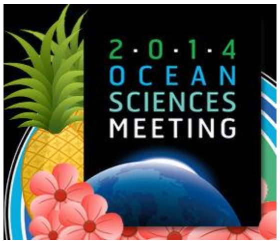
<u>Layer 3: Regulations, Economic Instruments, Equity, and Policy</u>

<u>Offsets for Water Management</u>. We have submitted a manuscript to the journal *WIRES Water* as part of a symposium on PIRE-related projects. A panel has also been proposed at the fall 2014 Indo-USA Research Foundation conference in India.

<u>Drought, Policy Evolution in Melbourne, and Comparisons to California</u>. We are submitting a manuscript to the journal *WIRES Water* as part of a symposium on PIRE-related projects, and a portion of the findings will also be incorporated into a forthcoming book titled *The Water Sustainable City* (Edward Elgar).

<u>Layer 4: Watershed Scale Processes</u>

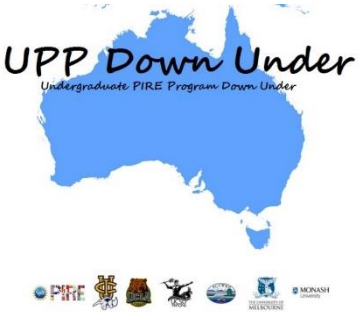
<u>Linking Low Impact Development and Flood Risk</u>. A manuscript is under preparation, and T. Fletcher and M. Burns have shared preliminary results with Melbourne Water in southeast Australia.



<u>Linking Low Impact Development and Receiving Water Quality</u>. A manuscript describing the results of storm drain discharge on water quality at estuarine beaches was prepared and submitted to the journal Environmental Science and Technology. Additional results were also presented by M. Rippy and A. Ciglar (a M.S. student in the Environmental Engineering program at UCI) at the February 2014 Ocean Sciences Meeting in Honolulu, HI.

<u>Assessing Resilience of Water Resources to Climate Change</u>. A. AghaKouchak and A. Mehran presented this project at the American Geophysical Union (AGU) Fall meeting in 2013. A manuscript will be prepared and submitted in summer 2014.

Goal 2--Education and Workforce Development



The centerpiece of our education and workforce development effort is an ongoing U.S./Australian boot camp on urban water sustainability called the Undergraduate PIRE Program (UPP) Down Under (http://water-pire.uci.edu /uppdownunderabout/). "UPP", as we call it, is a 6-week summer field-based program for undergraduates interested in pursuing a Ph.D. in urban water sustainability. It includes a combination of traditional classroom lectures, workshops, field trips, field sampling, laboratory testing, data synthesis and analysis, and scientific writing and conference presentations. The UPP is truly bi-national; students spend part of their time in Southern California (on the campus of UCI) and the rest of their time in Southeast Australia (on the campuses of Melbourne University and Monash University). Dissemination of this effort is through our PIRE website (http://water-pire.uci.edu/uppdownunderabout/, http://water-pire.uci.edu/2014-upp-down-under-agenda-abstracts/) and press releases organized by partner organizations in Australia. The best "advertisement" of the program, however, is the UPP participants themselves, who are selected through a competitive application process. This year, we had approximately 60 applications from UCI, UCLA, and UCSD undergraduates for 12 slots. Testimonials from the 2013 UPP class can be found on the UCI Water PIRE website (http://water-pire.uci.edu/uppdownunderabout/).

Formal evaluation of the program found students achieved statistically significant gains in all four areas of evaluation, including knowledge, education, partnerships, and institutional capacity (see attached documents). Pictures and short descriptions of the 2013 and 2014 UPP cohorts can also be found on the UCI Water PIRE website. Students in the 2013 UPP cohort have done extremely well after completing the program. Most are either in graduate programs, or will begin graduate study in Fall 2014. Several have received local and international prizes, including the prestigious National Science Foundation Graduate Research Fellowship.

