Section 7

Resource Conservation and Augmentation

7. RESOURCE CONSERVATION AND AUGMENTATION

Through its review of existing demands, authorized planned uses, and hydrologic data, the CWRM has found that some areas of the State of Hawaii are approaching the limits of groundwater resource development. Nearly all of Oahu, Molokai, and part of Maui have been designated as Water Management Areas, where ground water use and development is regulated by the CWRM. From 1999 to 2001, statewide municipal water consumption increased by almost three percent with most of the increase occurring in the City and County of Honolulu. On Oahu, it is anticipated that ground water resources will be committed within 20 or 30 years, requiring the use of more expensive alternatives like reusing treated wastewater, treating surface water, and desalinating brackish or ocean water.

Estimates of ground water availability throughout the state are based on the best available, albeit limited, data. There are emerging indications of threat to our ground water sources that cannot be ignored. For example, on Molokai, ground water sustainable yield for the Kualapuu Aquifer System, which was initially estimated at seven mgd, was later revised to five mgd, and much of that water has either been allocated or reserved. On Maui, the overpumping of the Iao aquifer has threatened the island's major source of drinking water. Elsewhere in the State, there are indications that environmental effects and responses due to imposed stresses may be affecting the viability of certain aquifers, warranting closer monitoring and the implementation of management strategies to protect these aquifers from potential damage and depletion. With increasing demand for potable water and uncertainties about ground water availability, all four counties are actively promoting water conservation and are taking steps to increase the use of alternative sources of water.

There are several State and county agencies that currently implement various water conservation measures. Private businesses and organizations have also incorporated varying degrees of water conservation within their operations. Despite these efforts, the State of Hawaii lacks an overall, statewide water conservation program to provide guidance to agencies and businesses beginning a conservation program and to coordinate the various ongoing conservation efforts across the State. Water conservation planning should be an integral component of Hawaii's overall water resource management efforts.

Resource augmentation should also be embraced as an important component of sustainable water resource management. Water augmentation sources include: water that is imported from neighboring regions, water reclamation and reuse, and desalination of brackish water and seawater. Several of the county water and wastewater agencies employ reclamation techniques to process surface water and wastewater. However, as is the case with water conservation, a statewide water resource augmentation program remains to be developed.

This section reviews existing conservation and augmentation activities in Hawaii and establishes goals and priorities for statewide planning programs. The State Water Code states that CWRM shall plan and coordinate conservation and augmentation programs in cooperation with other federal, State, and county agencies, and private and public entities created for the utilization and conservation of water.[1] The State should provide leadership

[1] HRS §174C-5(12) and §174C-31(d)(4).

and guidance for the establishment, development, and implementation of statewide water conservation and augmentation programs.

7.1. Goals & Objectives

CWRM, on behalf of the State of Hawaii, establishes the following goals and objectives for water conservation and resource augmentation programs and projects statewide[2]:

- Foster the collaborative development, implementation, and update of short- and long-range plans for conserving and augmenting water supplies.
- Promote coordination and cooperation among agencies and private entities.
- Provide guidance, assistance, and oversight in the establishment, development, and implementation of statewide water conservation and augmentation programs.
- Encourage coordination between conservation activities and augmentation planning.
- Promote the utilization of the best available information and technology in planning and implementing conservation and augmentation projects.
- Provide the regulatory and planning framework for integrating resource conservation and augmentation into a comprehensive water management program.
- Support county and community-based conservation efforts by providing information resources and advisory assistance.
- Encourage water conservation and use of alternative water sources, whenever possible, through comments provided during land use planning and permitting review.

7.2. Developing a Water Conservation Program

Water supply planning and water conservation programs are closely related. Conservation programs directly affect short- and long-term water requirements and help reduce the risk of water supply deficiencies. Water conservation measures are implemented to achieve the following objectives:

- Reduce the demand for water;
- Improve efficiency in use and reduce losses and waste of water; and
- Ensure the long-term viability of the resource.

[2] HRS §174C-5(12) and §174C-31(c)(1).

Although government has taken the initiative in pursuing water conservation policies, the success of any water conservation program ultimately depends on public participation and cooperation. It is essential to the development and implementation of a good water conservation program that the community embraces and adopts a conservation ethic. Community leaders, elected officials, government agencies, private water companies, and environmental groups must be involved in the planning process. Representatives from industry, commercial associations, civic organizations, churches, labor unions, school boards, and the media can actively engage in public education and planning efforts to help formulate a cost-effective water conservation program. Public and private input will ensure that conservation measures are publicly accepted and cost-effective as compared with the design and construction of alternate water supply projects.

Water conservation programs may involve short-term and long-range conservation measures. Short-term measures may include such practices as the implementation of temporary restrictions on lawn watering and car washing. Long-range water conservation measures may include the installation of low-flush toilets, low-flow showerheads, pressure regulators, and water-efficient appliances in homes and offices. In industry, water conservation can be achieved through the recirculation of cooling water and the re-use of treated wastewater. In agriculture, drip irrigation and tailwater recovery are effective conservation measures. Surface mulches, xeriscaping, and pressure regulators can also help conserve water for landscaping applications.

Finally, a water conservation program must also include a mechanism for updating program elements. The conservation program should undergo periodic assessment to measure program effectiveness and be revised accordingly. An advisory committee is an effective forum for program review, evaluation, and update.

7.3. Water Conservation Measures

Water conservation measures may be described in four general categories:

1. Resource conservation;
2. Water system conservation;
3. Consumer conservation; and
4. Public education programs.

Resource conservation and water system conservation are primarily the functions of a water utility. As discussed below, however, the utility should also promote consumer conservation and incorporate a significant public education component in its water conservation program.

7.3.1. Resource Conservation

Resource conservation is intended to assure optimum development of sources to protect them against contamination, waste, and overdraft. In Hawaii, public control of watershed lands has long been advocated to conserve and protect ground water resources.

Watersheds are precipitation infiltration areas that are crucial to the replenishment and preservation of basal aquifers.

Rules and regulations to control the drilling of private wells and to guard against wasteful operation have long been in effect in Hawaii, particularly on the island of Oahu. The State Water Code empowers CWRM to designate Water Management Areas (WMAs) where it finds that water resources therein are in danger of overdraft. Designation of a WMA provides for CWRM jurisdiction over water use within the WMA.

An important aspect of resource conservation is the continued surveillance of hydrologic conditions to provide data, enabling long-term assessments of ground water conditions. The results of these assessments provide the basis for corrective action in the overall management of ground water resources.

The preservation of ground water resources is dependant on the effective use of all water resources. Wastewater reclamation, surface water recovery and storage, desalination, improved irrigation practices, and other means to make greater use of our total water resources all play a part in protecting ground water resources against overdraft.

7.3.2. Water System Conservation

A water utility can take various actions to affect savings by better operation and control of transmission and distribution systems. Under certain conditions, the county water departments have the authority to impose mandatory restrictions on water use. Under typical conditions, there are two primary areas where water-system conservation can be most effective: metering of water supplies and leak detection and control. To a lesser extent, reduction in water pressure can result in some degree of reduced consumption.

Some water utilities bill their customers on a flat-rate basis. Many others, especially among larger municipalities, require the installation of water meters and bill customers for metered water use and service. The practice of charging customers on the basis of water use provides a strong incentive for customers to use less water. The use of a tiered rate structure based on water use and the discouragement of master metering for large developments are two effective means for promoting conservation.

Customer use does not account for all the water passing through a water system. Water utilities must also consider the volume of unaccounted-for water. Unaccounted for water includes system leaks, unmetered water use through fire hydrants, water illegally taken from the distribution system, inoperative system controls, and water used for street cleaning and flushing water mains and sewers. On Oahu, the Honolulu BWS accounts for some of these losses by metering water used for street and sewer flushing.

A program of leak detection, meter testing and replacement, and pipe relining and replacement can appreciably reduce the amount of unaccounted for water. A good program of prevention, including proper water system design, careful installation, and effective corrosion control measures, is the best way to reduce water losses. However, each county must determine the cost-effectiveness of such a program.

Although not a major factor, reduction of water pressure can save water. The county must determine whether operating at a lower pressure is practical and if certain services, such as fire-fighting, would be negatively impacted.

7.3.3. Consumer Conservation

In general, residential water use includes more than half of the total water use from county systems. Residential water use can further be classified as water used inside and outside the house. A typical home uses between 60 and 80 gallons per capita per day (gpcd).

A 1999 study published by the American Water Works Association (AWWA) Research Foundation reported that homes with water conservation measures in place use an average of 32% less water compared to homes without water conservation measures. Inside the home, most water is used in the bathroom. Many states now require the installation of water-efficient devices in new construction. Some of the more common water-conserving fixtures are as follows:

- **Low-flush toilets:** These units use no more than 3.5 gallons per flush, approximately half the volume of water used in older toilets. Ultra low-flush toilets are also available, which use only 1.5 gallons per flush. These toilets can be more expensive than the standard models.

- **Low-flow showerheads:** Ordinary showerheads deliver from five to eight gallons per minute (gpm). A low-flow showerhead uses about 2.75 gpm, resulting in a savings of roughly 50% or more.

- **Low-flow faucets:** The AWWA reports that the savings from the use of low-flow faucets is estimated to be less than 1.0 gpcd.

- **Water-efficient dishwashers and clothes washers:** These appliances use significant amounts of water. New units on the market now make it possible to save about five gallons per load for dishwashers and about six gallons per load for clothes-washing machines.

Because of wide variations in climate and landscaping, water used outside the home may vary between 30 and well over 100 gpcd. Water used outside the home is primarily water for landscape irrigation. Water conservation measures that can be used include improved irrigation techniques, better turf preparation, and alternative landscaping designs that reduce water use. Improved irrigation techniques can save from 20 to 50% of the water applied.

The potential savings from lowering landscaping water use can be considerable. Efficient irrigation combining the appropriate sprinkler heads, uniform water application rates, automatic controllers, and the proper zoning of turf and planting beds can reduce water use substantially.

7.3.3.1. Reduction of Commercial Water Use

Water use for commercial establishments is confined mainly to sanitation and landscape irrigation. Many of the residential water-saving techniques discussed above apply to commercial establishments. Some of these are as follows:

- Installation of water-saving devices;
- Adjustment of valves on toilets and urinals;
- Use of water-efficient appliances;
- Use of low-flow shower heads;
- Elimination of leaks;
- Adoption of water-recycling practices, such as car-wash water;
- Use of low water-use landscaping; and
- Installation of automatic irrigation systems and moisture sensors.

7.3.3.2. Reduction of Industrial Water Use

Water consumed by industry is primarily used for cooling, landscape irrigation, sanitation, and production (process) water. Conservation of water used for irrigation and sanitation may be realized through the same methods recommended for residential and commercial users. Other means of reducing industrial water use are as follows:

- Conversion of once-through cooling systems to closed systems;
- Reclamation of wastewater;
- Elimination of water waste during cleanup; and
- Design of more efficient systems for process water use.

In Hawaii, the potential of reducing industrial water use is not as great as in other parts of the country. Nevertheless, opportunities for savings still exist, especially in canneries, power plants, and milk-processing plants.

7.3.3.3. Water Pricing

Water rates are designed to provide revenues for a utility to defray operating and capital expenses. Various types of rate structures have been employed by utilities to encourage water conservation. The principal types of rate structures are:

- **Uniform rates:** The uniform rate structure charges the same unit rate for all water usage. This method provides little incentive to conserve, especially to above-average per capita consumers.

- **Inclining rates:** This rate structure applies a unit charge that increases with water usage, thus making the large users responsible for the incremental cost of providing the additional water consumed. This structure encourages the large users to conserve, especially if the rate increases are significant.

- **Seasonal rates:** Under this rate structure, the unit cost of water increases during peak seasonal use periods, primarily during the summer. The seasonal rate structure is becoming more common throughout the country. The obvious objective is to provide consumers with an incentive to reduce water use during peak demand periods.

The rate structures listed above are basic concepts, and can be implemented in a number of variations and combinations. Water utilities must consider local and regional conditions when developing rate structures.

7.3.4. Public Information Programs

Public information programs are intended to foster a conservation ethic among water users. In order to achieve reductions in water use, it is essential for consumers to make a voluntary commitment to conserve water and to practice resource stewardship.

Public information programs can educate consumers on how to prevent waste by discouraging activities such as indiscriminate flushing of toilets, and running water unnecessarily while taking showers, shaving, teeth brushing, car washing, or watering lawns. The program should include educating consumers on the nature of water sources, the cost of operating a water system, the limited capacity of these sources, and the importance of water conservation.

The effectiveness of a public information program is difficult to measure. However, past programs have demonstrated that in order to be effective, a public information program must be carried out on a long-term basis.

7.4. State and County Water Conservation Programs

Under the State Water Code, CWRM is responsible for planning and coordinating of a water conservation program. CWRM has a State Drought & Water Conservation Coordinator, however, outside designated Water Management Areas or Water Emergency situations, the Water Commission does not have the authority to require the counties and other jurisdictions and interests to actually implement water conservation measures. County governments, however, have the authority to institute mandatory conservation measures, as necessary, by enacting the appropriate ordinances, rules, and regulations.

It is important for a statewide conservation program to be coordinated with the four counties, the Federal Government, and private interests. Establishing a conservation program requires extensive planning and consultation, and successful program implementation requires widespread public participation and cooperation among government agencies, water users, water purveyors, and various community and special interest groups.

The basic goal of a water conservation program is to enhance the welfare of the people of the State through proper development, protection, control, and regulation of the water resources of the State for all beneficial uses. To this end, all water utilities and water agencies are encouraged to adopt policies, principles, and practices for efficient water use through a balanced approach, combining demand management with judicious source development.

The State can provide the counties with guidance and general water conservation plan components that can be adapted to suit local conditions and needs, including policies, strategies, expected results, and guidelines for implementation. A statewide water conservation program should employ the following principles and practices:

- Ensure judicious management and efficient utilization of sources of supply.
- Employ methods and technology to accurately monitor water consumption.
- Conduct inspections of water distribution systems to detect leaks and facilitate timely repair and replacement.
- Establish water use efficiency standards for new plumbing fixtures and appliances. Retrofit existing fixtures with low-flow units.
- Improve land management practices to conserve water.
- Employ efficient irrigation methods and practices.
- Increase distribution and use of educational materials as part of a broad public information program on water conservation.
- Encourage implementation of self-administered water conservation programs for all water users.
- Encourage the use of alternative water sources for non-potable uses.
- Recommend and pursue research on more efficient water use techniques and practices.
- Explore incentives and disincentives for water conservation program compliance.

In hopes of encouraging water conservation programs that apply the principles and practices listed above, CWRM developed a prototype water conservation plan for five of the Department of Land and Natural Resources' facilities. The long-term intent of the *Prototype Water Conservation Plan for the Department of Land and Natural Resources* (February 2005) is to provide a framework for the development of water conservation plans for all State agencies, and to provide conservation program options and strategies for water purveyors throughout Hawaii. To facilitate State agency implementation of water conservation programs, CWRM developed the *Conservation Manual for State of Hawaii Facilities* (May 2007), which contains information on designing a program and water conservation guidelines for indoor domestic uses, landscaping uses, cooling and heating applications, and medical facility uses. The *Prototype Water Conservation Plan for the Department of Land and Natural Resources* and the *Water Conservation Manual for State of Hawaii Facilities* are available on CWRM's website at http://www.hawaii.gov/dlnr/cwrm/planning/conserve.htm.

7.4.1. DLNR Prototype Water Conservation Plan

The *Prototype Water Conservation Plan for the Department of Land and Natural Resources* was completed in February 2005. The plan was designed to serve as a pilot project, with potential application for the development of water conservation plans for typical government institutional facilities.

