Chapter 7

O Ka mea ukuhi ka I ike I ka lepo o ka wasi; o ka mea inu ‘a’ole ‘oia I ‘ike

“He who dips knows how dirty the water is, but he who drinks does not. He who does the work knows what trouble it takes, he who receives it does not.”

Sewage treatment and Polluted Runoff

Human waste is not a subject discussed with ease or finesse, yet it is an unavoidable byproduct of human existence that can contaminate the surrounding environment and water systems if not disposed of in a safe and deliberate fashion. Within traditional Hawaiian culture, the disposal of human waste was treated with extreme care, associating it with a number of kapu to protect the purity of Hawai‘i’s water. It was forbidden to relieve oneself in any of the natural water sources, including streams, wetlands, and the ocean. So, on long outrigger canoe voyages, detailed ceremonies were performed to absolve the travelers for tainting the respected resource.

The Point about Point Source

Today, the City and County of Honolulu treats about 113 million gallons a day of wastewater.[1] When this effluent is emitted from a pipe or some other identifiable point of discharge, it is termed *point source pollution*. Although the term often conjures up ugly images of brown sewage pouring into the ocean from a large, rusty pipe, this is rarely the case. Wastewater is generated from many sources including agricultural processing, industrial facilities, military outfalls, and sewage treatment plants, each with unique properties of contamination. Most of Hawai‘i’s wastewater comes from industrial sources, generated from cooling water, metal cleaning waste, and power generation stations. Sewage and, to a lesser extent, agricultural wastewater make up the rest.

Hawai'i has seven major wastewater treatment plants that discharge into coastal waters. Sand Island with a design capacity of 82 million gallons per day and Honouliuli at 38 million gallons per day are the two largest and they serve the urban metropolitan region on Oahu's south shore. These two offer *advanced primary treatment*, below the required *secondary treatment* mandated by the U.S. Environmental Protection Agency. Sand Island and Honouliuli, as well as Wai'anae, Kailua, and Hilo wastewater plants all discharge in waters below 130 feet depth. It is widely believed by scientists that this is sufficient to prevent sewage from returning to the coastal area, though there have been challenges to this. Three outfalls are located in water shallower than 130 feet and these are located at East Honolulu, Ft. Kamehameha, and Wailua (Kauai). Other than Sand Island and Honouliuli all sewage is treated to the secondary level.

That is all well and good but the question on most of our minds is, "What happens after you flush?"

What Happens After you Flush?

After you flush, you have liquid waste, solid waste, toilet paper and other paper products, various types of medicines, cleaners, and other synthetic chemical compounds all carried by gravity into a buried pipe under your street. This toxic brew combines with the sewage of your neighbors and is carried by gravity, aided by pumps, to the closest sewage treatment plant. There, your tax dollars pay for it to be processed into a form that can be disposed of. This process consists of *primary treatment*, secondary treatment, and in some cases *tertiary treatment*.

All of these methods of treatment are used in Hawai‘i. The City and County of Honolulu, responsible for the largest portion of the state's population, has six plants using secondary treatment: Kailua, Wahiawa, Kahuku, Wai'anae, Waimanalo, and Pa‘ala‘a Kai wastewater treatment plants. At these locations, treated wastewater is injected into the ground, discharged into a lake, or discharged into the ocean. These discharges return the water and left-over impurities for recycling back into our ecosystem. Honolulu has two plants using advanced primary treatment. These are the Sand Island and Honouliuli wastewater treatment plants that process sewage for the urban core in Honolulu and the Ewa Plain. These two plants treat most of the wastewater (more than 85%) generated on the island of O'ahu.[2]

When your treated sewage is discharged into the sea, it is assumed that it is harmlessly diluted in the immense volume of the Pacific Ocean. Ground disposal assumes that by flowing through island bedrock, our waste water is adequately purified. Behind these steps lays the recognition that in the ideal world of a closed ecosystem there is no such thing as waste. Just about everything organic (meaning a carbon compound made by a living organism) is eventually recycled. For example, as animals exhale carbon dioxide, plants use this gas and water in the process of photosynthesis to make their food. Plants thrive on natural fertilizer from the droppings of animals and in return provide food to the animal kingdom as well as oxygen to breathe. Nutrients, water, and carbon are constantly being recycled through the ecosystem.

The treatment of wastewater from humans borrows this natural recycling. The most popular wastewater treatment methods (secondary treatment, mandated nationwide by the federal Environmental Protection Agency under the Clean Water Act) are simply amplifications of what occurs naturally.

Wastewater Treatment

Treating wastewater consists of several steps, and most treatment facilities employ a unique blend of several methods to best suit their needs. All sewage goes through *preliminary treatment* when it enters a facility. Preliminary treatment is a mechanical process with the goal of removing physical objects and grit from the wastewater. Sewage arriving from neighborhood pipes is run through large screens, grinders, and grit channels to catch physical materials such as rags, large food items, sand and stones, and other garbage.

The next step is *primary treatment*, which relies on physical separation to remove solids from the wastewater. This mostly involves letting water slowly move through large sedimentation basins to permit fine solids and organic compounds to settle to the bottom or float to the top. Mechanical scrappers and belts clear the "sludge" from the bottom of the tank while slow-moving rakes cross the surface and remove floating "scum". Scum includes grease, oils, plastics, and soap (compounds lighter than water, hence they float). Scum is thickened and pumped along with the sludge to enclosed heated tanks called *digesters*. There, solids are kept for twenty to thirty days while bacteria digest organic material, reducing its volume and odors, and getting rid of some of the organisms and compounds that may cause disease. The finished product is mainly sent to landfills but sometimes can be used as fertilizer.[3]

A pair of aeration tanks at a wastewater facility.

Secondary treatment employs mostly biological processes to remove much of the remaining dissolved and microscopic organic matter. Several different techniques are used to achieve this. One common type is the *activated sludge system* that consists of two parts, an aeration tank and a settling tank, or clarifier. The aeration tank contains a culture of bacteria, protozoa, fungi, and algae that is constantly mixed and aerated with compressed air or large mechanical mixers. Wastewater enters the tank and mixes with the culture, which uses organic compounds in the sewage for growth - producing more microorganisms - and for respiration, which results mostly in the formation of carbon dioxide and water. Both growth and respiration destroy organic compounds in wastewater using the natural metabolism of the bacteria. The process can also be set up to provide biological removal of the nutrients nitrogen and phosphorus.

After sufficient aeration to reach the required level of treatment, wastewater flows into the clarifier. Once there, sludge settles to the bottom of the tank producing a reasonably clear upper layer that is removed and discharged, or further treated.

Other techniques can be employed to further purify the water with chemical treatment, filtering, and radiating the water in ultraviolet light to kill bacteria.[4] Clarified wastewater may flow into a “chlorine contact” tank, where the chemical chlorine is added to kill bacteria, just as is done in swimming pools. The chlorine is mostly eliminated as the bacteria are destroyed, but sometimes it must be neutralized by adding other chemicals. This protects fish and other marine organisms that might be harmed by the smallest amounts of chlorine when the treated wastewater is discharged.

Sometimes cities also use filtration in sewage treatment. After solids are removed, liquid sewage is filtered through a substance, usually sand, by the action of gravity. This method gets rid of almost all bacteria, reduces turbidity and color, removes odors, reduces the amount of iron, and removes most other solid particles that might remain in the water. Water is sometimes filtered through carbon particles, which is also effective at removing organic matter.

Combined primary-secondary treatment removes about 97% of suspended solids, 95-97% of oxygen-using organic waste, 70% of most toxic metal compounds and non-persistent organic chemicals, 70% of phosphorous, 50% of nitrogen, 5% of dissolved salts.[5] However, only a small percent of persistent chemical compounds such as pesticides are removed.

Less than Perfect

The federal government plays a significant role in regulating the discharge of point source pollution through the Clean Water Act (CWA) of 1972.[6] The Act’s primary goals are to ensure that all waters in the United States are clean enough for fishing and swimming and to end all discharges of pollutants into navigable waters. The National Pollution Discharge Elimination System (NPDES) – part of the CWA – requires all dischargers to have permits, and mandates all publicly owned treatment facilities to achieve *secondary treatment* of effluent to protect public health.

