# Abstracts

# 2014 UPP Down Under Lectures

# Welcome and Overview of UCI Water PIRE

*Stan Grant*

Southern California is in the grip of a major drought, yet urban areas throughout the region "throw away" vast quantities of stormwater by letting it flow to the ocean. The UCI Water PIRE's mission is to solve, through interdisciplinary research and education, the biophysical and social barriers that currently limit the capture, treatment, and reuse of urban stormwater runoff in southern California. Our focus is on distributed green systems, such as biofilters and constructed wetlands, that simultaneously augment municipal water supplies (through potable substitution) and provide myriad co-benefits, including: receiving water quality and ecosystem protection, flood mitigation, urban heat island mitigation, carbon sequestration, urban green space creation, and local community engagement. To that end, the UCI Water PIRE focuses on interdisciplinary research with colleagues and industrial partners in Australia; specifically the innovative technologies and water saving approaches Australians implemented during the "Millennium Drought," and how their experience might apply (or not) to the arid Southwest U.S. By facilitating joint research and knowledge sharing, our mission is to accelerate education and training in this critical area of water sustainability, and diffuse knowledge about sustainability options to K-12 students, undergraduate STEM majors, graduate students, post-doctoral researchers, and practitioners.

**Monday, June 16th**

## Stormwater and Wastewater – U.S. versus Australia
## Urban Water Supply and Wastewater Systems of Southern California

*Stan Grant*

In this talk I will provide an overview of the water supply, flood control, and wastewater systems in southern California. I will focus on following questions: (1) Where does southern California's water come from? (2) What are the four massive interbasin water transfer systems in California and how do they function? (3) What are the energy costs associated with these systems, and why is moving and treating water so energy intensive in California? (4) What threats do these water supply systems face in the years ahead? (5) What role does groundwater play in southern California's water supply? (6) What are the major wastewater systems in Southern California? and (7) How might the water supply, wastewater treatment, and drainage systems all be integrated to provide a more sustainable water system for the region?

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## Introduction to the Governance, Regulatory, and Planning Contexts for Stormwater and Wastewater – U.S. versus Australia

*David Feldman*

This talk introduces the ways stormwater and wastewater are managed in the U.S. and Australia by focusing on 1) governance – how public authorities and affected interests collaborate to manage and treat these media; 2) regulation – how standards for public health and environmental protection are made and enforced; and 3) planning – the ways public authorities design and modify the built environment, especially in urban areas, to permit harvesting and use/reuse of these water media.

We will begin by summarizing the major ways both nations' traditionally govern stormwater and wastewater, including the major laws and institutional frameworks they use, and the challenges both have faced in recent years as a result of new policy challenges (ranging from how to minimize adverse human contact and/or reduce flooding on one hand, while also considering ways that stormwater and wastewater can also be used as new sources of potable and non-potable supply on the other. We also compare stormwater and wastewater decision-making in both countries by considering the respective roles of local, state and federal governments in managing these media – as well as special problems both nations confront in coordinating different levels of governance and their competing aspirations. We also compare how both nations incorporate public and community concerns; hasten and encourage innovations in the management of stormwater and wastewater; and the goals and objectives of current policies as articulated in laws, framework documents, and agency directives.

Finally, attention is paid to various built-environment (i.e., planning) challenges in the management of stormwater and wastewater including public perceptions of the desirability of their use/reuse, regulatory challenges in serving potable and non-potable needs, the role of private-public partnerships in resolving stormwater and wastewater management issues, and the likely future direction of policies in both nations with regards to low-impact development, public outreach, land-use controls, and wider adoption of innovations.

## Key Terms:

**Governance** – power and control over water resource exercised collaboratively by public and private authority.

**Regulation** – the establishment of top-down rules by government to prescribe standards for protecting human health and the environment.

**Planning** – the process of improving the welfare of people and their communities by creating more convenient, equitable, healthful, efficient, and attractive places for present and future generations through the design of city-scapes.

**Stormwater** – precipitation that is captured before hitting the ground and which is harvestable for potable and non-potable uses.

**Wastewater** – water that has been used, as for washing, flushing, or in a manufacturing process, and so contains waste products and/or sewage.

# Climate and Hydrology of Southern California and Southeast Australia

*Amir Aghakouchak*

The Intergovernmental Panel for Climate Change (IPCC) 2013 Report presents clear and robust conclusions in a global assessment of climate change science—not the least of which is that the science now shows with 95 percent certainty that human activity is the dominant cause of observed warming since the mid-20th century. The report confirms that warming in the climate system is unequivocal, with many of the observed changes unprecedented over decades to millennia: warming of the atmosphere and the ocean, diminishing snow and ice, rising sea levels and increasing concentrations of greenhouse gases. Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. These and other findings confirm and enhance our scientific understanding of the climate system and the role of greenhouse gas emissions; as such, the report demands the urgent attention of both policymakers and the general public. In this program, two presentations will focus on this topic. This presentation reviews the latest findings of the IPCC 2013 with a focus on California and Australia. The presentation entitled Climate Change and Non-stationary Processes: Detection and Modeling (July 18th) will outline the methodological basis of climate assessment in time series.

# Freshwater Ecology and Anthropocentric Impacts: An Overview

*Peter Bowler*

Humans rely heavily on our freshwater resources; directly for drinking, food production, recreation, and certain industrial uses, but also indirectly through the many benefits these resources provide to our local habitats and the other members of our ecosystems (e.g. flood control and nesting sites). However, humans have modified and altered freshwater systems for many thousands of years. In the United States the historic conversion of wetlands for human uses was predominantly for agricultural purposes, followed by urban development and other causes of habitat take. Besides interior sites, since the 1700's the United States has lost 53% of coastal wetlands (from 5 million to 454,000 acres). California has lost 91% of its natural wetlands – the greatest loss of any state – and in southern California only 3% of the natural floodplain riparian habitat has survived. In the Sacramento River floodplain, only 1.5% of the original gallery riparian forest is still present.

Direct anthropogenic threats to freshwater resources include: drainage for crop production, timber production and mosquito control; dredging and stream channelization for navigation channels, flood protection, coastal housing development and reservoir maintenance; filling with dredged spoil and other solid waste disposal, roads and highways, and commercial residential and industrial development; construction of dikes, dams, levees and seawalls for flood control, water supply, irrigation and storm protection; discharge of materials (e.g., pesticides, herbicides, and other pollutants, nutrient loading and domestic sewage, agricultural runoff, sediments from dredging and filling, agricultural and other land development); and mining of wetland soils for peat, coal, sand, gravel, phosphate and other materials. Indirect threats include sediment diversion by dams; grazing and loss of riparian habitat; deepening of channels, and other kinds of anthropogenic physical and structural change; hydrological alterations by canals, spoil berms, roads and other structures, and subsidence due to extraction of groundwater, oil, gas, sulfur and other minerals. Natural threats include subsidence, sea level rise, droughts, hurricanes and other storms, erosion, and biotic effects. In this overview discussion we will review wetland types, the river continuum concept, nutrient spiraling, lake turnover, the effects of dams and impoundments, the consequences of eutrophic and oligotrophic conditions, mitigation and restoration, and a broad ecological discussion that will give context to the course.

## Key Terms:

**Wetlands** – shallow-water habitats with emergent vegetation. They have water-dependent plants (hydrophytic vegetation), alluvial soils (formed by processes involving water), and are wet at least part of the year.

**Lacustrine** – lake or lake-like habitat.

**Lentic** – habitats that are still water sites such as lakes or impounded water behind dams.

**Lacunae system** – a system of lattice-like tissue (arenchyma) allowing oxygen entrapped in plant leaves (cattails, bulrushes) to be delivered to the roots in plants whose roots are in the oxygen-poor benthic environments in many wetland types.

**Compensation Point or Zone** – the place in the water column at which photosynthesis and respiration are equal.

**Eutrophic** – nutrient enriched, particularly with $NO_3$ and $PO_4$.

**Oligotrophic** – nutrient "poor" – very low levels of $NO_3$ and $PO_4$.

**Nutrient spiraling** – the capture, use, and reuse of energy as it flows through a lotic system.

**Mitigation** – amerliorating or "making pale" impacts – often by altering the layout or design of a project so that it is less damaging.

**Compensatory mitigation** – the trade-off of being legally allowed to take wetlands in exchange for replacing them. The ratio of creation acreage to elimination/conversion is greater than 1, and in southern California it is usually 1 acre to take and 3 acres of wetland creation.

**Tuesday, June 17th**

## Urban Water Sustainability: Definitions and Applications

*David Feldman*

Urban water sustainability is the provision of freshwater in ways that meet the needs of present-day cities without compromising the needs of future generations or other species. These needs include growing food and fiber, producing energy, manufacturing and transporting goods, and meeting domestic and household functions. This presentation shows how urban water sustainability must meet these needs while balancing environmental protection, economic development, and social equity. Achieving this balance requires wedding natural and physical science knowledge of urban freshwater provision with engineering and infrastructural considerations; knowledge of economic benefits and costs; information regarding behavior change via social science; and knowledge regarding ethical tradeoffs.