The DLNR Water Conservation Plan examines five selected facilities as models for other planning efforts. DLNR is an appropriate agency for piloting water conservation planning because the agency has multiple types of facilities and water usage characteristics (e.g., office buildings, baseyards, harbors, municipal/irrigation demands, potable/non-potable water systems). The plan addresses both potable and non-potable water demands, identifies appropriate water conservation measures, provides implementation schedules and budgets for the installation of water conservation measures, and recommends post-installation monitoring of water use.

The plan development was partially funded through the Water Conservation Field Services Program (WCFSP) administered by the U.S. Department of the Interior, Bureau of Reclamation. The WCFSP is designed to: encourage water conservation; assist water agencies to develop and implement effective water management and conservation plans, coordinate with state and other local conservation program efforts, and generally foster improved water management on a regional, statewide and watershed basis. The program emphasizes: water management planning, conservation education, demonstration of innovative technologies, and implementation of conservation measures. The Bureau of Reclamation's *Municipal and Irrigation (M&I) Conservation Plan Guidebook*, which provides methods and measures aimed at improving overall water management, assisted CWRM in the scoping of the DLNR Water Conservation Plan.

The goals of the DLNR Water Conservation Plan are summarized for each facility as follows:

- **Kalanimoku Building:** Achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Kakaako Waterfront Park:** Achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Ala Wai Harbor:** Account for all water usage at the facility, achieve a 15% water use reduction, estimate cost savings over the long term, and free up water supplies for additional uses.

- **Honokohau Harbor:** Account for all water usage at the facility, achieve a 15% water use reduction, estimate cost savings over the long-term, and free up water supplies for additional uses.

- **Hilo Baseyard:** Achieve a 15% water use reduction, estimate cost savings over the long term, free up water supplies for additional uses.

The plan recommends monitoring all conservation measures installed pursuant to the plan through metered water use (water billings).

As stated earlier, one of the key objectives of the project was to serve as a model for developing a statewide water conservation plan. Another goal was to develop an assessment approach and planning methodology that could be used in the formulation of facility water conservation plans. The development of facility-specific water conservation plans begins with understanding each facility's water usage. Creating and adopting a consistent assessment methodology to evaluate water usage and identify possible water conservation measures is the first step in developing a facility-specific water conservation plan. The water conservation assessment methodology could be used as a template by State agencies to conduct internal evaluations of their facilities (either by their in-house staff or by consultants).

The water conservation assessment methodology consists of the following basic steps:

1. Identify current water use at the facility:
   a. Complete a water system inventory to understand the facility's current water system layout.
   b. Gather past water consumption data (e.g., water billings, and water metering records).
   c. List all water uses including domestic, irrigation, maintenance, etc.
   d. Measure water quantities used on average in each water use category. This may require the installation of sub-metering systems to determine specific water usage throughout the facility.
   e. Identify significant water uses.

2. Identify existing conservation measures:
   a. List all existing water conservation measures.
   b. Assess existing water conservation measures and any previous attempts to implement conservation measures to understand relative success or failure.
   c. Identify areas without water conservation measures.

3. Identify applicable/practical water conservation measures:
   a. List potential water conservation measures to be considered.
   b. Discuss potential water conservation measures with facility staff.

4. Complete cost benefit analysis and environmental assessment of potential water conservation measures:
   a. Develop projected water conservation plan implementation costs.
   b. Develop estimated water savings based on water conservation measures selected.

c. Evaluate water conservation plan feasibility through cost /benefit analysis.
d. Complete environmental assessment identifying resources and any possible negative impacts.
e. Develop final recommended water conservation plan based on cost/benefit and environmental analysis.

5. Create a conservation plan implementation schedule:
   a. Develop a timetable of interim and long-term conservation measures for agency implementation.

6. Develop initial steps to be taken by facility:
   a. Consider installing sub-metering systems to monitor water usage.
   b. Identify implementation costs, including labor.
   c. Identify activities for monitoring performance and results.
   d. Educate facility staff on water conservation measures.
   e. Post signs to educate water users on water conservation.
   f. Post signs identifying contacts if facility is in need of repair.

The development of facility-specific water conservation plans for State agencies is an appropriate starting point for a statewide water conservation program. Cooperative efforts between the State and counties can enhance program development and expand its application. General recommendations of the DLNR Water Conservation Plan include:

- Government agencies should pursue public/private partnerships to increase public awareness and to implement and promote water conservation efforts.

- Each State facility/site should designate a project manager to develop and implement a site-specific water conservation plan.

7.4.2. Water Conservation Manual for State of Hawaii Facilities

On January 20, 2006, Governor Linda Lingle issued Administrative Directive No. 06-01 requiring all State agencies and programs to increase their commitment towards implementing innovative and resource efficient operations and management. Examples of better management practices cited in this directive include:

- Reduced energy and water use;

- Reuse and recycle options;

- Improved construction and demolition waste management;

- Environmentally preferable purchasing;

- Efficient use of transportation fuels, especially greater use of alternative fuels; and

- Increased incorporation of sustainable building practices.

New State facilities and augmentations to existing facilities are to be designed and constructed to meet and achieve certification requirements of the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) standards. State agencies are specifically directed to implement water and energy efficient operational practices to reduce waste and increase conservation.

The *Water Conservation Manual for State of Hawaii Facilities*, developed by CWRM in 2007, contains information and guidelines to help State agencies comply with Administrative Directive No. 06-01. The manual provides detailed information on how to implement water efficient practices at State buildings and facilities. The conversion of State buildings and facilities to water-efficient status will assist State agencies in their efforts to obtain LEED certification, as required by the Governor's directive.

7.4.3. County Conservation Programs

In general, the counties practice conservation by protecting watershed areas in order to realize dependable yields. Counties also practice conservation by reducing system leaks and losses, adopting universal metering, encouraging or requiring the installation of devices to reduce water use, implementing public education programs, adjusting water rates to influence demand, and as a last resort, rationing water use during severe shortages.

Water conservation can be beneficial to a water utility and its customers by reducing demand in dry years and prolonging short supplies during other emergency conditions. Efficient water use can also result in energy savings, particularly on hot-water use. It has been estimated that hot-water use can be reduced by almost one-third through effective water conservation measures.

Reduced water use also results in energy savings, as less water must be treated and distributed throughout the system. Moreover, water conservation within the home and in industry decreases the volume of wastewater flow. This, in turn, reduces treatment and collection system costs. In Hawaii, reductions in pumping costs could be significant, and deferred development of new water sources will postpone capital improvement costs.

In planning a water conservation program, a water utility should consider some of the potential disadvantages involved. One of these considerations is the reduction of revenues, the effect of which is felt almost immediately. Less revenue may postpone needed capital improvements, which means the utility could later face higher construction costs.

However, water conservation can also make water available to service undeveloped areas. Water conservation and land-use planning efforts should be coordinated so as to avoid inadequate water availability for future use.

Water conservation cannot be regarded as a substitute for a utility's obligation to maintain an adequate reserve capacity. Without adequate reserves, water shortages may become more frequent, and drought impacts may threaten public health.

Many states and municipalities throughout the continental United States have developed water conservation programs with varying degrees of success. Noteworthy programs have been implemented in cities such as Denver, Oakland, Los Angeles, and Washington, D.C.

The counties of Maui, Kauai, Hawaii, and the City and County of Honolulu have independently undertaken water conservation programs and strategies. Their conservation efforts are summarized below.

7.4.3.1. Maui Department of Water Supply Conservation Program

The County of Maui Department of Water Supply (DWS) provides water service via distribution systems in Central Maui, Upcountry Maui, West Maui, East Maui, and Molokai. Central Maui has the largest number of customers, and includes the areas of Wailuku, Paia, Kahului, and Kihei. The water system in Upcountry Maui covers the largest geographic area and services Kula, Pukalani, Makawao, and Haiku. The East Maui system serves the Lahaina area, and the West Maui system serves Hana. The limited areas on the island of Molokai are served by a county system. Water service on the island of Lanai is provided by a private company.

Water for most parts of Maui County comes from ground water sources. However, the Upcountry water system is supplied by surface water sources, i.e., streams and ditches in East Maui. Likewise, parts of Lahaina are supplied by surface water sources from the West Maui streams and ditches. Surface water is treated and disinfected at three treatment plants in Upcountry, two in Lahaina, and one in Wailuku before it is distributed to customers for drinking. It should be noted that Maui County also provides non-potable water from surface water sources to agricultural users.

The mission statement for the Maui Board of Water Supply is "Provide clean water efficiently." The Board's Strategic Plan includes the following goals related to water conservation:

- Develop adequate water sources, storage, and transmission for both urban and agricultural uses, including mitigation of drought.
- Systematically replace, upgrade, and improve, as needed, existing infrastructure (pumps, distribution and transmission lines, storage, and appurtenant facilities).
- Create long-term innovative and cost-effective financial management programs to accomplish the mission of the department.
- Provide programs to the public to facilitate conservation and promote greater awareness and support of the department and its activities.
- Review the feasibility of integrating the management of public and private water systems.
- Participate in watershed and well-head protection programs, and management of all of Maui County's water resources.
- Maintain a living Water Use and Development Plan through the integrated resource planning process.

The Maui DWS has implemented a water conservation program that includes a significant public outreach component. Information on consumer conservation measures, waste prevention, and general conservation information are available to the public, as well as free low-flow shower heads, faucet aerators for the kitchen and bathroom, and leak-detection dye tablets. The following are accessible from the department's website (http://mauiwater.org):

- Information on the Wellhead Protection Program to ensure ground water quality;
- Checklist of conservation ideas for the home;
- Checklist of conservation ideas for the yard;
- Checklist of conservation ideas for condominiums;
- Information about detecting leaks in faucets, toilets, and outside taps;
- Guide to fixing a leaky faucet;
- Maui planting guidelines, with an emphasis on native Hawaiian plants, describing suitable plants and planting methods for different areas of the county;
- Information on the concepts of conservation landscaping and xeriscaping;
- "25 Things You Can Do To Prevent Water Waste" (in the home) and;
- "55 Facts, Figures, and Follies of Water Conservation," including facts and simple suggestions that encourage water conservation.

The Maui DWS is developing and expanding its conservation program, which includes both supply side and demand side measures.

Supply-side measures to date include leak detection, preventive and predictive maintenance, use of reclaimed water, use of alternate system backups, and resource protective measures:

- Leak Detection: Though the Maui DWS has long practiced leak detection, due to staffing, such work has historically been primarily reactive. Leak detection staff were sent out when a leak was suspected, either based on system performance, or flow and pressure monitoring undertaken as part of hydraulic model development or other efforts. The Maui DWS is now instituting a proactive program. A preliminary water audit by district has been completed, and ten miles of distribution line have been surveyed in the first quarter of this year. Program pace is expected to increase with familiarity and additional staffing. Leak detection equipment include: digital correlating loggers, a digital correlator, a leak detector, and a line tracer.

Systematic survey and detection of leaks may be supplemented by flow and pressure monitoring as needed.

- Preventive & Predictive Maintenance: This two-pronged approach involves the regular maintenance of facilities and the periodic calibration of pumps. In the course of such maintenance, facilities are regularly checked for signs of wear. The Maui DWS also has a system inventory with age, diameter, and material of water lines and other facilities. The Maui DWS maintains a 30-year project list based upon the status and performance of system facilities and upon known inventory status and demand trends. Preventive and predictive maintenance can help reduce unaccounted-for water in the system by targeting old and substandard lines for replacement.

- Reclaimed Water Use: About 3.905 mgd is in use throughout Maui County with 1.8 mgd utilized in South Maui. As part of its Water Use & Development Plan process, the Maui DWS is currently investigating the costs and benefits of large scale capital investment to further expand reclaimed water use to offset potable use.

- Back-up Sources: In the event of a major leak, any key portion of the system can be isolated if necessary, and most areas of system can be served by other sources.

- Watershed and Resource Protection: The Maui DWS spends a million dollars annually on projects to protect and monitor water resources, including more than $600,000 on watershed protection. Staff conducts outreach and runs advertisements on the importance of watershed protection, as well as co-sponsoring events at the Maui Nui Botanical Gardens facility.

Demand-side conservation measures include fixture distribution, a tiered rate structure, educational programs, and regulations as well as resource protection. Ongoing planning efforts are evaluating the benefits and costs of increased aggressiveness in these efforts:

- Fixture Distribution: As of June 2008, Maui DWS has given out 31,671 low flow showerheads, 30,536 bathroom aerators, 18,636 kitchen aerators, 16,948 self-closing hose nozzles, and many more leak detection dye tablets, for a customer base of about 35,000 meters. Despite what would seem like high market penetration, estimated savings based on these giveaways is only about half a million gallons per day. More aggressive fixture distribution programs under consideration include audits and direct install programs, as well as rebates and incentives for larger appliances.

- Audits/Retrofits: Maui DWS co-funded its first direct install retrofits in the late 1990s with low flow toilets. However, no large scale programs were funded. More recently retrofit trials of high efficiency toilets have been started. Ongoing retrofit trials include:

- Ka Hale A Ke Ola - a homeless resource center with about 70 units and two dormitories. Seventy-four toilets, two urinals, 76 showers and 76 faucet aerators will be replaced with the most water efficient products available.

- Hale Makana O Waiale - a low income housing complex with 200 units. Two hundred showerheads, 200 bathroom and kitchen faucet aerators will be replaced with more water efficient models.

- All of Maui DWS's properties and the 5th and 9th floors of the county building will be retrofitted with 10 waterless urinals, 22 dual flush toilets.

- Maui DWS staff is working with the Maui Parks Department staff to retrofit aquatic facilities with more efficient fixtures and conserve water other ways.

The County of Maui Water Use & Development Plan update is in progress. The plan evaluates the costs and benefits of high efficiency fixture rebates and direct installation programs. Ongoing trials will help to provide some preliminary data on the effectiveness of some of these options. Longer term options for the future may also include review of various means of sub-metering multi-family units and multi-purpose buildings. Studies indicate that metering un-metered units is among the most effective of conservation measures, by billing explicitly for use rather than hiding this cost in the rent.

Conservation Pricing: Maui DWS currently has a tiered rate structure to encourage conservation. Data improvements under way could enable Maui DWS to move toward a more aggressive tier structure.

Regulation: Maui County has the following existing regulations and rules that support conservation: 1) Prohibition of discharging cooling system water into the public wastewater system; 2) Requirements that low flow fixtures are required in new development; 3) Requirements that all commercial properties within 100' of a reclaimed water line utilize reclaimed water for irrigation and other non-potable uses; 4) A water waste prohibition with provision for discontinuation of service where negligent or wasteful use of water exists; 5) A provision enabling the water director to enact special conservation measures in order to forestall water shortages. In addition, a comprehensive conservation ordinance has been drafted, and may be implemented in stages. Discussion with various consultants about how to phase such implementation is under way. Though the draft is fairly comprehensive, initial provisions enacted may focus on simple measures which have been proven effective - such as limited landscape watering days.

Education and Behavior Modification: Conservation marketing efforts include advertisements run on all local radio stations and newspapers to encourage water conservation. The permit review process is also utilized as an educational tool, with use-specific conservation tips and location-specific landscape tips included in each review. The Department participates in about 25 public events per year, such as the County Fair, Earth Day and Taro festivals. In order to provide an ongoing educational facility with demonstration and participatory learning, Maui DWS funds the operations of the Maui Nui Botanical Gardens.

Expanded education and marketing efforts under consideration include targeted marketing survey and campaign development, a hotel awards program, a building manager users group, and an agricultural users group.