In 1977, Congress amended the CWA to allow municipalities to discharge at less than secondary standards if they established that it would not harm the environment.[7] This stipulation has received widespread attention across the Hawaiian Islands because our two major sewage plants, Sand Island, and Honouliuli, seek to remain at the level of primary treatment due to the great expense of upgrading, and because it is thought that dilution in the deep water adjacent to our islands is sufficient to mitigate potential health and environmental impacts.[8] Experts, and the court of public opinion, continue to debate whether the high levels of nutrients, suspended solids, organic matter, and industrial chemicals in primary treated effluent pose a threat to sensitive marine habitats. Likewise, opinions vary with regard to the potential health impacts of effluent dumped in the deep waters offshore of island beaches. But our major treatment facilities are slowly improving the quality of water that makes its way into the oceans as they add components such as disinfectors, larger digestion facilities, and upgrades to sewage delivery pipes beneath our streets.

Poised for battle is the Environmental Protection Agency (EPA), pressuring Hawaiʻi to treat all sewage to the secondary level, while the City of Honolulu struggles to convince them that appropriate treatment standards and disposal guidelines specific to its unique mid-ocean environment should be exempt from the CWA. Because of the CWA, most U.S. cities have combined primary and secondary sewage treatment plants.

To reduce the environmental and public health risks associated with primary wastewater effluent, managers have three basic options at their disposal: improve the treatment level, change the discharge location, and upgrade the facilities' operation to minimize leakage and emergency bypassing of untreated water due to flooding during rainstorms. Each, or all, of these steps will lessen the negative environmental impacts related to sewage discharge; and each has been employed in the Hawaiian Islands.

The Hawaiʻi Department of Health monitors locations where public wastewater treatment plants discharge into Hawaiian ocean waters. These are listed below with their average dry season discharges in millions of gallons per day (mgd).

1. **Island of Hawaiʻi –**
   a. Hilo Wastewater Treatment Plant (secondary) - 5 mgd
   b. Kulaimano Wastewater Treatment Plant (secondary) - 0.1 mgd
   c. Papaikou-Paukaa Wastewater Treatment Plant (secondary) - 0.09 mgd
2. **Kauaʻi**
   a. Wailua Wastewater Treatment Plant (secondary) – 1.5 mgd
3. **Oʻahu**
   a. East Honolulu Wastewater Treatment Plant (secondary) - 4 mgd
   b. Fort Kamehameha Wastewater Treatment Plant (secondary) – 13 mgd
   c. Kailua Regional Wastewater Treatment Plant (secondary) - 15 mgd
   d. Sand Island Wastewater Treatment Plant (advanced primary) - 82 mgd
   e. Waianae Wastewater Treatment Plant (secondary) - 5 mgd
   f. Honouliuli Wastewater Treatment Plant (advanced primary) - 38 mgd

The advanced primary treatment being performed at Sand Island and Honouliuli are controversial. Both plants have been granted waivers under the Clean Water Act to legally discharge sewage treated at the primary level. Upgrades at the Sand Island plant allow it to operate with increased capacity, as much as 90 mgd, and to provide ultraviolet disinfection, improved filtering, and recycling of treated sludge into fertilizer pellets. Extension of sewage outfalls at Sand Island and Kāne'ohe Bay from shallow water to deeper water in the 1970's and 1980's has resulted in significant improvements with regard to seafloor ecology and human health concerns.[9] Outfalls, placed far enough out to sea, benefit from oceanic currents that carry sewage offshore, trap it below a *thermocline* (temperature boundary), and otherwise mix the waste in the vast cauldron of the ocean. But is this sufficient?

The EPA says "no", citing studies done in March 2007 at both Honouliuli and Sand Island of bacteria levels that were higher than national standards to protect swimmers, surfers, and others from gastrointestinal diseases. Effluent from both plants was tested to determine impacts on sea urchin fertility. Results indicate the production of excess ammonia that may harm other aquatic organisms. Samples from both plants also contained excess levels of two pesticides, dieldrin and chlordane.[10] The City and County of Honolulu says "yes", citing the enormous cost of retrofitting to secondary treatment ($1.2 billion) as unaffordable and pointing to Hawai'i's unique position in the Pacific ocean that renders secondary treatment unnecessary. They fought the EPA with a battalion of scientists who testified that the use of sea urchins as a telltale was inappropriate, pesticide measurements fell within acceptable guidelines, and the ammonia measurements were contradicted by real-world evidence. Over the course of four public hearings, not a single scientist or engineer familiar with the system testified that denying the CWA waiver would result in any environmental benefit. The City also argued that the money would be better spent upgrading the county's sewage collection pipes.[11] Holes in this delivery network are a main source of non-point source pollution that enters our coastal ocean and groundwater system.

Facility Improvements

Though treatment standards for wastewater and disposal location are both important factors dictating the environmental impacts of wastewater, facility operations and maintenance problems have been at the heart of many water quality violations in Hawai'i. The Clean Water Act played a key role in improving facility-level operations across the United States, beginning in the 1970's. The CWA not only imposes financial penalties when violations occur, but the federal government also offers a carrot of financial assistance for facilities that desire to improve their operations.

During the 1970's, federal funds were made available, under a Construction Grants Program, to build municipal wastewater treatment plants.[12] Through this program, the net cost of building or upgrading facilities in Hawai'i significantly decreased from their original cost. Maui capitalized on the opportunity, and as a result, all of its sewage is treated to the secondary level and disposed of using injection wells located in coastal areas below potable aquifers, rather than through ocean outfalls. Kaua'i also seized the opportunity to upgrade its treatment facilities, recognizing that the island's increasing population could overburden its aging systems. The County of Hawai'i used federal construction grant money to expand and even over-build their plants, making them operate considerably below their capacity. However, wastewater treatment on the Big Island is not without its problems. The Kealakehe Wastewater facility in north Kona has no disposal unit. It discharges a daily load of 1.5 million gallons of wastewater directly into Honokohau Harbor on the Kona coast. This is a major problem that has no parallel on the other islands.

Wrestling with Outfalls

In the last decades of the 20th Century, heightened public awareness, a rash of federal water-quality violations, and several notorious and lengthy lawsuits prompted the placement of outfalls deeper in the ocean and farther offshore. Studies associated with these lawsuits have highlighted Hawaiʻi's deep water location, ideal in many ways for rapid diffusion of pollutants provided it can be established that effluent-carrying currents are not delivering waste to bathing waters or sensitive ecologies.

The problem is that environmental politics sets different standards for different people. No scientific study is failsafe and absolute. All have built-in assumptions and under-sampling of the desired information. Depending on your inclination, two people may view the same study in a very different light. One person's thorough study is another person's flawed research. Hence in the politics of environment, environmentalists remain skeptical that our outfalls are safely located and not impacting nearshore water quality. They continue to call for wastewater treatment to the secondary level at all facilities, and there are experts that back their opinions.

With fewer people inhabiting the outer islands, their wastewater dilemmas have not reached the same boiling point as on Oʻahu. In the past, treatment plants have only been built when population density has reached a critical mass and public concern erupts. On Kauaʻi, there are only four treatment facilities, all of which treat their sewage to the secondary level and the majority of this water is used for golf course irrigation now. Due to the island's former character of intense agricultural production and sparse population, farming waste comprises a larger proportion of Kauaʻi's wastewater than any other island – but that is changing in the 21st Century. The more rural islands of Molokaʻi and Lanaʻi have only a few point source dischargers, including a handful of agriculture processing plants, and a number of resorts that dump primarily treated wastewater into the ocean.

Improvements to Sand Island

In the late 1990's and early this century the City and County of Honolulu spent hundreds of millions of dollars on improvements to its largest sewage treatment plant, Sand Island. The Sand Island Wastewater Treatment Plant services an area stretching from Kuliouou Valley on the East side of Honolulu to Aliamanu on the West side of Honolulu. The facility diverts sewage from the city of Honolulu into the sea with advanced primary treatment. However, with deteriorating infrastructure, upgrades to the plant equipment have been necessary in order to correct federal Clean Water Act violations. These include:

- expansion of capacity from 82 million gallons per day (mgd) to 90 mgd;
- increased wet weather capacity from 210 mgd to 270 mgd;
- introduction of an ultraviolet disinfection system to reduce pathogenic organisms;
- construction of new main lines, pumps, and delivery/receiving components for sewage;
- refurbishing clarifiers, new screening channels, new aerated grit chambers;
- installation of biofilter trickling filters and carbon scrubbers to reduce hydrogen sulfide gas emissions.[13]

Despite these corrections, however, the plant continues to operate at the advanced primary level and, in the past, the U.S. Environmental Protection Agency has threatened to revoke permits to operate the plant if it is not upgraded to the level of secondary treatment.

