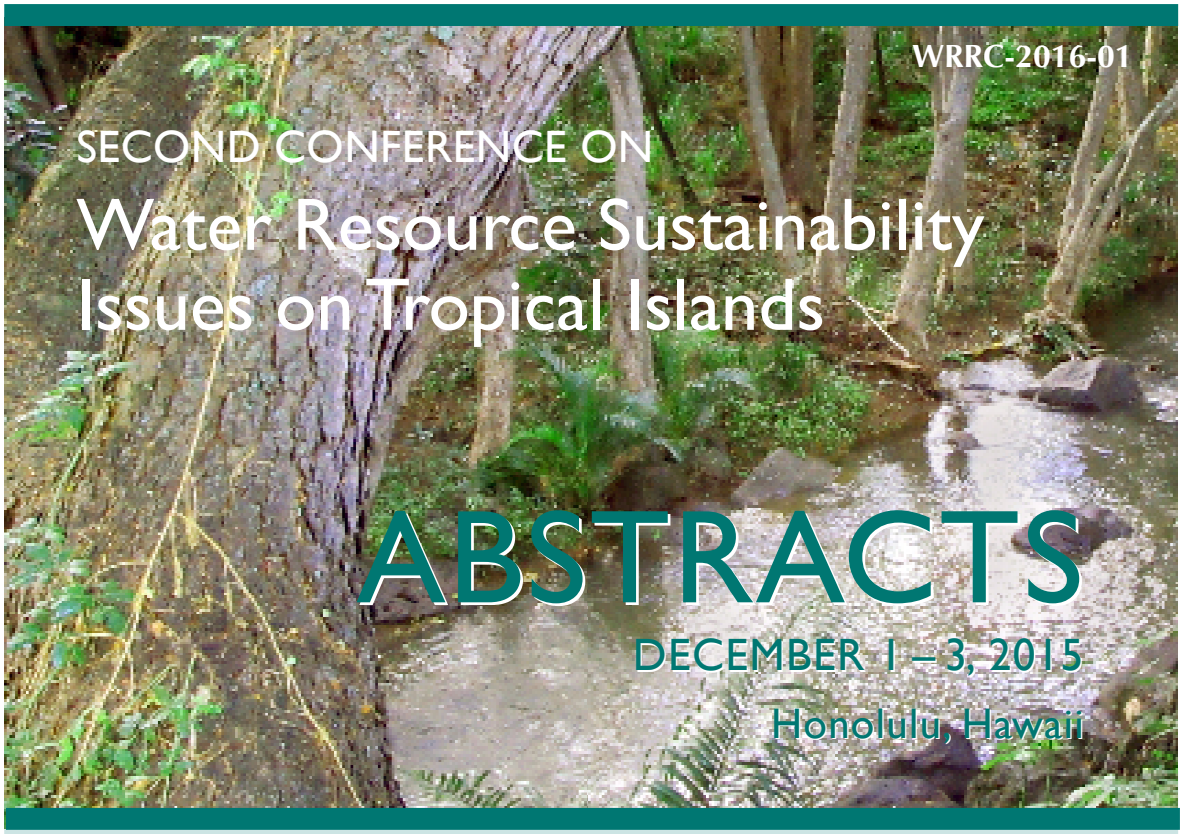

WRRC-2016-01

SECOND CONFERENCE ON

Water Resource Sustainability Issues on Tropical Islands

ABSTRACTS

DECEMBER 1 – 3, 2015

Honolulu, Hawaii

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WRRC-2016-01

The Second Conference on
Water Resource Sustainability Issues on Tropical Islands

ABSTRACTS

December 1–3, 2015
Hilton Hawaiian Village Hotel ■ Honolulu, Hawaii

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Preface

This document contains abstracts presented at the *Second Water Resource Sustainability Issues on Tropical Islands* conference held in Honolulu, Hawaii, December 1–3, 2015. This conference was sponsored by the four water resources research institutes in the Islands Region of the United States (Guam, Hawaii, Puerto Rico, and The Virgin Islands), which are part of the Geological Survey's National Institutes for Water Resources Program. The Hawaii WRRC is also representing American Samoa. The conference is a follow-up to a conference held by the institutes in November 2011 to provide a platform for discussion between water resources researchers and others on existing water resources issues facing tropical islands and those issues that are likely to develop in the future, particularly due to the anticipated changes in climate.

Island states are faced with a unique set of environmental and cultural issues pertinent to the management of water resources. Fresh water resources are under threat on many islands from both overuse and contamination. Ocean waters in these tropical regions are ecologically sensitive and valuable, and similarly threatened by pollution. On some islands, sea level rise is degrading groundwater resources. Specific problems are related to the following.

- Island states are heavily dependent on importing essentials, such as food, fuel, and manufactured goods to satisfy their resource needs. On most of these islands, population growth is placing increasing pressure on water resources. It is imperative that these threats to the welfare of island communities be addressed by sound scientific research before they reach crisis proportions. Sustainable management and protection of island water supplies is even more critical than it is on the continents, as island communities have no resources to import in the event of failure of their water supplies. Officials dealing with resource protection and management need access to scientifically sound research that is specific to island environments.

- The projected growth in population on tropical islands will add further stress to these islands in regard to water supply, wastewater disposal, management of solid wastes, and meeting energy needs. Reliable supplies of high quality water are essential to sustain development and quality of life in any community, but tropical islands face unique challenges to maintaining sustainable water resources. Another concern is that land clearance and obsolete land use practices continue to induce erosion in watersheds, which impacts coral reefs in near shore environments.

- Drought associated with El Niño creates significant stresses on all islands in the western Pacific, particularly “low” atoll islands. During drought conditions, there is little recharge to the groundwater, so the thin freshwater lens can become contaminated with saltwater. Atolls are also vulnerable to wash over events, especially during times of heightened sea levels and storm passages. Flooding of the island by seawater can displace many or all of the residents and ruin crops and infrastructure, but may also leave the shallow aquifers contaminated with salt water even after residents could otherwise return and resume normal activity.

The above issues are universal to island states yet researchers in these far flung and isolated places seldom have the opportunity to share knowledge and experience with one another. They work largely in isolation. The great distances that separate most island states from larger centers of academia and government means that there is less frequent exchange between researchers on the islands and their colleagues in the major population centers. Enhanced communication and collaboration between island researchers can provide a vital, synergistic link, which will strengthen all the researchers programs. It is a truism that the greatest scientific advances usually result from the collaboration of groups of researchers working together. A common platform is always needed to discuss these pressing issues and potential solutions. The objective of this conference is to present the state of research and its applications concerning water resources of tropical islands and aim at providing a platform to address water sustainability challenges therein.