Landscaping: Maui DWS co-funds operations of the Maui Nui Botanical Gardens and funded construction of its nursery and portions of other facilities and displays. This provides a resource for promoting expertise in propagating and maintaining native plant materials, helps to increase the potential marketability of appropriate plants, promotes a conservation ethic, provides training on appropriate propagation, planting, irrigation and maintenance techniques, and generally helps to increase the likelihood of successful appropriate landscapes with a "Hawaiian Sense of Place". It also helps to protect watersheds by promoting native and non-invasive plants over potentially invasive species, providing for educational opportunities on the importance of the watershed and how to protect it, and serving as a major demonstration and educational facility. The nursery is also a source of native plants for DWS outreach projects and give-aways. Maui DWS developed (with help from the arborist committee) a brochure entitled “Saving Water in your Yard, What and How to Plant in your Area”, which is distributed by the Maui Nui Botanical Garden and the DWS at events and through the permit review process. Future plans for landscape conservation include a conservation ordinance, landscape audit and retrofit program and smaller satellite demonstration projects. Maui DWS is also investigating the costs and benefits of major capital expenditure in reclaimed water transmission to offset use of potable water in South Maui landscapes. The pending conservation ordinance includes mandatory watering schedules and irrigation efficiency measures among other requirements.

Ongoing Planning Efforts: Source options considered as part of the County of Maui Water Use and Development Plan process will include consideration of extensive conservation measures as a source supply. In order to displace or delay source development, an aggressive program is required. Preliminary design of such a program is ongoing as part of the Water Use & Development Plan process. Anticipated program elements include targeted audit and direct install programs, rebates and incentives, expanded conservation requirements for landscaping and other uses, expanded marketing efforts including user groups, such as a hotel awards program, a building manager information program, agricultural user working groups/services, as well as energy production and efficiency measures, continued watershed protection and restoration, and possible major capital expenditure to support reclaimed water use.

7.4.3.2. Honolulu Board of Water Supply Conservation Program

The Honolulu BWS manages an integrated island-wide water system that serves all parts of Oahu. The system pumps an average of 150 million gallons of groundwater per day from wells, shafts, and water tunnels. To protect the long-term viability of ground water resources on Oahu, the Honolulu BWS has adopted an integrated approach to ensure a sustainable water supply, by balancing the needs of the community, the economy, and the environment.

Pursuant to the goal of sustainability, the Honolulu BWS's water conservation program seeks to foster effective water management policies and practices that reduce per capita use of potable water through resource management, supply system optimization, and consumer education. The program applies the following strategies:

- Public education and outreach;
- Leak detection, repair and maintenance;
- Large water user programs;
- Regulation; and
- Alternative source development, recycling, and conservation alternatives.

The Honolulu BWS conducts extensive outreach and educational programs and participates in community events to promote resource protection and increase collective awareness of the importance of water. The Honolulu BWS strives to assist in the development of water awareness and implementation of conservation efforts through educational programs that can be described under four program headings:

- **Public Education Program:** This program targets both adults and children through printed materials, the Water Conservation Week Contest for elementary school children, public service announcements and television/radio/print interviews, public speaking engagements, and participation in a number of community events and activities. Group tours of watershed areas, the Halawa Xeriscape Garden, and the Honouliuli Water Recycling Facility are also offered.

- **School Education Program:** Teachers and students from preschool through high school are provided with publications, brochures, and other media explaining Oahu's water resources. Water conservation information, statistical reports, and summaries are also provided. Other publications provide students with a comprehensive understanding of water and water systems nationwide. The Honolulu BWS sponsors a Water Conservation Week Poster Contest for public and private elementary schools on Oahu, and participates in the Hawaii State Science and Engineering Fair by sponsoring water quality and water conservation awards. Classroom visits and speaking engagements are also done by BWS staff.

- **Watershed Education Program:** This program is designed to teach people in the community about the importance of healthy watersheds to replenish ground water resources. Watershed and forest protection, active stewardship of the land, and public and private partnerships are emphasized. Participants include State, City and County of Honolulu agencies, community groups, and school and environmental organizations.

- **Community Education Program:** Community education efforts include the Honolulu BWS Neighborhood Board Liaison Program, which encourages grass roots involvement and relationships between the Honolulu BWS and Oahu communities. Volunteer neighborhood representatives have a personal Honolulu BWS contact for information, concerns, and inquiries. The Honolulu BWS participates in community events such as the Aloha Fun Run/Health and Fitness Fair, Building Industry Association Show, Food and New Products Show, Farm Fair, and City-sponsored "Sunset" events (e.g., Sunset on the Beach, Sunset on the Plain, Sunset in the Park).

The Honolulu BWS provides assistance to watershed partnerships, agencies, and organizations through the Watershed Management Partnership Program. Project proposals for grant awards are submitted to the Honolulu BWS for consideration. To be eligible for the program, projects must be located on Oahu and should be relevant to watershed studies, watershed resource protection, educational outreach for watershed management and protection, invasive species control, forest protection, or water conservation activities.

The Honolulu BWS also utilizes the agency's website for conservation education and outreach. The "Kid's Corner" page includes interactive, educational activities designed for children. The website's conservation page includes information and links for consumer conservation measures inside and around the home, information on the Ultra-Low Flush Toilet Rebate Program, xeriscaping resources and planting guide, and a registry of nurseries that grow "less thirsty" plants.

The agency also provides a Water Waste Hotline (808-748-5041) for the public to report broken water pipes, a malfunctioning irrigation sprinkler, faucets left running, or other water waste.

7.4.3.3. Kauai Department of Water Conservation Program

The Kauai Department of Water (DOW) operates 13 separate, unconnected water systems from Kekaha to Haena. Kauai DOW pumps water from 48 underground wells and tunnels and stores it in 43 tanks. Nearly 18,000 accounts are served through 400 miles of pipeline. Many of the water systems date back to the plantation era, and some pipelines are 80-100 years old. Most of the water that is provided to the department's customers is from ground water sources. Hanamaulu and Lihue receive a portion of their water from surface water sources. A new water purification facility uses a microfiltration system to treat surface water for drinking.

Information on conservation measures and other public outreach materials listed below are accessible through the Kauai DOW's website:

- Water conservation brochure, "35 Tips to Save Water";
- Table tents for restaurants, "Water served on request only";
- Free low-flow water fixtures;
- Tips for conserving water around the house and outdoors;
- Leak detection and instructions on fixing a leaky faucet;

- Xeriscape resources and information on DOW's demonstration project at the agency's Lihue office;

- Kids page with educational activities; and

- Public education programs for schools, clubs, and organizations.

7.4.3.4. Hawaii County Department of Water Supply Conservation Program

The County of Hawaii's Department of Water Supply provides domestic water service via 24 water systems and 67 sources located throughout the island. The individual water systems are not interconnected, except in the more densely populated districts of South Hilo and Kona. The Department of Water Supply services approximately 35,000 customers with about 8.5 billion gallons of water annually.

The Hawaii County water rates are designed to encourage conservation through an inverted-block rate structure, which charges higher unit costs for heavy water users. The Department of Water Supply has also published educational brochures and handouts that are available to the public. During periods of drought or low rainfall, the department may publish water conservation notices in local newspapers and include notice inserts in customer's water bills. These notices typically call for a voluntary reduction of domestic use by 10% and restrict agricultural irrigation to the hours between 8 p.m. and 6 a.m. Water conservation notices also includes tips on how to reduce water to meet the 10% voluntary reduction. If subsequent use reductions are insufficient, the department may issue notices for mandatory use reductions until the water supply situation has stabilized.

7.4.4. Recommendations for Water Conservation Programs

Several State and county agencies currently implement various water conservation program measures. Private businesses and organizations (e.g., Hawaii Green Business Program) have also incorporated water conservation in their daily operations. However, a coordinated conservation program is still lacking. The State should develop a water conservation framework for government agencies and private entities. The following are recommended:

- DLNR should implement the site-specific recommendations of the DLNR Water Conservation Plan. Funds should be sought from the Legislature and DAGS, and other financing options should be pursued, such as rebate programs, performance contracting, and public/private partnerships.

- Government agencies should pursue public/private partnerships to contribute funds, implement and promote water conservation efforts, and increase public awareness.

- The State should encourage water conservation planning efforts in all State agencies, as the State is one of the largest water users across all counties. State agencies should be encouraged to apply the water conservation planning method described in the DLNR Water Conservation Plan and follow through with plan implementation.

- Existing and developing State agency conservation efforts should be identified in the next update of the SWPP. The SWPP should also suggest specific agency conservation goals and actions.

- Military installations should be encouraged to develop site/facility-specific water conservation plans that expand on the existing general conservation policies of the Army, Navy, and Air Force. Site/facility-specific military conservation plans should delineate conservation goals and present implementation schedules for these measures. The military should undertake conservation planning efforts with sensitivity to local, regional, and statewide water resource management issues and incorporate extensive personnel and public outreach programs to encourage a conservation and stewardship ethic in the context of Hawaii's particular water concerns.

- Water purveyors should encourage large industrial, commercial, agricultural, and institutional users to develop operational water conservation plans and introduce financial incentives to reward users who implement conservation measures and demonstrate reduced consumption.

- The State, as trustee of water resources, should promote and coordinate ongoing water conservation efforts across the state, to provide guidance for businesses lacking conservation programs. Cooperative efforts between the State and counties can enhance program development and expand program application.

- The State Water Conservation Coordinator should manage water conservation plans and initiatives at the State level, including encouraging the designation of a project manager for each facility/site and working with the project manager to develop and implement a plan for each facility.

7.5. Developing a Resource Augmentation Program

To meet future water demands throughout the State, alternative water sources should be developed to augment naturally occurring water supplies. The order in which to pursue development of alternative sources is influenced by local and county-level needs and constraints. In some areas of the state, water availability is limited by the extent and capacity of the pump and distribution system, rather than a scarcity of surface and ground water resources. In other areas, increasing water demands may only be met by augmentation and alternative water sources.

Judicious management of water resources is the primary tool for sustaining Hawaii's people, environment, economy, and lifestyle. Water can be a factor limiting growth and development, and in turn, growth and development can limit and decrease the viability of the resource. Land use planning and water resource planning are thus closely linked.

Resource augmentation must be recognized as an important component in water resource management. Alternative water supplies are renewable, drought resistant, environmentally sound, and socially responsible. Goals and priorities must be established to integrate the use of alternative water resources into daily life, and to encourage the development of these supplies in an efficient and safe manner.

It is the responsibility of the State to encourage and, when necessary, advise county and private-sector efforts to pursue safe and efficient resource augmentation. The development of alternative water resources is challenging. The planning horizon, funding, and the availability of technical resources are major considerations in developing water augmentation sources. Aside from regulatory requirements, Hawaii lacks a program to encourage innovation in augmentation methods and incentives for implementation. The State Water Code states that CWRM shall plan and coordinate conservation and augmentation programs in cooperation with other agencies and entities.[3] The following section reviews various resource augmentation methods and describes CWRM's role as an advisory agency for expansion and further development of augmentation programs statewide.

7.6. Water Supply Augmentation Resources

Hawaii's freshwater supplies have been developed thus far through traditional means, including ground water wells, stream diversion systems, and surface water reservoirs. However, current and anticipated demands for water are outpacing source development and will likely surpass the volumes of naturally occurring ground and surface water. In order to sustain Hawaii's growing population and to meet the needs of industry, the State and county governments must actively pursue alternative water supplies. Alternative water sources should be developed not only to meet certain water demands, but also to help ensure the long-term viability of our ground water aquifers and watershed areas. There are several issues to consider in exploring resource augmentation. They are:

- **Reliability considerations:** The source is vulnerable to drought conditions or seasonal variations in precipitation; there is a dependence on fuel types that are susceptible to shortages or cost inflation; the economical development of the source must have sufficient capacity to meet demand.

- **Quality considerations:** The treatment process must be capable of producing water that can meet increasingly stringent water quality standards; the source should be suitable for the production of drinking water, irrigation water, or industrial water.

- **Efficiency & economic considerations:** The cost of developing alternative water sources in comparison to that of traditional source development must be considered; cost implications of alternative source development in planned stages to meet demand is also important; long-term operation and maintenance costs must be compared.

- **Technology:** An understanding of the history and dependability of related technologies must be gained; it is beneficial to investigate foreseeable advances

[3] HRS §174C-5(12) and §174C-31(d)(4).

in technology; including specialized technology and equipment requirements; public opinions/concerns regarding the technology should be solicited.

- **Environmental Impacts:** Environmental impacts of alternative water source development should be compared to that of traditional source development; utilities need the ability to mitigate negative impacts; it would also be appropriate to compare benefits of traditional source development with alternative source development.

Several alternatives could increase or extend freshwater supplies. Reclaimed wastewater can provide for non-potable demands, including irrigation and industrial applications. Reclaimed stormwater could be used for artificial ground water recharge, environmental restoration, fish and wildlife habitat support, recreation, municipal uses, irrigation, and industrial uses. Desalinated water is well-established as a source of drinking water in other parts of the U.S. and in the Middle East, Japan, and the Caribbean. Other alternatives on the household-level, including the use of grey-water systems and rain barrels for landscape watering, can also help extend freshwater supplies.

The following sections discuss the larger scale alternatives of stormwater and wastewater reclamation and desalination methods to augment ground and surface water supplies. Each method is also briefly evaluated with regard to the issues listed above.
For clarification purposes, the following definitions are offered:

Wastewater reclamation: *The treatment of wastewater such that it may be used for beneficial purposes.*

Recycled water: *The useable end product of the wastewater reclamation process.*

Water reuse: *The beneficial use of recycled water.*

7.6.1. Wastewater Reclamation

Wastewater reclamation has been practiced for decades in the continental United States and other parts of the world, especially in areas where freshwater sources are limited. Water reuse should be viewed as a key component of sustainable water resource management. Recycled water can be a drought-proof and reliable supply of water. It can replace potable water currently being used for non-potable purposes. In some instances, the availability of recycled water has stimulated Hawaii's economic development by attracting business activity. Water reuse also provides a mechanism for nutrients in wastewater to be utilized by vegetation, thereby reducing the need for fertilization. Finally, when compared to the traditional disposal methods through outfalls and injection wells, wastewater reclamation and reuse is recognized as an environmentally preferred method of effluent disposal. While water-reuse applications have grown significantly in Hawaii in recent years, recycled water is still an underutilized resource. CWRM completed the *2004 Hawaii Resource Survey and Report* as the intitial step toward development of a statewide waste-water reuse program. The information presented in this section of the WRPP has been adapted from the 2004 report.

In 1999, approximately 13% of the volume of municipal consumption in Hawaii was attributed to recycled water sources, and this figure continues to increase with the eventual implementation of planned and proposed reclamation and reuse projects. As Hawaii's population increases, wastewater volumes will increase proportionally, creating more recycled water and reuse opportunities. Integration of water reuse into the statewide water use policy will be critical as water demands increase.

Recycled water must meet strict water quality standards set by the Environmental Protection Agency (EPA) and the Department of Health. These water quality standards ensure proper treatment and disinfection, although treatment levels differ depending on the end use. The EPA and DOH regulations require wastewater treatment and encourage the availability and reuse of its by-product, recycled water. In some cases, it may be less expensive to develop recycled water distribution systems than to develop new sources of water and continually pay effluent-disposal costs. While there are significant initial capital costs for communities to develop recycled water distribution systems, the addition of recycled water to municipal water budgets will secure long-term sustainability of communities and economic growth. The typical Wastewater Treatment Plant (WWTP) is a large facility that requires significant amounts of land and operational resources, but smaller scale applications of reclamation technology are becoming more common in subdivisions, and even serve single-family homes. Small and decentralized wastewater management systems provide local solutions for wastewater collection, treatment, and reuse. Such systems also avoid costs associated with transmission of large, regional facilities.

7.6.1.1. Potential Applications for Recycled Water

There are numerous uses for recycled water. Some of the reuse applications listed below are already taking place in Hawaii on a small scale:

- Constructed Wetlands
- Ground Water Recharge
- Irrigation
- Recreational Uses
- Construction-Related Uses
- Recharge of Natural Wetlands
- In-Stream Flow Restoration
- Composting
- Toilet and Urinal Flushing
- Industrial Uses

CWRM completed the *2004 Hawaii Water Reuse Survey and Report* to monitor the utilization of recycled water in Hawaii. The report discusses the existing and potential uses of recycled water appropriate for Hawaii (see Section 7.7.1).