An exemplar of this balance is integrated urban water management (IUWM) which departs from traditional patterns of water management that compartmentalize water supply, water quality/pollution control, wastewater, and stormwater into separate managerial "pockets." By contrast, IUWM seeks to systematically regenerate, substitute, and conserve water by moving beyond "path dependent" reliance on large-scale engineering solutions to water problems toward smaller-scale; adaptive innovations that rely on neighborhood-level approaches, community engagement, and satisfaction of multiple objectives simultaneously (e.g., flood attenuation, pollution abatement or mitigation, and groundwater recharge).
The remainder of the talk discusses the role of international efforts to promote urban freshwater sustainability through addressing the tangible needs of human and ecological health, and underlying needs for long-term renewability of freshwater stocks; reliable, accessible, and readily useable data and information; and means to alleviate urban water conflicts. Global efforts such as the Dublin Conference (1992) speak to these needs, and the fact that urban freshwater is a finite, vulnerable resource that must be managed through a participatory approach, involving water users, planners, and policy-makers at all levels of governance; which further recognizes the economic value of water in all its competing uses; and fuses partnerships between public, private and not-for-profit non-governmental sectors.

## Key Terms:

**IUWM** – integrated urban water management; an effort to simultaneously manage water supply and demand through comprehensive coordinated planning and the regeneration of water supplies.

**Dublin Conference** – 1992 United Nations meeting that focused on water as a human right that must be met through a combination of equitable transfers of innovations, public participation, gender and ethnic justice, and local innovation.

**Carrying capacity** – the determination of how many people, and what quality of an environmentally-defined region, can be sustained through available water or other resources.

**Substitution** – use of lower-quality freshwater for urban uses such as, industrial cooling and landscape irrigation.

**Regeneration** – deriving high quality water from lower-quality water, including wastewater and storm-water through direct or indirect (e.g., treatment and groundwater replenishment) methods.

**Conservation** – reducing use through water-saving appliances, innovative rate-structures, and water-less toilets and urinals – among other methods.

## Panel Discussion: What Are the Varieties of Careers in Environmental Engineering?

*Moderator: David Feldman*

Careers in environmental engineering are potentially wide-ranging, especially with regard to those engineering specialties related to water supply, water quality, and waste-water treatment. This panel aims to explore not only conventional, well-established career paths in academia, research, industry, government, and the utility sector but - in the spirit of PIRE - to show how new career patterns and opportunities may arise through the transformation of environmental management institutions that are becoming aware of the importance of conserving, regenerating, and holistically-managing water. In short, there is a real need for environmental engineers who are able to understand and implement integrated water management strategies and approaches, and who can work with urban planners, developers, regulators, and others in defining the parameters for sustainable environmental practices.

# Detecting Human Pathogenic Viruses, Bacteria, and Protozoans I

*Sunny Jiang*

Microbial risk is the key concern for water recycling and reuse applications because of the threat of large scale outbreaks of infectious diseases. Routine monitoring of water quality is the number one priority for public health protection. Fecal indicator bacteria (FIB), a group of bacteria that commonly found in warm-blooded animal feces, are currently used as the surrogate for indicating human pathogens in water. However, the characteristics of true human pathogens can be very different than FIB. This lecture introduces the concept of FIB and different groups of human pathogens. An overview of fundamental microbiological techniques for detecting FIB and human pathogenic viruses, bacteria and protozoans will be discussed. This lecture lays the foundation for two future lectures that will introduce the current trends of pathogen detection using molecular biotechnology.

## Key Terms:

**FIB** – fecal indicator bacteria. These bacteria are not typically disease-causing, but are correlated to waterborne bacterial pathogens and provide an indication of water quality/safety.

**Virus** – an obligate intracellular parasite that typically consists of a nucleic acid molecule in a protein coat.

**Bacteria** – unicellular microorganisms that have cell walls but lack organelles and an organized nucleus.

**Protozoan** – a single-celled microscopic animal of a group of phyla of the kingdom Protista, such as an ameba, flagellate, ciliate, or sporozoan.

# Panel Discussion: Direct Potable Reuse

*Moderator: Sunny Jiang*

Could you image cooling off one day with a chilled glass of toilet water to drink? It's an unpleasant idea to say the least. The thought of having anything to do with toilet water beyond its original purpose is distasteful to most. However, for water engineers searching to relive the demands that a growing population and drought conditions have placed on the community, it's a refreshing notion. Currently, there are several endpoints for treated wastewater here in Orange County: 1) as a buffer against saltwater intrusion into groundwater 2) as a replenishment of our groundwater and 3) as non-potable irrigation water. While these uses are beneficial they fail to meet growing water demands. To be considered safe for human consumption, drinking water must meet certain EPA standards. If wastewater can be treated to these standards, can it be delivered to the public? Direct potable reuse is the use of treated wastewater for potable purposes without a period of time spent in an environmental buffer (e.g. the groundwater supply). Direct potable reuse is not permitted at present. The public must first be sold on this idea and the government must first be assured of effective fail-safes. Wastewater poses a significant risk to all members of the population, while children, the elderly, and immunocompromised persons are especially susceptible to pathogens that could survive or break through the treatment process. Is direct potable reuse worth the risk? How costly would the appropriate fail-safes be? Can we ever be assured of the fail-safes in place and can the public ever accept the thought of consuming former toilet water? This panel discussion endeavors to address these questions and more as you will be presented with the ins and outs, pros and cons of direct potable reuse while interacting with experts actively engaged in water reuse.

# Flood Risk and Drainage Systems of Southern California and Southeast Australia

*Brett Sanders*

Urban floods can occur from ponding of excess precipitation, blockage of drainage pathways, and channel flows that exceed design capacity. In coastal areas, urban flooding can also be caused by high ocean levels and waves. Historically the primary design consideration in the engineering of urban drainage systems was public safety and damage avoidance from flooding. Channel stability represents another key design consideration, for which many urban channels are either lined with concrete or armored with riprap (rocks) although natural, soft bottom channels can be found in peri-urban settings. Additionally, urban channels are sometimes engineered with raised embankments (levees) to contain relatively larger flows and higher flood stages. Collectively, these systems act to drain storm water runoff far faster than under pre-development conditions and to fundamentally change stream hydrology, morphology, water quality and ecology (urban stream syndrome).

Floods can occur with a wide range of magnitudes, and records of annual peak discharge tend to follow a lognormal distribution (precisely, the Log Pearson Type III probability distribution is recommended in the USGS). In turn, the capacity of drainage systems is prescribed based on a specific annual exceedance probability p=1/T, where T represents the return period for an event with a probability p. For example, local drainage systems are typically designed for 10-25 year return period, while larger urban channels are designed for a 50-100 year return period, and major rivers (e.g., Santa Ana River) are often designed to handle 100 year and longer return period flows.

Engineers use a risk-based approach to manage flooding hazards, where risk is defined as the annual probability of flooding multiplied by the expected damages. By using computer models of flooding, and economic data on flood damages, engineers can simulate the losses from a wide range of possible flood events (5, 10, 25, 50, 100 and 200 year floods) and then compute the Expected Annual Damage (EAD). Improvements to the drainage system are subsequently justified with a cost-benefit analysis where costs are associated with design and construction and benefits are measured by the reduction in EAD, which represent the “damages avoided.” This approach does not inherently account for other costs and benefits such as those associated with water supply, water quality, ecology, quality of life, and environmental justice, just to name a few. New policies based on Integrated Water Resources Management aim to address this problem and are increasingly applied in practice.

**Key Terms:**
**Flood Risk** = Probability of Flooding * Damages from Flooding

**Return Period** = 1/p where p = annual exceedance probability

## Constructed Wetlands for Wastewater Treatment

*Peter Bowler*

With dwindling water supplies and universal water shortages, reuse of water is critical all over the world. Constructed wetlands are a natural and low cost method of treating and removing a significant quantity of the pollution borne in wastewater. The reclamation of wastewater provides an alternate source for irrigation, and can assist in the purification of secondary wastewater, stormwater runoff, and effluents from farms and many industrial processes. Treatment wetlands are self-sufficient and can be constructed at any size or scale needed in remote areas or onsite at pollution sources, and they can serve as either point source or non-point source drains. They are effective in removing pollutants using natural processes and rival conventional treatment methods. Disadvantages to the constructed treatment wetland approach are that they are slow in treatment, require a commitment of land, are seasonal in efficiency (dry season primarily), they often have constituent build-up and a removal requirement, and, like all wetlands, they produce mosquito populations that might require control. The two most common types of treatment wetlands are surface flow wetlands with a soil substrate over an impermeable layer and subsurface flow wetlands where water to be treated flows through a gravel substrate. Treatment wetlands are relatively low flow and can't take high volumes of water continuously. Constructed wetlands can reduce biochemical oxygen demand through microbial degradation and sedimentation/filtration, suspended solids by sedimentation/filtration, nitrogen (ammonification-nitrification, plant uptake, and volatilization of ammonia), and phosphorous (soil sorption/plant uptake). Constructed wastewater treatment wetlands are widely employed throughout the world, and their use has been growing for the past thirty years. There are approximately 500 sub-surface systems operating in Europe and there are over 600 surface flow systems in North America.