The Conference Technical Advisory Committee
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Acknowledgments

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ABBREVIATIONS

EPA	Environmental Protection Agency
DLNR	Department of Land and Natural Resources
DOD	Department of Defense
PIWSC	Pacific Islands Water Science Center
SOEST	School of Ocean and Earth Science and Technology
UHM	University of Hawaii at Manoa
USGS	United States Geological Survey
WERI	Water and Environmental Research Institute of the Western Pacific
WRRC	Water Resources Research Center

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ORAL PRESENTATION (Day 1, Session C)—*Continued*

ORAL PRESENTATION (Day 2)—*Continued*

ORAL PRESENTATION (Day 3, Session M)—*Continued*

POSTER PRESENTATION (Session P-1)—*Continued*

SESSION P-2: Water Quality

POSTER PRESENTATION (Session P-2)—*Continued*

Featured

PRESENTATION

DAY 2: DECEMBER 2, 2015

DAY 3: DECEMBER 2, 2015

The Push for Distribution of Chamorro Land Trust Properties and Its Implication

Senator Thomas C. Ada

33rd Guam Legislature, 155 Hesler St., Hagatna, Guam, USA; tom@senatorada.org

The Chamorro Land Trust (CLT) Program has a backlog of about 8,000 applications that were submitted beginning in 1995. There is a renewed push to accelerate the distribution of land. Most of the properties available for residential and agricultural use are located in the northern part of Guam, over the aquifer. Can technical rationality to protect the aquifer prevail over political rationality to gain votes? And if it cannot, how can we mitigate the impact.

Keywords
Policy analysis, planning, groundwater protection

Measuring Progress: Water Security and the Aloha+ Challenge

Josh Stanbro[1] and Celeste Connors[2]

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John E. Jones said, "What gets measured gets done." The *Aloha+ Challenge* is a statewide commitment to achieve six sustainability targets by 2030 in the areas of clean energy, local food production, natural resource management, solid waste reduction, smart growth and climate resilience, and green jobs and education. The Aloha+ Measures Project helps to facilitate this by measuring and sharing data on key indictors. Aloha+ receives the highest level of support from state leadership including support from the Governor, four mayors and Office of Hawaiian Affairs, allowing the measures initiative to move forward successfully during changes in leadership, and continually build momentum.

Within the natural resource management target there are five subtargets, including freshwater security. Guided by the measures process, teams of experts and leaders are currently working together to determine indicators and metrics to track progress on freshwater security. Results will be shared in my presentation. Broad participation determines how existing data, messaging, and other data coordination efforts such as the Freshwater Blueprint, Promise o Pae Aina, and Hawaii Conservation Alliance, Effective Conservation Project can be leveraged and integrated into Aloha+. The measures process strategically establishes a framework for a statewide sustainability network and helps to strengthen county-based action networks, which are key to implementation.

Upon completion of the measures process, indicators and data are displayed on the ***Aloha+ Challenge*** Dashboard, an online platform designed for decision makers and the public to track progress on achieving the *Aloha+ Challenge* 2030 targets. The Dashboard currently features indicators at the state and county levels for clean energy and solid waste reduction. Natural resource management targets will be showcased on the Dashboard in 2016, in time for the World Conservation Conference. Presenters will provide an update on the Freshwater metrics selected for the Dashboard and the next steps.

Keywords
Aloha+ Challenge, water security, water metrics

Oral

PRESENTATION

DAY 1: December 1, 2015

SESSION A
Sustainability Groundwater and Watershed Studies, Part 1
Session Chair: Henry Smith

SESSION B
Water Resources Exploration
Session Chair: Darren Lerner

SESSION C
Protection Strategies for Island Watersheds and Aquifers
Session Chair: Jorge Rivera-Santos

SESSION D
Water Quality: Application of Technology and Adaptive Management
Session Chair: Roger Fujioka

Exploring Best-Practice Capacities of the Northern Guam Lens Aquifer

Nathan C. Habana[1], **John W. Jenson**[1], and Stephen B. Gingerich[2]

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The Northern Guam Lens Aquifer (NGLA) provides 80% of Guam's drinking water. Recent modeling results provided insights into how the existing water-production system might respond to new development and natural changes in recharge, but local policy makers and water managers have also asked "What is the *ultimate* volume of water that *could* be sustainably withdrawn from the aquifer if we had the best possible production system?" Answering this question requires, first, specifying a *best-practice production system*—which we define as one that is constructed and operated to deliver maximum production attainable for a given quality standard, constrained by the available technology and capital. Second, it requires reliable knowledge of the *natural limits* imposed by recharge and aquifer properties.

We present preliminary results from an ongoing modeling study directed at estimating total production rates that could be achieved by a system of about 100 wells (the same number as in the present system) but in which well depths, locations, and pumping rates are chosen to maximize production for the given upper limits of salinity. Natural limits are imposed by specifying the same recharge and aquifer properties employed in the recent successful modeling study of the existing system.

Although an ideal production system as defined above is not feasible in practice, an estimate of the total production that could be obtained by such a system, for specified salinities, provides helpful insights for long-term planning and future decisions regarding sustainable management of the NGLA.

Keywords

Guam, numerical modeling, groundwater management, groundwater sustainability

Unraveling the Role of Deep Groundwater Circulation on the Coastal Freshwater-Lens System of Kona, Hawai'i Island

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Groundwater in the coastal freshwater-lens system of the Kona area on the western side of Hawai'i Island is important for nearshore ecological systems and cultural practices. Groundwater-fed brackish-water ponds and anchialine pools provide habitat for threatened or endangered native species, and are noteworthy cultural features historically used by Native Hawaiians. The quality of the brackish groundwater in the freshwater-lens system is affected by (1) recharge from rainfall on land overlying the lens, (2) freshwater inflow from adjacent groundwater bodies (as evidenced by the isotopic composition of the water), (3) circulation of cold saltwater derived from the ocean, and (4) human activities, including groundwater withdrawals and water disposal. Understanding how these factors affect groundwater flow is critical for developing effective management strategies for this important groundwater resource.