Goal 3--Partnerships

The UPP program is also being leveraged to create K-12 instructional materials through our pilot program with The Academy. In particular, students at the Academy participate in a problem-based learning exercise set up by their teacher, Mr. Blaine Jones, a professional hydrologist who incorporates urban water sustainability into his earth sciences teaching. We have prepared a library of short video lessons tailored to Mr. Jones' lesson plan (http://water-pire.uci.edu/outreach/outreach/), and we have taken his students to our field research station at UCI (San Joaquin Marsh Reserve) for tours and lectures on the ecological services performed by constructed wetlands.

UCI Water PIRE students and staff participated in the Children's Water Education Festival through the creation of interactive presentations and games, inspiring interest in sustainability research and environmental stewardship. This annual program, which takes place during Spring Break on the UCI campus, hosts thousands of 3rd, 4th, and 5th graders from schools all over Orange County. In March, the festival hosted approximately 10,000 children.

Dissimenation of results to our industrial partners and research communities is taking the form of workshops and special sessions at practice-oriented conferences (as described earlier in the annual report) and focused sessions at research conferences (AGU Fall meeting) and manuscript generation for peer reviewed journals.

Goal 4--Institutional Capacity.

The impact of our work on campus is broadcast primarily through regular posts to our website newsfeed (http://water-pire.uci.edu/), involvement in the broader campus community in our various outreach activities, and occasional talks at UCI functions, such as the Orange County Children's Water Education Festival (see last section).

What do you plan to do during the next reporting period to accomplish the goals?

Goal 1--Knowledge/Research/Discovery.

<u>Layer 1: Improving Pollutant Removal in Biofilters, Wetlands, and Streams</u>

<u>Biofilter Ecology: Lab Studies.</u> As described above, columns are maturing and stormwater trials will commence in Sep 2014 and end in Dec 2014. Results from these trials will be available Jan 2015. Manuscripts will be prepared and submitted to leading journals in the field. Columns at UCLA can be used for further optimization studies in the future.

<u>Biofilter Ecology: Field Studies.</u> Two manuscripts (one on root structure and another on preliminary invertebrate data collected during the 2013 UPP Down Under course) will be prepared and submitted to Ecological Engineering in Aug/Sep 2014. Invertebrate sorting from soil cores will be completed by the end of 2014, and a manuscript that focuses on invertebrate community structure and heavy metal accumulation in biofilter soils over time will be prepared.

<u>Chemical Pollutant Removal in Natural Treatment Systems</u>. Revisions will be implemented on the surface microlayer project submitted to Environmental Science and Technology, a manuscript will be drafted and submitted on the Australian pesticide dataset, a review article will be prepared and submitted to WIREs Water on trade-offs associated with biofilter designs, and additional lab and field studies will be conducted to characterize the partitioning

and removal of pesticides in constructed wetlands and biofilters. In particular, four large columns will be constructed and infiltrated with synthetic stormwater runoff from August to December 2014. Two columns will be planted and two (one planted one unplanted) columns will be seeded with earthworms.

Pathogen Removal in Natural Treatment Systems. Over the next year we will: (1) complete sample analysis for pathogen quantification using digital PCR; (2) complete seeding studies to quantify pathogen concentration recovery rates; and (3) continue characterizing pathogen concentrations in constructed wetlands in Australia and Orange County. This multi-year project will provide valuable information on the optimal design and management of constructed wetland systems and biofilters for pathogen removal.

Multi-Physics Models and Measurements of Hyporheic Exchange. Three new manuscripts will be prepared and submitted to leading journals in the field, and the flume-in-a-box system will be built and tested, initially for its ability to reproduce log-normal residence time distributions typical of hyporheic zone treatment systems.

Layer 2: Public Health Risks, Energy Savings, and GHG Emissions.

GHG Fluxes from Sediments in Urban Wetlands. We aim to develop a model that explains the factors affecting variability in N_2O emissions among urban wetlands, and to compare CO_2 and CH_4 fluxes among urban wetland types. We are using C and N measurements and stable isotope data to assess the degree to which macroinvertebrates in the three system types utilize methanotrophic bacteria as a food source. During the next reporting period we will have access to 5 sites within the Western Treatment Plant, and will conduct two additional sampling efforts in those sites as well as in the previously-sampled golf course ponds and constructed stormwater wetlands during July/August and November/December. We will present our findings at an international conference and will prepare a manuscript.

