As reported in the Feb. 2009 WRRC Bulletin, the County of Hawaii is considering an expansion of the South Hilo Sanitary Landfill (SHSL). To be in compliance with State and Federal regulations, any new landfill cells constructed at this site will have to include an underliner system to collect and remove leachate water that soaks through the waste pile. The collected leachate must then be properly treated and disposed of.

Due to the large amount of rainfall in the Hilo area it is anticipated that a substantial volume of leachate will be generated by any new landfill cell. The expansion under consideration therefore requires careful planning for effective management of this water. To aid in the selection of the most appropriate leachate treatment options, Dr. Roger Babcock and Islam Alboji of the University of Hawaii’s Water Resources Research Center and Department of Civil and Environmental Engineering assisted with a feasibility study to provide recommendations on technically feasible, cost-effective approaches.

This technology evaluation for treating future Hilo landfill leachate in part followed a process, outlined by the EPA, for characterizing the nature and extent of risks posed by uncontrolled hazardous waste sites, and for evaluating potential remedial options for the Superfund program. The process the UH researchers used consisted of four main steps; 1) site characterization, 2) development and screening of alternatives, 3) a treatability study, and 4) alternatives analysis.

Site Summary:

The SHSL serves the eastern side of the Big Island of Hawaii. As shown in Figure 1 the SHSL is located just outside the eastern edge of urban Hilo, in an area of industrial, airport, and farm lot use. The SHSL, which is owned and operated by the County of Hawaii has been in operation since the 1960s. It encompasses approximately 40 acres, most of which is used for municipal solid waste disposal. The figure also shows rainfall lines and the underground injection control (UIC) line around Hilo. Areas upgradient of this line overlie aquifers that are actual or potential sources of drinking water. The SHSL is downdgradient of the UIC line, which means that treated waste could be disposed of via injection wells if approved by a state-issued permit.

Hilo enjoys the warm tropical climate common to all the Hawaiian Islands and, importantly for the purposes of the study, an abundance of rainfall - around 3500 mm/year. The existing landfill has no underliner system, and precipitation that infiltrates through the waste pile currently discharges directly into the underlying aquifer system, constituting an ongoing source of potential groundwater contamination.

Because there is no liner or leachate collection system from which to take samples, leachate was collected on October 07, 2008 from a side cut penetrating into the current waste pile where water drainage was frequently observed, for analysis. This leachate was analyzed for 32 chemical constituents.

It is not known how representative the sample was of deep-interior leachate in the SHSL waste pile. The side cut collection area did not have significant overlying waste, and may not have been in contact with waste materials for as long as leachate migrating through to the base of the landfill.

Based on the laboratory results, the leachate generated from the Hilo Sanitary Landfill site can be considered to be of relatively low strength compared to typical landfill leachate. The concentrations of all tested chemicals were near the lower end of typical ranges. This could be due to short retention time in the pile (actual retention time unknown) resulting in reduced time for the rainwater to leach material from the waste, or to the area’s high precipitation rate resulting in a dilated leachate.

Development and Screening of Remedial Action Alternatives:

Based on the EPA’s Comprehensive Environmental Response, Compensation, and Liability Act’s (CERCLA) “Interim Final Guidance for Conducting Remedial Investigations and Feasibility Studies” the process that the researchers used to develop and screen alternative treatment options consisted of the following series of steps:

1. Develop Remedial Action Objectives,
2. Develop General Response Actions,
3. Identify Volumes or Areas of Media,
4. Identify and Screen Remedial Technologies and Process Options,
5. Evaluate Process Options,
6. Assemble Technologies into Alternatives.
7. Screen Alternatives, if required

These steps were used to develop and initially screen the appropriate alternatives for the Hilo site.

Based on an analysis of feasibility of several process options including off-site treatment, in-situ treatment, biological treatment, physico-chemical treatment and constructed wetlands, the researchers concluded that constructed wetlands represent the most appropriate on-site technology to effectively treat landfill leachate at SHSL.

Remedial technologies consisting of more high-tech, brick-and-mortar treatment options such as activated sludge, trickling filters and physico-chemical treatment require construction of tanks, pipes, valves, pumps, aeration systems, buildings, and computer systems which use a lot of electricity and require professional operations staff to monitor and maintain. The simpler, wetlands technology alternatives don’t require tanks or aeration or operations personnel, and represent a natural or “green” alternative that is less expensive to construct and operate and is more appropriate for the site under review.

Wetlands are areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, (and that under normal circumstances do support), a prevalence of vegetation typically adapted for life in saturated conditions, such as swamps, marshes, bogs, and similar areas. Plants and microorganisms that live in wetlands can trap, breakdown or absorb nutrients and bacteria. Wetlands are usually very full of life, and thus home to a very complex food chain. At the bottom of the food chain...
Chain various microbes and bacteria, which
invertebrates, such as insects, feed on.

Wetlands are effective at trapping sediments. The slow-
moving water in a wetland allows particulates to settle out
and be degraded by natural processes. The plants and
animals in wetlands are effective at removing nutrients
from water. By intercepting nutrients from migrating to
environmental waters wetlands play an important role in
preventing degradation of those waters.