Offshore discharge of treated sewage has improved since 1972 when sewage from Honolulu, amounting to about sixty-two mgd, was being discharged off Sand Island at a depth of thirty-eight feet.[14] The discharge was raw sewage, totally untreated, and thick sludge deposits accumulated on the seafloor with measurable impacts to the reef community. The ocean surface was marred by an ever-present thick, grayish-brown plume usually heading in the direction of Ewa Beach and Barbers Point. During calm winds the sewage was carried toward the shore and could be found at Ala Moana Beach Park. Studies revealed that viruses from the discharge were being carried into recreational waters.

By 1976, Sand Island had installed a new seventy-eight inch diameter outfall that extended about 1.5 miles offshore where the ocean was 225 to 240 feet deep.[15] The new outfall was designed with a long diffuser section to discharge sewage over a greater length of the seafloor. The combined effect of extending the outfall, the diffuser head, and upgrades in treatment level at the plant have considerably improved water quality and virtually eliminated impacts to the seafloor ecology.

The diffuser heads distribute wastewater across a wider area of the seafloor. Instead of discharging sewage in one big mass from the end of a pipe, the outfall at Sand Island has a 3400-foot long diffuser section with 282 openings, ranging from 3 to 3.5-inches in diameter and spaced twenty-four feet apart. This way sewage is discharged in small amounts from each port and spread out over the length of the diffuser. The County monitors bacteria levels, micromollusk populations, over 64 chemicals in the flesh of fish caught in the area, abnormal growths in the livers of fish caught in the area, nutrient levels (nitrogen, phosphorus), chlorophyll levels (related to algae growth), turbidity, temperature, and properties of the sand and sediment from the sea floor. The data from these tests help to determine how the ocean environment is changing and whether the wastewater discharge is having any effects.[16]

East Honolulu and Kāneʻohe

In 2002, a study of the Sand Island and East Honolulu sewage outfalls by researchers at the University of Hawaiʻi found: 1) an area off Sand Island that was essentially destroyed when the discharge was located in about thirty-five feet of water has fully recovered to the same level as nearby natural ecologies now that the outfall has been relocated below 200 feet depth, and 2) discharge from East Honolulu at Sandy Beach has negligible effect on reef communities, but the communities are continually oscillating in coral abundance as a result of periodic large storm surf from the east.[17]

During the 1970's, Kāneʻohe Bay's marine organisms suffocated under a deluge of sewage being dumped daily into the nearshore environment. In response to the community's outrage over such environmental negligence, a new deep-water outfall was completed in 1977 to divert sewage into the open ocean off of Mōkapu Peninsula on the outskirts of Kailua Bay. It took two years for visible improvements in the water quality, and evidence suggests that the reef-based community is recovered and thriving.[18]

Injection Wells – A Common Way to Get Rid of Waste

Still the most common method for disposing wastewater in Hawai‘i is through the *injection well*. Wastewater injected into the ground becomes part of the groundwater system, and eventually discharges into the ocean. Along the way dilution and chemical processes can reduce the nutrient load.

Managing the location of injection well sites is based on a simple map (an underground injection control map, or UIC) of each island that outlines the periphery of salty groundwater levels around the islands and the location of drinking water aquifers. Most injection wells are drilled close to shore, based on the assumption that treated effluent will mix with the salty groundwater and not threaten potable aquifers. The basic operating principle behind an injection well’s location is to protect drinking water from any possible contamination. This responsibility belongs to the wastewater plant using the well or the County, which oversees wastewater treatment. Yet one may question whether we have sufficient understanding of the details of each island’s subsurface geology to know where to safely place these wells. Over the years, compliance with federal and state regulations has decreased, which has led to discussions on implementing more stringent regulations of injection well locations.

Subsurface injection wells can also pose problems for Hawai‘i’s environment. First, a percentage of injection wells experience problems such as clogging, with over half of O‘ahu’s monitored injection wells periodically or continuously overflowing. Secondly, if the well’s effluent migrates far from the site without a sufficient amount of dilution, potable groundwater and coastal waters might become contaminated. Groundwater flows from the mountain to the shore carrying a background nutrient load from the adjacent watershed. As this water moves beneath urbanized lands along the coast it picks up additional nutrients from nonpoint sources such as fertilizers, septic systems, and leaks in the sewer system. Wastewater injection at treatment plants adds to this load that potentially enters the ocean. With this possibility in mind, the USGS conducted a study of the effluent from one injection well on the Kihei coast of Maui[19]. While they are careful to point out that the study only focused on one well, results indicated that the nutrient load was considerably attenuated (reduced) during flow through the permeable coastal zone. They found that despite this attenuation nutrient flux was 3.5 times the background flux for both nitrogen and phosphorous. Compared to Big Island Golf courses, the nitrogen flux was one-half to one-third in the Kihei study.

Crumbling U.S. Sewage System

The mainland has a million mile network of sewage collection pipes and pumps designed to carry over fifty trillion gallons of raw sewage daily to some 20,000 treatment plants. But parts of this complex and aging infrastructure are crumbling resulting in spilled sewage entering neighboring groundwater, watersheds, and even homes. Hawaii is included in this pattern and many are of the opinion that fixing this aging infrastructure in the islands is the most important priority. This pollution poses a health risk to communities across the nation. Spilled, discharged, and leaked pollution costs Americans billions of dollars every year in medical treatment, lost productivity and property damage.

A statement by the Association of Metropolitan Sewage Agencies says the Congressional Budget Office, the Government Accounting Office, and the EPA all agree there is a national funding gap estimated to be as high as $1 trillion for upgrading water infrastructure.[20] Researchers found in 2001 there were 40,000 sanitary sewer overflows and 400,000 backups of raw sewage into basements.[21] The EPA estimates that 1.8 million to 3.5 million individuals get sick each year from swimming in waters contaminated by sanitary sewage overflows.[22]

A large part of the problem is one of aging infrastructure, some pipes still in use are almost 200 years old, although the average age of collection system components is between thirty and forty years. Federal officials predict that without substantial investment in the nation's sewage infrastructure, by 2025 U.S. waters will again suffer from sewage-related pollutant loadings as high as they were in the record year 1968.

Hawai‘i’s Sewage Transport System

Hawai‘i’s sewage transport system mirrors problems across the nation. While the 1980’s were spent attempting to resolve many sewage disposal problems with relocated outfalls, the 1990’s verified that Hawai‘i’s antiquated delivery and transmission system was one of the biggest contributors to sewage-based pollution. And in early 2006 this was brought to appalling relevance with the largest sewage spill in state history – forty-eight million gallons of raw untreated human sewage were dumped directly into the Ala Wai Canal to prevent it from surging out of toilets and sinks into hotel rooms and apartments throughout Waikiki.[23] That same week another 1.85 million gallons of raw sewage spilled into Hawaiian waters in smaller spills located at half a dozen other sites around O‘ahu. One man who fell into the sewage-laden canal died a week later of massive infections that included a form of flesh-eating bacteria, although his case was compounded by additional factors.

Raw sewage spills, leaks in pipelines, plant level problems, sewer-line blockages, structural failures from corrosion, sewage infiltration to groundwater, groundwater infiltration to overwhelmed treatment facilities, limits in sewer line capacity, and poor maintenance programs, together with Hawai‘i’s moist environment, have created a persistent and pervasive water quality hazard on O‘ahu. As more sewer lines are added and the entire system continues to age, the likelihood of problems increases. The majority of the state’s lines were installed between the 1930’s and 1950s, while some of O‘ahu’s most decrepit pipes are approaching 100 years old.