7.6.1.2. Guidelines for Treatment and Use of Reclaimed Water

The DOH issued the *Guidelines for the Treatment and Use of Reclaimed Water* (Guidelines) in November 1993 and updated the Guidelines in May 2002. They are now referred to as the *Guidelines for the Treatment and Use of Recycled Water*. The document identifies requirements for both purveyors and the users of recycled water. The intent of the DOH is to eventually incorporate the Guidelines into Chapter 11-62 of the Hawaii Administrative Rules (HAR).

All projects that use recycled water must first receive DOH approval. The DOH approval process has certain design and site inspection requirements. Purveyors of recycled water are required to keep operational records of the daily volumes and water quality produced by their water reclamation facilities. These records are subject to review by DOH during annual operation and maintenance inspections of each facility.

Maui County is the only county in Hawaii thus far to establish rules for recycled water use. These rules, adopted in June 1997, are referred to as *County of Maui Rules for Reclaimed Water Service.* They incorporate the *State of Hawaii Guidelines for the Treatment and Use of Recycled Water*, the *State of Hawaii Water System Standards,* and Chapter 11-62 of the HAR. The Maui County rules include sections on establishing recycled water service, design standards for on-site and off-site recycled water facilities, operational guidelines, monitoring and enforcement provisions, and fees and charges.

7.6.1.3. Recycled Water Classifications, Definitions, and Allowable Uses

Recycled water is classified as either R-1, R-2, or R-3 based on the level of treatment it has received. The first step in wastewater reclamation is primary treatment, which removes settled or floating solids. In secondary treatment, organic matter is removed, usually through “biological cleansing” using bacteria. Tertiary-treated recycled water is filtered and disinfected to remove up to 99% of impurities and suspended solids. Purveyors of recycled water must meet the treatment and water quality standards summarized below for R-1, R-2, and R-3 waters.

R-1 water is tertiary-treated recycled water that has undergone a significant reduction in viral and bacterial pathogens and meets the highest recycled water standards. R-1 water is oxidized, filtered, and exposed to disinfection processes to remove bacteria and viruses. It is of non-potable quality, but it is deemed safe for human contact. R-1 water is now approved for a number of applications including spray irrigation of golf courses, parks, athletic fields, school yards, residential properties that are managed by an irrigation supervisor, road sides and medians, and for vegetables and fruits that are eaten raw. The number of projects in Hawaii utilizing R-1 water has increased significantly in recent years.

R-2 water is disinfected, secondary-treated recycled water. R-2 water has been oxidized and disinfected; however, the disinfection criteria are not as stringent as that of R-1 water. Therefore, the reuse applications of R-2 water are limited. Spray irrigation using R-2 water is limited to evening hours, and a 500-foot buffer zone between the approved-use area and adjacent properties is required. Several golf courses in Hawaii are irrigated with R-2 water, although some are exempt from the 500-foot buffer zone requirement because they existed before the DOH established the Guidelines. Food crops that are irrigated with R-2 water must be either irrigated via a sub-surface irrigation system or, if irrigated with spray irrigation, must undergo extensive commercial, physical or chemical processing determined by the DOH to be sufficient to render it free of viable pathogenic agents, before it is suitable for human consumption.

R-3 water is undisinfected secondary-treated recycled water, and there are severe limitations on its use. Currently, the Parker Ranch pasture-irrigation project on the Big Island and the Puu O Hoku Ranch constructed-wetlands project on Molokai are the only projects in Hawaii that utilize R-3 water.

Reverse osmosis (R-O) is a method of treatment that is used in wastewater reclamation and in seawater or brackish water desalination. R-O water is wastewater that has undergone secondary treatment, followed by purification through an ultra-fine membrane that allows only water to pass. R-O water is then disinfected prior to use.

A complete list of the allowable uses of recycled water is summarized in the DOH Guidelines under Chapter III – Uses and Specific Requirements for Recycled Water.

7.6.1.4. Wastewater Reclamation Issues and Constraints

In the development of water reuse programs and projects, there are several issues that can delay progress. Certain planning and preparatory efforts must be carried out to address economic issues, legislative constraints, and public acceptance. Jurisdictional and regulatory obstacles, however, cannot be surmounted without first addressing the issue of public perception of water reuse.

To realize success, a water reuse program or project should incorporate the following elements:

1. Gain public acceptance.
2. Encourage cooperative planning among agencies.
3. Overcome regulatory hurdles.
4. Strategize on funding sources.
5. Grow a customer base and encourage demand.

The following sections provide information and strategies for achieving these program elements and for facilitating water reuse projects.

1. Gain public acceptance.

Sound and proactive communication and education programs are essential for water reuse projects and programs to succeed. Failure to educate the public early on may delay or even stop the implementation of water reuse projects or programs.

Two key concepts must be emphasized in public outreach programs:

- *Recycled water can be an important component of the community's overall water supply.* The main reason for implementing water recycling programs is to supplement limited freshwater supplies.
- *Recycled water is safe for approved uses.* The community must gain a basic understanding of how wastewater is treated and made safe through the recycling process. The community may have concerns regarding the safety of using recycled water for landscape irrigation, especially in locations such as parks, school yards, shopping centers, hotels, and condominiums. Proactive public education programs, with emphasis on disinfection, monitoring, and quality assurance, will help the community feel more comfortable with the idea of using recycled water.

Target audiences for education and outreach programs include politicians, schools, the general public, community organizations, and new and potential recycled water users. The educational outreach program described below is based on the County of Maui Department of Public Works and Environmental Management, Wastewater Reclamation Division program, and may be used as a template for other outreach programs throughout the state. The following are examples of outreach methods that are appropriate for each target audience:

Government Officials: A significant amount of time should be expended educating local government officials on the benefits and applications of recycled water through presentations at council meetings and other public meetings. Literature and testimony from local and national water reuse experts are also effective, and personal meetings allow elected officials to ask questions and broaden their knowledge of reuse.

Schools: Educating young people is the best way to establish long-term support for the concept of recycling water, and to develop behavior that will enhance sustainability within the community. Outreach programs should first notify school administration and teachers of the availability of an environmental-education program on water conservation and wastewater reclamation and reuse. Components of the program could include classroom presentations, water quality lab activities, wastewater reclamation facility tours, career-day speaker appearances, and assistance with school science projects. Desktop demonstrations, slide shows, videos, poster boards, and information booklets can be incorporated into the program, along with the distribution of promotional items such as rulers, stickers, magnets, and water conservation kits.

General Public: In addition to printed informational materials and promotional items, the general public can benefit from tours of wastewater reclamation facilities, where information can be shared on-site and face-to-face. Educational videos can be broadcast on community-cable access television, and copies of the video can be made available for loaning upon request. Additionally, press releases announcing improvements and expansions to recycled water programs and facilities and media coverage can help spotlight and reinforce the importance of recycled water.

Community Organizations: Presentations can be developed and shared with community groups such as the Rotary Club and other community associations, the local Chamber of Commerce, hotel and other business associations, and engineering, architecture, and contractor associations, which often have regular meetings and welcome guest speakers. These speaking engagements can be utilized to provide the most current information on recycled water programs, and can encourage public involvement by raising interest and identifying groups who will champion the program.

New and Potential Recycled Water Users: Educational presentations that focus on the production, safety, and proper management of recycled water can be made to the owners, managers, and employees of new and potential water reuse projects. Such presentations should emphasize water quality monitoring of the recycled product, including turbidity monitoring, automatic diversion of substandard recycled water, and fecal coliform monitoring. The presentations should also discuss best management practices and examples of successful local and national water reuse projects. Facility tours should be offered as a follow-up to these presentations, along with educational pamphlets and promotional items.

2. Encourage cooperative planning among agencies.

Water reuse provides benefits in both water supply and wastewater disposal. A common issue encountered by municipalities in the early stages of a water reuse program is the determination of which agency, the water supplier or the wastewater-services provider, will champion and administer the program. Recycled water is the link between water and wastewater. Therefore, no matter which agency takes the lead in the development and operation of a reuse program, the other agency should support the program in some capacity.

To implement recycled water use, county agencies must also coordinate permitting and management actions. For example, designing office and commercial buildings with dual water supplies for the purpose of flushing toilets and urinals with R-1 recycled water represents an excellent opportunity to displace the use of large amounts of potable water. The DOH Guidelines allow R-1 water to be used for toilet and urinal flushing, if the county plumbing code incorporates language pertaining to dual water supplies within buildings. Therefore, all counties in Hawaii should incorporate Appendix “J” of the 1997 version or later of the Uniform Plumbing Code into their respective county plumbing codes. Appendix “J” includes the provisions required to meet DOH Guidelines. Failure to update county plumbing codes for dual water supplies within buildings could result in the DOH denying projects that want to utilize recycled water for toilet and urinal flushing.

3. Overcome regulatory hurdles.

There are at least two state regulatory issues in Hawaii that restrict recycled water from use in potentially high-volume applications. Both of the issues are related to the DOH regulations and are summarized as follows:

1. The DOH Wastewater Branch does not permit the use of R-1 water for single-family lot irrigation; and

2. The DOH Clean Water Branch does not permit the discharge of recycled water into State waters.

In examining the first issue, it should be emphasized that yard and landscape irrigation consumes significant amounts of potable water, and such use can comprise up to 65% of a home’s consumption on the leeward sides of the islands. The DOH Guidelines state that R-1 water may be used for “any form of irrigation served by fixed irrigation system supplied by buried piping for turf and landscape irrigation of a residential property where managed by an irrigation supervisor.” In the past, the DOH has approved the use of R-1 water for multi-family residential developments.

However, the DOH has not approved projects proposing the use of R-1 water for irrigation in single-family residential developments. The Guidelines do not allow the use of recycled water on privately owned single-family residential lots and do not address specific requirements for dual-plumbed, recycled water facilities.

The DOH also is concerned that, even if the irrigation system for an entire single family development is managed by an irrigation supervisor, the agency cannot ensure adequate protection of public health due to insufficient staff. The agency feels that they lack personnel to properly monitor for conditions such as cross connections to the potable water system and overspray of R-1 irrigation water.

Concerns regarding monitoring and R-1 overspray can be addressed through reporting requirements and design requirements for irrigation systems. Future planned communities wishing to utilize R-1 water for irrigation could be required to provide the DOH with periodic cross connection inspection reports by a licensed plumber. Further, the development’s single-family lots should be designed and built with subsurface drip irrigation systems. Maintenance of the common-area irrigation components should be performed by one contractor, and homeowners in the development would be required to use the same contractor for any necessary irrigation system repairs within their property.

As for the second issue regarding the discharge of R-1 water to State waters, it should be noted that recycled water is commonly used on the continental U.S. and in foreign countries for recharging natural wetlands and for instream flow restoration. The U.S. Bureau of Reclamation encourages the use of recycled water for these purposes. In Hawaii, this type of application of recycled water is not permitted as it is considered an unauthorized discharge to State waters.

Chapter 11-54-04 of the HAR, which lists the basic water quality criteria, also states that all waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including substances, or conditions or combinations thereof, in concentrations which produce undesirable aquatic life. The DOH Clean Water Branch's primary concern with the use of recycled water for recharging natural wetlands or restoring stream flows is that nutrients in the recycled water could result in excessive algal growth in the receiving waters.

The nutrient levels in recycled water can be reduced through a process called anoxic zone biological nutrient removal. Wastewater recycling facilities can be designed or retrofitted with anoxic zones that significantly reduce nitrogen and phosphorus concentrations in wastewater. Maui County has added this nutrient-removal process to the treatment at all three of the County's wastewater reclamation facilities.

In order to move toward expanding the use of recycled water for environmental purposes, the DOH should amend HAR Chapter 11-54-04 to allow nutrient-reduced, recycled water to be discharged to natural wetlands or streams. The DOH could establish maximum nutrient levels for recycled water, as well as institute other constraints on the location, means, quantity, and frequency of discharge. In many cases on the continental U.S., recycled water has improved the water quality of wetlands and streams that have been compromised by drought, urban-stormwater runoff, and other pollutants.

4. Strategize on funding sources.

To find effective funding sources, an understanding of the economics of recycled water must be attained. An important component of implementation of water reuse programs is to determine how to pay for recycled water reuse projects. Water reuse projects in general, with the development of recycled water distribution systems in particular, are expensive to construct and operate. The revenues earned from selling recycled water are often insufficient to pay for the full capital and operating costs associated with the production and delivery of the recycled water. This is especially true if the recycled water purveyor sets the recycled water rate comparable to the user's existing water rate. Setting recycled water rates at levels that will allow the purveyor to recover the full capital and operating costs of the recycled water system will most likely result in rates that are significantly higher than the rates paid for traditional water sources. Thus, there would be no economic incentive for a user to convert to recycled water.

Rather than laying the entire financial burden on the recycled water user, it is preferable to spread the cost of financing water reuse projects. There are four main potential sources of funds for water reuse projects:

- Recycled water users
- Potable water users
- Sewer users
- Government grants

Fees from recycled water users can be charged through recycled water rates (dollars per thousand gallons of recycled water used) or through direct, up-front payment of a portion of the project costs. These up-front payments are called assessment fees, capacity fees, connection fees, impact fees, or system-development fees, but they all basically represent a “joint venture” between the recycled water purveyor and the user to pay for all or a portion of the capital costs of the project.

Potable water users may be charged an appropriate portion of recycled water project costs, if they benefit from the implementation of the recycled water program (e.g., if water reuse results in reduced chances of potable water rationing). Similarly, sewer users may be charged a fee for water reuse projects if they receive benefits from reuse. Because future injection wells or outfall discharges of effluent in Hawaii may be limited in the future by regulatory agencies, water reuse becomes an acceptable alternate disposal method, and it is appropriate for sewer users to pay for a portion of water reuse projects.

Government grants currently represent an unlikely source of funds, due to limited state and federal budgets, but recycled water purveyors in Hawaii should be vigilant in the search for potential sources of government grants from various state and federal agencies. (Government loans are not considered sources of funds because they must be repaid. They do, however, represent a low-cost method of obtaining construction funding and are desirable for that reason.)

A good way to encourage reuse and public support of any fees associated with a reuse project is to develop the rate structure and fees with significant community input. A successful example is the County of Maui’s recycled water rate structure. The community-based committee formed to help develop the rate structure consisted of representatives from large landowners, the Maui Chamber of Commerce, the Maui Hotel Association, the Maui Realtor Association, members from the County of Maui's Wastewater Reclamation Division and Department of Finance, and the County's consultant. The committee decided upon a "composite" rate structure for its water reuse program that identified three main user classes: Major Agriculture ($0.10 per thousand gallons), Agriculture, including golf courses ($0.20 per thousand gallons) and All Other ($0.55 per thousand gallons). The recycled water rates were set to levels that were somewhat less expensive than the conventional alternative water sources used by the three user classes. Connection fees and meter fees were also developed. Because effluent disposal was an important factor driving Maui's water reuse program, sewer user rates were also slightly increased.

Maui's approach has allowed recycled water to become an attractive non-potable water source because it is less expensive than conventional alternative water sources. At the same time, sewer users help pay for the water reuse program because it is believed that they must be held responsible for not only the collection and treatment of wastewater they produce but for its ultimate disposal, whether it be through injection wells or though water reuse. It is recommended that recycled water purveyors in Hawaii attempt to recover the capital and operations cost of their respective water reuse programs by having recycled water users, sewer users and potable water users all contribute through their bimonthly user fees.

5. Grow a customer base and encourage demand.

Ordinances that require commercial properties to utilize recycled water for irrigation or other purposes have been used in several states to establish a strong customer base and maximize recycled water usage. Mandatory use ordinances are established because of a shortage of potable water resources or due to environmental problems associated with effluent disposal. Several cities in the continental U.S. have passed ordinances as part of their water reuse programs. Thus far, Maui County is the only county in Hawaii to have a mandatory use ordinance in place. The DOH Wastewater Branch attempted to establish such an ordinance in 2001, but it was not approved by the Legislature.

