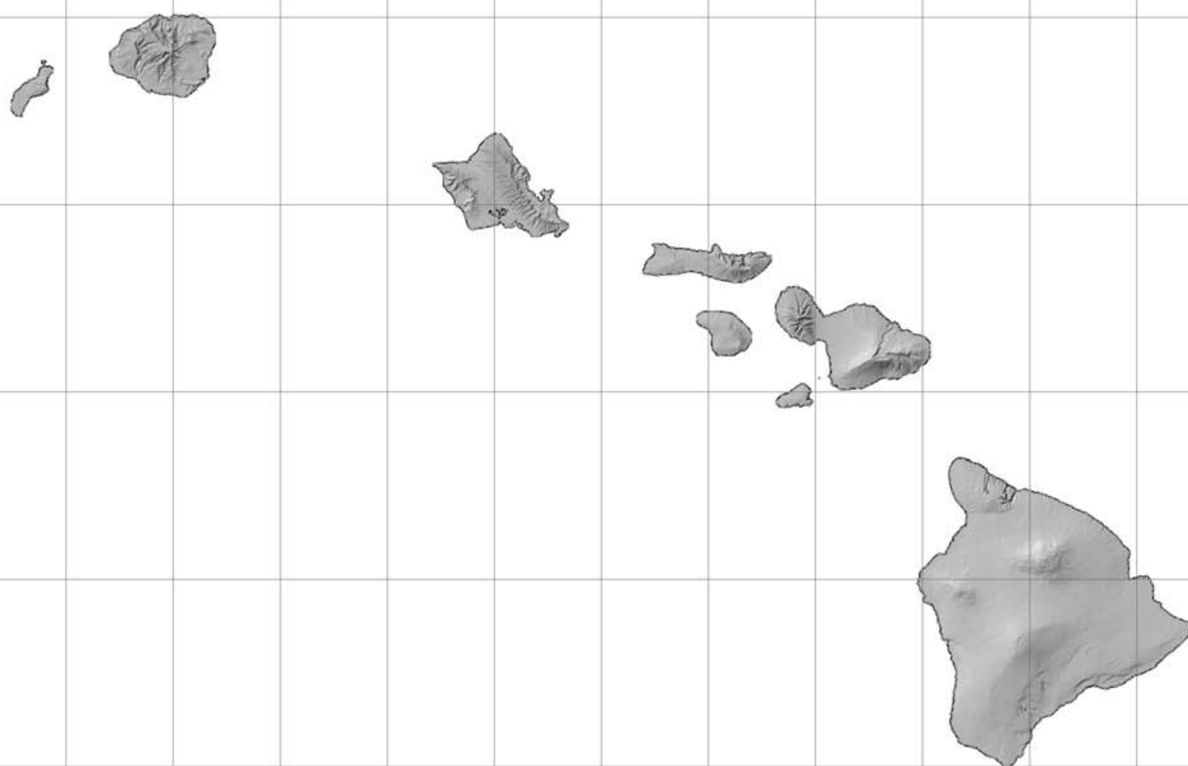
# AGRICULTURAL WATER USE AND DEVELOPMENT PLAN

## December 2003

(Revised: December 2004)