Each county owns, operates and maintains their sewer collection system, while budget constraints commonly limit the amount of attention the counties give to these systems. With more than 2,000 miles of sewer lines dug beneath the soil of O‘ahu and lesser amounts on neighboring islands, the challenge of monitoring and maintenance is daunting. A flurry of bypass and overflow events that accompany every heavy rain are proof enough to warrant the vigorous and unending upgrade of facility level operations. Indeed, this refrain is not new to the ears of county managers as sewerage upgrades perennially top the list of major expenditures in county budgets. However, the combination of making up for past neglect, keeping up with ever expanding housing growth, and getting out in front of the ever-aging infrastructure proves to be a daunting task.

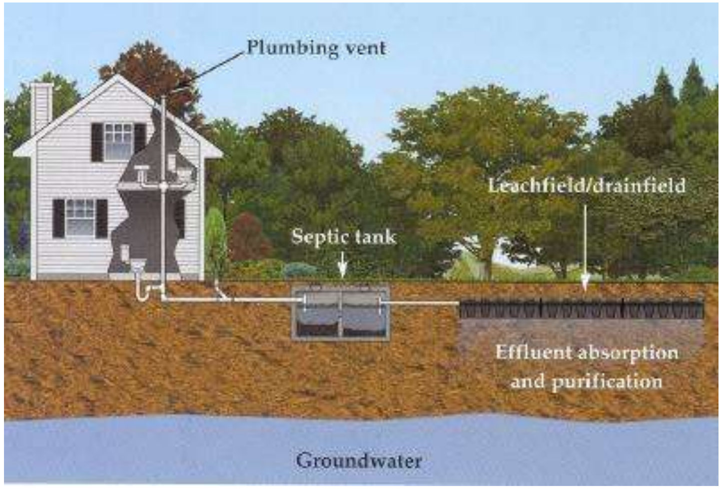
The federal government ordered a major overhaul of Honolulu’s ailing sewer system, blamed for at least 200 spills, overflows, and bypasses, in the 1990s.[24] In 1999, O‘ahu embarked on the ambitious mission of upgrading 1,800 miles of sewer pipes. However, by 2008 the U.S. Environmental Protection Agency proposed to not renew Honolulu's permit variance to exempt the Sand Island Wastewater Treatment plant from full secondary treatment requirements. While the case continues to play out in court, if the variance is denied, Honolulu may have to spend as much as $1.2 billion to upgrade the plant. There is good news however; Honolulu's Department of Environmental Services announced in mid-2008 that sewage spills were down for the second-straight quarter. Records show 20 spills from gravity mains, lower laterals, pump stations and force mains from April 1 through June 30, 2008 This was a 51.2% reduction compared to 41 spills recorded during the second quarter of 2007. In addition to the second quarter decline, there was a 40.8 percent drop (42 to 71) in sewage spills during the first six months of 2008 as compared to the same stretch in 2007. The majority of spills were attributed to grease, roots and debris clogging pipes, as well as broken or sagging pipes and wet weather

On Kaua‘i, the Lihue sewer system was expanded to 2.5 million gallons per day, allowing more properties to connect to the county system, but the network still remains inadequate for planned development. As of 2008 however, authorities had produced the Final Environmental Assessment for the ‘Ele‘ele Wastewater Treatment Plant Facility Plan. The plan consists of three planning intervals: near term, middle term and far term. The near term improvements will be implemented by 2010; the middle term should be in place from 2010 to 2015; the far term developments should be applied in the following 10 years leading up to 2025.

As the state’s tourism population continues to skyrocket past seven million per year, however, most of the existing systems are simply not adequate to handle the increased loads. Most counties are locked into playing an expensive game of catch-up that incrementally improves their sewage system with each passing year, but is it fast enough?

Un-Sewered Land

A growing area of concern is not only the overall amount of community effluent, but how waste is managed at the household level. In the U.S., 75% of sewage is treated in municipal treatment plants while 25% is treated in household septic systems, mostly in suburban and rural areas.[25] A large proportion of the private property in Hawai‘i, perhaps as much as 40%, is not attached to the county sewer system. Sewer systems are only installed in areas where the population reaches a level high enough to justify the cost and effort of trenching for lines, hooking individual homes and properties to pipelines, and building treatment facilities to handle the transported sewage.



The objective with septic tank sewage treatment is to retain the effluent in the septic tank for at least 30 hours. This allows time for solids to settle on the bottom and grease to float to the top. As a general rule of thumb, a two bedroom home will require a 1000 gallon septic tank; three bedroom 1250 gallon septic tank; and four bedroom 1500 gallon septic tank. All of these are minimum requirements - to some extent, the bigger the better. A longer retention time allows the solid waste more time to decompose. (www.thenaturalhome.com/ septic.html)

In much of Hawaiʻi, particularly in rural areas, residents are forced to deal with sewage on an individual basis. Oftentimes individuals simply dig a cess pool, nothing more than a hole in the ground, and divert raw, untreated sewage directly into the earth. The environmental risk of cesspools and septic tanks depends on what lies beneath the property, and varies from island to island. Hawai’i has the largest number of cess pools in the nation, approximately 100,000, and the greatest number per capita. However, cess pool construction has been banned on the island of Oahu and Kauai, and on Maui, Molokai, and Hawaii cess pools are only allowed in certain areas.

The alternative to septic and cesspool systems is for communities to hook up to a nearby sewer system. Unfortunately, these costs are always high, particularly in sparsely populated areas where sewer lines and centralized systems have yet to be built. In new developments, property owners incur the cost of hooking up to a public system and are also charged a monthly service fee. Communities that have enjoyed free services up until now by relying on self-supported inexpensive methods are hesitant to assume the financial responsibility of hooking up to a county system.

Monitoring Individual Systems

Monitoring of cesspools and septic systems has been a difficult and costly dilemma for the state. Ideally, the state would monitor the safety and condition of each cesspool and septic field, but rarely are funds allocated specifically for this purpose. Monitoring is made even more difficult by the fact that there are no records of how many private systems are in place, or of how much wastewater they generate.

Over time the wastewater from cesspools and septic tanks seep into the underlying substrate and frequently overflow during rainfall, generating serious public health risks. Studies by the

University of Hawai‘i affirmed the suspicion that increased levels of nitrogen and phosphorus are leaching into surrounding aquifers from cesspools and septic systems.[26] The problem is that wastewater engineers still disagree on how much of a threat cesspools and septic tanks pose to Hawai‘i's environment and its people. Additional problems may result from septic systems located in coastal areas. Some feel that noxious algae blooms on the Maui coast (*Hypnea musiformis*) are at least partially feeding on nutrients coming from household systems. However, scientists studying the problem[27] have determined that natural nutrient levels in coastal water are sufficient to support the algae explosion and that this is a case of a new species (introduced to Maui ~20 years ago) finding a niche in the ecosystem where it enjoys relatively little competition, a low wave environment, and a broad fringing reef that supports algae growth. The problem with the noxious algae is that it should never have been introduced to Hawaii in the first place.

Today, septic and cesspool complaints are handled on a case-by-case basis, and as of now the only mechanism for improving the situation occurs when individual building permits are requested. The state still has very few courses of action in place to promote sewering for proposed subdivisions. It seems glaringly obvious that Hawai‘i will need to dedicate a worthy portion of its financial resources to this problem, as it is affecting the purity of Hawai‘i's groundwater, stream and coastal water, and our public health and safety.

Paving Paradise – Non-point Source Pollution

Most of Hawai‘i's lowland forests are gone, having been felled by a combination of native Hawaiians and westerners for intensive agriculture and urban development. Thousands of acres of soil that once supported the native vegetation, absorbed the rain, and naturally filtered water runoff are now buried and vaulted beneath paved impermeable surfaces. As asphalt replaces forests and fields, and rainfall is forced to flow across denuded landscapes, the water degrades into *polluted runoff*. Once referred to as "any pollution that doesn't come out of a pipe," non-point source pollution is sinister in that it is diffuse and difficult to trace. Nonpoint source pollution is simply a term for polluted runoff.