Maui County's mandatory use ordinance was passed in 1996, primarily as a means to reduce the use of injection wells for effluent disposal, and secondarily to proactively supplement the limited potable water supplies within the County. Although the bill was eventually passed, it faced substantial opposition from some landowners, and an extensive public education and outreach effort was required. The ordinance required commercial properties within one hundred feet of the County's recycled water distribution system to connect to the system within one year of the system's availability, and to use the recycled water for irrigation. Thus, the ordinance was successful in reducing effluent, supplementing the water supply, and building a broad customer base for recycled water.

The passage of mandatory use ordinances in the other three counties could accelerate the development of water reuse programs. The DOH could also propose a statewide, mandatory reuse ordinance to support the agency's goal of increasing Hawaii's recycled water use. For an ordinance to be passed at the State or county level, a comprehensive, educational effort should be undertaken as early as possible to convince lawmakers and the general public of the many benefits such an ordinance can provide. At a minimum, any proposed mandatory use ordinance should contain sections on connection requirements, cross-connection control measures, an inspection policy and penalties for violation, system-reliability requirements, water quality requirements, and fees and rates for recycled water service.

7.6.1.5. Evaluation of Wastewater Reclamation

Wastewater reuse in Hawaii is being aggressively implemented in some parts of the state, namely Maui County. However, wastewater recycling is not a priority in other areas. As stated earlier, the integration of water reuse into the statewide water use policy will become more critical as our potable water demands increase.
CWRM completed the *2004 Hawaii Water Reuse Survey and Report* as the initial step in the development of a statewide, wastewater reuse program. The report inventories and describes existing reuse projects in the state, and more importantly, identifies opportunities for future reuse projects in Hawaii.

The program elements and strategies discussed above for developing and expanding reuse programs and the results of the *2004 Hawaii Water Reuse Survey and Report* should be incorporated into a guidance document to assist county reuse initiatives. Recycled water remains an underutilized resource with many opportunities for expansion.

7.6.2. Stormwater Reclamation

Stormwater flows are part of the urban water cycle. Stormwater consists of the runoff water from the impervious surfaces in cities and developed areas, such as streets, sidewalks, roofs, parking lots, and other areas where water cannot percolate into the subsoil.

Stormwater reclamation, sometimes referred to as rainwater harvesting, can potentially provide water for numerous uses. Non-potable water demand for uses such as irrigation and flush toilets can be supplied by reclaimed stormwater. Many communities in the southwestern region of the U.S. already incorporate stormwater reclamation and reuse into green buildings and developments. The lack of water sources in these areas has made stormwater reclamation an important component of water resource planning and management.

In addition to the various use benefits, stormwater reclamation reduces the amount of pollutants that are deposited into waterways and nearshore waters, and also provides for flood control and containment. Since most urban areas are already applying programs for flood control and the reduction of non-point source pollution, stormwater reclamation and reuse can be viewed as a sensible extension of the urban water cycle. These flood and pollution controls could help provide an alternative water source for non-potable demands.

Stormwater quality can vary dramatically depending on the rainfall amount, frequency, and collection location. Contaminants such as petroleum products, fertilizers, and animal feces are picked up by stormwater runoff. Therefore, stormwater reuse applications require different treatment levels, depending on the risk of public exposure to the recycled water. Secondary treatment with disinfection removes solids and organics, and produces recycled water of adequate quality to meet many non-potable water demands. Tertiary treatment (which removes nutrients) may be required for applications where people are more likely to come in contact with the recycled water. The risk of exposure to pathogens and contaminants is further reduced through measures such as regular pipe and system maintenance, reliable disinfection, application controls, and crop-irrigation restrictions.

County and public health agencies ensure the protection of public health through management programs that delineate risk-reducing management and monitoring actions. In addition to treatment and disinfection requirements, stormwater reuse programs provide rules and recommendations for application methods. For example, stormwater reused in irrigation may need to be applied through sub-surface drippers, rather than surface sprinkler systems. Futhermore, irrigation may be restricted to non-food crops.

Another risk-reducing management action is to provide guidelines and rules for stormwater reuse in various soil types. Soil influences the effect that nutrients, salts, heavy metals, and organic hydrocarbons may have on the environment and nearby surface water bodies. It may be necessary to implement controls to prevent excess irrigation runoff from entering nearby streams or the ocean.

7.6.2.1. Methods for Stormwater Reclamation

On the household scale, rain barrels can be used to collect, store, and distribute stormwater in landscaping. Rain gardens, or vegetated infiltration basins, constructed in the vicinity of the home to take advantage of natural site drainage patterns are another means of containing stormwater runoff that facilitates infiltration. These methods of stormwater reclamation can be classified as “source reuse” and “small lot reuse” technologies. There are five categories used by the U.S. Bureau of Reclamation (Reclamation) to classify stormwater runoff reclamation technologies. Table 7-1 lists and describes each of these technologies.

Water-impounding reservoirs, which are regulated by DLNR’s Dam Safety Program, have been used for irrigation and flood control purposes in a few areas across the state. These include Hawaii County’s Waimea Reservoir, Kauai’s Wailua and Kapahi Reservoirs, the Waikamoi and Olinda reservoirs on Maui, and the Wahiawa reservoir on Oahu.

In the past, a number of projects were envisioned to impound surface water for treatment and domestic use. Although these projects were not completed, the Kohakohau River Dam project on Hawaii and the Kokee Water Project on Kauai were two outstanding project ideas. Proposed surface water impoundment projects, however, can significantly impact the environment and ecosystem. For example, the diversion of water from its natural course or the construction of a dam would have direct and cumulative impacts on stream flows, aquatic habitats, riparian habitats, land use patterns, public health, farming operations, and other downstream and stream-related uses. However, proper planning, site selection, design, construction, and operation of an impoundment facility could be appropriate for certain areas, allowing the capture, containment, and treatment of stormwater to provide for non-potable demand. With this benefit in mind, programs for dam safety, flood control, and stormwater capture should be designed to be mutually complementary.

Table 7-1:
Stormwater Reclamation Technologies

Technology	Description
Source Reuse	Use rain barrels or cisterns to collect precipitation or stormwater runoff at the source to provide water for a variety of non-potable purposes or, with treatment, potable water.
Small Lot Reuse	Manage precipitation or runoff as close to source as feasible. Examples: infiltration planter boxes, vegetated infiltration basins, eco roofs (vegetated roofs), porous pavements, depressed parking lot planter strips for biofiltration, narrowed street sections with parallel or pocket bioswales.
Stormwater Capture	Employ ditches, storm drainage system interception, dry wells, infiltration galleries, and injection wells to capture stormwater.
Stormwater Storage	Use aquifer storage and recovery, stream-bank storage, detention basins, and surface reservoirs to store stormwater.
Stormwater Distribution	Distribute stormwater via gravity ditch or pipe networks, operated/regulated ditch systems, pressure pipe networks, onsite wells.

Source: CH2MHill. *Hawaii Stormwater Reclamation Appraisal Report.* Prepared for the U.S. Bureau of Reclamation and the State of Hawaii Commission on Water Resource Management. July 2005

Related to stormwater impoundment are other types of structures used to facilitate stormwater infiltration into the subsurface. These structures are sometimes built primarily for the purpose of artificially recharging ground water aquifers. Artificial recharge is the process by which the natural infiltration of surface water or precipitation into a ground water body is supplemented by infiltration induced by man. It is typically accomplished via three methods:

- Water spreading
- Infiltration pits, shafts, or tunnels
- Injection or disposal wells (sometimes called recharge wells)

Water spreading promotes the recharge of ground water aquifers by encouraging infiltration. Water is spread over a large surface area and allowed to percolate into the ground. This can be accomplished by diverting runoff into shallow basins or depressions, ditches, or open irrigation systems. Another method of water spreading is to build dams across stream channels, in order to increase the wetted perimeter and spread the stream over a larger cross section of the stream channel and banks.

Where space is limited or in areas where impervious layers near the surface tend to restrict the infiltration of water, artificial recharge is achieved by diverting water into infiltration pits, shafts, or tunnels. These excavations are used to either penetrate the impervious layer or to provide direct access to the ground water body.

In the 1990s, numerous injection (disposal) wells were constructed throughout the state. The primary purpose of these wells is to dispose of stormwater runoff, and the amount of recharge that results from these disposal wells is uncertain.

Throughout the era of sugar and pineapple plantations, artificial recharge was incidental to irrigation practices, but in some areas contributed largely to ground water recharge. Leakage from reservoirs and ditches, together with percolation from irrigated fields, constituted a considerable amount of recharge. Some agricultural users returned excess irrigation water to the ground water sources. For example, the McBryde Sugar Company formerly recharged the ground water body beneath Kauai's Hanapepe River Valley through a system of tunnels and shafts. At one time, it was hypothesized that return irrigation water was responsible for greater than 60% of the total recharge. However, a 1987 study by Mink and Yuen indicated that the figure was closer to 40%. Since the agriculture industry has shifted from plantations to diversified agriculture and some former crop lands have been developed for non-agricultural uses, the amount of water being applied for irrigation has decreased significantly, and it remains to be determined how the change in land use has affected ground water recharge.

The disposal of stormwater in wells, pits, and tunnels currently contributes very little recharge to our ground water supply. Regulations restrict the construction and use of injection wells for storm water disposal to coastal areas to avoid potential contamination of drinking water aquifers.

Several reservoirs, such as the Waiawa reservoir, probably lose some seepage to the ground water body, but supporting hydrologic data is not available. The Honolulu BWS operates four open reservoirs in Nuuanu Valley, but it is doubtful that seepage from these reservoirs reaches the basal water body. A formal evaluation of the risks, impacts, costs, and benefits of an artificial recharge program using stormwater should be conducted before it is further considered for resource augmentation.

7.6.2.2. Urban Runoff Recycling: A Model Facility

The first full-scale, dry-weather, stormwater runoff recycling facility began operating in Santa Monica, California in December 2000. This project is truly innovative, because it contributes to the Santa Monica's Sustainable City Program goal of reducing urban runoff into the Santa Monica Bay. It also provides a significant public education opportunity that takes advantage of the plant's location in the tourist area near the Santa Monica Pier.

The Santa Monica Urban Runoff Recycling Facility (SMURRF) is an outstanding example of how a public facility can be constructed to integrate educational and art components that are responsive to the immediate neighborhood, and serve to enhance community pride. The facility is open to the public and is designed to move visitors through the plant via an elevated walkway, descending from one end of the site to the other, also providing an alternate access to the beach. Each piece of equipment is emphasized with a prominent base, dramatic lighting, and colorful tile work, and the visitor is directed past the plant components in a logical manner. Visitors are able to observe the results of the treatment process at five locations throughout the plant, and information plazas teach visitors about the workings of the facility, the local urban watershed, and the public's role in preventing stormwater pollution. By investing in architecture, landscaping, and art, the project was successfully integrated into the lively atmosphere of the Santa Monica Pier, while showing a sense of respect for the local community and achieving a positive effect on public perception in the community and among the governing bureaucracy.

SMURRF uses conventional and advanced treatment components to remove debris, sediment, oil, grease, and pathogens from stormwater collected by the city's storm drain system. The plant can treat a maximum of 500,000 gallons per day (gpd) of runoff from a 5,100-acre drainage area that produces stormwater flows averaging 265,000 gpd. The treatment processes include: coarse and fine screening to remove trash, plant material, and debris; degritting systems to remove sand and grit; dissolved-air floatation to remove oil and grease; microfiltration to remove turbidity; and ultraviolet radiation to kill pathogens. The treated product water meets the standards of the California Department of Health Services and California's Title 22 requirements. The treatment train was recommended because it was able to meet current reclaimed water requirements, while allowing for future expansion with reverse osmosis, to meet ground water recharge requirements.

The product water is distributed for landscape irrigation and flush toilets. Landscape-irrigation water is provided to street-median landscaping, city parks, and a cemetery. Dual-plumbed customers using the product water for indoor use (flush toilets) include the City of Santa Monica Public Safety Facility and the City's Water Garden.

The project was funded by the City of Santa Monica, the City of Los Angeles, the State of California Water Resources Control Board, the Metropolitan Water District, Federal Intermodal Surface Transportation Efficiency Act grant funds, and Los Angeles County Proposition "A" grant funds. Capital costs totaled $9 million: plant costs totaled $6.3 million, and distribution system costs were $2.7 million. Approximately $2 million of the plant costs are attributed to the 500,000-gallon concrete storage tank, which had to be designed and constructed for tight site considerations (with one side of the tank serving as a retaining wall for a freeway onramp). Approximately $750,000 of the plant cost can be attributed to architectural components designed to incorporate public art and education. The actual cost of the stormwater treatment system is estimated at $2.9 million ($5.80 per gallon).

7.6.2.3. Stormwater Reclamation Issues and Constraints

Stormwater reclamation is not commonly practiced in Hawaii. This section provides an overview of the broader issues related to establishing the economic, social, and technical climate to expand water reuse and develop reclaimed stormwater as an alternative water supply. The discussion below is adapted from the June 2005 *Hawaii Stormwater Reclamation Appraisal Report,* prepared by the U.S. Bureau of Reclamation in cooperation with CWRM, to investigate opportunities for stormwater reclamation in Hawaii (Section 7.7.1 provides a summary of the project).

Demand and Pricing: Reclamation and reuse of stormwater often provides opportunities for multipurpose benefits, for example, flood control and ground water recharge. In many ways, these activities have potential to mitigate impacts of development or provide water supply to maintain or increase traditional land uses such as agriculture. With the exception of some types of urban or industrial runoff, quality of reclaimed stormwater is often good and does not share the same stigmas associated with reclaimed wastewater.

For these reasons, there have not been significant obstacles identified in establishing a market for reclaimed stormwater. With a few exceptions, demand for reclaimed stormwater is primarily a function of scarcity of the resource in general, rather than any particular association with the supply. One significant exception to this finding is use of urban or industrial runoff for drinking water.

At the same time, this appearance of a commodity status for reclaimed stormwater places it more firmly in competition with more traditional methods of supply based on price alone. This must be evaluated case-by-case, but emphasis must be placed on long-term economic benefits associated with reducing the need to establish new sources of supply. In urban areas, increased development may actually increase the potential yield of reclaimed stormwater, without the need to develop new sources, based on changing land use conditions.

Needed Research and Demonstration Studies: It is necessary to establish that public health and safety are maintained with the use of reclaimed stormwater. It is also necessary to proceed in an environmentally sound manner. The areas of greatest concern regarding reuse of stormwater are: potential contamination of aquifers and other potable water supplies by poor-quality runoff, and environmental or habitat degradation resulting from diversion of surface flows from the natural hydrologic regime. From a water quality perspective, urban runoff, particularly associated with industrial processes or transportation corridors, contains the highest concentration of contaminants, often hydrocarbons or heavy metals. In more rural areas, agricultural runoff can carry high concentrations of nutrients, pesticides, and in some areas, salts. Additional research and pilot studies are needed to demonstrate economical methods of adequately treating stormwater prior to injection into aquifers or introduction in potable water systems.

Seasonality: The fundamental challenge of most methods of stormwater reuse is that stormwater is primarily available in excess during the rainy season and most needed in the dry season. Therefore, it must be stored for at least a season, in sufficient quantity to justify the cost of construction of the impoundment. This relationship informs expectations regarding the size of storage needed. The closer beneficial reuse mimics the pattern in which stormwater is available, the less storage is needed. In such a case, the opportunity is primarily one of diversion to an alternate flow path, rather than storage.

Volume: For a reuse opportunity to be successful, the runoff volume that can be consistently collected for beneficial use must be in concert with the demand for water use. In some cases, such as aquifer recharge, it has been assumed that whatever stormwater is available can be absorbed into the aquifer, given an adequately designed infiltration or injection system. In other cases, such as storage for reuse as fire suppression, the amount of collected water is likely to be very small, compared to the expected stormwater runoff. This poses no problem, unless the intent of the opportunity is, for example, to provide flood control, which is not likely to be adequately addressed by such a limited reuse demand.