Quantitative Microbial Risk Assessment. Development of stormwater harvesting systems is often impeded by social and institutional assessments of risk. Risk perceptions are influenced by knowledge, attitudes, values, and beliefs. We aim to develop a risk assessment platform that accounts for a broader range of risks (not just microbial risk) to support stormwater harvesting development and adoption.

Layer 3: Regulations, Economic Instruments, Equity, and Policy

Offsets for Water Management: Governance and Policy. Two new manuscripts will be prepared and submitted to leading journals in the field. In the next phase, the team will review primary data sources and reports prepared by Victoria EPA and the Victorian Water Industry, engage stakeholders to explore potential offset solutions and capture data related to cultural and natural resources and determine the community's willingness-to-pay to achieve net social and environmental benefits.

Offsets for Water Management: Economics. Researchers from UCI (J.-D. Saphores, C. Patel), the Southern California Coastal Water Research Project (A. Sengupta), and the University of Melbourne/Center for Aquatic Pollutant Identification and Management (M. Arora, and V. Pettigrove) will be comparing the net gains that could be achieved using offsets compared to current regulations in the Jacksons Creek catchment.

Drought, Policy Evolution in Melbourne, and Comparisons to California. Two new manuscripts will be prepared and submitted. We will consult with water retailers in the Melbourne region to: 1) determine a time-sequence of events during the Millennium Drought that affected water use; 2) more precisely separate water uses by sector (i.e., residential, industrial uses); and 3) collect information on water governance in an effort to determine the influence of different layers of authority on drought policy development.

Public Perceptions. Researchers from UCI (K. Duong, J.-D. Saphores, S. Grant) and the University of Melbourne (M. Arora) are completing a review of obstacles to water reuse by households with a comparison between the United States and Australia. In addition, researchers from UCI (J.-D. Saphores, D. Feldman, and S. Grant) are completing the analysis of a pilot study of household attitudes toward various forms of water reuse based on a survey of U.S. households.

Layer 4: Watershed Scale Processes

**Linking Low Impact Development and Flood Risk*. A manuscript describing flood modeling results will be completed, presentations will be given at technical conferences, and the team may expand to include additional PIRE PhD students (A. Askarizadeh).

**Linking Low Impact Development and Receiving Water Quality*. We will explore potential links between the present U.S. studies and impacts of dry and wet weather runoff on beach water quality in Port Phillip Bay, one of the largest tidal embayments in Victoria, Australia.

**Assessing Resilience of Water Resources to Climate Change*. Graduate student Ali Mehran will continue to develop a framework for assessing vulnerability and resilience using the above mentioned model.

Goal 2--Education and Workforce Development

Continue to improve the UPP Down Under and K-12 outreach activities based on extensive feedback from our external evaluator and our own assessment of program performance.

Goal 3--Partnerships

Continue to expand outreach activities (e.g., through additional funding) and develop on-the-ground test beds for the biofilter and constructed wetland research activities.

Goal 4--Institutional Capacity.

Continue to identify sustainable funding models to support key staff (such as Dr. Janet Rowe, who led the UPP and K-12 outreach activities this year), by partnering with other NSF center-funded activities on campus, for example in Biological Sciences.