As water runs across paved surfaces, it absorbs whatever lays in its path: oil, grease and toxic chemicals from vehicles, pathogens from leaking sewage systems and cesspools, chemical spills from dry cleaners, paint stores, and automotive shops, fertilizers and pesticides from lawns, animal feces, petroleum products, heavy metals, and many other undesirable compounds that make their way onto the ground surface. Unlike natural landscapes where rainwater pools in gullies and filters slowly into the ground, urbanized streets, parking lots, driveways, rooftops, and gutters divert polluted runoff into channels, culverts and storm drains all headed at high velocity into our coastal waters. This artificial maze of conduits alters the natural course of the runoff, accelerating its pace, eroding stream banks, damaging streamside vegetation, and widening channels while carrying the polluted discharge into the ocean. The potential for polluted runoff to affect coastal and marine environments is immense in Hawai‘i as most of the population and its wastes reside within a few miles of the shoreline.

In places as diverse as Kona, Ka‘anapali, and Pearl City, paradise is disappearing under a labyrinth of paved surfaces. Outlet malls, shopping plazas, and miles of concrete roadways are connecting spillways, storm drains and culverts, and diverting the natural flow of *wai*. As prime real estate becomes increasingly scarce, remnant parcels of the arid coastal plains are acquired, and cities are created that depend on stressed water resources. Access to new development requires more roads.

The biggest determining factor of non-point source pollution is land use patterns. The state has assigned all lands into four land-use districts for zoning purposes: urban, rural, agricultural, and conservation. Water quality is diminishing in direct proportion to the pace in which land is converted under pavement. The fate of the islands' water quality is closely linked to the choices that will be made in coming years about how the vast agricultural fields will be used.

Polluted Components

One big contributor to polluted runoff is *sediment*. Derived from eroded soils, hillsides, construction sites, excavation pits, and most importantly abandoned or fallow agricultural fields, sand, silt and clay find their way into storm drains, streams, and ultimately into sensitive nearshore marine communities including reefs, fish habitats, estuaries, and other restricted shallow water environments where sediment accumulation may be harmful. Water turbidity increases where sediment loading is intense, suffocating delicate marine organisms or filling in wetlands and waterways. Although sediments are present naturally in water, any type of land-disturbing activity generally increases sediment delivery to surrounding water bodies. Few disagree that construction projects accelerate erosion, but best management practices can be adopted and enforced to minimize the damage.

Another major component of polluted runoff is derived from industrial and urban sources. Combined pollutants from roadways, vehicles, industrial facilities, oil refineries, and manufacturing plants create a lethal soup. Over the past few decades, many hazardous substances from industry have found their way into the environment through a combination of routine releases, leaks, and spills. Although regulations exist that govern the use and disposal of such substances, it's difficult to keep pace with the proliferation of new chemical compounds.

With more than 4,000 miles of roads and one million vehicles registered statewide, the residue of heavy metals from cars and trucks alone contribute significantly to non-point source pollution. In Hawai‘i, tons of lead were released into the environment in 1971 from the use of leaded gasoline, and it took seventeen years until all alkyl-leads were finally eliminated. Studies suggest that lead, possibly from brake pads, is still being added to the environment. Zinc and cadmium from car tires are worn off with constant treading. Chemical runoff from homes is also significant; copper from plumbing and gutter linings seeps into storm drains. The impacts of industrialization are growing daily.

Maps of impaired water bodies are available from the Hawaii Department of Health[28]. These areas, known as "water quality limited segments," are mapped so that practices within these regions can be monitored and regulated. According to the Environmental Protection Agency's National Water Quality Inventory 2000 Report, in Hawaii only 32% of surveyed rivers meet their designated uses, and 69% of surveyed rivers are impaired; all of the surveyed estuaries and bays in Hawaii fully support aquatic life, but only 86% fully support fish consumption and shellfish harvesting, and only 74% fully support swimming. The most significant pollution problems in Hawaii are siltation, turbidity, nutrients, organic enrichment, and pathogens from nonpoint sources including agriculture and urban runoff.

Managing Watersheds

Watersheds consist of the land traversed by run-off, stream channels and floodplains, and the coastal waters they enter. In Hawaiʻi, these are increasingly found to violate water quality standards set by the EPA. A list of impaired water bodies in 1998 included nineteen coastal sites and three streams. In 2002, this had risen to fifty-nine streams and 139 coastal stations exceeding federal regulations.[29] By 2004, the list included seventy streams and 174 coastal stations.[30] From 2002 to 2004 no stream or previously listed coastal station was delisted despite funding for mitigation from the State Department of Health and the U.S. EPA. Although watershed management, it appears, is losing ground to pollution every year, there are examples of individual stream systems and coastal sites where the level of degradation is improving due to community and state efforts.

The Hawaiians managed watersheds such that they lived sustainably for generations with a large community of many hundreds of thousands of people. The key to their success was that they managed the watershed as a whole system, not piece by piece. Watersheds today are managed by separate agencies primarily concerned with achieving isolated and uncoordinated mandates. The result is that over time, water quality declines, watersheds decay, and coastal water bodies accumulate pollutants.

Taking a cue from the ahupua'a system, the Department of Health (DOH) now recognizes that the fragmented management system employed in the Hawaiian Islands is failing to achieve advances in coastal water quality. Hence, DOH has combined with the Hawaii Coastal Zone Management Program, in the state Office of Planning to offer watershed planning guidance to agencies, nonprofits, industries, and neighborhood groups seeking to recover and sustain watersheds. The goal of the effort is to improve coastal water quality by reducing land-based sources of pollution and restoring natural habitats[31]. The guidance builds on the DOH coastal nonpoint pollution control program management plan (1996), implementation plan (2000), and action strategy (2004) to address land-based pollution threats[32].

A Control Program

The July 2000 implementation plan published by the Department of Health Polluted Runoff Control Program recognizes that polluted runoff is a major state-wide problem.[33] The plan presents an approach for handling key elements of non-point source pollution required by the EPA to qualify for federal funding. The plan identifies polluted water bodies, "water quality limited segments," resulting from polluted runoff, many of which are coastal and estuarine environments.

Prior to 1994, Hawaiʻi did not have a storm water program. Consequently, storm drains and stream channels served as conduits for rapid transport, accelerating the accumulation of toxic materials in our waterways. But in 1994, the federal government initiated a change with the Non-Point Pollution Control Act.[34] With more than 300,000 residents calling the capital home, the City of Honolulu was the first city in the state required by federal law to apply for a Non-Point Source (NPDES) permit. The permit obligated the City to institute a water-quality monitoring program. Recent amendments in federal regulations call for all cities with more than 100,000 people to apply for non-point source permits.[35]

Yet even in places where existing regulations have changed or new legislation has been passed, non-point source pollution is not being reduced as much as expected or hoped. Critics say that within the state there is ambiguity and confusion over which agency should lead the way in coordinating the various water quality programs and enforcing water quality mandates. One agency continues to channelize streams while another calls for reductions in polluted runoff. This lack of clarity among agencies means that the state has no integrated water management plan for watersheds that are included in the Department of Health's Polluted Runoff Control Program of 2000, a part of the Clean Water Branch and Coastal Zone Management Program.[36]

This program was initiated after a 1987 federal mandate, Section 319 of the Clean Water Act, specifically addressing non-point source pollution. The program administers grants and projects that purify bodies of water impacted by non-point source pollution. Under this mandate, the federal government provides funds to state agencies for polluted runoff mitigation programs, and pushes for individual states to allocate matching funds in return. To date, Hawai‘i has been very lax about contributing money towards polluted runoff alleviation, which means that the state has trouble getting the federal dollars that require matching state funds. Not only do state budget decisions determine the number and types of projects funded, but also the number of people dedicated to the issue of polluted runoff.