On the other hand, if the purpose of the opportunity is to provide irrigation to certain crops, a cost-benefit relationship exists between the expected crop yield increase due to irrigation and the cost of opportunity construction. It is important to understand how much stormwater may be available and the related storage requirements to evaluate the efficiency of the reuse alternative.

Timing: A distinction has been made among long-term seasonality, year-to-year hydrologic variability, and large-event conditions. The latter is termed “Timing”, as flood events are, virtually by definition, difficult to adequately capture. Large volumes of excess runoff are available during these infrequent events, but often it is not cost effective to construct storage to capture all that is available. Similarly, to have a positive impact on flooding, capture of a large volume of water is often required; however, it may be difficult to revise such volumes in an efficient way.

Spatial Separation: Hawaii has a complex infrastructure of under-used old drainage and irrigation-conveyance elements that may alleviate the challenge of water transfer from capture point to use. Nevertheless, it may be a significant challenge to improve and maintain such infrastructure to provide reliable transfer water across basin boundaries. Aquifer recharge can also alleviate this challenge by using subsurface connectivity to transmit water to the point of use.

Changing Conditions: Rapid development of urban areas (or, to a lesser extent, changes in agricultural land uses) has the potential to change the stormwater runoff hydrology of a basin, as well as the expected demand for a beneficial reuse. Estimates of the potential impact are only as accurate as estimates of the expected changes.

Sediment: For ambient water quality, habitat development, or potable water use, source water quality and sediment load can be a significant issue. In addition to soil particulates, urban runoff can contain a wide variety of contaminants associated with sediments, including heavy metals and hydrocarbons.

Temperature: Ambient water quality and habitat development often have associated temperature criteria. Releases from reservoirs, which may have stratified conditions, can lead to release temperatures that do not match ambient and seasonal conditions. Alternatively, increasing base flow by infiltration and percolation through ground water can restore more natural temperature management to stream systems.

Capture Location and Mechanism: Stormwater must be captured before it enters a natural stream system. In rural areas, this can present a significant challenge. In most cases, existing irrigation systems may be used to intercept surface runoff along hill slopes. In urban areas, storm drainage systems can be intercepted before the outfalls, but cost and space constraints can make it prohibitive to retrofit facilities.

Area of Application: Some types of uses may require small volumes of water distributed over wide areas. Others may have more localized demands.

Delivery Location and Mechanism: Some uses require subsurface delivery; others may require surface systems.

7.6.2.4. Evaluation of Stormwater Reclamation Methods

In order to thoroughly evaluate the appropriateness of stormwater reclamation practices and the associated infrastructure placement within communities or urban areas, all of the opportunities and constraints described previously must be carefully considered in terms of existing and planned land uses. In Hawaii, stormwater reclamation methods that employ capture and storage technologies would have to be planned, constructed, and operated to ensure minimal impact to streams, riparian environments, conservation lands, water rights, cultural practices, and community lifestyles.

The State, with the help of the U.S. Bureau of Reclamation, has taken the initial step towards the development of recycled stormwater as a water source with the completion of the *Hawaii Stormwater Reclamation Appraisal Report* (2005). The report assesses the relationship between supply and demand of stormwater for reuse opportunities. Specific opportunities are identified, evaluated, and ranked according to considerations in the following areas.

- flood frequency
- runoff volume
- water balance
- changing conditions/land use
- crop demand
- domestic demand
- fire flow
- water quality
- aquifer storage
- aquifer firm yield
- reservoir firm yield

The contents of the report and assessment methods are discussed in more detail in Section 7.7.1.

7.6.3. Desalination

Desalination can remove dissolved minerals, including but not limited to salt, from the source water. Seawater, brackish water, or treated wastewater can be processed through several desalination methods: distillation, vacuum freezing, reverse osmosis, and electrodialysis. Distillation and reverse osmosis are the more popular methods, and significant advancements in these technologies have been made since the 1980s.

Desalination plants can process a variety of input water, or feedwater types. Seawater can be taken up through offshore intakes or wells drilled into the beach or seafloor. Brackish ground water, which is generally less costly to process, and reclaimed water are other sources of feedwater. Pretreatment and post-treatment processes are also used for disinfection and elimination of other types of pollutants, including microbes and pathogens.

A variety of pretreatment processes are used to remove materials that interfere with desalination. Biocides, usually chlorine solutions, are used to remove algae and bacteria. Ozone or ultraviolet light treatments can be used to remove marine organisms. Some distillation plants must remove metals from the feedwater to prevent system corrosion. Reverse osmosis membranes can be impaired by chlorine, suspended solids, and particles. Thus the feed water must be further pretreated with dechlorination techniques, coagulation, and filtration.

Desalination plants that produce water for domestic use have post-treatment processes to ensure that the product water meets health standards and recommended aesthetic and anti-corrosive standards. The purity of desalinated product water is usually higher than drinking water standards, and the lack of dissolved solids and minerals creates acid pH levels that are corrosive to pipes. Therefore, desalinated water for municipal use is mixed with water that contains minerals or is otherwise adjusted for hardness, alkalinity, and pH prior to distribution.

7.6.3.1. Methods for Desalination

Common desalination methods can be described in two categories: phase change (distillation) methods, and membrane separation methods. These methods are generally described below.

Thermal Separation Methods

Distillation (Evaporation): Distillation involves heating saline or brackish water until it forms water vapor. This vapor, which is largely salt-free, is condensed to liquid form for storage and distribution. Common methods of distillation are multistage flash, multiple effect distillation, and vapor condensation. Some distillation plants produce freshwater, using a hybrid production process that employs two or more of these technologies. The waste product of distillation methods is a highly concentrated brine solution.

Freezing: This phase-change method is characterized by the formation of ice crystals with the dissolved salts remaining in the solution. Fresh water is produced by separating the ice crystals from the solution and melting the crystals. This process uses much less heat than the distillation method, but it has substantially higher operating and maintenance costs.

Membrane Separation Methods

Reverse Osmosis: Osmosis occurs when water passes through a semi-permeable membrane, separating two solutions of different salt concentrations. In natural osmosis, water moves out of the diluted solution until the concentrations of the two solutions become equal, or when the pressure on the concentrated-solution side of the membrane rises to the same osmotic pressure. The osmotic pressure may be referred to as the osmotic head, or the difference of the depths of the liquid surfaces of the two solutions. When a pressure greater than the osmotic pressure is exerted on the more concentrated solution, reverse osmosis occurs. The result is the movement of water from the more concentrated side of the membrane into the more dilute solution. In the reverse osmosis process, the concentrated solution can be either seawater or brackish water. The osmotic-pressure gradient is induced to move more water into the diluted solution. This water is then collected, stored, and distributed to various users.

Electrodialysis: Salts in solution disassociate into positively and negatively charged ions called cations and anions. Electrodialysis depends on the action of semi-permeable membranes than can selectively pass either cations or anions. When stacks of alternating cation- and anion-permeable membranes are placed in a direct current electric field and feed water is passed between the membranes, the cations migrate to the negative electrode (cathode) and the anions move to the positive electrode (anode). The membranes trap the ions in cells between the membranes, and the resulting solution is removed as waste brine. Water passing through the membranes is collected and removed for use as desalted water.

7.6.3.2. Desalination Issues and Constraints

The issues and constraints associated with different desalination methods are summarized in the following paragraphs. Other issues and considerations may also be relevant depending on the particular site or application.

Thermal Separation Methods

Distillation (Evaporation): Although distillation methods are capable of handling large quantities of saline water, there are disadvantages including, high thermal-energy requirements, high capital costs, high operating and maintenance costs, and severe scaling and corrosion problems. Scaling is a condition that results from the buildup of salt deposits on plant and pipe surfaces, and is caused by the high-salt concentration of seawater. Scaling increases in high-temperature environments, and in distillation plants it results in reduced plant efficiency and greater pipe corrosion. Scales can be removed by chemical or mechanical means and can be reduced by introducing additives to inhibit crystal growth, reducing temperatures or salt concentrations, removing scale-forming constituents, or seeding to form particles. In addition to problems with plant scaling, the intake and outfall structures and pipes can become corroded or fouled with marine organisms, and must be mechanically or chemically cleaned.

Distillation, in some cases, may not be competitive with other desalination methods. In Hawaii, the feasibility of using waste heat from a nuclear-power plant was considered by the Honolulu BWS and Hawaiian Electric Company (HECO) in the 1960s, but it was concluded at that time that the proposal was premature.

Freezing: The freezing method has limited applications, is relatively new, and is capable of producing only up to 100,000 gpd on a practical basis. Although it requires only about 15% of the energy used by the distillation process and results in minimal scaling and corrosion problems, its operating and maintenance costs are high. These costs are incurred in separating the ice from the brine, washing the ice crystals, and melting the crystals to form fresh water. As technology improves, the freezing method may have a future, especially in areas where only poor-quality water sources are available and where large quantities of product water are not required.

Membrane Separation Methods

Reverse Osmosis: Because reverse osmosis requires the use of permeable membranes, the feedwater must be pretreated to remove particles that can build up and clog the membranes. The quality of the product water depends on the pressure, the salt concentration of the feedwater, and the membrane's salt-permeation constant. Water quality can be improved by sending the product water on a second pass through the membranes.

The filters used for pretreatment of feedwater must be cleaned via backwashing, to clear accumulated particles and solids. The reverse osmosis membranes must also be cleaned several times a year with alkaline cleaners to remove organic fouling, and with acid cleaners to remove scale and inorganic precipitates. Membranes must be replaced every three to five years, and replacement procedures require partial or complete plant shut down.

Because reverse osmosis plants operate with lower temperatures, plant scaling is not as serious a problem as in distillation plants. However, reverse osmosis plant intakes and outfalls can also become corroded or fouled with marine organisms, and must be mechanically or chemically cleaned.

Electrodialysis: An electrodialysis reversal (EDR) system has been developed, which reverses the polarity of the electrodes several times an hour. This reversal process minimizes scaling and other adverse effects on the membranes. It should be noted that electrodialysis does not remove bacteria and other uncharged particles. Accordingly, it is necessary to stabilize and disinfect the product water before use.

7.6.3.3. Evaluation of Desalting Methods

Desalting methods must be compared with considerations to economics, location of area of need, availability and quality of feedwater, operational problems, energy demand, quantity and quality of product water needed, and environmental impacts. The most practical approaches for desalination in Hawaii would be electrodialysis and reverse osmosis. For the foreseeable future, we may conclude that Hawaii's municipal needs cannot be met through distillation, freezing, and ion exchange methods, although improving technology may make these methods more attractive in the future.

7.7. State and County Resource Augmentation Programs

7.7.1. CWRM Programs

The State is not a water purveyor, with the exception of small, park facilities and agricultural water systems. The county water agencies currently operate all public, municipal water systems and are responsible for developing municipal water sources. The DLNR Engineering Division is the agency that conducts source development for State facilities that are not on public water systems.

As far as resource augmentation, it is the State's responsibility to encourage the development and maximum beneficial use of alternative water resources. Therefore, the State should provide leadership and guidance to the counties and private water purveyors in the form of goals and priorities established through an integrated resource augmentation program. Such a program would ensure that the pursuit and development of alternative-water sources is executed in an efficient and sensible manner. Such a program would also encourage cooperation, development of implementation incentives, and innovative thinking among State, county, and private entities.

Planning for resource augmentation requires considerable lead-time for research and technical-resource acquisition, pilot programs and testing, and funding attainment. Resource augmentation program goals and priorities should be developed in consideration of a realistic time frame for implementation.

The State has recently completed two efforts toward the planning and development of alternative water sources. The *2004 Hawaii Water Reuse Survey and Report* was prepared to assist in planning efforts for wastewater reuse. In 2005, Reclamation, in cooperation with CWRM, completed the *Hawaii Stormwater Reclamation Appraisal Report*. These projects and the results of project efforts are described below.

7.7.1.1. 2004 Hawaii Water Reuse Survey and Report

The objective of the *2004 Hawaii Water Reuse Survey and Report* is to assist CWRM in understanding its role as a facilitator of water reclamation programs and as a proponent for the increased utilization of recycled water in Hawaii. The report is intended to help CWRM incorporate recycled water into statewide water resource management. It is the policy of CWRM to promote the viable and appropriate use of recycled water in so far as it does not compromise beneficial uses of existing water resources.

The report contains an overview of the current status of water reuse in Hawaii and descriptions of the existing water reuse projects within each respective county. Opportunities for future water reuse projects and ideas for future recycled water applications are also examined. New reuse opportunities, created through expansion of existing recycled water distribution systems, will significantly increase the volume of recycled water that is utilized, thereby improving the economies of scale for reuse program costs. The procurement of funding will determine if, and when, the existing systems will be expanded.

In addition to identifying reuse opportunities, the report discusses obstacles that restrict the growth and implementation of reuse projects, and their possible solutions. Finally, the report provides an overview of federal funding sources that may be applied to the development of reuse projects, and a directory of the existing projects in Hawaii. The report recommends regular updates every five years to inform and assist CWRM in the reuse-planning component of sustainable resource management.

7.7.1.2. Hawaii Stormwater Reclamation Appraisal Report

The *Hawaii Stormwater Reclamation Appraisal Report* was completed in June 2005 by Reclamation in consultation with CWRM. The report documents Reclamation's appraisal-level (planning-level) investigation of potential stormwater reclamation and reuse opportunities under Title XVI Program of Public Law 102-575, as expanded by Section 104(b) of the Hawaii Water Resources Act of 2000 (Public Law 106-566). Title XVI projects include reclamation water reuse and recycling, and Reclamation policy identifies the following uses as appropriate for funding under Title XVI: environmental restoration, fish and wildlife, ground water recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Within those broad categories, more specific uses, particular to stormwater capture and local needs, are identified.

In preparing the report, agency consultation meetings were conducted to collect stormwater reuse opportunity ideas, and this resulted in the identification of 31 opportunities for consideration. In this study, opportunities are specific locations where significant benefits may be gained from pairing supply and demand for reclaimed stormwater. Such opportunities must also be consistent with the goals of Title XVI and the desires of participating stakeholders.

The initial set of 31 opportunities was reduced to nine using a two-step screening process (preliminary and detailed). Preliminary screening criteria included factors such as implementability (institutional, regulatory, and land use), demand constraints, and generalized stakeholder acceptance. Detailed criteria such as operational flexibility, long-term permit compliance, flow augmentation, ground water recharge opportunities, and reuse potential were also considered.

The nine projects that came out of the screening process were evaluated and ranked on the basis of: ease of delivery and operation, dependability of water supply, simplicity of storage and water treatment, institutional considerations, the degree to which prior investment has been maximized, and cost. Specific areas of investigation included: basin land use, vegetation, soil, and slope characteristics; existing irrigation conveyance and natural stream networks; precipitation; expected demand area and size; and hydrology. Institutional factors were also assessed to identify potential direct and indirect effects on the institutional environment closest to the opportunity area. Existing knowledge and threshold-level information obtained informally during the study were used to establish the social and cultural context of the projects. Finally, preliminary cost estimates generated from rough general designs were examined and compared.

The nine candidate opportunities included locations on Molokai, Kauai, Oahu, Hawaii, and Maui. However, feasibility has not been established for all the opportunities described in the study. To move the opportunities toward funding for construction under Reclamation's Title XVI program, several key elements must be addressed:

- Congressional authorization needs to be obtained for Reclamation involvement in conducting feasibility studies.

- A project sponsor must be identified. In some cases, there is already an organization or entity that has taken responsibility for success of the project. In others, discussion with local stakeholders to date has focused on whether the project represents a "good idea" and is valuable and viable. It is vital to this process to investigate interest in ownership and market the opportunities to local groups capable of completing the funding and construction process.