Department of Agriculture

STATE OF HAWAII

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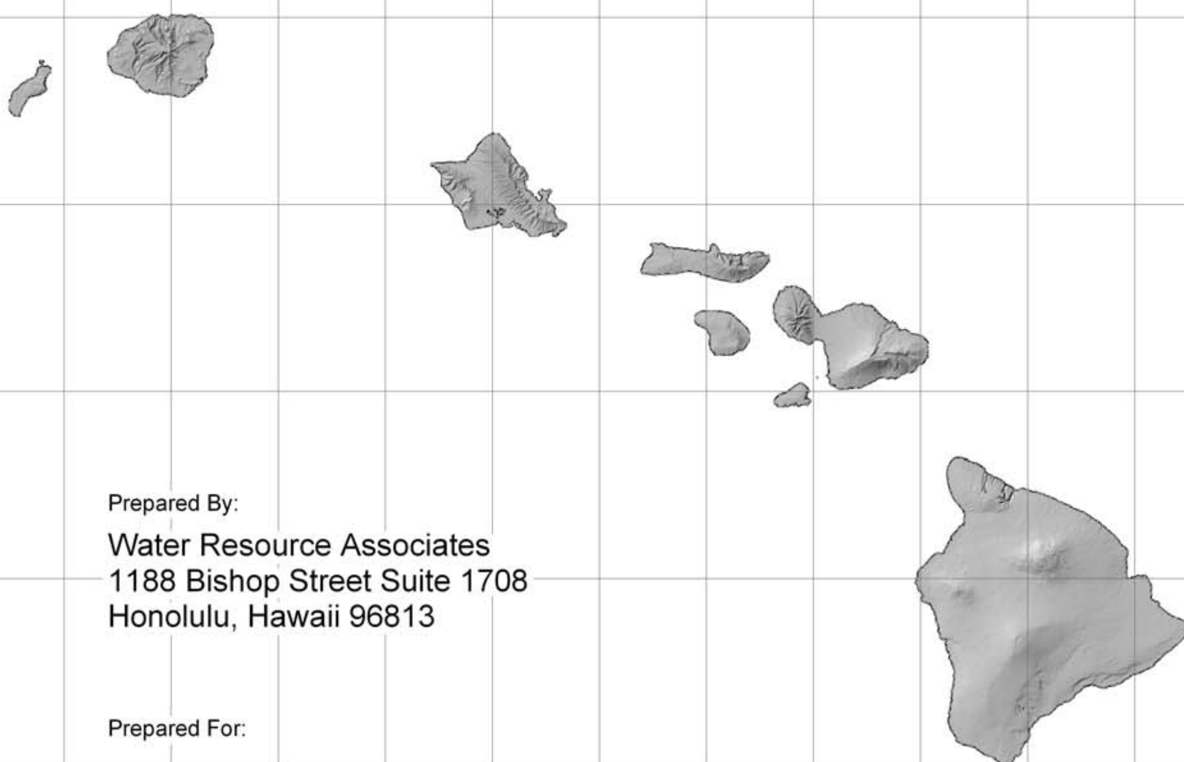

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Department of Agriculture
STATE OF HAWAII

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# FOREWORD

This Agricultural Water Use and Development Plan (AWUDP) documents thirteen active irrigation systems, ten of which are State-operated and three of which are privately owned. Broadly speaking, the Plan focuses on transforming former plantation systems to diversified agriculture use, as well as maintaining systems already devoted to diversified agriculture use. Its usefulness lies in its: (1) inventory and plan for the rehabilitation of the irrigation systems, (2) identification of irrigable lands for diversified agriculture, and (3) forecasts of acreage and water needs for diversified agriculture for each irrigation system over a 20-year planning period.

With large amounts of prime agricultural lands and irrigation systems made available for conversion to diversified agriculture by plantation closures in the 1990s, the State has an unparalleled opportunity to strengthen and expand Hawaii's diversified agriculture industry. Hawaii imports the majority of the produce it consumes and all of its fresh fruit needs, except for papaya, pineapple, watermelon, and some banana. With available farm lands and adequate irrigation water, a significant expansion of Hawaii's diversified agriculture industry is an attainable and economically worthwhile goal which can be achieved largely by: (1) replacing much of Hawaii's imported produce with locally grown produce, (2) pursuing niche and off-season markets of fruits and vegetables for export, (3) growing new or Asian-based specialty crops for export, and (4) meeting increased demand from the tourism and cruise ship industries for fresh fruits and vegetables..

As with any planning document, updates will be needed to complement this report. Additional work needed include field verification of farms, service areas, and inclusion of systems not covered in this report.

This AWUDP, upon approval by the Board of Agriculture, becomes the agricultural water use and development plan for the Hawaii Department of Agriculture.