To quality for federal funding for its polluted runoff program, Hawai‘i has successfully addressed nine key elements in its implementation plan for the polluted runoff program.[37] According to the EPA:

1. The state program contains explicit short-and long-term goals, objectives and strategies to protect surface and ground water.
2. The state strengthens its working partnership and linkages to appropriate state, interstate, Tribal, regional and local entities (including conservation districts), private sector groups, citizen groups and federal agencies.
3. The state uses a balanced approach that emphasizes both statewide non-point source programs and on-the-ground management of individual watersheds where waters are impaired or threatened.
4. The state program (a) abates known water quality impairments from non-point source pollution and (b) prevents significant threats to water quality from present and future non-point source activities.
5. The state reviews, upgrades, and implements all program components required by section 319(b) of the Clean Water Act, and establishes flexible, targeted, and iterative approaches to achieve and maintain beneficial uses of water as expeditiously as practicable.
6. The state reviews, upgrades, and implements all program components required by section 319(b) of the Clean Water Act, and establishes flexible, targeted, and iterative approaches to achieve and maintain beneficial uses of water as expeditiously as practicable.
7. The state identifies Federal lands which are not managed consistently with State non-point source program objectives. Where appropriate, the state seeks EPA assistance to help resolve issues.
8. The state manages and implements it non-point source program efficiently and effectively, including financial management.

9. The state periodically reviews and evaluates its non-point source management program using environmental and functional measures of success, and revised its non-point source assessment and management program at least every five years.

In its September 2000 review of this plan, the EPA commended the state of Hawaiʻi for integrating pollution control measures under the federal Clean Water Act and the Coastal Zone Act.[38] The level of public outreach and participation during the development of this plan was noted, and the Hawaiʻi implementation plan was described as "providing the needed framework to guide the continued development and implementation of the Polluted Runoff Program in Hawaiʻi."

Whether directly or indirectly, current state and county regulations address all of the coastal non-point source pollution programs and management measures. However, a lack of funding and an insufficient number of staff impedes the success of these regulations. Even in places where the program has been implemented, the measures are not reducing the inputs from non-point source pollution as much as expected. It is critical for a state agency to assume responsibility for coordinating all programs and enforcing water quality regulations, to ensure the health of our state waters.

Persistent Pesticides

As large-scale agriculture took hold in Hawaiʻi during the early 20th century, there was an escalating demand for fumigants, nutrients, pesticides, and fertilizers. Though groundwater sources typically rest 1,000 feet below the leeward plains, runoff from heavily irrigated fields leached downward. While saltwater encroachment has long been the source of groundwater contamination, the discovery of trace quantities of several toxic organic chemicals in well water has raised serious concerns.

Prior to the discovery of agrochemical contamination, it was thought that pesticide use posed no threat to human life. Because chemicals are highly volatile, their residues were expected to evaporate as they percolated down through the rock and soil before intercepting the groundwater source. However, since pineapple fields accelerate recharge faster than natural surfaces, the leaching process is catalyzed. Contaminated runoff percolates rapidly into groundwater stores, leaving less opportunity for evaporation and filtration. Not surprisingly, the spatial pattern of contamination shows the highest concentrations of pesticides in the wettest pineapple fields where percolation is highest.

Urban Honolulu streams contain high levels of the pesticides chlordane, dieldrin, and DDT[39]. Fumigants and insecticides such as DDT, aldrin, chlordane, heptachlor, and others used in termite control and agribusiness are present in Hawaii's water. Studies by the USGS have detected these "organochloride" pesticides in stream sediment and fish tissue from selected streams on Oahu. Concentrations declined following bans on their use in the early 1970's and then appeared to level off in the 1980's. Even though they are no longer used, concentrations of these poisons continue to persist in Oahu aquatic ecosystems. The sources of these are agriculture and urban soils that erode and enter watersheds. Although little can be done to correct the concentrations of these compounds in soil, controlling soil erosion (especially during land clearing and construction activities) could reduce levels of pollutants entering streams, and ultimately estuaries and coastal marine ecosystems.

Chemicals of Concern in O‘ahu Drinking Water

Name	Use	Where found	Health effects
Carbon Tetrachloride*	Industrial solvent	Del Monte Navy well (Kunia); Wahiawa; Haleiwa; Wheeler; Camp Stover; Waikele (Navy well)	Probable carcinogen (respiratory cancer, liver tumors, leukemia)
DBCP (1,2-Dibromo-3-chloropropane	Soil fumigant (nematicide)	Hawai‘i Country Club; Waialua; Haleiwa; Wahiawa; Kunia; Mililani	Probable carcinogen; may cause infertility and sterility in exposed workers; probable mutagen
DCP (1,2-Dichloropropane)	Solvent; pesticide in Shell-DD fumigant; contaminant in Telone II fumigant	Mililani	Decreased red blood cells; liver, kidney damage
Dieldrin	Insecticide (termiticide)	‘Aiea to ‘Ainakoa	Probable carcinogen; may damage liver, central nervous system; gastro-intestinal system, kidneys, adrenal glands
EDB (Ethylene dibromide; 1-2-dibromoethane)	Soil fumigant (nematicide); grain fumigant	Waipahu; Kunia	Probable carcinogen; may cause infertility and damage to liver, gastro-intestinal system and adrenal glands
PCE* (Tetrachloroethylene, also known as "perc")	Industrial solvent; dry-cleaning solvent	Del Monte Navy well (Kunia); Wahiawa; Schofield Barracks	Probable carcinogen; (leukemia); damage to nervous system; possible reproductive effects; liver, kidney damage
TCE* (Trichloroethylene)	Industrial solvent; inert ingredient in pesticide formulations	Del Monte Navy well (Kunia); Kunia; Hawai‘i Country Club; Kipapa Gulch; Moanalua; Waialua Waipi‘o Heights; Waipahu; Schofield Barracks; Mililani	Probable carcinogen; (including leukemia); damage to liver, heart, kidneys, central nervous system
TCP (1, 2, 3-Trichloropropane)	Degreasing agent; inert ingredient in some pesticide formulations	Hawai‘i Country Club; Waialua; Waipahu; Kipapa Gulch; Haleiwa; Wahiawa; Waipi‘o Heights; Ho‘ae‘ae; Kunia; Mililani	Probable carcinogen; damage to central nervous system, liver, kidneys

*Contaminant whose primary source is almost certainly a military application.

Source of information on contaminated areas is the Department of Health Safe Drinking Water Branch list of contaminated wells, printout dated March 5, 1996, and news reports of Dieldrin contamination, early April 1996. The DOH list reports all positive test results for regulated chemical contamination at drinking water sources going back to 1991.

Environment Hawai‘i – 1996

In central O‘ahu, contamination by dibromochloropropane (DBCP), ethylene dibromide (EDB), and trichloropropane (TCP) forced the temporary closing of several drinking-water wells because of their suspected health risks. The public health hazards posed by agricultural contaminants are very real, and potentially lethal. EDB and DBCP are now banned from use in the islands. Other chemicals of concern are nitrates, trihalomethanes, atrazine, and the industrial chemicals TCE, EDB, and carbon tetrachloride. Groundwater contamination maps showing chemical compounds found in Hawai‘i's drinking water are posted annually on the Department of Health website.[40] These maps show locations of wells that are keyed into tables of contaminates and their concentrations as measured in DOH water samples.

Although contamination events in the 1970s and 1980s frightened residents with regard to the safety of their drinking water, they served as a warning for regulators and residents. Contamination of water supplies reaffirmed the basic importance of water for life, and the concept of cause and effect within the hydrologic cycle. Thanks to these experiences, a more effective statewide system of monitoring developed. Although we must now pay for our past mistakes, we are also learning how to avoid repeating them, and how to mitigate future fumbles.

The Water We Drink: *Wai Manalo*

Frightening though some accounts may sound, the drinking water in Hawaiʻi remains some of the best in the world. The water we drink principally comes from groundwater, including the flow from artesian wells and springs, or from surface waters. The source of water plays a major role in determining our water quality. The headwaters of our streams generally have pristine chemical quality, but as streams travel through dense agricultural fields, residential developments and urbanized centers, the flow entrains dissolved solids, nutrients, bacteria, sewage effluent, industrial wastes and urban byproducts. Because of its innate purity, groundwater is often preferred for municipal use. However, despite nature's capacity for filtering out unwanted substances, contaminants are finding their way into some subterranean aquifers.