Numerical groundwater models capable of representing density-dependent flow, salinity, and heat transport were constructed to test selected conceptual models and improve understanding of the role of deep groundwater circulation in the Kona freshwater-lens system. Modeling results indicate that the presence of a dipping confining unit near a depth of about 300–400 m below mean sea level can help explain (1) the presence of a deep zone of freshwater separated from the overlying brackish water by a zone of saltwater, and (2) temperature-profile anomalies observed in a deep borehole.

Results of this study indicate that deep groundwater circulation is an important control on brackish water in the coastal freshwater-lens system of the Kona area. Human activities that alter the deep circulation pattern could potentially affect the groundwater system and the ecological and cultural resources in the area.

Keywords
Groundwater, modeling, conceptual model, Hawai'i

Determining Groundwater Sustainability—A Public-Trust Resource Perspective

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Sustainable practices maintain the ecological integrity and cultural authenticity of water-related public-trust resources for the use and enjoyment of current and future generations. This management strategy must extend to regional scales and beyond short-term time horizons to preserve groundwater levels and groundwater-fed springs, streams, pools, lakes, wetlands, and estuaries. One challenge is overcoming the idea that sustainable groundwater development depends solely upon the recharge to the groundwater system. This persistent misconception has important consequences for water-resource sustainability. For example, the method used by the State of Hawai‘i to determine the “sustainable yield” of the Keauhou Aquifer System Area is a function of recharge. Nevertheless, saltwater intrusion into public water supply wells has occurred at withdrawal rates well below the sustainable yield. This focus on recharge also does not explicitly consider the effects of withdrawals on groundwater-dependent habitat for culturally important and endangered species in the Keauhou Aquifer.

Hydrogeologists develop groundwater-flow models to study the response of groundwater systems and to predict future behavior. Models evolve over time as new data are acquired, but the underlying theories describing groundwater flow remain valid. Analytical and numerical model results were compared to evaluate whether planned groundwater development is sustainable. The models clarify that the response of groundwater systems depends upon aquifer properties and the location and magnitude of withdrawals relative to aquifer boundaries. These factors determine how much groundwater discharge can be captured by a well without causing saltwater intrusion or habitat loss.

From a public-trust perspective, sustainable groundwater development must consider factors other than just recharge and the protection of production wells. The magnitude of sustainable development should be guided by estimates of capture. Numerical groundwater models can readily estimate the effects of withdrawals on capture in the form of decreased groundwater discharge to surface-water bodies and the ocean.

Keywords
Groundwater models, recharge, capture, sustainable yield

Next-Generation Geophysical Characterization of Watersheds

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Watershed systems are essential for providing water resources and cycling biologically critical elements, yet the capabilities to quantify and predict the functioning of these systems are lacking. This limitation stems partially from the difficulty in quantifying critical interactions and feedbacks that occur across a range of scales and watershed compartments, including vegetated land surface, soils, vadose zone, groundwater, hyporheic zone, and surface waters.

We describe several new geophysical approaches developed to improve the understanding of hydrological fluxes and hydrology driven biogeochemistry across scales and compartments in watershed systems. Although the approaches are tested in different types of watershed systems (including Mediterranean, semi-arid, and Arctic climates), the approaches have applicability to a broad range of watersheds. The first approach is a networked sensing system that coincidently measures vegetation, land surface inundation, and subsurface soil moisture. The approach takes advantage of autonomous data acquisition approaches using platforms such as unmanned aerial vehicles, tram-based sensors, and electrical resistivity tomography. The dense datasets enable 'visualization' of interactions that occur across watershed compartments in response to dynamic seasonal temperature changes and runoff processes. The second advance is the development of the hydrogeophysical inversion schemes that take advantage of spatially extensive geophysical data as well as direct but sparse measurements in the quantitative monitoring of terrestrial processes, including infiltration into the vadose zone and seasonal riverbed clogging. The third is the development of stochastic 'zonation' approaches, which uses multi-type, multi-scale datasets to identify regions within watersheds that have unique distributions of properties that influence watershed biogeochemical cycling.

Together, the new sensing, modeling, and integrative functional zonation approaches hold value for documenting how both press and pulse hydrological perturbations drive biogeochemical transformations—from local scales where native processes occur, to watershed scales where resources are managed.

Keywords
Hydrogeophysics, geophysical methods, watersheds, parameter estimation, biogeochemical cycles, scaling

Recent Findings of the Humu'ula Groundwater Research Project and Implications for Groundwater Modeling

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The Humu'ula Groundwater Hydrology project was undertaken to determine whether a viable groundwater resource was present in the central saddle region of Hawaii Island. Although identification of a drinking water source was the primary objective, the project allowed us to conduct a broader study of the hydrology of the region as well as the subsurface structures that produced the hydrological conditions encountered. The effort included both Magnetotelluric (MT) surveys over the region, to identify favorable drilling targets, as well as the use of core drilling technology that recovered a complete stratigraphic record.

The MT surveys yielded resistivity data suggesting the presence of saturated formations at elevations of more than 1 km above sea level. Subsequent drilling of two test holes encountered a sequence of unexpected findings. The first hole, near the Saddle's center at 1940 m amsl, encountered a 130 m thick perched aquifer more than 1700 m amsl, a regional aquifer standing at 1400 m amsl, and a deep temperature gradient of ~165 °C/km. Recovery of (quite thin) clay-rich ash beds account for the perched aquifer encountered, whereas evidence of intense diking in the region (where a rift zone had not previously been postulated) accounts for what appears to be a high-level dike impounded regional aquifer. The second borehole, at the western edge of the Saddle, recovered nominally similar geologic formations, but instead of perched aquifers, encountered a sequence of confined aquifers with pressures sufficient (at depth) to lift water more than 1000 m in the borehole from the point of entry.

Our findings suggest that the internal structure of Hawaii's volcanic islands is far more complex than current conceptual models account for, and that accurate assessment and modeling of our groundwater resources requires much more detailed subsurface information than has traditionally been collected.

Keywords
Volcano, structure, modeling, capacity, reserves

Island Sust**ʻāina**bility: Rooftop Rainwater Harvesting Study for Moku-o-Loʻe, Oʻahu, Hawaiian Islands

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Island Sust-**ʻāina-**bility is a conscious movement within the Hawaiian Islands to find human, environmental, and cultural harmony. There are many islets off the coast of Oʻahu; however, only three of them are inhabitable. Moku-o-Loʻe is the proper Hawaiian name for a 28-acre island off the coast of Kāneʻohe Bay, Oʻahu that houses the premier research center Hawaiʻi Institute of Marine Biology. The institute envisions Moku-o-Loʻe, also known as Coconut Island, to be an independent islet and model of sust**ʻāina**bility in water, waste, and energy nexus.