The use of constructed wetlands for leachate treatment
incorporates the advantages of natural wetlands within a
more controlled environment. The many advantages of
constructed wetlands include site location flexibility, optimal
sizing for anticipated waste load, and potential to treat more
wastewater in a smaller area than within natural wetlands. Constructed wetlands are generally designed to have
hydraulic retention times (HRT) of 15 days or longer.
Constructed wetlands are divided into two general types;
free water surface systems (FWS) and subsurface flow
systems (SSF).

Types of Constructed Wetlands:
Free Water Surface Systems (FWS)

FWS systems mimic natural wetlands in that open water
flows through the wetland plants. The FWS system consists of an impervious liner such as
geotextile material or a clay layer; soil to support the growth
of plants; an inlet device; an outlet device; and
vegetation. The configuration of the system (which is often in
the form of a long narrow channel), the shallow water
depth, low flow velocity and presence of plant stands
provide the necessary conditions for a near “plug-flow”
hydraulic pattern ensuring that the water moving through
the system moves through as a “plug” and therefore has a
uniform length of stay (and degree of treatment) in the
system. Typical retention times for FWS systems are 5 to
15 days.

FWS systems are best suited for applications where there is
limited land availability or the leachate contains large
amounts of suspended solids. They are easier and simpler
to build than SSF systems but they have higher operations
and maintenance requirements. Usually FWS are cheaper
to construct than SSF; however, this depends on the price
and availability of land and substrate/porous media.

Subsurface Flow Systems (SSF)

In SSF systems water flows below the surface through a
porous medium. SSF systems consist of inlet and outlet
devices, seepage media, and wetland plants. SSF wetlands
slow the influent by passing it horizontally or vertically
through the medium which is planted with wetland plants.
Typical retention times for SSF systems are 2 to 15 days.
In horizontal systems the water flows parallel to the
ground surface in one end and out the other through the
bed. In vertical systems the water passes down through the
porous medium from the surface to the liner and out
to collection pipes at the bottom. SSF wetland
systems are more suitable for applications where there is
a risk of public contact, the leachate contains hazardous
constituents, there are potential odor problems, or land
availability is a major concern.

Pilot/Bench Scale Study:
The researchers are recommending that a bench scale
study be conducted using actual leachate
generated from the SHSL to examine the effectiveness of
constructed wetlands by determining treatment efficiencies
and general design parameters. The primary objective of
the bench scale study will be to compare free water
treatment, conventional horizontal subsurface and vertical
subsurface constructed wetlands for their effectiveness in
treating leachate in Hawaii. This phase of the project has not
been completed yet, but the plans include the following:

Since SHSL leachate will not be readily available, a surrogate
leachate from the Waimanalo Gulch Landfill (WGL) on Oahu
will be used. A follow-on larger pilot scale
study to be conducted in Hilo is also
planned.

Effluent quality analyses:
The recommended water quality parameters to be tested are biochemical oxygen demand (BOD5), chemical oxygen
demand (COD), total organic carbon (TOC), total nitrogen (TN), total phosphorus (TP), total suspended solids (TSS), ammonia-N, Nitrate/nitrite-N, and pH.

Basic setup:
Three cells (conventional free water surface [FWS], conventional horizontal subsurface flow [HSSF], and conventional vertical subsurface [VSSF]) have been
constructed. Treated and untreated leachate samples will be analyzed at the
Environmental Engineering Laboratory at the University of Hawaii at Manoa.

Vegetation to be used:

Normally, reed-type water plants (Phragmites) that are found in natural
wetlands are used in constructed wetlands. However, many constructed systems use
other types of plants where natural wetland
plants are not available, as long as the
plants can tolerate the waste
characteristics and water conditions of
the application. Based on discussions with
personnel at the University of Hawaii
College of Tropical Agriculture and Human
Resources (CTAHR), a locally available, hardy plant, Guinea Grass (Panicum maximum) will be used for the bench-scale study. Guinea Grass is recognized for its
ability to take up prodigious amounts of
nitrogen, phosphorus, and metals, and for its tolerance of almost
any amount of water, from very little to flooding. Researchers at
CTAHR have also investigated the nitrogen uptake of native
Hawaiian wetlands plants and found that two species of sedges
(Cyperus javanicus [Java sedge, Ahu‘awa] and Cyperus
polystachyos [manyspike flatsedge, Kioloa]) and
one grass (Cladium jamaicense [sawgrass, Uki]) are well suited as wetland plants, and could be
substituted for Guinea Grass if it is desired to re-
establish native plants. However, it is likely that
Guinea Grass will be much more resilient and that
is why the researchers recommend it. It is worth
mentioning that Guinea grass has not been used
before in constructed wetlands; therefore, this
study offers an opportunity to examine its suitability for
this use.

Conclusions:

Constructed wetlands are a promising technology for
leachate treatment at the Hilo landfill site.

Because of reduced inlet and outlet piping
requirements HSSF could be a preferable alternative to
VSSF. Although FWSs are less costly than HSSFs, the
subsurface systems have non-financial benefits
that may outweigh cost
considerations. This
conclusion is based on the assumption that treatment outcomes are similar and that treatment objectives
are met by all three
alternatives. When the treatability study water
quality data are available, they will provide another
tool to help decide on the
best alternative. At this
point, there is not a clear winner between FWS, VSSF, and HSSF.