- Owing to the significant nonfederal funding contribution required, additional education and outreach to local stakeholders is needed. In many cases, matching contributions for a project will be allocated by nonfederal, elected representatives. To maximize the chances of success, key constituent groups would have to be identified and approached regarding the potential benefits of the project. Such groups must be given ample opportunity to explain concerns and needs for making the project successful for all involved.

7.7.2. County Resource Augmentation Programs

The following sections describe resource augmentation programs currently administered by the counties, as well as other private projects. The County of Maui has a well-developed and successful wastewater reclamation program. In the City and County of Honolulu, wastewater reclamation and desalination are being championed by the Board of Water Supply. Wastewater reclamation is also being practiced at a smaller scale in the counties of Kauai and Hawaii.

7.7.2.1. County of Maui

Wastewater Reclamation

The County of Maui's Wastewater Reclamation Division is considered to be a water reuse leader in Hawaii. In 1990, Maui County developed a plan and embarked on a long-range program to reuse millions of gallons of a valuable resource, high-quality recycled water, which previously had been disposed into injection wells. To lay the foundation for the county's program, several key components were initiated including: water reuse feasibility studies; a community-based rate study; the creation of a Water Recycling Program Coordinator position; upgrades to the Kihei (South Maui) and Lahaina (West Maui) wastewater reclamation facilities to R-1, tertiary-treatment capability; passage of an ordinance mandating the use of recycled water at commercial properties; adoption of rules for recycled water service; and the creation of a recycled water rate structure, which recovers monies spent on distribution-system development from both recycled water and sewer users.

Program Development: The impetus behind the development of Maui County's water reuse program was a regulatory-agency belief that Maui's effluent-disposal practices were causing environmental problems. The United States Environmental Protection Agency and local environmental groups expressed a concern that injection wells may contribute nutrients that cause alga blooms in coastal waters. In 1995, the EPA placed a limitation on the amount of effluent that could be disposed into the injection wells at the county's Lahaina Wastewater Reclamation Facility (WWRF). This factor played a major role in the passage of the bill, which led to the mandatory recycled water use ordinance on Maui. Increased recycled water use on the island and the results from scientific studies, which indicated that other non-point nutrient sources might be the cause of the periodic alga blooms, have eased this concern somewhat. Nevertheless, effluent disposal will continue to be a factor driving the County of Maui's water reuse program, since most of its wastewater reclamation facilities rely on injection wells. As performance of these injection wells eventually decline, increasing the use of recycled water from the respective facilities, rather than drilling additional wells, may be required by regulatory agencies.

Potable Water Supply: Water supply is now a factor driving the County of Maui's water reuse program. The island of Maui has limited supplies of available fresh water. The island's main water source, the Iao Aquifer System Area, supplies most of Central and South Maui with potable water. Much of this water is used for landscape irrigation at parks, schools, condominiums, hotels and single-family residences. Due to increasing development in these areas, the Iao Aquifer System Area is showing signs of overpumping. Over the past several years, monitoring of the aquifer's wells has indicated that chloride levels are increasing and freshwater levels are decreasing. CWRM recently designated the Iao Aquifer System Area as a Ground Water Management Area. The nearby Waihee Aquifer System Area has also been the subject of designation concerns. CWRM designates water management areas to ensure the long-term sustainability of the resource by establishing administrative control over the withdrawal of ground water in the area.

Recycled Water Infrastructure: Wastewater Reclamation Division uses recycled water from all five of its facilities. Distribution systems have been developed in South Maui and West Maui. South Maui has the most complete distribution system at this time and as a result, the most water reuse projects. The South Maui system now provides recycled water to eighteen separate projects, with more scheduled to connect to the distribution system in the near future. Uses include landscape irrigation, agricultural irrigation, fire control, industrial cooling, composting, construction activities, and toilet and urinal flushing.

West Maui distribution is limited, due to insufficient recycled water storage, but it does service Maui County's largest water reuse project, the Kaanapali Resort. Up to 1.2 mgd is utilized by the resort for golf course and landscape irrigation. Plans are now being developed to expand this system to provide R-1 water to condominiums and hotels in the Kaanapali area. R-1 water is also pumped to Maui

Pineapple Company, but use has been limited due to above-average rainfall since the distribution system was built. Maui Pineapple Company will also phase out pineapple production in west Maui in the year 2006.

In addition to the major distribution systems described above, recycled water is utilized from Maui County's facilities on Lanai, Molokai, and in central Maui. On Lanai, wastewater is processed to R-3 quality utilizing stabilization ponds, and then the entire plant flow of approximately 0.25 mgd is sent to an auxiliary WWRF owned and operated by the Lanai Company where it is upgraded to R-1 quality and used for golf course irrigation. On Molokai, the State Department of Transportation utilizes R-2 water for landscape irrigation along the Maunaloa Highway. Finally, in central Maui, R-2 water is used to irrigate coconut trees and native Hawaiian plants at the Kanaha Cultural Park, which is adjacent to the Kahului WWRF.

Economics: Since water supply and wastewater disposal were both important factors driving Maui County's water reuse program, both recycled water users and sewer users share the costs associated with recycled water production and delivery. A portion of the sewer fees collected from all commercial and residential users of Maui County's sewer system is used to pay for the recycled water program's operation, maintenance, and infrastructure costs. Maui County officials believed that sewer users must not only pay the costs associated with wastewater collection and treatment, but must also help bear the costs of effluent disposal, whether it is through the use of injection wells or through water reuse. This approach allowed Maui County officials to set the price of recycled water at rates that encourage users to connect to the distribution system. The following user classes, with corresponding costs of recycled water, were created:

- Major Agriculture (> 3.0 mgd): $0.10/1000 gallons;
- Agriculture (including golf courses): $0.20/1000 gallons; and
- All Others: $0.55/1000 gallons.

The rates were set at levels slightly below the costs of the water sources typically used by the three recognized user classes. An "avoided cost" category was also created which allows recycled water consumers to pay the same rate for recycled water as they were paying for other non-potable water sources. Connection fees for the south and west Maui areas, where major R-1 distribution systems were developed, were also established to help pay for the recycled water program.

Public Education and Outreach: Proactive public education has played an important role in the success of Maui County's water reuse program. The Wastewater Reclamation Division's Water Recycling Program Coordinator conducts up to 100 presentations per year on water conservation, wastewater treatment, and water reuse to schools, community groups, and the general public. Tours of the County's wastewater reclamation facilities are also provided. In addition, the coordinator issues press releases announcing new projects that use recycled water and expansions to County recycled water distribution systems. Promotional items such as bumper stickers, magnets, rulers and pamphlets are also utilized.

Generally, the public has supported the concept of reusing wastewater within the community. As a result of its proactive approach to public education, the County has encountered little opposition to its water reuse program.

Most of the water reuse projects in Maui County are provided recycled water by the County of Maui's WWRD. There are also private systems, including resorts and housing developments that treat their own wastewater and utilize the recycled water for golf course irrigation. The Pukalani and Makena Golf Clubs on Maui, the Challenge at Manele on Lanai and the Kaluakoi Golf Club on Molokai blend recycled water with other non-potable sources to satisfy their respective irrigation demands.

Lanai has changed its economic base from pineapple cultivation to tourism in recent years. Two resorts, the Lodge at Koele and the Manele Bay Hotel, are located on the island and both recycle their wastewater at their respective golf courses. Water reuse is important on Lanai, because the island typically receives below-average rainfall and Maui County prohibits the use of potable water for golf-course irrigation.

Molokai is lightly populated and one of the least-visited islands in the Hawaiian chain. The bulk of the wastewater produced is treated at the County of Maui's Kaunakakai WWRF and disposed of via injection wells. A small volume is used for landscape irrigation along the Mauna Loa Highway. The Kaluakoi Resort on the west end of the island also recycles its wastewater for use on its golf course.

Puu O Hoku Ranch is located in south-central Molokai in Kaunakakai and recently commenced operation of a constructed wetlands system in the year 2004. The system is relatively small and is designed for only 3,700 gpd. Wastewater is collected from the ranch and treated to R-3 quality using septic tanks, effluent screening, and a constructed wetland. The R-3 water is used to irrigate trees and shrubs via a sub-surface drip irrigation system. The ranch benefits from the improved wastewater treatment capability and the creation of a drought-proof supply of water that satisfies much of its irrigation requirements.

Program Expansion: The County of Maui has two existing R-1 recycled water distribution systems, both of which have the potential to be expanded. The South Maui system is the most complete, as it has recycled water storage both at the Kihei WWRF and offsite at an elevated, covered storage tank. The West Maui system does not have adequate storage, and is thus limited in the number of projects that it can serve.

7.7.2.2. City and County of Honolulu

Wastewater Reclamation

In contrast to the County of Maui, where water reuse has been championed by the municipal-wastewater agency, Honolulu BWS has emerged as the lead agency for water reuse in the City and County of Honolulu. The use of recycled water has increased significantly on Oahu since the Honolulu BWS developed a comprehensive water reuse program in the late 1990s. The Honolulu BWS recognized that recycled water is a resource valuable to extending Oahu's potable water supplies.

Program Development: Most water reuse growth on the island has occurred in the arid Ewa district of southwest Oahu, where significant development has occurred in recent years. Sugar cane cultivation has given way to numerous residential, commercial, and industrial developments. The change in land use has adversely affected the region's water resources. The recharge of the region's caprock aquifer has been significantly reduced by the elimination of sugar-cane irrigation, and the construction of impermeable surfaces. Also, the amount of potable water used in the region has dramatically increased, placing a strain on Oahu's aquifers.

Development in the Ewa area includes: a number of golf courses that use brackish water from the caprock aquifer for irrigation; residential subdivisions, which use potable water for irrigation of yards, parks and median strips; and the Campbell Industrial Park that uses potable water for industrial processes.

Recycled Water Infrastructure: The City and County of Honolulu was required to build the secondary treatment facilities at the Honouliuli Wastewater Treatment Plant (WWTP) to comply with a 1993 consent order by the DOH. The main objective of the consent order was to establish secondary treatment at the plant, and to reuse portions of the treated effluent. Improvements to the facility were completed in 1996, with approximately 2.0 mgd of recycled water being used for in-plant demands. In 1995, EPA, the DOH, and the City entered into a consent decree that required the City to develop a water reuse system that would allow the City to recycle 10 mgd of water by July 2001. The Honouliuli WWTP was selected for implementation of the water reuse requirements, because of the increasing demands on the Ewa aquifer, the reduction of recharge due to the cessation of sugar cane cultivation, and the close proximity of the facility to potential users of recycled water.

The City and County of Honolulu selected Veolia Water North America (formerly U.S. Filter Corporation) to oversee construction, own, and operate the Honouliuli Water Recycling Facility (WRF). Recycled water distribution systems were built to deliver R-1 and R-O water to the potential users. CWRM adopted a policy to champion direct and indirect water reuse in the Ewa plain. Recognizing that recycled water is a valuable resource in the Ewa plain, and knowing that R-1 water would ultimately be available in the area, CWRM issued interim water use permits to the planned golf courses and other nonpotable users in the area, and conditioned these water use permits on conversion to R-1 water once it became available and acceptable for use.

The Honolulu BWS purchased the Honouliuli WRF in 2000 from Veolia Water North America, with the intent of integrating water reuse into a plan to conserve water resources through conservation and the development of new water supplies. The Honouliuli WRF receives secondary effluent from the Honouliuli WWTP and produces both R-1 and R-O grades of recycled water. R-1 water is now delivered to eight golf courses, three parks, and a median strip, where it is used for landscape irrigation. R-O water is delivered to refineries and power generation facilities in Campbell Industrial Park. Hawaiian Electric Company's Kahe power plant and the proposed Campbell peaking power plant are scheduled for connection to the RO water system within the next two years. Veolia Water North America operates and maintains the Honouliuli WRF on a contractual basis, while the Honolulu BWS operates and maintains the distribution system.

Program Economics: The Honolulu BWS has individual agreements in place with its recycled water customers. In general, golf courses and other landscape irrigation customers pay less than industrial customers. The initial rates for R-1 water were set significantly lower than what it costs the Honolulu BWS to produce and deliver the recycled water to the golf courses. Once the agreements expire, the Honolulu BWS may need to increase its recycled water rates, to recover the costs associated with production and delivery. The rate increase may place an economic hardship on the golf courses, and they may decide to revert back to less-expensive caprock wells for irrigation. Irrigation use is allowed, as long as well pumpage remains within permitted allocations and chloride levels in well water do not exceed 1,000 milligrams per liter. If the golf courses do revert back to ground water sources for irrigation, the Honolulu BWS recycled water program could be affected.

Public Education and Outreach: The Honolulu BWS's water reuse program is staffed by a recycled water program manager and three recycled water program coordinators. As in the case with the County of Maui, proactive public education has been an important component of the Honolulu BWS's water reuse program. The Honolulu BWS hired a public relations firm to develop a strategy and promotional/educational items to gain public acceptance of its program. The program's recycled water coordinators play a key role in outreach efforts. The coordinators participate in outreach efforts, conduct numerous tours of the Honouliuli WRF, and provide presentations to the community on a regular basis.

Program Expansion: Water reuse has been successfully practiced on Oahu for decades. The oldest Hawaiian reuse project is at Waialua Diversified Agriculture, where recycled water has been blended with stream water and used for irrigation of sugar cane and diversified agriculture since 1928. Other projects with successful track records include the Marine Corps Base Hawaii Kaneohe Klipper Golf Course, where R-2 water has been used to irrigate the base golf course since 1966, and Hawaii Reserves, Inc., where R-1 water has been used to irrigate diversified agriculture and the athletic fields at the Brigham Young University Hawaii campus since 1995. Most of the growth in water reuse on Oahu has taken place in the Ewa district of southwest Oahu, due to the Honolulu BWS's water recycling program. Of the City and County of Honolulu's eight WWTPs, the Honouliuli and Wahiawa WWTPs are under consideration for expansion. A third facility, the Waianae WWTP on the Leeward Coast, is under consideration for a future water reuse project.

Desalination

Desalination on a municipal scale has been considered intermittently in the past. In the 1960s, the Honolulu BWS conducted studies on the feasibility of desalination using seawater and brackish water. At that time, the estimated cost of desalting brackish water (water containing up to about 1,500 parts per million chloride) was $0.50 per 1,000 gallons, and for seawater, the cost was about $1.00 per 1,000 gallons.

In 2003, the Honolulu BWS completed construction and testing of a seawater-desalination pilot plant that could eventually produce 5 mgd of potable water. The plant is part of the BWS's strategy to diversify water sources, and it is located between Campbell Industrial Park and Barbers Point Naval Air Station in Ewa Beach. The Honolulu BWS intends the desalination plant, which employs reverse osmosis technology, to provide water for drought mitigation and to meet projected water demands for the Ewa and Kapolei areas. When completed, the $40 million facility will contain an administrative building and visitors center, a chemical storage building, a reverse osmosis building, injection and source wells, a brine pond, and parking, as well as an off-site electrical substation.

If brackish ground water is pursued for desalination, the sustainable yield of caprock-brackish water on Oahu is limited to probably not more than 15-20 mgd. For basal-brackish water, the supply is greater, but care must be exercised in the use of this source because of possible jeopardy to the basal ground water body and nearby wells.

7.7.2.3. County of Kauai

Wastewater Reclamation

The County of Kauai has not formalized its water reuse program. R-2 recycled water from three of its facilities is provided at no cost to nearby projects. For years, effluent from County wastewater reclamation facilities was used to irrigate sugarcane. Transmission systems, consisting of ditches and reservoirs, were used to transport the effluent to the sugarcane fields. These same transmission systems are still used today to deliver R-2 water to the Kauai Lagoons Resort and to Kikiaola Land Company. The County now has agreements in place with the Kauai Lagoons Resort and Kikiaola Land Company to accept effluent from the Lihue and the Waimea WWRFs, respectively. The Wailua WWRF's effluent is reused at the adjacent Wailua Municipal Golf Course. This is a convenient situation for both the Wailua WWRF and the golf course, since the County of Kauai owns both facilities. As these projects are the primary disposal sites for the effluent from the County wastewater facilities, the County has no plans at this time to charge for the recycled water.