A rooftop rainwater harvesting study and engineering feasibility study pertaining to potable and non-potable uses will be presented. An initial site visit found 26 buildings as potential sites for rainwater harvesting. Roof catchment areas of available roof space and roofing materials were evaluated to make schematic designs for rooftop rainwater harvesting. This information, combined with available historical islet rainfall data, water fixtures study and water supply/demand evaluations, were used to estimate potential available rainwater captures, tank size and treatment needs.

Recommendations and cost/benefit analysis will be presented on best available sustainable island engineering and management practices in rooftop rainwater harvesting and catchment systems to meet the Institute's indigenous water needs. Moku-o-Loʻe hopes to serve as a model to mainland Oʻahu in water sust**ʻāina**bility, water resources independence, and water security.

Keywords

Rooftop rainwater harvesting, engineering feasibility study, water security

Understanding the Fate of Chemicals in Tropical Environments: Site to Regional Scales

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Contamination of ground water from pesticides, volatile organics, and more recently with pharmaceuticals and personal care products is becoming a serious concern to the public and regulatory agencies. In tropical island settings, where ground water serves as the primary source of drinking water, contamination from these chemicals poses a serious threat to public drinking water supplies. The mobility of these chemicals in unsaturated soils or vadose zone depends on soil properties, sorption and degradation potential of these compounds, as well as the property of the solution in which these chemicals are present.

Extensive laboratory experiments on disturbed and undisturbed soil cores for a number of tropical soils are presented for chemical breakthrough as well as understanding their degradation in the soil. Impact of soil type, salt content, and the amount of dissolved organic carbon in the water are evaluated for their role in chemical transport. Validity of anions such as bromide as tracers in variable-charge tropical soils was also examined. Field plot experiments were conduct to evaluate the leachability of several pesticides at five sites on three islands of Hawaii.

Additionally, a regional scale leaching tool is presented that provides the relative leachability of various chemicals in the Hawaiian Islands while accounting for the soil and pesticide properties and annualized recharge in a GIS framework. Chemicals tested in this Tier-I leaching tool include pesticides, volatile organic compounds, and pharmaceutical compounds. Soil property information from digital soil maps (SSURGO data base of US Department of Agriculture) along with the sorption, degradation, and volatilization data for these compounds were used in the leaching assessment. The mean and standard deviation values were considered for appropriate uncertainty analysis. The finalized map is a visual representation of the likelihood (likely, unlikely, or uncertain) of a chemical to appear in ground water. This information is currently used by the State of Hawaii for registration decisions on new chemicals or to develop monitoring waiver plans for drinking water wells.

Keywords

Chemical transport, tropical soils, pesticides, volatile organics, pharmaceutical, Tier-I leaching model

Watershed Management: Ugum, Piti-Asan, Geus Watersheds

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Erosion and associated sedimentation poses one of the primary threats to Guam's terrestrial and aquatic environment. The Coastal Zone Act Reauthorization Amendment of 1990 requires the development of a multi-year watershed restoration strategy. This includes watershed assessment and identification of opportunities to reduce nonpoint-source pollution. In response, WERI completed watershed assessments for three major southern Guam watersheds: Ugum, Piti-Asan, and Geus. These three watersheds have heightened interest by the local/Federal government.

The Ugum watershed serves as a major source of Guam's domestic water supply. The water treatment plant has been frequently shut down during major rain storms due to high turbidity. Using low-elevation aerial photos and site visitation, likely locations of nonpoint-source pollution were identified. Attention was focused on steep river sections and areas of identifiable bank erosion, land slumping and off-road vehicle activity. The Piti-Asan watershed contains several conservation areas and two large proposed developments. The baseline hydrological conditions were established for this watershed. The Geus watershed is ranked as a "pristine watershed." Its baseline hydrological conditions were determined through field observations and hydrological data collection for one year. For all three watersheds, the geographic information system erosion model was used to assess the impact of human activities and to make estimates of erosion within the watersheds.

The Guam Clean Water Action Plan divides Guam's 19 watersheds into four categories based on their highest priority for assessments. The criteria for category assignment are based on public health impairment, drinking water, coastal resources, endangered species, and degradation of biodiversity. Assessment of the hydrological conditions of the three high-priority watersheds (Ugum, Piti-Asan, and Geus) is now complete. The findings are covered in this talk. Funding was provided to WERI by the National Oceanic and Atmospheric Administration (NOAA) through the Guam Coastal Management Program, Bureau of Statistics and Planning.

Keywords

Watersheds, modeling, management, erosion, sedimentation, hydrology

Assessing Groundwater Availability in Hawai'i's Diverse Hydrogeologic Settings

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Any amount of groundwater withdrawal has consequences. Assessing how much groundwater is available for human use ultimately hinges on what consequences a community is willing to accept.

In Hawai'i, even within an island, groundwater can exist in diverse settings, such as (1) fresh groundwater lenses overlying saltwater in high-permeability lava-flow aquifers with or without caprock, (2) dike-impounded groundwater, (3) groundwater in thickly saturated low-permeability aquifers, and (4) groundwater in perched aquifers. The consequences limiting groundwater availability differ substantially among these settings—in some areas of Hawai'i, availability will be limited primarily by saltwater intrusion, whereas in other areas it is more likely to be limited by streamflow depletion, reduction of discharge to nearshore environments, or reduction in subsurface flow to adjacent aquifers. In some enigmatic or recently discovered groundwater settings, consequences of development are not completely known, and groundwater availability is difficult to assess.

Identifying a given area's hydrogeologic setting, connecting it with the appropriate set of consequences, and deciding whether the consequences are acceptable, are prerequisites to assessing groundwater availability in Hawai'i.

Keywords

Groundwater availability, groundwater management, groundwater conceptual models, Hawai'i

In Situ Monitoring of Watershed Following 'Revegetation' Efforts for Reducing Sedimentation and Improving Water Quality in the Micronesian Island of Rota, CNMI

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The Talakhaya watershed in Rota is identified as a Coral Reef Management Priority site for the Commonwealth of the Northern Mariana Islands (CNMI). In 2010, federal and jurisdictional partners came together to develop a Conservation Action Plan (CAP) for the Talakhaya watershed. The CAP highlights the need for continued revegetation of eroding areas, as well as assessing rate of soil loss in the watershed.