Publications:

Journals

AghaKouchak, A.; Feldman, D.; Stewardson, M.J.; Saphores, J.D.; Grant, S.B.; Sanders, B.F. (2014). Australia's Drought: Lessons for California. *Science*. 343 1430. Status = PUBLISHED; Acknowledgment of Federal Support = No ; Peer Reviewed = No

Hao, Z.; AbhaKouchak, A.; Phillips, T.J. (2013). Changes in concurrent monthly precipitationa dn temperature extremes. *Environmental Research Letters*. 8 034014. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1088/1748-9326/8/3/034014

Hao, Z.; AghaKouchak, A.; Nakhjiri, N.; Farahmand, A. (2014). Global integrated drought monitoring and prediction system. *Scientific Data*. 1 140001. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1038/sdata.2014.1

Lim, K.Y.; Jiang, S.C. (2013). Reevaluation of health risk benchmark for sustainable water practice through risk analysis of rooftop-harvested rainwater. *Water Research*. 47 7273. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes

Mehran, A.; AghaKouchak, A.; Phillips, T.J. (2014). Evaluation of CMIP5 continental precipitation simulations relative to satellite-based gauge-adjusted observations. *Journal of Geophysical Research: Atmospheres*. 119 1695. Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: 10.1002/2013JD021152

Stanley B. Grant, Tim D. Fletcher, David Feldman, Jean-Daniel Saphores, Perran I. M. Cook, Mike Stewardson, Kathleen Low, Kristal Burry, Andrew J. Hamilton (2013). Adapting urban water systems to a changing climate: lessons from the Millennium Drought in Southeast Australia. *Environmental Science and Technology*. 47 19727.

Status = PUBLISHED; Acknowledgment of Federal Support = Yes ; Peer Reviewed = Yes ; DOI: dx.doi.org/10.1021/es400618z

Websites

UCI Water PIRE website

http://water-pire.uci.edu/

The website for our PIRE project, including news feeds, up-to-date listing of project personnel, outreach activities, etc.

Participants/Organizations

What individuals have worked on the project?

Name	Most Senior Project Role	Nearest Person Month Worked
Grant, Stanley	PD/PI	6
Feldman, David	Co PD/PI	3
Jiang, Sunny	Co PD/PI	1
Sanders, Brett	Co PD/PI	1
Saphores, Jean-Daniel	Co PD/PI	1
AghaKouchak, Amir	Faculty	2
Ambrose, Richard	Faculty	1
Bowler, Peter	Faculty	2
Brouwer, Jack	Faculty	1
Brown, Rebekah	Faculty	0
Cook, Perran	Faculty	1
Cooper, William	Faculty	0
Davis, Kristen	Faculty	1
Deletic, Ana	Faculty	1
Fletcher, Tim	Faculty	1
Hamilton, Andrew	Faculty	2
Levin, Lisa	Faculty	2
McCarthy, David	Faculty	0
Peel, Murray	Faculty	0
Rosso, Diego	Faculty	1
Stewardson, Michael	Faculty	2
Mehring, Andrew	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Rippy, Megan	Postdoctoral (scholar, fellow or other postdoctoral position)	12
Rowe, Janet	Postdoctoral (scholar, fellow or other postdoctoral position)	6
Winfrey, Brandon	Postdoctoral (scholar, fellow or other postdoctoral position)	5

Name	Most Senior Project Role	Nearest Person Month Worked
Beam, James	Other Professional	12
Crompton, Chris	Other Professional	1
Peng, Jian	Other Professional	1
de Guzman, Edith	Staff Scientist (doctoral level)	1
Sengupta, Ashmita	Staff Scientist (doctoral level)	3
Stein, Eric	Staff Scientist (doctoral level)	1
Sutula, Martha	Staff Scientist (doctoral level)	0
Askarizadeh, Asal	Graduate Student (research	12
Azizian, Morvarid	Graduate Student (research	12
Burry, Kristal	Graduate Student (research	2
Duong, Kimberly	Graduate Student (research	6
Gomez, Edgar	Graduate Student (research	4
Huang, Eric	Graduate Student (research	12
Lim, Keah-Ying	Graduate Student (research	12
Low, Kathleen	Graduate Student (research	12
Mehran, Ali	Graduate Student (research	12
Parker, Emily	Graduate Student (research	4
Patel, Cameron	Graduate Student (research	4
Robinson, Alice	Graduate Student (research	6
Stuvick, Lindsey	Graduate Student (research	12
Cheung, Lynze	Undergraduate Student	1
Gonzalez, Sylvia	Undergraduate Student	1
Hernandez, Dana	Undergraduate Student	1
Hornstra, Allison	Undergraduate Student	1
Kraikittikun, Diana	Undergraduate Student	1
Marquez, Joaquin	Undergraduate Student	1
McAlpine, Caitlin	Undergraduate Student	1
Moussavi-Aghdam, Ava	Undergraduate Student	4
Robert, Roderic	Undergraduate Student	1
Rosser, Clint	Undergraduate Student	1
Sy Su, Elena	Undergraduate Student	1
Welzem, Madeline	Undergraduate Student	1
Yan, Joey	Undergraduate Student	1
Grey, Mark	Consultant	1
Hill, Mark	Consultant	1
Kohne, Lisa	Consultant	4
Yeager, Matt	Consultant	1