Kauai has abundant surface water resources, and water from rivers and streams has been diverted through ditch conveyance systems to provide non-potable irrigation water for many golf courses and agricultural projects. As a result, recycled water use at most of Kauai's water reuse projects is considered more of a convenient wastewater effluent disposal option, rather than a water supply resource. A total of six projects utilize recycled water for golf course irrigation. A seventh project at Kikiaola Land Company blends R-2 recycled water from the Waimea WWRF with stream water for seed-corn irrigation.

There are no plans in place at this time to expand any of the County of Kauai's recycled water distribution systems.

7.7.2.4. County of Hawaii

Wastewater Reclamation

The County of Hawaii is developing a water reuse program, and currently provides R-2 recycled water to only one project, Swing Zone Golf Practice Facility in Kona. In this case, the owner of Swing Zone installed the recycled water distribution system from the County's Kealakehe WWRF to the practice facility at his own expense. The County's Wastewater Division is contemplating developing a distribution system to provide recycled water from its Kealakehe WWRF to a number of irrigation projects, including parks and future golf courses. Lack of available funding, however, has delayed implementation of these ideas. Technical-planning assistance has been provided to Hawaii County by Reclamation, to plan and design a proposed constructed wetlands system that will utilize recycled water from the Kealakehe WWRF. Federal authorization is being pursued in Congress for funding of this project, along with two other county water reclamation projects (on Maui and Oahu). Federal funding shall be subject to authorization and subsequent Congressional approval for appropriation of funds on a cost-shared basis.

Water reuse on the Big Island mainly takes place at five private, resort developments where wastewater is treated at resort-owned wastewater reclamation facilities, and then blended with other water sources and reused for irrigation of the resorts' golf courses. Other projects include the State Department of Transportation's Keahole International Airport, where R-1 water is used for irrigation of the airport's landscaping, and at Parker Ranch, where R-3 water is used for pasture irrigation. Swing Zone is a unique reuse project, because the owner installed a recycled water transmission system at his own expense to convey 0.06 mgd of R-2 water to the Swing Zone property, where it is used to irrigate the facility's turf grass.

The County of Hawaii's Wastewater Division is in the planning stages of developing a recycled water distribution system that will utilize recycled water from the Kealakehe WWRF. Phase one, which will satisfy the requirement of a consent decree for the County to use recycled water, involves constructing a pipeline to deliver recycled water to the Honokohau Harbor for landscape irrigation. This phase was to be completed by June 2005, and could also serve a future development by the Department of Hawaiian Home Lands. Phase two is in the design stage, and involves the development of a pipeline and reservoir system that could deliver recycled water to a possible future golf course as well as a future development. The Wastewater Division will continue to attempt to obtain federal funding for a constructed wetlands system to upgrade the Kealakehe WWRF to produce an R-1-quality water system.

7.7.3. Recommendations for Water Resource Augmentation Planning

The State Water Code states that CWRM shall plan and coordinate programs for the conservation and protection of water resources.[4] The Water Code also states that the Hawaii Water Plan shall include programs to conserve, augment and protect the water

[4] HRS §174C-5(12).

resources.[5] Therefore, it is recommended that CWRM act in an advisory capacity, guiding policies and planning efforts for augmentation projects.

The State Water Code also enables CWRM, via conditions placed on water use permits, to require the use of dual line water supply systems in new industrial and commercial developments located in designated water management areas.[6] CWRM should coordinate with county agencies to obtain regular updates for recycled-water service areas and capacities, and apply the dual line water supply system requirement to permit applications within the portions of water management areas served by recycled water distribution systems. CWRM and the DOH should also explore the use and application of gray water and gray water systems, and pursue the development of DOH use guidelines for gray water, to encourage county governments to include provisions for gray water systems in the county planning codes.

It is also recommended that CWRM explore partnerships with governmental agencies and stakeholders in order to coordinate resource augmentation planning and policies. Suggested agencies for involvement include, but are not limited to: water agencies, energy agencies, coastal-management agencies, natural-resource management agencies, economic-development agencies, and public-utility commissions. County water departments, county wastewater departments, county planning departments, DBEDT, DLNR, DOH, Coastal Zone Management program and Special Management Area program administrators, the Bureau of Reclamation, and the EPA should specifically be consulted. Environmental groups, private industry, and economic interests should also be invited to participate in creating a vision for the program. Furthermore, government agencies involved in resource augmentation planning should be encouraged to establish cooperative relationships with professional organizations like the American Water Works Association, the American Society of Civil Engineers, the American Public Works Association, the Water Environment Federation, the American Planning Association, the American Counsel of Engineering Companies of Hawaii, and other such organizations that have extensive industry expertise and skilled, knowledgeable membership bases.

The water resource augmentation planning efforts and policies must be designed to complement the water conservation program recommendations in Section 7.5, and incorporate the intent of these recommendations whenever appropriate. A long-term goal for CWRM should be to establish a resource augmentation planning program and framework to identify augmentation goals, objectives, and priorities to promote the use of alternative water resources and to encourage the development of these supplies in an efficient and sensible manner. Reiterating the assertion noted in Section 6 of the WRPP, land use planning and water resource planning should be accomplished with ongoing, mutual consultation in order to be successful and sustainable.

7.7.3.1. Recommendations for Wastewater Reclamation in Hawaii

It is recommended that the goals and strategies discussed above, as well as the results of the *2004 Hawaii Water Reuse Survey and Report,* should be used by the counties as a guidance document to assist county reuse initiatives. It is recommended that county governments examine the potential recycled water

[5] HRS §174C-31(d)(4).
[6] HRS §174C-51.5(a).

expansion and application projects identified in the *2004 Hawaii Water Reuse Survey and Report*. Counties should use the report to help strategize ways to develop and expand water reuse within their jurisdictions.

Furthermore, counties should include their current water recycling program, or strategies for program development, into subsequent updates of the County WUDPs to maintain consistency with the WRPP.[7] County recycled water rates should be published or made available upon inquiry to users, potential customers, and the general public.

It is recommended that the DOH controls and regulations for the application of recycled water address potential safety and public health concerns, including but not limited to the application of recycled water over potable water aquifers.

7.7.3.2. Recommendations for Stormwater Reclamation in Hawaii

The amount of stormwater runoff from urban areas is indeed significant, as is evidenced by existing storm drain systems and flood control installations. This water could be captured, treated, and applied to beneficial uses; however the feasibility of large-scale stormwater reclamation remains to be assessed.

State regulations are in place to ensure the protection of stormwater receiving waters. The DOH administers the National Pollution Discharge Elimination System and Total Maximum Daily Load programs that regulate the discharge of stormwater. State and county government should encourage the use of stormwater reclamation and reuse measures that could be used to meet some of these program requirements.

The *Hawaii Stormwater Reclamation Appraisal Report* identified possible sites for stormwater reclamation, but these projects may be premature. On the other hand, small-scale reclamation technologies, such as rain barrels, are easily implementable at residences and small facilities. Landscape features, such as rain gardens for infiltration, can also be incorporated into building and parking lot design.

Therefore, it is recommended that county governments encourage the use of small-lot and source-reuse technologies to manage precipitation and runoff as close to the source as feasible, and to provide water for a variety of non-potable uses. Government facilities can provide excellent demonstration sites for these simple technologies. The county could also provide incentives, in the form of water credits or speedy-permit processing, to encourage the implementation of on-site stormwater reuse.

Counties should also examine the potential stormwater reclamation opportunities described in the 2005 appraisal report for future application. Additionally, counties should look beyond the recommendations of the 2005 report in formulating potential local reclamation opportunities, and be able to contribute new or updated information to future report updates.

[7] HRS §174C-31(b)(1).

7.7.3.3. Recommendations for Desalination Programs in Hawaii

Desalination plants are in use in other parts of the country, but it is only recently that technological developments have reduced the costs and energy requirements to be comparable to that of new well construction in many coastal areas of the continental United States. Coastal communities generally lack experience in evaluating the environmental impacts or public-resource issues associated with the construction and operation of desalination plants, and this remains a matter of concern as the number of desalination plants increase.

In 2004, approximately 24 desalination facilities were being planned for various locations along the California coast. Recognizing the need to anticipate information and evaluation requirements for proposed desalination plants, the California Coastal Commission published a report in March 2004 titled *Seawater Desalination and the California Coastal Act.* The report clearly emphasizes that the "concerns about desalination are due primarily to its potential to cause adverse effects and growth that are beyond the capacity of California's coastal resources." The purpose of the report is to provide information on issues related to desalination and its possible effects on coastal resources and coastal uses, describe existing and proposed facilities, identify and discuss policies of California's Coastal Act that apply to desalination programs, and identify information required during coastal development permit review for proposed facilities.

Many of the report's primary findings may be considered in terms of their applicability to water augmentation and desalination facility planning in Hawaii. It is recommended that all proposed county and private desalination facilities evaluate the potential impact on coastal resources and uses.

7.8. Effects of Global Climate Change on Hawaii's Water Resources

The impacts of global climate change in the Hawaiian Islands can potentially devastate our considerable natural resources. Climate change causes alterations in temperature and precipitation patterns, and Hawaii's water resources are almost exclusively dependent on rainfall. This section focuses on potential impacts of climate change to the state's freshwater resources.

7.8.1. Overview

Climate is defined as the long-term average of weather conditions such as temperature, precipitation, and cloudiness.[8] Long-term trends in these weather elements are used as an indication of climate change. The most conspicuous evidence of climate change is the widespread rise in temperatures over the past century. Data has shown that the mean global temperature has increased by 1.4º F since the early 1900s and about 0.9º F of this increase occurring since around 1979.[9]

[8] The National Academies. 2005. Understanding and responding to climate change, highlights of National Academies Report. The National Academy of Sciences. 20 p.
[9] The National Academies, 2005.

Causes of climate change have been linked to human activities—mainly the increase in carbon dioxide due to the burning of fossil fuels. Increased carbon dioxide concentrations in the atmosphere are closely related to increases in global temperatures. Although some climate change can be attributed to natural causes, climate temperature model predictions closely match observed temperature changes when both natural and man-made causes are accounted for in these models.[10]

Global climate change can affect precipitation patterns, ocean temperatures, and sea levels. Scientists also have identified potential impacts to society and the environment. Generally, there may be impacts to human health, agriculture, forests, water resources, coastal areas, freshwater ecosystems, coral reefs, species diversity, and natural areas.[11] Consequently, potential impacts to Hawaii's surface and ground water resources due to global climate change need to be considered when planning for water resource protection in Hawaii.

7.8.2. Local Climate Trends

A 2004 USGS study has shown that from 1913 to 2002, there was a downward trend in annual rainfall over much of the state and an associated general downward trend in stream base flows across the state. However, the same study identified far fewer rainfall stations with a downward annual rainfall trend for the period 1893 to 2001.[12] Further study is required to determine whether the downward trends in stream base flows will continue or whether the observed pattern is part of a long-term cycle where base flows may eventually return to higher levels.

Short-term rainfall variation in Hawaii can be attributed to the El Niño/Southern Oscillation (ENSO) phenomenon, with lower winter rainfall associated with El Niño events. The recently discovered Pacific decadal oscillation (PDO) describes a low-frequency, long-term (inter-decadal) anomaly in North Pacific sea-surface temperatures and can be characterized by a PDO index. Research has shown that ENSO and PDO are interrelated and that inter-decadal Hawaiian rainfall trends are negatively related to the PDO index.[13]

While mean global temperature has increased by 1.4º F since around 1900, one paper notes that the average temperature in Honolulu has increased 4.4º F over the last century.[14]

General circulation models (GCM) can be used to predict future climate trends; however, current GCMs do not have a fine enough horizontal resolution to accurately predict climate

[10] The National Academies, 2005.
[11] National Assessment Synthesis Team. 2000. Climate change impacts on the United States: the potential consequences of climate variability and change. US Global Change Research Program, Washington DC. http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm (accessed 23 March 2006).
[12] Oki, D.S. 2004. Trends in streamflow characteristics at long-term gaging stations, Hawaii, U.S. Geological Survey Scientific Investigations Report 2004-5080. 120 p.
[13] Chu, P.S., and Chen, H. 2005. Interannual and interdecadal rainfall variations in the Hawaiian islands. Journal of Climate, v. 18, p. 4796-4813.
[14] United States Environmental Protection Agency, Office of Policy. 1998. Climate change and Hawaii, EPA 236-F98-007e. United States Environmental Protection Agency. 4 p.

changes on a regional or island scale.[15] Current models predict increased atmospheric and ocean warming based on future increases of carbon dioxide in the atmosphere.

Some climate model projections indicate more frequent El Niño events and stronger La Niña events due to a warmer climate. Some climate models also suggest more persistent El Niño conditions.[16] While future precipitation changes in Hawaii are uncertain, the frequency and variability of extreme weather such as floods and droughts may increase, although climate models differ in estimating future changes in precipitation.[17]

Finally, a warmer climate is expected to cause a rise in sea levels due to thermal expansion of the oceans and the melting of glaciers and ice caps. According to the EPA, the sea level is already rising at a rate of 6 – 14 inches per century at Honolulu, Nawiliwili, and Hilo.[18] This may have an impact on fresh and brackish water aquifers near Hawaii's shorelines.

7.8.3. Impacts to Hawaii

Although there may be multiple impacts to Hawaii due to climate change, this section focuses on any impacts to the State's freshwater resources. Since Hawaii's water resources are almost exclusively dependent on rainfall (and fog drip to a lesser degree), any changes in the frequency and duration of droughts, and rainfall patterns can affect Hawaii's ground water and surface water supplies. Increased temperatures can affect evapotranspiration and the hydrologic cycle (i.e., water balance). More frequent and intense El Niño -related drought events could reduce ground water recharge and surface runoff (stream flow). Long periods of reduced precipitation, combined with rising sea levels, may cause seawater intrusion into near shore aquifers and affect drinking water quality.

As mentioned above, a downward trend in annual rainfall and stream-base flows occurred across the state from 1913 to 2002. Long-term trends in ground water characteristics are more difficult to identify and have not been thoroughly investigated.

Issues and Unknowns

Although much progress has been recently made in climate modeling, due to improved computer technology and climate model sophistication, there are many uncertainties on how a warming climate will affect Hawaii's water resources. Current climate models cannot accurately predict precipitation changes for Hawaii, due to the coarse horizontal resolutions and the complex local topography. Clearly, any changes in rainfall patterns and trends will impact ground water and stream flows. Temperature changes will affect evapotranspiration and the hydrological water balance. Prudent water resource planning should consider the long-term impacts of global climate change and how this could affect Hawaii's water supplies, however more research is needed to determine more specifically what these impacts would include.

[15] Chu, 2005.
[16] National Assessment Synthesis Team. 2000
[17] United States Environmental Protection Agency, 1998.
[18] United States Environmental Protection Agency, 1998.

7.8.4. Recommendations to Mitigate Impacts of Climate Trends

Given the high degree of uncertainty as to how climate change will impact Hawaii's freshwater supplies, CWRM should seek appropriate legislative funding to undertake the following investigative actions in pursuit of fulfilling CWRM's mandate for comprehensive water resource planning to address the supply and conservation of water:

- Conduct research on the impacts of global climate change to long-term precipitation patterns in Hawaii.
- Conduct research on how global climate change would impact Hawaii's hydrologic budget and water resources.
- Conduct research on how global climate change would impact Hawaii's potable and non-potable water demands.
- Develop improved El Niño forecasting tools.
- Together with the county water departments, design and implement mitigation measures to address the range of potential impacts to Hawaii's water resources due to global climate change; identify critical water sources and design mitigation alternatives that may include actions such as partial backfilling of deep wells, construction of hydraulic barriers, and relocation of wells further inland.
- Encourage sustainable water supply practices.

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