However, the revegetation efforts in the watershed did not have monitoring system in place to quantify the effects they were having in terms of reduced sedimentation. This 'Talakhaya Watershed Soil Loss Assessment Project' assisted in evaluating the revegetation objectives of 'Reducing the Soil Loss' of the Talakhaya CAP. The project objective was to quantify the reduction in sediment by determining the hydrology and by measuring the hydrological parameters following the installation of equipment such as water meters, barometric level loggers, turbidity meters, and rain gauges. The water flow as well as the turbidity level of each stream leading to the ocean from the Talakhaya watershed was therefore measured and sedimentation level was assessed accordingly. The stream monitoring was compared in areas where no mitigation techniques were applied with areas where the Vetiver grass as well as other vegetation were planted as means of controlling erosion. The comparison was also made with other areas where tree plantation was being practiced as a mean of reducing sedimentation load into the ocean shorelines.

The preliminary results of the first years of monitoring are being reported here for evaluating the effectiveness of the aforementioned mitigation techniques so far.

Keywords
Watershed management, Vetiver grass system, coral, Badlands, Micronesia, Rota

Kaelepulu: An Investigation of Flow Restoration, Mixing and Exchange in an Urbanized Estuary to Help Define Restoration Alternatives

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Construction of a flood control levee and alternative drainage for Kawainui Marsh in 1966 effectively protected the town of Kailua from flood threat but deprived the Kawainui Stream and the connected Kaelepulu Pond system 9 cfs of flow. Meanwhile, the Kaelepulu Pond area was undergoing major urbanization. Decreased flow out of the stream mouth resulted in increased periods when the stream mouth was blocked by beach sand accretion. During summer (low precipitation), evaporation would often result in the pond surface falling below mean sea level. During winter, the sand berm at the stream mouth would often build up above flood levels, requiring "emergency" openings during intense rain events. Over decades, a decrease in oyster population, increase in macro algae, growth of invasive mangrove, and inflow of pollutants from construction and urban runoff, resulted in poor water quality and increased incidence of odors.

Oceanit conducted bathymetric and physical water transects to understand the physical limitations of the exchange and mixing processes and to develop restoration alternatives. Four primary controlling factors were determined: 1) decreased water supply from the Kawainui Marsh due to the levee, 2) efficacy of stream mouth opening events, 3) the presence of non-native mangrove, and 4) the presence of a sill, limiting flow of salt-water to the upper estuary. A test of partial flow restoration (2 cfs) was conducted by siphoning water over the levee from Kawainui Marsh to Kawainui Stream. Physical water quality and water surface elevations were monitored in the estuary.

Increased exchange and improved water quality resulted directly from the restored flow of fresh water and indirectly from the improved flow through the stream mouth, the latter induced by the higher stream head. An engineering design is proposed for a permanent water flow restoration structure including a water level control to prevent the system from overfilling.

Keywords

Watersheds, restoration, levee, wetlands, marsh, urban runoff, water quality, tidal circulation, Kawainui Marsh

Restoring Ecological Integrity in Hawaiian "Mountain-to-Sea" Environments

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Humans' unsustainable use of natural resources and degradative impacts on ecosystems have created serious environmental challenges for watershed landscapes globally. The core problem is the inability of decision-makers to understand, value, measure and to establish conservation regulations to protect the "ecological integrity" within the watersheds they exploit. Natural ecological systems maintain vigor, organization, and resilience created by the evolutionary and biogeographical processes of a particular place; however, these features erode rapidly as human impacts on watersheds escalate. Hawaiian "mountain-to-sea integrated natural resource management systems" (*ahupua'a*), because of their compact size, biophysical uniqueness, and insular nature, are particularly vulnerable to human-induced disturbance as evidenced by the extensive landscape degradation imposed by over a century of large-scale monoculture agriculture, stream diversion/dewatering, and urban development.

For the past two decades, we have logged hundreds of fieldwork hours in Hawaiian stream environments evaluating their health in natural and degraded watersheds using the Hawaii Stream Index of Biological Integrity (HS-IBI). These data were used to calibrate Watershed Health and Reef Health indexes able to evaluate *ahupua'a*-scale human impact on linked Hawaiian watersheds and adjacent reefs. The results facilitate an understanding of the interaction between ecological processes, spatial patterns, and human activity that can then be applied to improve the regional-scale conservation and sustainable natural resource management in Hawaii.

Based upon this assessment of watershed and linked stream-reef health, we provide ten management and/or decision-making recommendations to improve the long-term ecological health of Hawaiian *ahupua'a* and their stream ecosystems. Recommendations range from updating policies for protecting biophysical stream conditions by maintaining at least 50% of base flows, reducing urban stormwater discharge levels, amending stream habitat definitions, establishing watershed governance by "*ahupua'a* councils," and conducting a comprehensive assessment of the status/biophysical impacts of stream diversions statewide.

Keywords

Sustainable watershed management, stream ecological integrity, *ahupua'a* councils

Community Management of Water Resources and Delivery

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The Marianas Islands are blessed with bountiful rainfall. Fortunately, the climate change evaluations indicate that these islands are at a seesaw fulcrum location for El Niño/La Niña oscillations, and climate change effects will remain minimal for the predictable future. The critical issues then remain with management of the resource.

Attempts to evaluate the extent and accessibility of aquifer have been going on for a long time. The fact that anthropomorphic use of the aquifer can disturb/destroy it are well documented (especially on Saipan) where the growth of sugar resulted in the thinning of the water lens to the point that even agriculture became infeasible due to upwelling of the underlying sea water. The recovery of an overused aquifer is a long, very slow process.

Because of the movement of military personnel into Guam, a management coalition of WERI, DOD, USGS, GWA, land owners and private well owners was formed and is active. In addition, the idea that a single water system on Guam would be more robust and reliable than the present state where GWA has a system and DOD has a system, each of which often operates in duplication of the coverage area. This has led to a working group looking at how to link the two systems together where shared resources can eliminate problems like one system pumping water north while the other system pumps water south along the same easement. This kind of mutual assistance "adaptive management" looks to be an opportunity not only of economy, but one that directly impacts the sustainability of the aquifer.