Full details of individuals who have worked on the project:

Stanley B Grant
Email: sbgrant@uci.edu
Most Senior Project Role: PD/PI
Nearest Person Month Worked: 6
Contribution to the Project: Principal Investigator.
Funding Support: Australian Research Council
International Collaboration: No
International Travel: Yes, Australia - 0 years, 6 months, 0 days

David Feldman
Email: david.feldman@uci.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 3
Contribution to the Project: Leader of Layer 3: Regulations, Economic Instruments, Equity, and Policy; also main coordinator for research program with SCCWRP and CAPIM.
Funding Support: None
International Collaboration: No
International Travel: Yes, Australia - 0 years, 0 months, 14 days

Sunny Jiang
Email: sjiang@uci.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Leader of Layer 2: Public Health Risks, Energy Savings, and GHG Emissions and the UPP Down Under Program
Funding Support: None
International Collaboration: No
International Travel: Yes, Australia - 0 years, 0 months, 14 days

Brett F Sanders
Email: bsanders@uci.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Leader of Layer 4: Watershed Scale Processes
Funding Support: NSF
International Collaboration: No
International Travel: No

Jean-Daniel M Saphores
Email: saphores@uci.edu
Most Senior Project Role: Co PD/PI
Nearest Person Month Worked: 1
Contribution to the Project: Contributed to Layer 3, and the Educational Outreach
Funding Support: None
International Collaboration: No
International Travel: Yes, Australia - 0 years, 0 months, 14 days

Amir AghaKouchak
Email: amir.a@uci.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: Lead of Industrial Outreach.
Funding Support: NSF
International Collaboration: No
International Travel: No

Richard Ambrose
Email: rambrose@ucla.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Head of Plant Ecology group.
Funding Support: NSF
International Collaboration: No
International Travel: Yes, Australia - 0 years, 0 months, 14 days

Peter Bowler
Email: pabowler@uci.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 2
Contribution to the Project: Lead of Educational Outreach
Funding Support: NSF
International Collaboration: No
International Travel: No

Jack Brouwer
Email: jb@apep.uci.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Provided perspective on energy consumption issues associated with distributed LID.
Funding Support: None
International Collaboration: No
International Travel: No

Rebekah Brown
Email: rebekah.brown@monash.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0
Contribution to the Project: A Professor at Monash University working with David Feldman's Layer 3 team
Funding Support: Australian Research Council
International Collaboration: Yes, Australia
International Travel: No

Perran Cook
Email: perran.cook@monash.edu **Most Senior Project Role:** Faculty **Nearest Person Month Worked:** 1
Contribution to the Project: A professor at Monash University working with Professor Grant and Dr. Mehring on biogeochemical cycling in biofilters, wetlands, and the hyporheic zone of streams.
Funding Support: Australian Research Council

International Collaboration: Yes, Australia
International Travel: No

William Cooper
Email: wcooper@uci.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 0
Contribution to the Project: Helped to supervise a M.S. student (L. Weiden). Currently on leave as a Program Director for NSF Environmental Engineering.
Funding Support: NSF
International Collaboration: No
International Travel: No

Kristen Davis
Email: davis@uci.edu
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: Contributed to a manuscript on the effects of dry weather runoff on beach water quality.
Funding Support: NSF
International Collaboration: No
International Travel: No