# CONTENTS

## SECTION III – HDOA SYSTEMS

**SECTION IV – PRIVATE SYSTEMS**



**SECTION V – AGRICULTURAL WATER USE**

## FIGURES



## TABLES



## MAPS

## ABBREVIATIONS

| | |
|---|---|
| ADC | Agribusiness Development Corporation |
| AWUDP | Agricultural Water Use and Development Plan |
| BOR | Bureau of Reclamation |
| CRM | Concrete Rubble Masonry |
| CWRM | Commission on Water Resource Management |
| DHHL | Department of Hawaiian Home Lands |
| DLNR | Hawaii Department of Land and Natural Resources |
| EKIS | East Kauai Irrigation System |
| EKW | East Kauai Water Company |
| EKWUC | East Kauai Water Users' Cooperative |
| ERS | Economic Research Service |
| HASS | Hawaii Agricultural Statistics Service |
| HBOA | Hawaii Board of Agriculture |
| HC&S | Hawaiian Commercial & Sugar Co. |
| HDOA | Hawaii Department of Agriculture |
| HDPE | High-density polyethylene |
| KEDIS | Kekaha Ditch Irrigation System |
| KODIS | Kokee Ditch Irrigation System |
| kW | Kilowatt |
| LHDIS | Lower Hamakua Ditch Irrigation System |
| LLC | Lihue Land Company |
| LPC | Lihue Plantation Company |
| MDWS | Maui Department of Water Supply |
| MG | Million gallons |
| mgd | Million gallons per day |
| MIS | Molokai Irrigation System |
| MLP | Maui Land and Pineapple Company |
| NEPA | National Environmental Policy Act |
| NRCS | Natural Resources Conservation Service |
| O&M | Operations and Maintenance |
| PMIS | Pioneer Mill Irrigation System |
| SCADA | Supervisory Control and Data Acquisition |
| SCS | Soil Conservation Service |
| USDA | United States Department of Agriculture |
| WDIS | Waiahole Ditch Irrigation System |

# EXECUTIVE SUMMARY

***Background.*** In Hawaii, many irrigation systems were built by sugar plantations, beginning in the late 1800s. However, by the late 1900s sugar economics had begun to change drastically, and today only two plantations remain operational, leading to abandonment, idling, and deterioration of many of these systems. The alternative uses of these irrigation systems, particularly for diversified agriculture have become a challenge to the State of Hawaii, farmers, and corporate growers. For Hawaii's diversified agriculture industry to develop, strengthen, and grow, viable and secure irrigation systems are essential. Reliable irrigation systems give assurances to financial institutions providing agricultural financing and loans that there will be adequate water supply to grow crops which will generate revenues.

Thus, the Agricultural Water Use and Development Plan (AWUDP) was conceived by the State Legislature as a document to ensure that the plantation irrigation systems affected by plantation closures would be rehabilitated and maintained for future agricultural use. Thus, in 1998 the Legislature enacted Act 101 to provide authority for the AWUDP to become a part of the Hawaii Water Plan on a par with municipal water use and development plans.

Under Act 101, the Hawaii Department of Agriculture (HDOA) was authorized to: (1) inventory the irrigation water systems of the State, (2) identify the extent of rehabilitation needed for each system, (3) subsidize the cost of repair and maintenance of the government systems, (4) establish criteria to prioritize the rehabilitation of the systems, (5) develop a 5-year program to repair the systems, and (6) setup a long-range plan to manage the systems. These responsibilities were carried out in the HDOA report entitled, *Agricultural Water Use and Development Plan, December 2003.* Under a separate part of Act 101, the Commission on Water Resource Management (CWRM) was charged with incorporating the AWUDP into their Hawaii Water Plan.