Keywords

Resource, aquifer, anthropomorphic, management, climate change

Studies of Enhancement of Sewage Treatment and Composting of Sludge on Yap Island

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On the island of Yap in the Federated States of Micronesia, the centralized sewage treatment plant is designed to provide only primary treatment. Though the plant is functioning well in accordance with its design, the treatment level is clearly inadequate, resulting in the discharge of nearly raw sewage to the ocean. Furthermore, waste sludge from the plant is being used for crop production by the local population, which constitutes a potentially hazardous situation.

A pilot test was started to investigate the use of an attached-growth medium in the existing treatment unit to serve as a biocarrier, which would allow for the retention of the beneficial biomass to enhance treatment efficiency. The pilot testing unit is in place and functioning properly; however, because of extremely erratic levels of organics in the influent due to dilution from storm-water intrusion, data suitable for making statistically significant inferences are yet lacking. Thus, data collection for the current project has been extended for another year. In addition, testing for nitrogenous compounds has been initiated, which would yield additional valuable information about system performance. Furthermore, addition of a composting pilot test has been implemented to assess the adequacy of this natural technology for treating the excess sludge generated at the plant.

The results of these pilot tests would allow for making designed-based estimates for upgrading the plant and related sludge handling/ treatment practices to acceptable levels. The benefits of this plan would lead to improvements in the quality of the seawater in the shallow bay where the plant discharges. In addition, production of a composted sludge would allow for reuse of the nutrients and organic matter in a form that would be safe for use as a fertilizer or soil conditioner, thus enhancing the environmental sustainability of the island and reducing risks to public health.

Keywords
Wastewater, treatment, sludge, composting, reuse, public health, sustainability

Adapting Bioretention (Rain Garden) Designs to Maximize Nutrient and Sediment Pollution Removal from Stormwater

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Stormwater pollution is a leading cause of impairment of water resources and a contributing factor to flooding. Green stormwater infrastructure (GSI) is an alternative approach to stormwater management, yet the mechanisms driving pollutant removal are not well understood. The total mass of N and P pollutants in various forms of speciation in stormwater across a gradient of precipitation depths is not well quantified, yet is essential for bioretention performance assessment (% removal) on a mass basis. Pollutant removal performance of the bioretention design parameters and the robustness of these designs to changes in the climate have not been assessed.

The objective of this research was to develop a repeatable monitoring system and to investigate the internal physical, biological and chemical pollutant removal mechanisms of bioretention (on a mass basis) under a series of soil media, vegetation and simulated climate change treatments. Results indicate that the traditional definition of first flush (0.5 inch rainfall depth will remove 90% of pollution) was not found to be reliable for mass loads. The traditional bioretention design, which often includes compost, was found to export soluble forms of N and P. Soil media designs, which specifically focused on chemical sorption, were the only designs capable of removing soluble P (>70%). Larger pollutant constituents (IP, TKN, and TSS) were consistently removed in all treatments. Peak flow and volume reductions were also consistently high.

This research reiterates the importance of field based monitoring of bioretention and the need to focus on the removal mechanisms of both soluble and insoluble nutrient components through adsorption, physical filtration, and uptake by plants. Stormwater treatment targets may need to reflect the actual pollutant mass removed from the paved road surface by various precipitation depths.

Keywords
Stormwater, first flush, water quality, nutrients, bioretention, rain garden

Oral PRESENTATION

DAY 2: December 2, 2015

SESSION E
Water Quality: Surface Water
Session Chair: Roger Fujioka

SESSION F
Water Quality: Outreach and Education
Session Chair: Roger Fujioka

SESSION G
Climate Change and Variability and Impacts on Water Resources, Part 1
Session Chair: Stephen Anthony

DAY 2—*Continued*

SESSION H
Coastal Groundwater
Session Chair: Shahram Khosrowpanah

SESSION I
Water Quality: Groundwater and Surface Water
Session Chair: Roger Fujioka

SESSION J
Sustainability Groundwater and Watershed Studies, Part 2
Session Chair: Henry Smith

From Rain Tanks to Catchments: Use of Low-Impact Development to Address Hydrologic Symptoms of the Urban Stream Syndrome

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Catchment urbanization perturbs the water and sediment budgets of streams, degrades stream health and function, and causes a constellation of flow, water quality and ecological symptoms collectively known as the urban stream syndrome. Low-impact development (LID) technologies address the hydrologic symptoms of the urban stream syndrome by mimicking natural flow paths and restoring a natural water balance. The objective of this study is to use an environmental flow management approach to identify the optimal mix of LID technologies needed to maintain stream hydrology in a pre-urban state.

Over annual time scales, the volume of storm water that should be infiltrated and harvested can be estimated from a catchment-scale water-balance given local climate conditions and pre-urban land cover. For all but the wettest regions of the world, the water balance predicts a much larger volume of storm-water runoff should be harvested than infiltrated to maintain stream hydrology in a pre-urban state.

Efforts to prevent or reverse hydrologic symptoms of the urban stream syndrome will require (1) selecting the right mix of LID technologies that provide regionally tailored ratios of storm water harvesting and infiltration; (2) integrating these LID technologies into next-generation drainage systems; (3) maximizing potential co-benefits including water supply augmentation, flood protection, improved water quality, and urban amenities; and (4) long-term hydrologic monitoring to evaluate the efficacy of LID interventions.

Keywords
Urban stream syndrome, low impact development, water security, ecosystem

Micro- and Nanosized Titanium Dioxide Particles Immobilized in Sintered Recycled Glass for the Degradation of Trihalomethane Precursors from Surface Waters

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Trihalomethanes (THM) are a group of chemicals that forms when chlorine reacts with the natural organic matter in raw waters. THM are of concern because they are potential carcinogens and many water systems are facing non-compliance problems. One strategy to address this is by removing their precursors (natural organic matter) before chlorine is added. This research intends to evaluate a low cost alternative made of sintered recycled glass embedded with titanium dioxide (TiO_2) nanoparticles for the degradation of organic matter in raw waters under the influence of UV light. The goal is to develop a porous filter-like composite made out of glass to support TiO_2 nanoparticles.

A performance map was developed for the glass composite to specify the percolation rate as a function of sintering temperature and time. The highest percolation rate attained was 16.05 gpm/ft^2 for a temperature of 975 °C for 45 minutes. X-ray diffraction analyses confirmed that TiO_2 polymorph structure of anatase still remains after the sintering temperatures (anatase phase has the best photocatalytic performance). TiO_2 particles have been immobilized by sintering them along with the glass powder. Although good adhesion is observed, alternatives methods of deposition should be evaluated. Using the glass/TiO_2 composite to degrade humic acid (major component of natural organic matter) showed less than 5% reduction, suggesting that TiO_2 particles within the composite, making the UV light hard to penetrate and photoactivate them. For instance, no humic acid levels are detected when treated in a TiO_2 suspension.