More in-depth information about this project is
contained in WRRC Unedited Report WRRC-
2010-01. For further information on this or any
other WRRC project please contact Philip
Moravcik at 808-956-3097 or morav@hawaii.edu.
Some experts believe that Oahu’s groundwater resources will be fully “committed” within the next 20 or 30 years, at which point utilization of costlier alternatives like desalinated seawater will become necessary to meet the water needs of island residents. Our studies show that in order for water sources to be developed and allocated to their highest and best uses, demand-side conservation must be combined with integrated supply-side management. The current tools of choice for evaluating the sustainable yields for Hawaii’s basal aquifers include the robust analytical model (RAM) proposed by Honolulu hydrologist John Mink in 1980, and an updated version - RAM2 (Liu, 2006; Liu, 2007), which extends RAM by accounting for upwelling and a brackish transition zone. We verify from an economic perspective that the minimum equilibrium head levels identified for the Pearl Harbor and Honolulu aquifers by RAM2 are consistent with the economically optimal long-run targets. The corresponding maximum sustainable yields (MSY), therefore, serve as appropriate long-run targets for groundwater pumping.

Efficient groundwater management involves determining the welfare-maximizing patterns of extraction from available resources in both the near and long-term, as well as designing instruments to achieve the target rates of water consumption over time. When the Pearl Harbor and Honolulu aquifers are jointly optimized, the efficient extraction profile for each aquifer starts below its respective MSY, eventually rises above it over time, and then declines back to MSY in the very long-term (Fig. 1). More specifically, efficient management is characterized by complete drawdown of Pearl Harbor aquifer to its minimum equilibrium head level while allowing Honolulu aquifer to replenish in an initial stage, followed by MSY withdrawal from Pearl Harbor aquifer, supplemented by extraction from Honolulu aquifer. The optimal sequencing is determined primarily by the reduction in freshwater leakage along the coast resulting from drawing down Pearl Harbor aquifer.

In addition to efficient patterns of groundwater extraction, we identify the optimal timing and amounts of supplementary desalination, which become efficient as demand for water continues to grow over time. Desalination is optimally postponed well into the next century under joint aquifer management. Welfare is higher under efficient management because costly desalination is delayed by over 90 years in comparison to the case when Honolulu aquifer is optimized independently. Prior to the implementation of desalination, users enjoy more consumption in every period and do so for an extended period of time. Potential welfare gains are approximately $4.7 billion or nearly 65% of the aggregate welfare obtained by optimizing groundwater for each district independently.

Having efficient consumption schedules in hand, water managers must choose methods of implementation. In general, management instruments either control the

Figure 1. Optimal Extraction vs. Maximum Sustainable Extraction, Honolulu and Pearl Harbor Aquifers Considered Jointly

Recent months have seen several retirements of long-term WRRC faculty and staff:

WRRC’s director for the last ten years, Dr. James Moncur, has retired from the University where, in addition to being our director, he was a professor in the Economics Department. Jim arrived in Hawaii in 1969, straight out of grad school. He spent two years in Thailand at Thammasat University, and two and a half years in total (two different times) at Brigham Young University in Provo, Utah. Jim became Director of WRRC when Roger Fujioka stepped down in 1999. Here at UH he taught economic statistics, econometrics, and mathematical economics at the graduate and undergraduate levels, and undergraduate environmental economics, among other courses.

Jim reports that having retired, he plans to sleep more, work (but not too hard) on a couple of writing projects, clean out 40+ years of files and books from his Economics Department office, and “refine the fine art of recreational complaining”.

Dr. Roger Fujioka who preceeded Dr. Moncur as WRRC Director, also retired officially at the end of 2009. Dr. Fujioka came to the University of Hawaii in 1972 having recently received his doctorate in Virology from the University of Michigan. Roger was on the faculties of Microbiology and Public Health during his tenure of 38 years at UH. His seminal work on pollution managers must choose methods of implementation. In general, management instruments either control the

Dr. Chittaranjan Ray, Professor in Civil and Environmental Engineering and long-time WRRC researcher will be acting as Interim Director of the Center. Dr. Ray has already been working hard to take on the extra responsibilities and help WRRC prosper during these challenging times for UH. Dr. Ray is well known in the state for his work on the potential of agricultural chemicals to contaminate our ground water supplies.

While we are very sorry to see our colleagues and good friends leave us, we can’t begrudge them their well-earned and long-awaited retirements.

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Over the more than 30 years of it’s operation WRRC researchers have produce a considerable number of publications. Until recently the only way to access the information in these reports was to visit the Center or the University of Hawaii Library. Now the Center’s Technology Transfer Office is collaborating with UH Manoa’s ScholarSpace institutional repository program to upload full text of our reports so that anyone with an internet connection can get copies of our reports.

As of May 2010 some 260 WRRC reports are now online in PDF format. You can access these at: http://scholarspace.manoa.hawaii.edu/handle/10125/1678.