## Key Terms:

**Primary effluent** – wastewater as it enters a constructed treatment wetland.

**Subsurface flow wetland** – emergent macrophyte treatment system with horizontal subsurface flow; plants are established in a gravel substrate over an impermeable layer, and the influent water flows through the gravel in the root zone.

**Surface flow wetland** – emergent macrophyte treatement system with surface flow; plants are established in a soil substrate over an impermeable layer (clay, bentonite, liner).

**Treatment wetlands** – constructed wetlands that have the natural characteristics of wetland plants, bacteria, and chemical processes to “treat” or reduce many kinds of pollutants.

**Wetland effluent** – the water discharged from a constructed treatment wetland.

**Thursday, June 19th**

# Constructed Wetlands for Stormwater Treatment

*Peter Bowler*

In southern California's Mediterranean climate with winter rains (cool, moist winters) and an extended summer drought, runoff is limited to the winter and spring. Many streams dry up (are ephemeral), and overall perennial flow is seasonal and declines in the summer and fall. Stormwater control to protect cities has historically focused upon flood control (concrete-lined or non-lined) channelization of rivers and streams. Other complementary strategies have included water retention dams in the headwaters (to capture runoff before it reaches the floodplain) and stormwater basins at lower elevations. Storage basins are facilities that can capture runoff, retain it, and slowly release it. More progressive and recent approaches include collecting and using stormwater onsite in bioswales/swales, raingardens, roof gardens, green roofs, cisterns for subsequent dispersed uses, bio-retention cells, detention structures, subterranean stormwater retention galleries, and constructed natural treatment system wetlands. In-line Structural Treatment Chambers, a Best Management Practice, remove oil, grease and sediment from stormwater runoff before it reaches wetlands. Low Impact Development (LID) uses bioswales, raingardens, pervious pavement and other approaches to reduce and disperse concentrated stormwater runoff.

**Key Terms:** Images are available at http://www.dubuqueswcd.org/urbanpractices.html
**Swales** – shallow ditches used to carry away/convey water; they may be vegetated or non-vegetated.

**Vegetated swales** (also known as grassed channels, dry swales, wet swales or biofilters) – constructed open-channel drainageways used to convey stormwater runoff. They do not pond water for a long period of time – water flows in, through, and out.

**Bioswales** – vegetated swales that capture, convey, and treat low-flow and stormwater runoff through biofiltration to remove solids, sediment, and nutrients.

**Rain gardens** – gravel filled and vegetated basins to capture, treat, and retain stormwater from roof drainage systems to provide biofiltration and percolation; depressional sites that receive runoff from impervious surfaces and are landscaped with perennial flowers and native vegetation.

**Native landscaping** – landscaping with native plant species that can use natural runoff and require little watering.

**Low Impact Development (LID)** – the use of an integrated system of bioswales, raingardens, permeable/pervious paving, design, and other approaches to disperse and accept stormwater runoff.

**Pervious paving –** permeable pavers, water infiltrating pavers, and porous concrete all allow water to flow through them and penetrate the soil rather than be shed as runoff as is the case in standard hard-scaping.

**In-line Structural Treatment Chambers** – CDS©, continuous deflective separation, and Stormceptor© non-turbulent treatment systems to treat street, parking lot, and parking structure runoff to remove suspended solids, oils, metals, and nutrients.

**Stormwater basins** – flood control basins that are kept empty, then fill during storms and gradually dissipate flood waters.

**Stormwater retention galleries** – large subterranean gravel-filled galleries that provide collection, biofiltration, and percolation of stormwater runoff from parking lots.

**Friday, June 20th**

# What do "Natural" and "Conventional" Treatment Systems have in Common?

*Brandon Winfrey*

Engineers have been using ecosystems to treat wastewater for decades. Since the 1970s, specific treatment systems were designed to mimic natural ecosystems using ecological engineering principles. This lecture will introduce the history of ecological engineering with respect to treatment of various types of wastewater. We will then compare the processes in natural treatment systems to processes in conventional treatment systems. We will focus on constructed treatment wetlands for natural treatment systems. For conventional systems, we will expand on the processes in a typical wastewater treatment plant (e.g., sequencing batch reactor, activated sludge system, etc.) that have natural treatment analogs. The concept of the unit process will be platform from which we approach similarities between natural and conventional treatment systems. Examples of commonalities of these two types of treatment systems are: biofilm production for nutrient removal, aeration for organic matter removal, sedimentation for solids removal, volatilization for nutrient removal, and biomass production for organic matter and nutrient removal.

## Key Terms:

**Ecological engineering** – design of systems and solutions to environmental problems that benefit both society and nature.

**Environmental engineering** – discipline using science and engineering to improve the environment and prevent pollution.

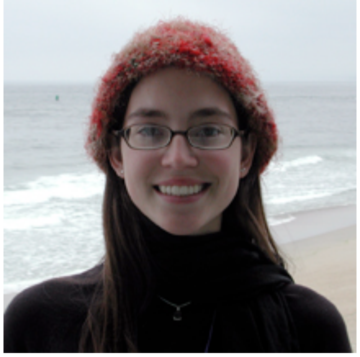
**Unit operations** – in environmental engineering, basic treatment step in a larger process of wastewater treatment. Typically used in design of wastewater treatment systems to remove specific pollutants.

**Active treatment** – treatment method that requires frequent and high maintenance and inputs over the lifetime of the system.

**Passive treatment** – treatment method that can operate with little to no maintenance and few ongoing inputs for long periods of time.

## Pollutant Removal in Biofilters Systems: Are there Tradeoffs?

*Meg Rippy*



Biofilter systems are designed for the simultaneous removal of entire pollutant suites. Because pollutants have different physicochemical properties and are utilized, transformed, and mobilized in different ways by biota, biofilter designs that favor the removal of one pollutant may actually enhance discharge of another. We call this effect a trade-off in pollutant removal efficiency. This lecture will focus on trade-offs in nutrient removal (nitrogen and phosphorous), virus and bacterial removal, and pesticide removal associated with biofilters designed with and without saturation zones at the base of the system. Currently, most biofilters in Australia contain saturation zones, while the majority in the US do not. This lecture emphasizes physicochemical and microbial removal mechanisms in biofilters, as less is known regarding the role of macroorganisms (particularly invertebrates) in these systems. This said, there will be some discussion of the roles invertebrates might play in pollutant removal in biofilters, and the effects different biofilter designs might have on these roles, in the latter half of this lecture.

### Key Terms:

**Biofilter** – vertical infiltration systems with a piped underdrain allowing for water collection. These systems are vegetated and contain microorganisms and invertebrates.

**Rain garden** – near identical to a biofilter, but without a piped underdrain. Water percolates directly into the sediments below the system.

**Saturation zone** – a moist, anoxic (no oxygen) layer that can occur at the base of a biofilter. The space between sediment grains (pore water) in saturation zones contains water only. These zones can be created in biofilters by elevating the end of the outflow pipe so that a certain amount of water pressure is required for water to exit the system.

**Unsaturated zone** – a zone (both in biofilters and natural systems) where sediment contains both air and water in its pore spaces. All water is at atmospheric pressure and is retained in the zone primarily by adhesion to sediment grains and capillary action. These zones tend to support aerobic (oxygen requiring) microbial metabolism.

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## Urban Stream Syndrome

*Rich Ambrose*

"Urban stream syndrome" refers to a set of conditions related to the ecological degradation of streams draining urban watersheds. The mechanisms driving the urban stream syndrome are complex, but a major factor is the rapid delivery of urban stormwater to streams resulting from the prevalence of impervious surfaces in urbanized watersheds and efficient stormwater drainage systems. Symptoms of the urban stream syndrome include a flashier hydrograph, altered channel morphology, elevated concentrations of nutrients and contaminants, and reduced ecological condition, which can include lower biotic richness and changes in species composition, including increased dominance of tolerant species. Most research on urban impacts to streams has concentrated on correlations between total catchment impervious area and stream ecological metrics. The threshold of urban development at which ecological degradation occurs varies, but is often around 10% or less impervious area in a watershed. Restoring streams exhibiting the urban stream syndrome can be challenging, but is most likely to be achieved through widespread application of innovative approaches to drainage design, including low impact development (LID) approaches. By "disconnecting" the impervious area from streams, the ecological degradation associated with a particular amount of impervious surface can be reduced. However, because ecological impacts occur at such low levels of development, some downstream aquatic ecosystem damage may be inevitable unless the extent of watershed development is very limited. Although LID approaches can be implemented in an existing developed watershed, doing so is logistically challenging and expensive; it is easier to implement LID as a watershed is being developed.

**Key Terms:**

**Hydrograph** – a graph showing the rate of flow (discharge) versus time past a specific point in a river, or other channel or conduit carrying flow. A "flashy" hydrograph is one where stream flow increases very quickly and decreases quickly.