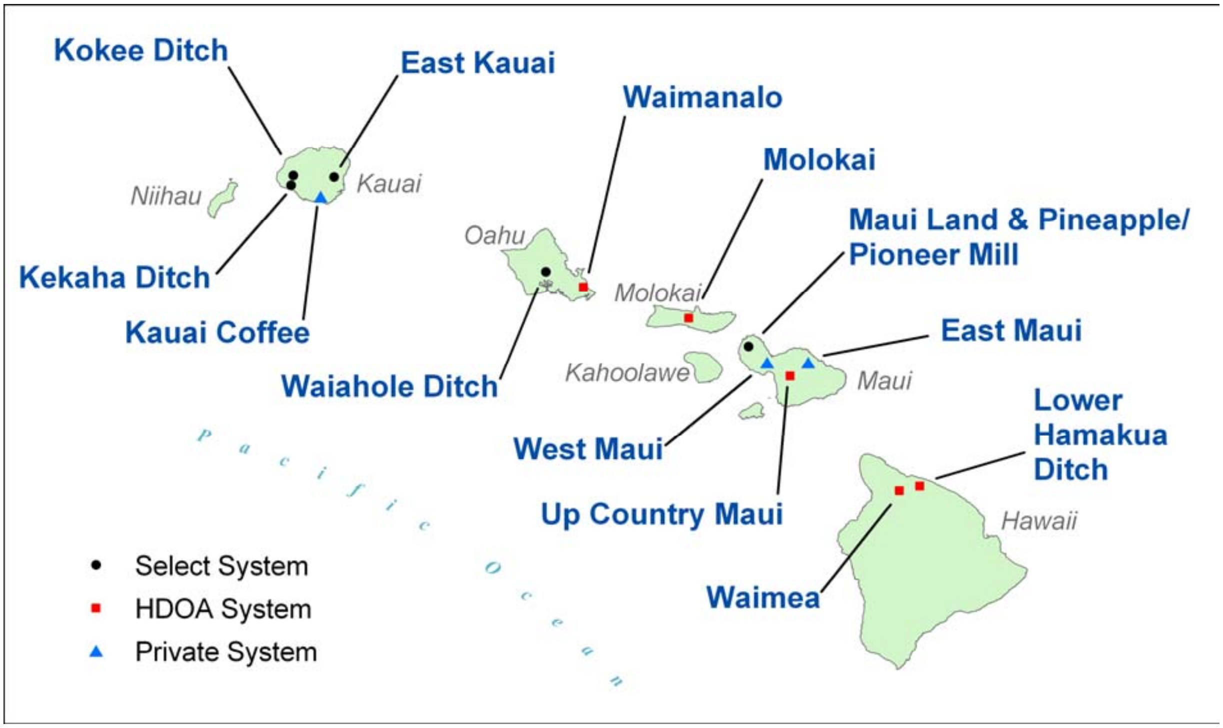
***Objective of AWUDP.*** There is an urgent need to develop a comprehensive statewide agricultural water use and development plan to bring an orderly sense to the current transitional period following plantation closures. There is no organized effort by any central authority to plan and coordinate the future of the thousands of acres of former sugar and pineapple lands and the complex irrigation systems associated with those lands. Without a concerted effort to bring together every stakeholder to discuss, exchange ideas, and evaluate the situation, these fallow lands and irrigation systems could be taken out of agricultural use forever. It is the State's (Legislative and Executive Branches) responsibility to carry out the mandate of Article XI, Section 3, of the State Constitution, which requires the State to conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency, and assure the availability of agriculturally suitable lands.

The AWUDP is envisioned as one of the necessary tools, a guide, to be used in carrying out this mandate. Unfortunately, there are no large agribusinesses or related organizations to champion the contributions of Hawaii's agricultural industry to the State's overall well-being. Following the demise of the sugar industry, there remains only the State government, together with Federal and County counterparts, to support and recognize agriculture as one of the State's most important industries. The AWUDP must first explore all facets of the potential opportunity for diversified agriculture. It needs to consider what, where, and how to meet the diversified agriculture demand on the potential needs for irrigation water on those former monocrop lands in diversified agriculture.

With properly planned and coordinated assistance from government, Hawaii could realistically become self-sufficient in producing most of its currently imported food supply, including fresh produce, fish, livestock, and poultry. For this to occur, the State must first adopt a viable agricultural water plan and then implement the improvements to the agricultural water systems which will supply the water needed to sustain a diversified agriculture industry.

A greater understanding and appreciation of the importance of Hawaii's agricultural industry, particularly diversified agriculture, to the overall interest and well being of the State is slowly taking root. Equally important is the funding support by the Legislature for the preservation and maintenance of the complex agricultural water systems which are the backbone of diversified agriculture. The AWUDP hopefully will be the cornerstone of this greater understanding and appreciation.

***Scope of This Report.*** The present report is a follow-up phase to the December 2003 AWUDP and is composed of two separate and distinct parts. The first part, Sections 1 through IV (*Chapters 1 through 16*), consists of the identification, preservation, and protection of large irrigation systems considered to be important to Hawaii's agriculture industry, including: (1) five select former plantation systems, (2) five HDOA owned or operated systems, and (3) three privately owned and operated systems. Each of the 13 irrigation systems are covered in separate chapters, most of which includes an historic description of the original infrastructure, a short narrative of the existing conditions, an assessment of the current concerns and needs, and estimates of rehabilitation costs.