Ana Deletic
Email: ana.deletic@monash.edu **Most Senior Project Role:** Faculty **Nearest Person Month Worked:** 1
Contribution to the Project: A professor at Monash University and head of the Cooperative Research Center for Water Sensitive Cities. She is involved with several projects in Layers 1 and 2.
Funding Support: Australian Research Council
International Collaboration: Yes, Australia
International Travel: No

Tim Fletcher
Email: timf@unimelb.edu.au
Most Senior Project Role: Faculty
Nearest Person Month Worked: 1
Contribution to the Project: A professor at the University of Melbourne working on Layer 4 research, primarily with Brett Sanders.
Funding Support: Australian Research Council, Melbourne Water
International Collaboration: Yes, Australia
International Travel: No

Andrew Hamilton
Email: andrewjh@unimelb.edu.au **Most Senior Project Role:** Faculty **Nearest Person Month Worked:** 2
Contribution to the Project: A professor at the University of Melbourne who is working with several PIRE faculty and graduate students on Layer 3 research activities.
Funding Support: Australian Research Council, Melbourne Water
International Collaboration: Yes, Australia
International Travel: No

What other organizations have been involved as partners?

Melbourne Water

Organization Type: Other Organizations (foreign or domestic)
Organization Location: Melbourne, Australia

Partner's Contribution to the Project:
In-Kind Support
Facilities
Personnel Exchanges

More Detail on Partner and Contribution: Melbourne Water worked with us to identify wetlands and biofilters to sample during the UPP Down Under program. They provided access to their facilities and technical information on each of the systems sampled.

Monash University

Organization Type: Academic Institution
Organization Location: Melbourne, Australia

Partner's Contribution to the Project:
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: As outlined in earlier sections, the Monash University is a primary partner on the PIRE project, and has worked with us to develop research partnerships and educational programs that involve US faculty, post-docs, graduate students, and undergraduates.

Southern California Coastal Water Research Project

Organization Type: State or Local Government
Organization Location: Costa Mesa

Partner's Contribution to the Project:
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Dr. Martha Sutula and Dr. Ashmita Sengupta provide hydrological and stream ecology expertise, provide industrial outreach to the stormwater management community in southern California, and are organizing special sessions at the California Stormwater Quality Association to showcase PIRE activities.

UCLA

Organization Type: Academic Institution
Organization Location: Los Angeles

Partner's Contribution to the Project:
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Professor Richard Ambrose and his post-doc Dr. Brandon Winfrey are key participants in the PIRE, contributing expertise and laboratory capability relative to the functional role that plants play in nutrient cycling and pollutant removal in constructed wetlands and biofilters.

UCSD Scripps Institution of Oceanography Organization

Type: Academic Institution
Organization Location: San Diego

Partner's Contribution to the Project:
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: Professor Lisa Levin and her post-doc Dr. Richard Ambrose are key participants in the PIRE, contributing expertise and laboratory capability relative to the functional role that animals play in nutrient cycling and pollutant removal in constructed wetlands and biofilters.

University of Melbourne

Organization Type: Academic Institution

Organization Location: Melbourne, Australia

Partner's Contribution to the Project:
Financial support
In-Kind Support
Facilities
Collaborative Research
Personnel Exchanges

More Detail on Partner and Contribution: As outlined in earlier sections, the University of Melbourne is a primary partner on the PIRE project, and has worked with us to develop research partnerships and educational programs that involve US faculty, post-docs, graduate students, and undergraduates.

Have other collaborators or contacts been involved? No

Impacts

What is the impact on the development of the principal discipline(s) of the project?

The research being conducted in Australia should lead to new approaches for improving water productivity in the U.S. Specific examples of impacts achieved during the first two years of the project include:

(1) Students and educators at all levels (K-12, undergraduates, graduate students, post-docs, and research university faculty) are learning from the interdisciplinary and inter-cultural challenges associated with urban water sustainability.