**Ecosystem** – a system consisting of a community of organisms in an area and their physical environment.

**Low Impact Development (LID)** – defined by the EPA as the following: LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements. By implementing LID principles and practices, water can be managed in a way that reduces the impact of built areas and promotes the natural movement of water within an ecosystem or watershed. Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions. LID has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

**Restoration** – ideally, returning a degraded habitat or ecosystem to its original state. In practice, it is not logistically practical to restore a degraded habitat to its original state, and it is not even clear what "original state" should be the target, since ecosystems are dynamic. The Society for Ecological Restoration defines ecological restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed."

**Watershed** – the area of land where all of the water that is under it or drains off of it goes into the same place.

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## Measuring Physical and Chemical Water Quality Parameters

*Meg Rippy*

Physical and chemical parameters in water bodies can often be measured using sensors in addition to (or instead of) evaluating water composition directly. This lecture will cover the use of sensors for determining water velocity and turbulence, dissolved oxygen, suspended solids, phytoplankton concentration, and nutrients. Standard chemical methods will also be presented for dissolved oxygen (titration based), solids (via filtration and weight), phytoplankton concentration (extracted pigment fluorescence), and nutrients (colorimetric methods). The pros and cons of sensor based vs direct chemical methods will be discussed, as will the assumptions involved in converting sensor or chemical measurements to parameters that are scientifically interesting (e.g. fluorescence to phytoplankton biomass). Finally the importance of physical measurements as a context for interpreting chemical and biological measurements will be discussed.

## Key Terms:

**Microlayer** – a thin (~ 60 um thick) layer at the surface of aquatic systems that is often enriched in plankton, bacteria, fine sediments, nutrients, and pollutants. This unique ecosystem contains organisms adapted to the air-water interface, many of which do not occur elsewhere.

**Pore water** – water contained within the space between sediment grains (i.e. pore spaces). Pore water is often enriched in nutrients and can have unique microbial and invertebrate communities relative to overlying water. Oxygen levels tend to decrease with increasing depth into the sediment, favoring anaerobic respiration processes over aerobic ones that use oxygen as a terminal electron acceptor.

**Subsurface water** – a general term for the "bulk" of the water column that occurs between the microlayer and the sediment-water interface.

**Phytoplankton** – microscopic organisms that photosynthesize and are near ubiquitous in the sunlit layers of aquatic systems. Some are motile and others drift with the currents. The base of many aquatic food webs.

**Chlorophyll *a*** – a pigment used for photosynthesis by phytoplankton (and terrestrial plants). Chlorophyll *a* fluorescence is often used as a proxy for phytoplankton concentration in aquatic systems.

**Total Suspended Solids (TSS)** – the fraction of solid material that is retained on a 1.2 um filter. Anything smaller is considered dissolved.

**Volatile Solids (VS)** – the organic fraction of TSS. This is the fraction that is lost when combusted at 550 deg C. The fraction retained is inorganic and called fixed solids (FS).

# Measuring Ecosystem Components of Biofilters and Constructed Wetlands

*Andrew Mehring and Brandon Winfrey*

In this lecture, we will discuss collecting organismal data in biofilters and constructed wetlands, with focus on the methodology of surveying macroinvertebrate and plants in engineered ecosystems. To measure macroinvertebrates, we will discuss the intention of the collected data, which will help us determine which environment to focus sampling. We will present methods for sampling macroinvertebrates in several environments, but focus on sampling in the top soil layer of biofilters and the benthic zone and water column in constructed wetlands. We will discuss the process of identifying macroinvertebrates and selecting the most appropriate level of classification for your research questions. For plant surveys, we will discuss the methods used to select sampling locations within a site and collecting vouchers to positively identify plant species after returning from the field. We will also present common uses of these ecosystem component data with a focus on ecologically engineered, natural treatment systems.

## Key Terms:

**Species richness** – number of species present in a community or ecosystem.

**Species evenness** – distribution of abundances of individuals of each species in a community or ecosystem.

**Species diversity** – measure of number of species and distribution of individuals in each species in a community or ecosystem.

**Diversity index** – mathematical representation of species diversity.

# Designing a Sampling Program for Constructed Wetlands and Biofilters

*Richard Ambrose*

Sampling physical, chemical and biological parameters in the environment is challenging because of large variability in space and time. Because we typically can't collect all possible samples or count all organisms in an area, we need to design a sampling program to collect representative samples. The sampling design is a fundamental part of data collection for a scientific research project; it determines whether or not you will be able to answer the question of interest and what types of inferences you can make from your data. The sampling design must be appropriate for the particular question being asked, so an important first step is clearly defining the question you want to answer. Besides the importance of collecting representative samples, there are important statistical issues that need to be considered when designing a sampling program. For example, most statistical tests require that replicate samples be independent. A common problem in environmental research and monitoring is pseudoreplication, where samples are treated as independent when they really are not. Another common problem is large environmental variability reducing statistical power (this can be thought of as a signal-to-noise issue). There are a number of strategies that can be used to reduce variability, with stratification being a common approach. In many cases, practical constraints preclude using an "optimal" sampling design in environmental research. For example, if the number of biofilters that have been constructed in an area is limited, it may not be possible to stratify sampling by watershed condition or to sample a large enough number of biofilters to have substantial statistical power. Sometimes these limitations are so serious that the question of interest can't be answered and there is no point in doing the study, but in any case the limitations must be recognized and taken into account when interpreting the data collected.

## Key Terms:

**Pseudoreplication** – according to Hurlbert (1984), the use of inferential statistics to test for treatment effects with data from experiments where either treatments are not replicated (though samples may be) or replicates are not statistically independent.

**Statistical power** – the probability that a statistical test correctly rejects the null hypothesis when the null hypothesis is false.

**Tuesday, June 24th**

# Statistical Approaches for Experimental Design and Data Analysis

*Megan Rippy, Andrew Mehring, and Brandon Winfrey*

Following identification of a good question, a successful scientific study begins and ends with statistics. Here we discuss statistical approaches for designing robust experiments, including statistical power, replicates, pseudo-replicates, and measurement error. The design of the UPP Down Under 2014 program will be evaluated based on these concepts. We will also discuss simple statistics (means, variances, standard deviations, standard errors, and confidence intervals), and frequentist hypothesis tests for data evaluation. These tests include comparisons of means (T-test) and variances (ANOVA, post-hoc tests) between datasets, as well as correlations between individual variables within datasets (Pearsons correlation coefficient and Spearmans correlation coefficient). Where possible, data from the 2013 UPP Down Under program will be used to illustrate these concepts.

## Key Terms:

**Control group** – a baseline group determined by the researcher as the “normal condition”, to which other groups are compared. The independent variables of interest are the only variables modified in the control group – conditions other than the variable(s) of interest should be the same in both control and experimental groups.

**Experimental group** – a group that receives a treatment and whose dependent-variable values are compared to those of a control group. When possible, all variables are the same as in the control group, except for the independent variable of interest.

**Dependent variable** – the observed variable that is expected to change in response to changes in the independent variable. Also known as the response variable.

**Independent variable** – variable which explains (predicts) the variability in the response variable. Also known as the explanatory variable or predictor variable.

**Extraneous variable** – a variable other than the independent variable that may affect the dependent variable. Also known as a nuisance variable or confounding variable.
**Distribution** – the range, as well as frequency or probability of values for a variable within a sample.

**Variance** – a measure of precision within an experiment.

**p-value** – probability that random chance alone leads to a test statistic as extreme as or more extreme than the one observed, if the null hypothesis is true. The smaller the p-value, the more unlikely it is that chance is responsible for the differences between groups, and the greater the evidence that the null hypothesis can be rejected.

**Standard deviation** – for a distribution of values, a measure of the amount of variability around the mean of the distribution. It is a measure of spread, interpreted as the typical distance between a single number and the set's mean. Denoted by σ for the population and by s for the sample.

**Standard error** – the standard deviation of a sampling distribution. The best guess about the likely size of the difference between a statistic used to estimate the parameter and the parameter itself. Denoted by SE.

## Plant and Animal Communities in Biofilters: Are they Sustainable?

*Brandon Winfrey and Andrew Mehring*

The class will first engage in a discussion on the concept of sustainability, focusing on lessons from previous lectures. These concepts will be related to the goals of biofilters as part of the urban water sustainability framework. Biofilters are low-energy options for treating stormwater. The plant and animal communities play an important role in these systems. However, most systems require maintenance to sustain desired plants. Does this requirement affect the sustainability of these systems? Management techniques that could be used to sustain plant and animal communities will be presented. These techniques include biomass harvesting, seeding macroinvertebrates, etc. The potential effects of these techniques, as well as their costs will be discussed by the class.

### Key Terms:

**Sustainability** – meeting the needs of the present without compromising the needs of the future.

**Ecological succession** – change in species makeup of a community over time.

# Biofilter Systems in the US and AUS: a Trans-Continental Comparison

*Brandon Winfrey and Andrew Mehring*

Design specifications for U.S. and Australian biofilters will be compared in this lecture. We will compare key design aspects such as inclusion of a saturated zone, infiltration to subsoil, plant and animal community types, location in the urban landscape, and sizing criteria in Melbourne, VIC and southern California. We will pay close attention to the differences in plant and animal communities between US and Australian systems in similar climates. Whether colonized over the lifetime of the biofilter or intentionally planted/seeded, the plants and animals present in a biofilter have profound effects on the pollutant removal and hydraulic performance of biofilters. Plant processes and characteristics such as root exudation, oxygenation, and uptake, mycorrhizal relationships, growth strategy and rate, transpiration, and turnover greatly affect nutrient removal and water movement in the soil layer. Macroinvertebrates can create macropores, cycle nitrogen, build soil organic matter, and contribute to plant nutrient availability. Australian and US biofilter plant and animal communities will be discussed from a perspective of the effects of species on biofilter performance.