LOCATION OF THIRTEEN IRRIGATION SYSTEMS STUDIED

Based upon the assessments, a list of improvements for each system's needs was developed. There are two categories of need—capital improvements and maintenance improvements. *Capital improvements* are considered to be those that add to or improve the value of the system, whereas *maintenance improvements* are considered to be those that are necessary to maintain operational efficiency and viability of the system. The other factor that sets these two types of improvement apart is that capital improvements require engineering design and construction by contractors, whereas maintenance improvements can be constructed by normal operation and maintenance crews with little or no subcontracting work required. Since capital improvements require additional costs for engineering and environmental studies, such costs were added to construction costs, resulting in a total rehabilitation cost. The rehabilitation cost estimates for the five select and five HDOA irrigation systems are summarized below:

## SUMMARY OF ESTIMATED REHABILITATION COSTS

| Irrigation System | Constr'n Costs | Constr'n Mgmt. & Contract Admin. | Environ. Permits & Clearances | Design Engineering | Easements Acquisition | Total |
|---|---|---|---|---|---|---|
| East Kauai | $ 6,750,000 | $ 2,025,000 | $ 500,000 | $1,012,000 | $ 100,000 | $10,387,000 |
| Kekaha Ditch | 3,907,000 | 1,172,000 | 1,000,000 | 586,000 | 125,000 | 6,790,000 |
| Kokee Ditch | 502,000 | 150,000 | 1,000,000 | 60,000 | None | 1,712,000 |
| MLP/PM | 5,853,000 | 1,756,000 | 250,000 | 878,000 | 175,000 | 8,912,000 |
| Waiahole Ditch | 7,787,000 | 2,336,000 | 50,000 | 545,000 | None | 10,668,000 |
| Lower Hamakua | 7,111,000 | 853,000 | -- | 1,422,000 | 200,000 | 9,586,000 |
| Molokai | 10,768,000 | 3,231,000 | 1,000,000 | 1,077,000 | 700,000 | 16,776,000 |
| Upcountry Maui | 6,959,000 | 1,044,000 | -- | 1,044,000 | 227,000 | 9,274,000 |
| Waimanalo | 3,191,000 | 957,000 | 1,000,000 | 319,000 | 25,000 | 5,492,000 |
| Waimea | 14,058,000 | 4,218,000 | 1,000,000 | 1,687,000 | None | 20,963,000 |

The second part of this report, Section V (*Chapters 17 through* 20), consists of identifying each system's sources and water use requirements for Hawaii's expanding diversified agriculture industry. The compilation of existing water uses and sources and the development of water demand forecasts were structured, as much as possible, in conformance with the Hawaii Water Plan and State Water Code. Section V's principal objective is to forecast agricultural water demand by evaluating the potential markets for diversified crops, current and future. Assumptions and projections used are based on information from many sources, as this effort is a first-cut attempt to arrive at a comprehensive diversified agriculture cropping and marketing plan. No attempt has ever been made to prepare an agricultural development plan which includes what crops to grow and which markets to serve

In order to forecast agricultural water demands, the market for diversified crops was first estimated. Then, such estimates were converted into the number of farming acres required. Thirdly, the acreages were then assigned in a logical manner to viable irrigation service areas of existing irrigation systems. Finally, the acreages were converted into the amount of irrigation water required, using the water application rate of 3,400 gpd/acre for diversified crops.

***General Status and Needs of Irrigation Systems.*** During the early 1900s, sugar plantations were diverting large quantities of water from perennial streams located on the windward sides (facing northeast trade winds) of the islands into miles-long ditches and tunnels, moving water to distant leeward plains where dry, fertile lands required irrigation to grow sugar cane. During the late 1990s, many plantation irrigation systems were abandoned, idled, and left to deteriorate. With lack of maintenance, ditches have become overgrown with vegetation, intake structures on streams have remained damaged or clogged by storm flows, and steel siphons and wooden flumes have suffered deterioration. At the same time, government economists, private businesses, and farmers began to advocate the development of an expanded diversified agriculture industry to replace the sugar plantations.

With fertile volcanic soils, a year-round mild climate, prime agricultural lands and irrigation systems made available by sugar plantation closures, the State of Hawaii has an unparalleled opportunity to support and develop a new and significant diversified agriculture industry (in Hawaii, diversified crops include any agricultural commodity, including orchards, livestock, and poultry, except sugar and pineapple).