Percolation rates equal to or higher than those in a rapid sand filter can be achieved within the sintered glass composite. This technology could be a feasible oxidation alternative to destroy THM precursors in water as long as the TiO_2 deposition method is optimized in such a way the UV light can easily reach them.

Keywords
Trihalomethanes, photocatalytic degradation, titanium dioxide, recycled glass, filtration

The Water-Energy-Food Nexus for Small Islands: Challenges and Opportunities

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The ability of small islands (SIs) to continue providing clean and affordable water, energy, and food in addition to maintaining adequate water resources for uncompromised quality of life is seriously challenged by several emerging issues (e.g., population growth, climate change, and change in living standards). Water, food, and energy resources will be adversely affected under most climate change scenarios developed by the Intergovernmental Panel on Climate Change. The intimate link between water, energy, food and quality of life is very obvious—we cannot separate one from the other. Water, energy, and food (WEF) are closely and reciprocally interconnected; energy and food production require large volumes of water, while water treatment and distribution is equally dependent upon readily available and low-cost energy.

Until recently, WEF issues have been separately addressed instead of adopting a WEF nexus approach. Water, energy and food security can be achieved through a nexus approach, a sustainable and holistic approach that integrates governance and management across these sectors and at different scales. It attempts to balance multiple development objectives by minimizing trade-offs and exploring opportunities for synergies in light of increasing demand for resources and other key drivers. A nexus approach minimizes trade-offs and builds synergies across all sectors.

Decision makers should develop appropriate strategies based on sound policies supported by adequate investments, to explore and exploit synergies, and to identify and mitigate trade-offs among the development goals related to WEF security. This presentation will review available information, identify knowledge and action gaps, share information on viable instruments and approaches, and suggest potential network ideas, and priorities for appropriate investment and actions by different stakeholders for moving toward action on the WEF Nexus for SIs environment.

Keywords
Water-food-energy nexus, sustainability, decision making

Increasing Access to Safe Drinking Water for Rural Hawai'i Island Communities Utilizing Rainwater Catchment

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Well-designed, installed, and maintained rainwater catchment systems can provide clean water for potable and non-potable uses in rural communities without municipal water service, as an emergency distributed water reserve during natural hazards and as a water source for irrigation, pets or livestock. However, poorly maintained or designed systems pose a potentially serious health risk, including the introduction of a water-borne illness. Approximately 60,000 people in the State of Hawai'i depend on rainwater catchment for their potable water needs, the majority of whom are in rural underserved communities on Hawai'i Island. We conducted an outreach project in 2015 to quantify practices of rainwater catchment system owners and users and increase access to safe drinking water in rural communities reliant on catchment.

Nine community workshops on Hawai'i Island were conducted on rainwater catchment best practices and measured participants knowledge, perceptions and behaviors through a voluntary survey. Among other findings, of 110 survey respondents, 87% (N=96) confirmed potable and/or bathing use of catchment water and of these 54% reported either never having tested their system water (N=41) or did not know if the water had been tested (N=11). Data were also collected on system components and understanding and use of water treatment practices. Post engagement, 68% of participants (N=75) *agreed* with the statement, "*I will change how I maintain my catchment system as a result of this workshop*."

The State of Hawai'i has no governmental oversight for ensuring the safety of rainwater catchment systems; it is the responsibility of system owners and end-users to maintain these water sources and use rainwater catchment systems in a safe and appropriate manner. Here, we demonstrate the efficacy of fact-based outreach in achieving behavior change and empowering stakeholders to make practical and informed decisions thereby increasing access to safe drinking water.

Keywords

Rainwater catchment, rat lungworm disease, outreach, Sea Grant, Hawaii

Sea Level Rise Impacts in Hawaii

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The State of Hawaii Interagency Climate Adaptation Committee is investigating community vulnerability to sea level rise. We have developed modeling to provide the committee with assessments of exposure to coastal erosion, wave run-up, and flooding based on the IPCC model of sea level rise over the 21st Century. We model the exposure to coastal erosion using a hybrid equilibrium profile model that integrates historical rates of shoreline change with a Bruun-type model of beach profile translation. Results are mapped in a GIS showing the 80 percentile probability of erosion at years 2030, 2050, 2075, and 2100. Wave run-up is modeled on a topo/bathy LiDAR DEM using data from the 2013 JBLTX survey of the Hawaiian islands. We use XBEACH (Delft Hydraulics) to estimate inundation at higher levels during the same time periods by a 3 m Hs wave to represent a seasonal high swell event. XBEACH is used in the 1D mode with settings for a permeable substrate. We develop a gridded product of depth and velocity for use in a vulnerability analysis. DEM scenarios of sea level flooding, the so-called “bath tub” method, provide estimates of storm drain flooding and groundwater inundation. Combined, these impacts of sea level rise are used with FEMA Hazus software to estimate exposure and loss of upland assets. My presentaton will review our findings as well as cover global knowledge of SLR as a result of climate change.

Keywords
Shorelines, modeling, sea level rise, climate change

Variability of Hawaiian Winter Rainfall During La Niña Events

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Rainfall in Hawaii during La Niña years have undergone abnormal variability since the early 1980s. Traditionally, Hawaii receives greater than normal precipitation during the La Niña wet seasons. Recently, La Niña years have experienced less than normal rainfall. A drying trend in Hawaiian precipitation during La Niña years is evident. A change-point analysis determined that the shift in precipitation occurred in 1983, forming two epochs in the study used for comparison. The first epoch runs from 1956 to 1982 and the second epoch from 1983 to 2010. Location specific changes in rainfall anomalies from epoch 1 to 2 throughout the Hawaiian Islands are examined, illustrating that the greatest difference in rainfall between epochs is found on the climatologically drier sides (i.e., south and west) of the Islands. Variations in tropical sea surface temperatures and circulation features in the northern Pacific Ocean have changed during La Niña wet seasons, thus changing La Niña year rainfall.