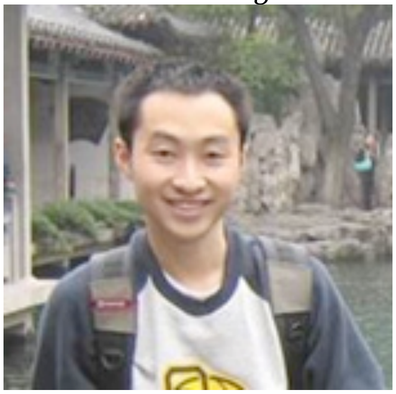
## Key Terms:

**Biofilters** and **rain gardens** – treatment systems designed to capture and treat stormwater runoff using vegetated filter media.

**Thursday, June 26th**

# Detecting Human Pathogenic Viruses, Bacteria, and Protozoans II

*Eric Huang*



Besides traditional culture-based methods, molecular microbiological methods have become more popular in waterborne microbial pathogen detection. There are two main challenges associated with this work. One, is the small size of the microbial pathogens and the other, is their low concentrations in environmental waters. In this lecture, we will first discuss methods used for pathogen concentration, including dead-end filtration (Centricon/Amicon filters and Nanoceram cartridge filters) and cross flow filtration (Hemoflow). Then, we will go over some basic knowledge of microbiology, such as pathogen classification, cell structure, and especially the genetic information carriers DNA and RNA, which we employ for pathogen detection. The core part of the lecture is to explain how PCR works, as many molecular microbiological methods are reliant upon PCR. We will discuss its advantages and disadvantages. And finally, I will give you a brief introduction to qPCR, sequencing, and microarray analysis.

## Key Terms:

**PCR** – polymerase chain reaction is a biochemical technology in molecular biology used to amplify a single or a few copies of a piece of DNA across several orders of magnitude, generating thousands to millions of copies of a particular DNA sequence.

**qPCR** – real-time polymerase chain reaction, also called quantitative polymerase chain reaction (qPCR), is a laboratory technique of molecular biology based on PCR, which is used to amplify and simultaneously quantify a targeted DNA molecule. For one or more specific sequences in a DNA sample, quantitative PCR enables both detection and quantification. The quantity can be either an absolute number of copies or a relative amount when normalized to DNA input or additional normalizing genes.

**Nanoceram cartridge filter** – a new type of positively charged water filter. In contrast to traditional water filter technology, which removes contaminants based purely on the physical pore size of the media, NanoCeram utilizes 2 to 3 micron nominal pore size to trap particles between 0.5 and 2 microns and combines this with a process called 'electro-adhesion' to trap fine and ultra-fine particles down to an incredible 0.02 microns.

**Pathogenic microorganisms** – microorganisms with the capacity to cause damage in a host. The microorganism may be a virus, bacterium, protozoan, or fungus that causes disease in the host. The immune system in the body of a human being is the system designed to fight pathogens.

**DNA sequencing** – the process of determining the nucleotide order of a given DNA fragment.

**Microarray** – a multiplex "lab-on-a-chip." It is a 2D array on a solid substrate (usually a glass slide or silicon thin-film cell) that assays large amounts of biological material using high-throughput screening miniaturized, multiplexed and with parallel processing and detection methods.

## Detecting Human Pathogenic Viruses, Bacteria, and Protozoans III

*Yiping Cao*

This talk introduces the next generation quantification technology: Digital PCR.

The first part of the talk will focus on the technology itself.  We will begin by summarizing PCR quantification technology in water quality testing. We will then cover 1) what digital PCR (dPCR) is, 2) how the technology came about, 3) the conceptual and simple mathematical basis for dPCR quantification, and 4) types of dPCR platforms.

The second part of the talk will discuss various applications of dPCR in stormwater and wastewater monitoring.  Examples may include 1) application of dPCR for simultaneously quantification of multiple indicators of fecal contamination, 2) dPCR for stormwater applications which are often hindered by PCR inhibition, and 3) dPCR quantification of viruses. We will conclude by looking into the future and discussing real time online pathogen monitoring systems that may transform how water monitoring is conducted.

**Key Terms:**

**PCR** – "Polymerase Chain Reaction" – the process involves heating a DNA sample to separate the two strands, cooling the sample so that specific primers can mark the region to be amplified, and using a DNA polymerase enzyme to copy the two strands (a.k.a amplification). As the process is repeated, the amount of new DNA increases exponentially. Simply, PCR is a process to quickly make millions of copies of DNA, thus enabling a small DNA signal be amplified and detected.

**PCR Inhibition** – the phenomenon where substances in water samples interfere with the PCR chemistry, and slow down or completely shut down the process of copying DNA.

**Digital PCR** – PCR where the bulk reaction is partitioned into thousands to millions of nanoliter or picoliter reactions inside small chambers on a chip (i.e. chamber digital PCR) or water-in-oil droplets (i.e. droplet digital PCR), prior to PCR amplification. This partitioning process approximates a Poisson distribution and renders the DNA target present in some of the partitions but absent in others. As a result, a portion of the partitions will be positive, i.e. a PCR amplification occurs as in end-point PCR. The positive partitions would be scored 1 and the negative partitions scored 0, hence the name “digital PCR”.  The frequency of positive partitions is then used with Poisson statistics to estimate the concentration of DNA in the original bulk reaction.

**Friday, June 27th**

# Application of Ecological Theory to Biofilter Design

*Lisa Levin*

Design of bioretention systems has much to gain from thoughtful application of ecological theory that describes how components within an ecosystem interact to achieve particular functions. This lecture will (1) outline ecosystem elements, their functions and emergent properties, (2) explain what ecological theory is and how its guiding principles apply to bioretention system services, and (3) discuss a suite of relevant ecological concepts, illustrating how their incorporation into design rules may enhance bioretention system efficiency. Key theories to be covered include: foundation species and ecosystem engineering, biodiversity and ecosystem function, complexity-stability, intermediate disturbance, and metacommunity dynamics.

## Key Terms:

**Biodiversity Ecosystem Function (BEF)** – theory explaining why high biodiversity can enhance ecosystems functions.

**Bioretention system** – a combination of filter media (soil), plants and animals that function to improve water quality and enhance infiltration.

**Complimentarity** – the idea that different species perform different functions best; when combined maximum function is achieved.

**Ecological engineering** – modification of the abiotic environment by organisms. This may be allogenic (involving changes to the organism) or autogenic (involving the organism structure itself).

**Ecological theory** – explanations for processes involving interactions of organisms and their environment. Spatial or temporal dynamics may be involved.

**Ecosystem-based management** – holistic approach to spatial planning based on managing the integrity of habitats rather than individual species.

**Foundation species** – species that exert a disproportionately large influence on other species, shaping the structure of the community.

**Geophageous** – eating sediments.

**Source-sink dynamics** – theory emphasizing connectivity among patches and the idea that some are sources of individuals while others are receptors (sinks).

**Water sensitive urban design** – term for low energy water purification systems: bioswales, biofilters, rain gardens, bioretention systems.

## Case Studies of Low Energy Treatment Systems for Stormwater Management

*Jian Peng*

Arid Southern California has a unique, heavily anthropogenic water cycle. Extensive investments have been expended on building a remarkably reliable and resilient regional water infrastructure. The world-leading effort on wastewater recycling and groundwater basin management has enhanced the water sustainability in the region. However, continued population increase and reluctance in changing a hydrophilic lifestyle continue to put pressure on water supply. Recently, a historic draught exposed the fragility of the regional water system. In this talk, we will discuss one important element of the human water cycle – stormwater, and the low cost options for stormwater capture, treatment, and reuse. The focus will be on case studies that encompass the following stormwater treatment/reuse options: engineering treatment, regional treatment, and green infrastructure. All case studies are based on southern California.

**Friday, July 4th**

# Basics of Cost-Benefit Analysis I and II

*Jean-Daniel Saphores*

Cost-Benefit Analysis (CBA) is a systematic process for estimating and comparing benefits and costs of a project/an investment (private or public) or a government policy. CBA encompasses a number of techniques to assess the merits of a stand-alone investment or to choose the best investment among mutually exclusive alternatives.

Although conducting a CBA to guide decision-making seems almost natural today, its systematic adoption for government decisions is relatively recent. CBA was originally proposed in 1848 by Jules Dupuit (1804-1866), a French Civil Engineer and Economist, and it was formalized by Alfred Marshall (1842-1924), an influential English Economist. In the United States, the use of CBA was pioneered by the Corps of Engineers following the Federal Navigation Act of 1936, which required CBA for analyzing federal waterway infrastructure projects. The use of CBA to analyze government policies was further expanded by Presidents Carter and Regan.