***Hawaii's Diversified Agriculture Potential.*** By the year 2000, only two sugar plantations (Gay and Robinson on Kauai and Hawaii Commercial and Sugar Company on Maui) and three pineapple companies (Maui Land & Pineapple Co. on Maui and Dole Company and Del Monte Corporation on Oahu) remained in operation with about 35,000 acres in production.

Hawaii has historically imported well over half of the fresh vegetables and fruits it consumes. In many instances, a significant amount of these imports could be replaced by locally grown crops of equal or better quality. However, the crops that are chosen to replace corresponding imports must be grown and marketed year-round in sufficient quantity to meet local market demand. Without this commitment to the local market, it is difficult for local growers to compete effectively with imported produce. Locally grown crops that have partially succeeded in competing with imports, include watermelons, bananas, watercress, sweet potatoes, fresh corn, and ginger root, according to reports by the Hawaii Department of Agriculture's Market Analysis and News Branch. The potential for locally grown crops to replace corresponding imports, needs to be evaluated in terms of the most suitable locations of available sugarcane lands, growing conditions, soils, transportation, etc. HDOA reports indicate that imports of asparagus, green beans, broccoli, carrot, lettuce (head), mushroom, dry onion, table potato, squash, avocado, tangerine, lime, lemon, strawberry, and grapefruit can potentially be replaced by locally grown crops.

Among the most promising new crops are the traditional fresh greens and herbs consumed by Hawaii's Asian immigrant population. There is some interest in expanding the existing seed crop (corn) industry to growing other seed crops such as sorghum, barley, sunflower, grasses, and legumes (soy beans and peas). Some market analyses indicate that fresh tropical specialty fruits (rambutan, cherimoya, lychee, etc.) have great potential for market expansion both in Hawaii and the U.S. mainland. The market for these new crops should be developed and marketed within the State until sufficient information and demand can be established through contacts with U.S. mainland or other overseas marketing areas.

With a year-round growing season, certain fresh vegetables and fruits can be grown in Hawaii to meet niche or off-season markets for export. For example, some pilot shipments have already proven successful such as the export of locally grown fresh green beans and bell peppers to Canada during the winter season; locally grown fresh strawberries for local hotel restaurants in the spring and winter seasons; and locally grown fresh fruits (avocado, mango, and navel orange) for local as well as west coast markets.

The most logical way to expand Hawaii's agriculture industry is to focus on the replacement of the large quantities of vegetables and fruits now being imported into the State from overseas (primarily U.S. mainland, South America, and Australia). With the availability of large tracts of former sugarcane lands throughout the State, large irrigation systems widely scattered throughout the State, and an all-season growing climate; now is the perfect time and opportunity to expand Hawaii's import replacement market.

***Irrigation Water Use and Demand Forecasts.*** One of the most practical and effective method of estimating agricultural water use is to measure the amount of irrigation water applied to an individual crop or group of crops, such as meant by the term "diversified crops" under actual conditions of farming. Contrary to past irrigation practices in Hawaii, agricultural water use is more and more being metered as irrigation system improvements are carried out and as required by system operators and the State Water Code. With the keeping of monthly records of metered water use and corresponding acreage irrigated, useful data is being collected on the application rate of irrigation water, especially for diversified agriculture operations. In fact, the HDOA-operated irrigation systems have accumulated many years of such monthly records and an analysis of the Lalamilo Section of the Waimea Irrigation System, where intensive farming of diversified crops has continued for many years, a value of **3,400 gpd/acre** was determined as the 8-year average rate of application of irrigation water for diversified crop farming at Lalamilo. This rate of 3,400 gpd/acre is the best available estimate of the irrigation rate for diversified crop farming in Hawaii and, consequently, was used in forecasting agricultural water demand in this report.

Using this average rate, the second step in forecasting agricultural water demand for the 20-year planning period was estimating the acreage required to meet Hawaii's future diversified agriculture needs based upon an analysis of: (1) annual population projections,

(2) replacing imported fresh vegetables and fruits, and (3) maintaining annual growth rate of farm values.