(2) A number of students in the UPP Down Under program are enrolling in Environmental Engineering graduate programs at top schools, and many have won awards for academic excellence.

(3) Environmental Engineering graduate students funded under the PIRE are conducting field and laboratory research in Australia.

(4) K-12 teaching modules on environmental engineering and urban water sustainability are being developed based on the UPP Down Under program.

(5) Post-doctoral researchers and faculty at US institutions are engaging with environmental engineering faculty at Monash University, University of Melbourne, and industrial partners at Melbourne Water and the Southern California Coastal Water Research Project.

What is the impact on other disciplines?

Designing biofilters and constructed wetlands involves biomimicry, and thus lessons learned from our project will inform ecological research on these systems.

What is the impact on the development of human resources?

(1) The K-12 modules and videos developed from this program should inspire high-school students from traditionally disadvantaged backgrounds to consider educational programs in environmental engineering and urban water sustainability.

(2) Through the UPP Down Under program, our project is inspiring undergraduate engineering students to apply to graduate programs in urban water sustainability, and many of these students are from traditionally underrepresented ethnic backgrounds.

(3) The international experience associated with this project is inspiring PIRE graduate students and post-docs to consider international research opportunities and careers, including with our partner institutions.

What is the impact on physical resources that form infrastructure?

The PIRE project is creating opportunities to carry out research that would be either impossible, or prohibitively expensive, without our Australian partners. Specifically, our research project is expanding the physical infrastructure available to US researchers and students by taking advantage of the following Australian resources: (1) a world-class biofilter facility at Monash University, (2) the world's first watershed experiment in which the impact of biofilters and constructed wetlands are evaluated relative to stream hydrology and health; (3) the world's largest wastewater stabilization pond; (4) world-class facilities for visualization of interfacial turbulence and hyporheic exchange; and (5) constructed wetlands and biofilters of various sizes and ages that are integrated into the Melbourne urban and peri-urban landscape.

What is the impact on institutional resources that form infrastructure?

The PIRE project has significantly impacted the human connections between the Henry Samueli School of Engineering (HSSoE) at UCI and:

1) Other departments and programs on the UCI campus;
2) Department of Integrative Oceanography Division at the Scripps Institution of Oceanography;
3) The School of Public Health at UCLA;
4) The Department of Infrastructure Engineering in the Melbourne University School of Engineering;
5) The Department of Civil and Environmental Engineering at Monash University;
6) The Cooperative Research Center for Water Sensitive Cities at Monash University and University of Queensland; and
7) The Southern California Coastal Water Research Project.

What is the impact on information resources that form infrastructure?

The PIRE project is exploiting a number of information technology innovations that facilitate communication across different continents and time zones, through the use of the information management platform TeamBox and conferencing softwater/hardware Skype and LifeSize.

What is the impact on technology transfer?

PIRE researchers are presenting their findings in Australia to various stormwater management forums, including the California Stormwater Quality Association, with the goal of providing on-the-ground managers with the information they need to make informed decisions about technology options available to improve water productivity in southern California and beyond. Furthermore, the PIRE team benefits enormously from interactions with industry, through formulation of research hypotheses, and identification of societally important problems and field sites.

What is the impact on society beyond science and technology?

Ultimately, by encouraging improvement in water productivity, urban regions in southern California and elsewhere in the US will be better prepared to withstand water stress created by population growth and climate- and human-induced changes in the availability of freshwater resources. Through education and outreach on options for improving water productivity, our PIRE will contribute to a sustainable future.

Changes/Problems

Changes in approach and reason for change
Nothing to report.

Actual or Anticipated problems or delays and actions or plans to resolve them
Nothing to report.

Changes that have a significant impact on expenditures
Nothing to report.

Significant changes in use or care of human subjects
Nothing to report.

Significant changes in use or care of vertebrate animals
Nothing to report.

Significant changes in use or care of biohazards
Nothing to report.

Special Requirements

Responses to any special reporting requirements specified in the award terms and conditions, as well as any award specific reporting requirements.
Nothing to report.