After a brief historical overview of CBA, Part I will cover the following themes:
- Limitations of CBA
- Time value of money
- Discounting and minimum acceptable rate of return
- Present worth and annual worth
- Internal rate of return
- Benefit-cost ratio

In Part II, we will learn how to introduce inflation, taxes, as well as risk in a CBA.
Students will gain a working knowledge of these techniques, which will be illustrated on simple water infrastructure investment examples.

## Key Terms:

**Cost-Benefit Analysis (CBA)** – a systematic process for estimating and comparing benefits and costs of one or several investments.

**Discounting** – a method used to assess how much future payments are worth today.

**Infrastructure** – the basic equipment and structures needed for a country, region, firm, or organization to function properly. Examples include ports, airports, and roads, communication systems, sewage lines and treatment plants, and the electric grid.

**Investing** – committing money, time, or energy to a project in the hope of obtaining future benefits in a specific time frame.

## Valuation Techniques to Assess Environmental Benefits

*Jean-Daniel Saphores*

To conduct a cost-benefit analysis (particularly for an investment in water infrastructure), it is critical to quantify all important costs and benefits of a project. In a market economy such as ours, the value of a good or a service is obtained by matching demand and supply. Unfortunately, markets are not complete (e.g., there are no markets for water quality or for biodiversity), so the value of many environmental amenities is unknown and must be determined by other means. This is particularly important for water infrastructure projects, because we are already using half of the available freshwater in the world, and water is essential to most ecosystems.

To quantify the value of environmental amenities/services that are not exchanged on markets, economists have created several techniques. After reviewing the different types of values relevant for public policy analysis, the purpose of this lecture is to get acquainted with the two most common valuation techniques used to infer missing environmental values encountered in water infrastructure projects:

1. Hedonic pricing (HP; Court, 1939; Griliches, 1961; Rosen, 1974) which relies on econometric techniques to analyze markets (such as the housing market) that reflect environmental values; HP posits that the price of a marketed good reflects its characteristics; and
2. Contingent valuation (Ciriacy-Wantrup, 1947; Hanneman, 1994), which is a survey-based technique for quantifying the value (including existence value) of non-marketed resources.

Some of examples of applications of these techniques to water/land use problems will be briefly discussed.

## Key Terms:

**Contingent valuation** – a survey-based technique used to quantify the value of non-marketed resources.

**Existence value** – a key component of non-use value, is the benefit people receive from knowing that a particular environmental resource (such as an endangered species or the Grand Canyon) exists.

**Hedonic pricing** – potential for losing something of value, where the magnitude and the probability of that loss are known.

**Use value** – the value of consuming a good or a service.

**Wednesday, July 9th**

# An Overview of Risk Assessment

*Sunny Jiang*

Nothing in the world is risk free. The challenge for adopting innovative water systems is largely related to the multitude of risk perceptions held by the multiple stakeholders. Risk perception is a subjective response to risk, which contrasts with the objective analytical process used for risk assessment. Due to our high-risk aversions of compromised health associated with any undertakings, decision-making within the water sectors is traditionally focused on the public health safety of water systems. However, the unique set of water problems faced by different regions have pushed for the incorporation of technical, socio-economic, and environmental risk assessment in the decision-making process.

Sustainable urban water systems are considered as "risk objects" by stakeholders due to the large amount of unknowns associated with it. While a health risk assessment of such systems can guide its implementation, the convoluted socio-economic costs-and-benefits (externalities) associated with it are often the underlying concerns for water planners. For context, the risk assessed by a health expert is a subjective risk perception to a water-project manager who has monetary budget concerns, or an environmental pollution expert who is more concerned about carbon footprint, and vice versa. Integration of sustainable urban water systems with conventional water systems is, however, necessary to meet our increasing resource-challenged world. Instead of centralizing water management responsibility on a single entity, risk assessment of sustainable urban water systems should be conducted in collaboration with multiple stakeholders. The main goal of which is to converge the divergent views of the stakeholders, allocate responsibilities, and to explore a wider array of options to address a complicated problem.

In this talk, we will explore the different types of risks, the approaches to assessing those risks, and the need and directions for integrating risk assessment explored from different perspectives for sustainable urban water systems.

**Key Terms:**

**Risk perceptions** – subjective risks as understood by an individual, community, or organization, which are influenced by their knowledge, attitudes, values, and beliefs.

**Risk assessment** – objective analytical process supported by scientific evidence that underpins risk management.

**Stakeholders** – group of parties that influence the receptivity of a practice, including the water users, planners, and policy-makers.

**Sustainable urban water systems** – innovative stormwater management approach that mimics pre-development hydrology through infiltration (treatment), storage, evaporation, and/or detention of stormwater using nature-fused infrastructures, such as biofilters, raingardens, and wetlands. This is in stark contrast of the conventional approach that is only aimed at efficient conveyance of stormwater to water bodies.

**Externalities** – costs and/or benefits associated with an action that are incurred by a party/parties who did not choose to incur them.

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## Urban Water Supply and Wastewater Systems of Southeast Australia

*Stan Grant*

Australia is the world's driest inhabited continent and its population is one of the most urban. As of 2006, over two-thirds of Australia's 21 million inhabitants lived in just a handful of large cities. Finding adequate water resources to sustain these cities is an ongoing challenge. Nowhere is this more apparent than in Melbourne, a coastal city of approximately 4 million people located in the country's southeast region. Over its 166-year history, Melbourne has experienced 8 major droughts. The most recent one, known as the Millennium Drought, started in 1997 and lasted more than a decade. During the Millennium Drought, below-average precipitation and above-average temperatures drained the city's drinking water reservoirs and stoked bush fires, including the 2009 "Black Saturday" fire that damaged 30% of the city's water supply catchment and claimed 173 lives. The Millennium Drought also altered public perceptions about global climate change, water conservation, and water-use behaviors, and energized city managers and politicians to adopt a wide range of approaches for augmenting water supplies and conserving water resources. In this talk I will explore how the Millennium Drought changed the way Melbournians source and use their water resources, and discuss what these changes portend for other large cities in water-scarce and climate-change-vulnerable regions of the world, in particular the Southwest region of the United States.

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## Public Perception of Water Risks: U.S. vs. Australia

*Jean-Daniel Saphores*

Public perception can be defined as the gap between truth based on scientific facts and a virtual truth shaped by popular opinion, media coverage and reputation. Understanding public perceptions of risks related to water infrastructure may therefore not seem worthy of the attention of Neanderthalian civil and environmental engineers, but ignoring public perception of water reuse risk is a sure way to condemn expensive infrastructure projects to failure.

After reviewing the concept of risk, this talk will present a summary of public perceptions of water reuse schemes based on an extensive literature review, with an emphasis on the Australian experience. Results of a pilot study on public perception of water reuse in the United States will then be presented and discussed. A side-benefit for students will be a glimpse at survey techniques and econometric models that can be used to analyze perceptions and preferences.

### Key Terms:

**Neanderthalian** – relating to, belonging to, or resembling Neanderthal man; by extension: believing that only civil and environmental engineering matters, and not other disciplines.

**Public perception** – the gap between truth based on scientific facts and a virtual truth shaped by popular opinion, media coverage and reputation.

**Risk** – potential for losing something of value, where the magnitude and the probability of that loss are known.

**Uncertainty** – potential for losing something of value when the magnitude of that loss is known, but not its probability.

**Friday, July 11th**

# Advanced Statistical Tools for Data Analysis

*Megan Rippy, Andrew Mehring, and Brandon Winfrey*

## Part 1.

This lecture will focus on multivariate analysis of data, specifically multiple linear regression (MLR). MLR models allow us to mine data and identify sets of variables that non-redundantly explain a portion of the variability observed in a parameter of interest (FIB, Nitrate, etc). Although simple conceptually, these models can be difficult to implement, and require a variety of assumptions. We will discuss some of these assumptions and methods for dealing with violations, when they occur: non-normal independent variables (transformations, GLM) and correlations amongst dependent variables (variance inflation factors). Interactions between measured variables and their importance in MLR analysis will also be discussed. This lecture will introduce EPA's Virtual Beach, a powerful, user friendly MLR package, and walk through some guided MLR analysis using data collected during the 2013 UPP Down Under Program.

## Key Terms:

**Linear regression** – A statistical approach for modeling the relationship between a dependent (response) variable and a independent (explanatory) variable. (Example: phytoplankton concentration "dependent variable" might be linearly correlated with phosphate concentration "independent variable", as phytoplankton require phosphate to grow).

**Multiple Linear Regression (MLR)** – A statistical approach for identifying relationships between multiple possible independent (explanatory) variables and a dependent (response) variable. (Example: phytoplankton concentration might be linearly correlated with a combination of phosphate concentration and zooplankton concentration, as phytoplankton require phosphate to grow, and zooplankton graze on phytoplankton, reducing their numbers.)

**Variable transformation** – A statistical technique for altering variable distributions so that they appear normally distributed (Example: log transforming a variable that appears to have a log-normal distribution will make the distribution normal). Transformations are performed because many statistical tests require normally distributed data.