Table 5.22-- FRESH WATER USE, BY TYPE, BY COUNTY: 2000

[Million gallons per day]

Use	State total	Hawaii	Honolulu	Kalawao	Kauai	Maui
Total	628.43	53.41	216.91	0.09	45.20	312.82
Ground water	428.00	44.55	208.84	0.09	25.83	148.69
Public supply 1/	242.83	31.16	164.81	0.09	14.94	31.83
Industrial	14.50	0.04	12.93	-	0.27	1.26
Thermoelectric	-	-	-	-	-	-
Irrigation	170.67	13.35	31.10	-	10.62	115.60
Surface water	200.43	8.86	8.07	-	19.37	164.13
Public supply 1/	7.60	2.50	-	-	-	5.10
Industrial	-	-	-	-	-	-
Thermoelectric	-	-	-	-	-	-
Irrigation	192.83	6.36	8.07	-	19.37	159.03

1/ Includes water withdrawn by public and private water systems for use by cities and military bases. Water withdrawn by these facilities may be delivered to users for domestic, commercial, industrial, and thermoelectric purposes, or may be used for water and wastewater treatment, pools, parks and city buildings.

Source: U.S. Geological Survey, Water Resources, records.

Contamination, defined as any substance hazardous to health when present in sufficient quantities, is rare at the headwaters of streams or in the groundwater below natural forests. However, Hawaiʻi's highly permeable geology, though responsible for the abundance of water, actually increases the mobility of contaminants, allowing them to flow quickly into the aquifer. As water travels over the land or through the ground, it dissolves naturally occurring minerals and can collect substances resulting from the presence of animals or human activity.

According to both state and national law, citizens of Hawaiʻi have a right to clean drinking water.[41] Federal laws have become increasingly stringent; potable drinking water systems are prohibited from tolerating any contaminants that could compromise public health, and must not contain pathogenic organisms, toxic material, or any other substances that may be deemed harmful. The national Safe Drinking Water Act of 1975 requires the EPA to establish clear drinking water standards for public water supplies, and monitoring of municipal and privately owned water systems.[42] Enforceable drinking standards, called Maximum Contamination Levels, are required for every region.

The State Legislature, in recognition of the need to support drinking water quality by protecting groundwater quality, authorized the Hawaiʻi Groundwater Protection Program[43] to monitor public drinking water wells. The EPA and the Hawaiʻi State Department of Health also require the Department of Water Supply to regularly test the drinking water. Several localized contamination sites have been identified, though widespread contamination has never been detected. Not surprisingly, the regulatory agencies disagree about the significance of these preliminary findings. Though the state is confident that monitoring is sufficient to detect potential threats, federal agencies are concerned that these initial findings will instill a sense of complacency. They recognize that although serious agricultural and industrial contaminants were not identified in initial surveys, they may still be present given the limited scope of early monitoring efforts.

In 1999, each household in the state began receiving Water Quality Reports in the mail.[44] The reports of drinking water contamination are based on current Department of Health monitoring data for public drinking water wells; however, each water supply board is responsible for sampling on individual islands. The reports educate citizens about their drinking water source, indicate any detected contaminants or elements in the water, and assure residents that drinking water meets all the safe drinking water standards. The DOH is establishing sampling protocols for drinking water wells including monitoring of micro-organisms, total coliforms, fecal coliforms, *E.coli*, inorganic and organic chemicals, radionuclides, and turbidity. Each property requires special tests for detection, yet critics of the program worry that not enough attention is being given to *endocrine disrupters*. This class of chemicals is thought to affect cells by interfering with the endocrine system, which controls reproduction, growth and development in humans and many animals.

Only regulated compounds have established maximum contaminant levels. During routine sampling by DOH across the state in 1998, trace amounts of organic chemicals were detected in separate water systems. Trichloroethylene, a common metal cleaning and dry cleaning fluid, was found in Honolulu Board of Water Supply pumps in Waipahu and Haleiwa. The contaminants were at levels far below federal MCLs (Maximum Contaminant Levels) of 5ppb. Isophorone, used in herbicides, paints and adhesives was detected in Punalu'u, but this contaminant remains unregulated to date, so no safe limits have yet been established in Hawaiʻi. The presence of ethylbenzene, a major component of gasoline, was confirmed in Volcanoes National Park, but also at levels far below MCL.[45]

Swimming with Bacteria

Frightened by a flurry of water quality violations and media scares in the early 1990's, Hawai'i residents became increasingly concerned about the health risks of swimming at Hawai'i's beaches. Monitoring of *Enterococcus*, a fecal bacterium, showed that waters off Kuhio Beach and Keehi lagoon were some of the most polluted in the state. When debris, including syringes, washed onto a few of O'ahu's crowded tourist beaches, at the same time that surfers and swimmers were reporting strange lesions on their bodies, a barrage of accusations started flying. The public demanded answers about the safety of Hawai'i's swimming waters.

Fears surfaced again following the forty-eight million gallon sewage spill in the Ala Wai Canal during the heavy rains in the spring of 2006. The horrifying death of Oliver Johnson after he fell or was pushed into the Ala Wai shortly after the spill galvanized local fears of beach bacteria to the point that Honolulu and Waikiki beaches and surf breaks were eerily empty for over six weeks following the spill.[46] Johnson died of massive organ failure brought on by septic shock caused by *Vibrio vulnificus*, a bacterium of the cholera family that multiplied in his body and eventually shut down his principle organs. An important aspect of Johnson's situation is that he did not go to a hospital until some time had passed after the first signs of infection, plus he had open wounds and suffered from chronic liver disease – both conditions that greatly elevate the risk from polluted waters.

The *V. vulnificus* that killed Johnson is from a family of bacteria that is "particularly happy" in seawater say microbiologists. It does not usually attack people but can mutate into an invasive form capable of overwhelming the body's defenses, especially in patients with chronic liver disease. Most of Hawai'i's *Vibrio* cases are from wound or blood infections and ear infections, the bacteria can cause vomiting, diarrhea and abdominal pain. *V. vulnificus* infections can be easily cured within the first day or two with antibiotics, but once it invades the bloodstream, there is a 50% chance of survival according to the Centers for Disease Control and Prevention.

In fact, deaths from waterborne bacteria encountered in our oceans and streams are relatively rare. There have been five deaths in Hawai'i from the family of *Vibrio* bacteria since 2001.[47] Also in Hawaiian waters are the potentially fatal bacterial infections *leptospirosis, staphylococcus aureus* and group *A streptococci*. Since 1974, a total of nine deaths in Hawai'i have been attributed to *leptospirosis*, a freshwater bacterium found in Hawai'i streams and splash pools.

Many swimmer infections that lead to severe complications are just a case of bad luck. One infectious disease specialist interviewed in 2006 said, "With all the people who get cuts and abrasions throughout the state of Hawai'i, only a small number come out with serious life-and-limb infections. It's an uncommon event, unless you're unlucky and pick up the wrong bug, the one that produces those chemical toxins" that can rapidly advance through the human body.[48]

So how do you protect yourself from waterborne bacteria? Health officials point out that an open wound or a weakened immune system put you at increased risk of contracting harmful bacteria in our waters. Certain conditions, such as warm seawater or freshwater streams and ponds likely to be contaminated with animal urine, boost the chances of exposure. The best thing is to avoid entering Hawai‘i’s streams and oceans when you have an open wound especially if you have a weakened immune system.

A good cleansing with antibacterial soap and water to remove dirt and damaged tissue from wounds is still the favored treatment. Keeping cuts and scrapes clean and dry remains the best prescription for preventing skin infections that can worsen and invade the bloodstream, causing life-threatening complications. And with the speed at which these infections can spread, physicians urge people to seek medical care at the first sign of fever, nausea and increased swelling, pain and redness. If you have swum or walked through a stream or waterfall and develop any flu symptoms, treat it as *leptospirosis* and immediately go to a doctor. If you have been in the ocean and develop an infection, do the same thing.

Beach Closures

Public reports in 2006 after the Ala Wai spill highlighted the fact that potentially harmful bacteria are present in the same waters where we swim and play – and have been all along. According to the Natural Resources Defense Council, the state has approximately twenty-four miles of shoreline considered safe, accessible, and generally suitable for swimming.[49] The process of establishing sampling protocols, indicator organisms, and beach closing standards for these swimming locations is complex. Even though Hawai‘i’s bacterial standard is one of the strictest in the nation, with water samples having to be less than a geometric mean of seven *Enterococcus/*100ml compared to a nation-wide value of 35/100ml, there is still considerable controversy over implementation of state guidelines.