The strengthening, broadening, and westward shifting of the eastern North Pacific subtropical high, coupled with an eastward elongation and intensification of the subtropical jet stream, are two main influences when considering the lack of precipitation during the recent La Niña wet seasons. Moisture transport analysis shows that variations in circulation structures play a dominant role in the reduction of moisture flux convergence in the Hawaiian region during the second epoch. Additionally, a storm track analysis reveals that the changes found in the aforementioned circulation features are creating a less favorable environment for the development of Kona lows and midlatitude fronts in the vicinity of Hawaii.

Keywords
ENSO, La Niña, Hawaiian rainfall

Water, Climate, and Local Governance: Experience from the Pacific Islands

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Based on the hypothesis that climate information has the potential to improve the capacity to address disasters in climate sensitive regions, the Pacific ENSO Applications Climate (PEAC) Center conducts research and issues long-range outlooks on seasonal climate variability and impacts related to the El Niño-Southern Oscillation (ENSO) climate cycle for small and vulnerable island countries in the Pacific. Therefore, PEAC's current mission is comprised of (1) providing locally tailored and easy-to-understand technical information and products to support planning and management in climate-sensitive sectors such as water resources, fisheries and aquaculture, agriculture, emergency management, utilities, and coastal zones; (2) identifying impacts from and providing advisories for current and expected one-year seasonal changes in rainfall, sea level, and tropical cyclones; and (3) providing periodic educational material and undertaking event warning outreach to Hawaii and the U.S.-Affiliated Pacific Islands (USAPI).

For over two decades, the PEAC Center has effectively provided ENSO-based climate information products and warnings for Hawaii and the USAPI region. This has enhanced the capacity of local governments to respond to natural disasters and has helped these tropical island communities to better manage their water resources.

This presentation synthesizes the role of the PEAC Center in the water resources management activities of Hawaii and the USAPI region by visiting various aspects of the historical and current operational framework of the PEAC Center, including (1) forecasting, (2) interpretation and message formulation, (3) warning preparation and dissemination, (4) response and feedback, and (5) review and analysis.

Keywords

Governance capacity, disasters, climate variability, PEAC, Pacific Islands

Unprecedented El Niño of 2015–16: Rainfall Outlook for the Pacific Islands

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The Pacific Ocean is the largest of the Earth's oceans and originates largest-to-year variation in climate. In this vast ocean, there are about 25,000 islands, including atolls that can be broadly divided into three groups, namely Melanesia, Polynesia, and Micronesia. The inhabited islands are home to over 9.7 million people living in a variety of climates and socio-economic conditions. Given continued population increase leading to enhanced withdrawal of freshwater from the aquifers, and further stress from periodic droughts that affects both water quality and quantity, skillful prediction (leading to measurable actions) of seasonal rainfall could help stakeholders budget freshwater resources to cope with the increasing demand of water.

Since May–June 2015, sea surface temperature (SST) observations along the equatorial Pacific in conjunction with coupled model predictions have indicated the development of an El Niño. As of September, under the influence of strong ocean-atmosphere interactions, El Niño has intensified into a strong one. Model predictions suggest for further intensification with SST anomalies upward of 3.5-4 °C along the eastern equatorial Pacific during late fall/winter to make this an *"unprecedented El Niño" that has not been previously observed*. In this presentation, a dynamical coupled model, and the methodology employed for seasonal prediction will be introduced. We will discuss model predictions of rainfall over the insular Pacific Islands during the ensuing winter (December to February 2015/16) and the following spring (March to May 2016) seasons. Specifically, we will discuss skill measures and the uncertainty involved in the model predicted *persistence of dry conditions* over the Pacific Islands for about six months (December 2015 to May 2016).

Our science-based results will provide pathways for mitigation strategies for stakeholders.

Impact of Waves and Tides on Coastal Groundwater Dynamics and Pollutant Discharge to the Sea

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Tide and waves lead to complex and dynamic groundwater flows and water-table fluctuations in coastal aquifers. These oceanic forcing also drive the recirculation of large quantities of seawater across the ocean-groundwater interface along permeable shorelines. This recirculation modifies submarine groundwater discharge rates, and by setting up an important zone of salt-freshwater mixing and reaction in the coastal aquifer, it can modify the ultimate loading of groundwater pollutants to the ocean. While numerous studies have quantified the influence of tides on coastal groundwater processes, wave effects and the combined effects of tides and waves are less understood. This is a consequence of the difficulty in quantifying wave effects due to the temporal complexity of the forcing (i.e., irregular and higher frequency). With most shorelines worldwide exposed to both tides and waves it is important to understand not only the individual but also the combined effects of these forcing on coastal aquifer processes.

This presentation will provide an overview of recent advances in our understanding of the impact of waves and tides on groundwater dynamics and pollutant fluxes along permeable coastal shorelines. Recent field data and numerical model results will be presented that illustrate the individual and combined effect of these oceanic forcing on coastal groundwater flow patterns, salt-freshwater mixing, and the discharge of pollutants (nutrients) from groundwater to the ocean.

Keywords
Oceanic forcing, submarine groundwater discharge, modeling, field work

Tropical Islands as Submarine Groundwater Discharge Hotspots

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Tropical islands have relatively high and heterogeneous fresh submarine groundwater discharge (SGD) rates as a result of high rainfall rates, steep relief, and high soil permeability. As a result, oceanic islands may contribute a disproportionate amount to global SGD. Current global fresh SGD estimates from islands rely primarily on typological extrapolations and are often put in the "to do list" in hydrological, biogeochemical, ecological, and pollution assessments in tropical islands. I will discuss how a combination of geochemical tracer approaches, modelling, and resistivity observations can close the gap in our knowledge of SGD in tropical islands.

Field observations have been made on a number of oceanic islands, including Cook Islands, New Zealand, Bali, Palau, and smaller sedimentary islands such as coral cays and mangrove islands. We have developed a field portable system that allows automated observations of groundwater tracers, greenhouse gases, and stable isotopes to provide insight into how SGD may contribute to hydrological budgets and drive the biogeochemistry and ecology of coastal ecosystems.

Our observations show that SGD is high and ubiquitous near tropical islands, and often exceed river inputs in small catchments where river channels are not well developed. In all cases, SGD was a source of dissolved species, including carbon, greenhouse gases, heavy metals and nutrients. In some cases, the SGD off tropical islands has been shown to alter the pH of the nearby ocean and influence coastal acidification in positive and negative ways. My presentation will summarize these findings and demonstrate that SGD is a major component of coastal hydrological and biogeochemical budgets near tropical islands.

Keywords
Subterranean estuaries, submarine groundwater discharge, water quality, radon