**Variance Inflation Factor (VIF)** – VIF is a statistic that indicates the degree to which the variance attributed to a given parameter in a model is inflated by the presence of another parameter with which it is correlated. Simply put, VIF indicates the degree of correlation amongst variables in a model. It is often used prior to MLR to detect highly correlated explanatory variables, and remove all but one from the model. This ensures that estimates of the variance explained by each remaining parameter in the model is unaffected by the presence/absence of other parameters.

**Akaike Information Criterion (AIC)** – AIC is a statistical used for model selection. AIC indicates the model or group of models that best fit available data with the fewest possible number of parameters. Models with a large number of parameters are penalized by the statistic. This guards against over-fitting, as any model can be perfect if the number of parameters included is equal to or greater than the number of data points being fit.

## Part 2.

This lecture will focus on bootstrap and resampling techniques, and their use in parameter estimation or hypothesis testing when data distributions are non-normal. Bootstrap is primary used to provide confidence bounds for means, variances, and correlations, while reshuffling methods are used for hypothesis testing. Data collected during the 2013 UPP Down Under program will be used to show how bootstrap and reshuffling methods can improve our analysis of non-parametric data: specific examples include bootstrapped confidence intervals for sample means, and reshuffling-based t-tests. This lecture will also briefly introduce pattern analysis methods like PCA and PARAFAC, discuss their utility for exploring multivariate datasets, and how bootstrap approaches can be used to estimate confidence intervals for these methods.

### Key Terms:

**Bootstrap method** – A kind re-sampling technique for data whereby a dataset of size N is randomly sampled with replacement, producing another dataset of size N that includes some samples from the original dataset multiple times and excludes others entirely. This process is repeated 1000's of times to produce multiple realizations of a dataset that allow calculation of confidence intervals about parameters of interest for that data-set (means, variances, etc.). This technique is powerful because it can be used to estimate confidence intervals when data-sets are not normally distributed.

**Reshuffling methods** – Conceptually similar to bootstrap methods. Reshuffling methods, however are typically used for hypothesis testing when the data-sets being compared are not normal. This differs from bootstrap techniques which are generally applied to parameter estimation for a single data-set.

**Principal Component Analysis (PCA)** – PCA is a technique used for data simplification and pattern detection. The first principal component captures the largest fraction of data variance, with each subsequent component capturing a smaller fraction of the remaining variance. Example: PCA could be used to identify dominant patterns in suites of physical, chemical, or biological variables measured at constructed wetland inlets and outlets. If all inlets were identical and all outlets were identical, the dominant principal component mode would group inlets and outlets separately. If inlets and outlets were different in Australia and the US, an additional secondary mode might group locations in Australia separately from those in the US.

**Parallel Factor Analysis (PARAFAC)** – Similar to PCA, but used for data with a clear 3D structure. This method is commonly employed to analyze excitation emission fluorescence spectra (EEMS), where each component represents an individual fluorescent compound (or suite of similar compounds) in excitation, emission, and fluorescent intensity space.

**Monday, July 14th**

## Communicating Scientific Findings in Written and Oral Forms

*Megan Rippy, Andrew Mehring, and Brandon Winfrey*

Technical communication is intended to convey specific information to a specific audience. Effective and efficient communication skills will be presented in this lecture. We will cover scientific publication writing (outline development, technical writing with a focus on grammar, document preparation and format), tips for successful poster design and poster presentations, and scientific talk guidelines (audience analysis, presentation style and construction, and public speaking). Emphasis is placed on short form scientific talks (< 15 minutes), including aesthetics (appropriate font styles/sizes for presentations, color schemes, text:image ratios), and the art of selecting a good story arc to present that includes enough detail to be informative, but not so much that methods drown the message. It is our intent that this lecture serve as a guide for the short format student presentations delivered at the conclusion of UPP.

## Communicating Broader Societal Impacts and Public Outreach

*Janet Rowe*

33% of Americans (over 100 million people) don't believe in evolution. Over half of the American population believes "there is a lot of disagreement among scientists" regarding global warming. Anti-vaccine campaigns have led to outbreaks of painful, preventable diseases. During the 2008 Presidential campaigns, Sarah Palin mocked the spending of less than half a million dollars on fruit fly research, unaware that the specific project she was targeting is seeking a solution to a multi-million dollar per year agricultural problem, and seemingly unaware that many other studies based on fruit flies have led to invaluable discoveries relevant to human genetics and genetic disorders. Though it is easy to ridicule Palin's ignorance, the journal, Nature, took a different approach. It reminded the scientific community that we need to do a better job of explaining our research to the public. Ultimately it is our responsibility. It is not only vital for maintaining funding, but for ensuring the continued progress in our areas of research by inspiring and educating the next generations of researchers. The phrase, "what you don't know can't hurt you", should really be "what others don't know can hurt you." You want your medical doctors to be well educated, yes? What about your politicians who propose legislation that affects your community or your research? What about the voting population deciding on the value of your research or the merit of a new proposition? There are many people responsible for educating the population at large, and now that you have been recruited into the UPP, you are one of them. Sharing your work with a layperson requires different tactics and different language than when you present to members of the scientific community. This lecture is designed to be an interactive discussion. We will brainstorm about the broader impacts of your field work and practice communicating this work and its significance to a general audience.

**Friday, July 18th**

# Quantitative Microbial Risk Assessment (QMRA) as an Approach to Assessing Public Health

*Keah-Ying Lim and Sunny Jiang*

Stormwater harvesting practice presents a unique sustainable urban water management strategy for preventing urban stream degradation, controlling stormwater pollution, and most importantly, diversifying the water supply portfolio. However, designing the fit-for-purposes of treated stormwater will require addressing its associated public health risks to the multiple stakeholders.

Harvested stormwater contains pollutants from urban and/or agricultural runoff, yet it is less contaminated than municipal and industrial wastewater. Thus, the application of harvested stormwater for non-potable uses requires much less treatment than wastewater. Development of this practice, however, is impeded by the uncertain microbial risks associated with the treated stormwater application. Conservative approaches to managing these risks usually involve advanced water treatment processes that are costly in monetary and energy terms, but are entirely unnecessary for purposes with negligible health benefits.

Passive treatment built around Low Impact Development (LID) or Water Sensitive Urban Design (WSUD) systems are presumed to be able to provide adequate treatment for alleviating these risks, while reaping the "green technology" benefits associated with the systems. A big question to this proposition is: "How "safe" is safe?" In order to answer this question, we use the Quantitative Microbial Risk Assessment (QMRA) approach to quantify the health risks associated with three non-potable uses of treated urban stormwater: 1) Toilet-flushing, 2) Showering, and 3) Food-crop irrigation. Quantified risks are then interpreted on the basis of the U.S. EPA annual infection risk benchmark, which set the nation's safety level for drinking water.

Our presentation will cover a brief background of the QMRA approach, a hypothetical example of QMRA for stormwater harvesting practice, and an in-depth discussion of the QMRA results.

**Key Terms:**
**Stormwater harvesting** – the practice of harvesting (and treating) stormwater from stormwater collection systems to meet human water needs.

**Fit-for-purposes** – the appropriate use of stormwater (potable or non-potable) with negligible health risks based on the level of stormwater treatment.

**Stakeholders** – group of parties that influence the receptivity of stormwater harvesting practice, including the water users, planners, and policy-makers.

**Microbial risks** – the risk or probability of contracting disease through exposure to pathogens in stormwater via different water application (i.e. toilet-flushing).

**LID** – also known as Water Sensitive Urban Design (WSUD) in Australia or Sustainable Drainage Systems (SuDS) in UK, is an innovative stormwater management approach that mimics pre-development hydrology through infiltration (treatment), storage, evaporation, and/or detention of stormwater using nature-fused infrastructures, such as biofilters, raingardens, and wetlands. This is in stark contrast to the conventional approach that is only aimed at efficient conveyance of stormwater to water bodies.

**U.S. EPA annual infection risk benchmark** – the nation's microbial standard for safe drinking water, which must assure less than 1 infection case in a community of 10,000 people drinking water from the tap in a year.

**QMRA** – Quantitative Microbial Risk Assessment – an objective and scientific microbial risk assessment approach proposed by the National Research Council, which follows four steps: hazard identification, exposure assessment, dose-response assessment, and risk characterization.

## Policies for Governing Watershed Risks and Associated Public Concerns

*Lindsey Stuvick, Ashmita Sengupta, and David Feldman*

This talk will explore the development and implementation of an innovative water quality offset policy in Victoria, Australia which is being adopted to achieve broad sustainability objectives (the so-called triple bottom line). This is done through permitting wastewater treatment plants to use recycled wastewater for achieving social and economic - as well as traditional ecological water quality - objectives. Adopting offsets for this purpose requires a number of governance innovations. These include using life cycle assessment to assess a wide-range of societal impacts, as well as evaluating environmental impacts beyond those strictly-limited to water quality (e.g. greenhouse gas emissions, land use effects, community economic opportunities).