The State has proposed a two-part system of designating harmful levels of coastal bacteria. Two types of fecal indicator bacteria are used, *Enterococcus* and *Clostridium perfringens*. If the *Enterococcus* standard exceeds the permitted level, and *Clostridium* exceeds set limits, then the state will close a beach. Yet, the federal government wants the state to close a beach even when just the *Enterrococcus* levels are exceeded, and will not accept the state’s proposal until studies clearly quantify the health risks associated with a particular level of *Closridium*. Getting such numbers will require extensive research in beach areas where there are a number of disease outbreaks, something Hawai‘i has not yet experienced.

The standards of the EPA for *Enterroccoccus* were created from data collected in places like New York City and the Great Lakes, where pollution-related disease was frequent enough to conduct a large-scale study. But in Hawai‘i *Enterroccoccus* may be found in uncontaminated soil as it grows naturally in our environment.

The bulk of the shoreline sewage problem is attributable to three sources:

1) Sewage spills from heavy rains that generate overflows in wastewater treatment plants,

2) Breaks in sewer lines delivering sewage from homes and businesses to treatment plants, and

3) Electrical failures at pumping stations and treatment facilities.

Periodically, a beach will close if fuel or oil from a boat threatens a swimming area. Wailua Beach on Kaua‘i closed after approximately 16,000 gallons of diesel fuel spilled from a grounded fishing vessel in 1999.[50] Interestingly, 99% of beach closures in Hawai‘i are due to spills, compared to 47% of postings on a national level. The question then becomes: does Hawai‘i truly have more spills than other parts of the country, or are we failing to detect contamination from other sources? The EPA feels that many potential sources of bacterial pollution are not being adequately monitored or addressed in the state.

One of the major causes of beach closures in other parts of the country is polluted runoff, particularly in urban areas. In 1995, an extensive study of Santa Monica Bay verified the link between illnesses in swimmers and polluted runoff.[51] This study found that people who swam within 100 yards of storm drain outlets are 50% more likely to get colds, flu, sore throats, and diarrhea than those who swam farther away. The study concluded that as many as one-in-ten of those individuals swimming near storm drains will experience symptoms similar to *pathogenic exposure*. Though this sort of exposure is not usually life threatening, the wellbeing of affected individuals can be compromised, and any viruses present in the water can be a serious health threat to children and the elderly.

Unfortunately, considerable amounts of misinformation about water quality continue to create anxiety about swimming in the ocean. One prevalent misconception is that all infections are from human-contaminated sources. Although swimmers are capable of transmitting infections to one another, such as *Stapylococcus aureua*, marine organisms can also carry communicable viruses and bacteria. The most common water-borne public health risk in Hawai‘i is related to *leptospirosis*, contracted from the urine of mongoose and rats in freshwater. The DOH recommends that school-aged children in particular should avoid all streams, in order to reduce the health risks of *leptospirosis*.

In Hawai‘i, only one beach, Lydgate Park on Kaua‘i, closed in the late 1990s because of water monitoring data.[52] Some people argue that this proves Hawai‘i’s excellent water quality, while others disagree, saying that if only one beach was closed due to monitoring data, then the water-monitoring program must be inadequate. Certainly in Hawai‘i far more beaches aren’t being monitored than those that are.

Surfrider provides a $6 do-it-yourself water quality testing kit, approved by the EPA, to check for levels of coliform bacteria. Since the state is most likely to detect problems from known sewage spills, the threat of polluted runoff may well go overlooked under the present monitoring system. As Surfrider’s program demonstrates, one way to protect the public from polluted water is to develop active citizen monitoring, where people claim responsibility for the waters they share.

Limited financial resources certainly play a role in the State’s monitoring program, but a cost-benefit analysis shows that increased water monitoring would be a sound financial decision for Hawai‘i. It would be sound planning for the state to protect the tourist industry by ensuring our waters are safe. The State of California recently adopted a “right to know” bill that requires monitoring of all public beaches with more than 50,000 annual visitors, and regular sampling near storm drains.[53] Critics of Hawai‘i’s program suggest that a protocol similar to California’s should be applied to Hawai‘i if the state is going to guarantee the safety of swimming water, especially against point source pollution.

The good news for those of us who wade, swim, fish, paddle, and surf is that Hawai‘i’s dirtiest monitored beaches are still clean by EPA standards. Based on counts of bacteria, viruses and protozoan pathogens, one study identified O‘ahu’s dirtiest waters, such as Kaelepulu Stream in Kailua Beach Park, as very poor, giving it a rating of 35 *enterrococcus* CFUs (colony forming units) per 100 milliliters. Though poor by Hawai‘i’s standards, this is still within EPA safe swimming guidelines.[54] Addressing the polluted runoff challenge may well be the best place to start to increase the quality of Hawai‘i’s waters.

Mamala Bay - the Final Word?

In 1990 the Sierra Club Legal Defense Fund and Hawaii’s Thousand Friends sued the City and County of Honolulu for violations of the Clean Water Act related to failing to upgrade sewage processing to the national standard of secondary treatment. The outcome of the suit was the creation of a study commission to establish the nature of ocean circulation in Mamala Bay (defined as the embayment between Diamond Head and Barbers Point) and the character of point and nonpoint pollutants and their potential impact on humans and the ecosystem.

Among the study’s findings in 1995 was that sewage plumes from City outfalls were greatly diluted within the zone of the diffusers at the head of outfall pipes[55]. Point sources of pollution had comparatively minor effects on phytoplankton and benthic communities and there was conclusive evidence that nutrient enrichment in shoreline areas was closely related to non-point sources such as cesspool and groundwater drainage or to localized discharges such as from Fort Kamehameha outfall and the Ala Wai Canal. The study found that discharges from Sand Island were able to reach most beaches in the bay (though only rarely), whereas those from Honouliuli were only able to reach only western beaches. The frequency of point source pollution on beaches was low and the risks of contracting an infectious disease by bathing, swimming, surfing or fishing in Mamala Bay waters was low. The Ala Wai Canal was determined to be a major source of contamination of Waikiki Beach, and non-point sources were the primary cause of contamination of beaches in the eastern portion of the bay. Since the report was issued more than a decade ago, Sand Island Wastewater Treatment facility, in keeping with the recommendations of the study commission, has moved to advanced primary treatment with the implementation of ultraviolet disinfection and increased removal of suspended solids.

Who is Watching Our Water?

Monitoring can be the most direct and defensible tool available for evaluating how water quality improves or does not, as a result of regulations and management actions. Hawai‘i’s Department of Health is the principal water-quality monitoring agency, and is tasked with the challenge of implementing a successful program. Monitoring is expensive and, in itself, not necessarily justifiable unless the results or information can be used for specific purposes. The state’s current monitoring plan incorporates four water quality categories: core network, recreational bathing waters, watershed protection, and toxic contaminant screening. Federal agencies such as National Oceanic and Atmospheric Administration (NOAA) and EPA give general guidelines for the state, but continental watershed models cannot necessarily be applied to Hawai‘i’s dramatically different environment.

The state of Hawai‘i and the City of Honolulu have suffered thousands of violations under federal regulations and has been criticized over and over again for its water quality management. The greatest impediments to water resource management may be the governmental and regulatory environment in which it operates. Ironically, overlapping jurisdictions may actually impede cooperation between agencies causing responsibilities to be shifted, ignored, and even resented. Compounding the problem is the recognition that agency programs may not be structured to solve complex watershed management problems. In the end one must ask, is there a demonstrable health problem?

The feasibility of establishing a comprehensive and successful water monitoring and clean-up program is limited by the reality that watersheds, groundwater, and coastal waters are segmented under a multitude of private owners, and county, state, and federal programs. For watershed management to be successful, all stakeholders must establish an overarching culture of positive support, common purpose, and mutual respect. This will require defining community goals, developing shared tools, and agreeing on common measures of success. How well we protect the remaining natural essence of our state's water supply and the cleanliness of natural coastal waters will foreshadow our success worldwide in preserving the ultimate island: Earth.

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[4] The Sand Island treatment plant has a disinfection unit that blasts treated wastewater with ultraviolet light to kill pathogens before it is discharged off-shore. See High-tech Sewage, supra note 3.
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