The process also embraces stakeholder-driven alternatives, allowing community values to inform decisions and ensuring that benefits and costs are acceptable to the public. In addition, because effluent generators participate in offset decision-making, a wider-array of environmental and economic tradeoffs are encompassed in negotiations over appropriate objectives than would otherwise be the case. We will discuss the governance arrangements of this approach, which exemplifies a form of adaptive governance - well suited for the achievement of broader sustainability objectives. Adaptive governance is characterized by: bottom-up, civil society collaboration, public participation, policy experimentation and social learning.

The offset policy being developed in Victoria has implications well beyond the use of recycled wastewater for achieving various social objectives. This approach is expected to eventually contribute to the development of a more expansive water quality offset framework that can be applied to point source discharges, nonpoint sources of pollution, and sewerage overspills. Furthermore, the approach holds important lessons for societies elsewhere that seek to manage ecologically stressed watersheds—including Southern California.

### Key Terms:

**Environmental offset** – an action(s) to address an adverse environmental impact of resource use, a discharge, emission, or other activity at another location to cost-effectively deliver a net environmental benefit.

**Triple bottom line** – An integrated approach to considering economic, social, and environmental values in the planning and decision-making aspects of policy development.

**Governance** – the manner by which decisions are made, implemented, and legitimized; the interactions among a myriad of parties and jurisdictions relevant to these decisions; and, the decisional outcomes themselves.

**Adaptive governance** – form of governance that emphasizes collaboration, public participation, policy experimentation, capacity building for resilient systems, and provides the enabling context for adaptive management.

# Summary, Limitations, and Future Learning Challenges

*Jean-Daniel Saphores and David Feldman*

This session reviews lessons from the UPP Down Under panels, talks and experiences with an emphasis on the challenges going forward with respect to synergies between the engineering, social science, economics, health, and ecological dimensions of water quality and supply management. Questions raised in the past weeks will be explored in detail.

**Wednesday, July 23rd**

## Panel Discussion: Desalination

*Moderator: Jean-Daniel Saphores*

“Water, water every where / nor any drop to drink.” We’ve probably all heard this excerpt from Samuel Taylor Coleridge’s The Rime of the Ancient Mariner. Unfortunately, it seems that these lines could soon describe the situation of some coastal areas in Southern California, given the severe drought we have been experiencing. One proposed solution is to build desalination plants to complement our water portfolio. However, not everyone in Southern California supports desalination. Desalination is costly, energy intensive, and may be risky to the environment and to some coastal fisheries.

Several countries already use desalination to meet their water demand. During the Millennium Drought, Australia spent $10 billion to build six desalination plants, of which, four were shut down after the drought ended and they were too expensive compared to other water sources. Here in California, Santa Barbara built a desalination plant in 1991 to combat drought. After only four months that plant was closed, here again the end of the drought brought cheaper alternatives. But desalination may be taking root in California: Carlsbad will see a new plant open by 2016, Santa Barbara is considering re-opening its plant, and other areas are toying with the idea of bringing in the full scale technology.

The purpose of this panel discussion is to explore the potential role of desalination in Southern California’s water portfolio. Can desalination plants be engineered to address environmental and fishing industry concerns? Can costs be brought down? How dependent is the viability of desalination on energy costs? What will happen to desalination plants when the drought wanes?

As you have learned by now, managing water resources is complex and requires knowledge from multiple disciplines. Where do you stand on desalination?

### Key Terms:

**Desalination** – the process of creating fresh, drinking water from saltwater.

**Millennium drought** – the 2000s drought in Australia, the worst recorded since settlement, which began in 1995 and continued Australia wide until late 2009.

**Portfolio** – a range of investments held by a person or organization.

# Recommended Readings for 2014 UPP Down Under

## Climate, Hydrology, Infrastructure, and Sustainability

*Professors Grant, AghaKouchak, and Sanders*

IPCC 2013, Climate Change 2013: The Physical Science Basis, SPM Report: http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf

IPCC 2014, Climate Change 2014: Mitigation of Climate Change, SPM Report: http://report.mitigation2014.org/spm/ipcc_wg3_ar5_summary-for-policymakers_approved.pdf

## Natural Treatment Systems: What Are They and How Do They Work?

*Professors: Levin, Ambrose, and Bowler*

Bratieres, K., et al. 2008. Nutrient and sediment removal by stormwater biofilters: A large-scale design optimisation study. Water Research. 42: 3930-3940.

Hatt, B.E., T.D. Fletcher, A. Deletic. 2009. Hydrologic and pollutant removal performance of stormwater biofiltration systems at the field scale. Journal of Hydrology. 365: 310-321.

Le Coustumer, S., Fletcher, T. D., Deletic, A., Barraud, S., & Poelsma, P. 2012. The influence of design parameters on clogging of stormwater biofilters: a large-scale column study. Water research. 46: 6743-6752.

Mehring, A. and L. Levin. Submitted. Can animals improve the efficiency of water sensitive urban design? Frontiers in Ecology and the Environment.

Moore, T. and W. Hunt, 2013. Predicting the carbon footprint of urban stormwater infrastructure. Ecological Engineering. 58: 44-51.

Read, J., T.D. Fletcher, T. Wevill, A. Deletic. 2009. Plant traits that enhance pollutant removal from stormwater in biofiltration systems. International journal of phytoremediation. 12: 34-53.

Walsh, et al., 2005. The urban stream syndrome: current knowledge and the search for a cure. J. N. Am. Benthol. 24: 706-723.

## Pollutant Removal in Natural Treatment Systems

*Professors: Jiang and Grant*

Jasper, J. T., et al. 2013. Unit Process Wetlands for Removal of Trace Organic Contaminants and Pathogens from Municipal Wastewater Effluents. Environmental Engineering Science. 30: 421-436.

Leverenz, H., G. Tchobanoglous and T. Asano. 2011. Direct potable reuse: a future imperative. Journal of Water Reuse and Desalination. 1: 2-10.

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Mohanty, S., A. Torkelson, H. Dodd, K. L. Nelson, A. B. Boehm. 2013. Engineering solutions to improve the removal of bacteria by bioinfiltration systems during intermittent flow of stormwater. Environmental Science & Technology. 47: 10791-10798.

Rodriguez-Lazaro, D. et al. 2012. Virus hazards from food, water and other contaminated Environments. FEMS Microbiol Rev. 36: 786–814.

Wintgens, T., F. Salehi, R. Hochstrat and T. Melin. 2008. Emerging contaminants and treatment options in water recycling for indirect potable use. Water Science and Technology. 57: 99-107.

## Cost-Benefit Analysis and Policies/Regulations to manage Natural Treatment Systems' Risks

*Professors Saphores and Feldman*

Bichai, F. and P.W.M.H. Smeets. 2013. Using QMRA-based regulation as a water quality management tool in the water security challenge: Experience from the Netherlands and Australia. Water Research. 47: 7315-7326.

Boston MAPC. 2003. *Low Impact Development: Do Your Local Codes Allow It?* http://www.mapc.org/regional_planning/LID/LID_codes.html

Braden, J.B. and A.W. Ando. 2012. "Economic Costs, Benefits, and Achievability of Low-Impact Development-Based Stormwater Regulations," *in Economic Incentives for Stormwater Control.*

California Department of Water Resources. 2013) *California Water Plan Update-public review draft.* Sacramento, CA. http://www.waterplan.water.ca.gov/cwpu2013/prd/index.cfm

Committee on Reducing Stormwater Discharge Contributions to Water Pollution, National Research Council. 2008. *Urban Stormwater Management in the United States*. Washington, DC: National Academies Press.

Dobbie, M.F. and R.R. Brown. 2013. A Framework for Understanding Risk Perception, Explored from the Perspective of the Water Practitioner. Risk Analysis. 34: 294-308.

Evans, BE and P. Iyer. 2012. Estimating the relative benefits of differing strategies for management of wastewater in Lower Egypt using quantifiable microbial risk analysis (QMRA). Research Report. The World Bank, Washington DC.

Hager, M.C. 2003. *Low-Impact Development: Lot-Level Approaches to Stormwater Management Are Gaining Ground*. Stormwater. http://www.lowimpactdevelopment.org/lid%20articles/stormwater_feb2003.pdf

Lim, KY and Jiang SC. 2013. Reevaluation of health risk standards for sustainable water practice through risk analysis of rooftop-harvested rainwater. Water Research. 47:7272-7286

Podolosky, L. 2012. *Barriers to Low Impact Development.* Prepared by the Local Government Commission for the Southern California Stormwater Monitoring Coalition, September, Sacramento, CA.

Sopranzetti, B. J., 2010. Hedonic Regression Analysis in Real Estate Markets: A Primer, in C.-F. Lee et al. (eds.), Handbook of Quantitative Finance and Risk Management, DOI 10.1007/978-0-387-77117-5_78, Springer Science+Business Media, LLC 2010.

United Nations Development Program. 2014 *Water Governance Facility (WGF)*. http://www.watergovernance.org/sa/node.asp?node=846

Whitehead, J.C. 1999. A Practitioner's Primer on Contingent Valuation. Published in the Handbook on Contingent Valuation, edited by Anna Alberini and James R. Kahn, 2006.