A best case and worst case scenario of acreage requirements were developed by determining the ratio of locally grown to the total market supply. These two scenarios were developed to meet CWRM Framework's water demand forecast element in Chapter 18. A conservative estimate of 40% was used for the best case scenario of acreage required. For the worst case scenario, a review of studies by others on continued development of farming revealed that status quo operations generally range between 10 and 20 percent. Again, conservatively 10% was used for the worst case scenario.

The third and final step in estimating future agricultural water demand for diversified agriculture is simply to multiply the forecasted acreage times the irrigation water application rate of 3,400 gpd/acre. It is assumed that the irrigation water application rate is based upon good farming practices to meet the consumptive needs for plant growth and upon good conservation practices encouraged by the economic cost of metered water use. Consequently, the irrigation water application rate of 3,400 gpd/acre is considered to be based upon optimum water use, exclusive of irrigation system water losses.

The additional acreage needed for the 20-year planning period for diversified agriculture were first estimated for the State as a whole (see Table 6a). Then, based on the estimated acreage available (see Table 6b), the acreage total and corresponding agricultural water demands were allocated among the individual islands and irrigation systems (see Tables 7a to 7e). A majority of the acreages assigned in Tables 7a to 7e are privately owned and controlled. Until the AWUDP is adopted and accepted by the private land owners on whose land the systems and acreages are located, these tables serve only as a guide. Although the research and analyses conducted in this report were constrained by time and availability of funds, the authors believe that the acreage requirements and water demand forecasts presented in Tables 7a to 7e are reasonable estimates for the 20-year planning period.

In allocating the overall acreage requirement to different islands and irrigation systems, the authors took several factors into consideration: (l) climate and growing conditions (wind and solar radiation), (2) proximity to transportation facilities and market, (3) availability of water, (4) availability of irrigable agricultural land, and (5) personal knowledge of the various irrigation systems. Not taken into account was the availability of willing farmers, marketing conditions, transportation and shipping conditions, and pricing. This report provides a snapshot of the potential growth and irrigation water needs of the diversified agriculture industry in Hawaii, based upon current knowledge and conditions. However, due to the uncertainty of economic conditions and policy changes in the years ahead, the forecasts are subject to change. Consequently, this AWUDP report is a dynamic document which highlights the needs and serves as a guide for Hawaii's diversified agriculture industry.

# Chapter 1. INTRODUCTION

## HAWAII'S AGRICULTURAL BACKGROUND

For the first half of the twentieth century, Hawaii's economy was dominated by its monocrop (sugar and pineapple) agriculture industry which in turn was dominated by corporate farming enterprises that included plantations, irrigation water companies, sugar mills, and pineapple canneries. The monocrop industry was a principal driving force behind multi-ethnic culture, having invested extensive capital and human resources. The industry, as the economic engine, also provided the basis for Hawaii's newly developing economy.

Beginning in the late 1950s, the tourism industry gradually moved to the economic fore front and the monocrop agriculture industry began to lose its prominence. However, the agriculture industry continued to make a significant contribution to Hawaii's economic base.

Prior to the decline of monocrop farming, Hawaii's diversified agriculture farming developed in small pockets throughout the State in regions that were already inhabited by persons with some farming background. Marketing of diversified crops were mainly localized to within the county or transshipped to Honolulu, the State's population center.

The decline of the monocrop industry in Hawaii was the result of many factors. Several of these factors included: (1) transfer of monocrop cultivation to emerging third world countries, (2) reductions in price supports for sugar, (3) gain of collective bargaining by industry-wide labor forces, (4) adjustments in U.S. sugar quota formula, (5) urban pressures, and (6) enactment of stringent environmental laws and regulations. Over several decades beginning in the 1970s entire plantation operations were closed or consolidated for cost effectiveness, and by the late 1990s very little of the monocrop agricultural industry remained.

Irrigation systems, sugar mills, roads, drainage, hydropower systems, housing camps, various structures (offices, well filtration, and pump stations), and equipment were abandoned, idled, or sold; as a result of plantation closures. This was a serious blow on the agricultural communities that had developed around a plantation culture, and efforts were undertaken to salvage the associated infrastructures by transforming them into other uses or converting them to support new enterprises.

Diversified agriculture seemed to be a logical choice to replace monocrop farming as it could with minimum effort utilize much of the existing plantation infrastructure. The major concern was whether or not agricultural water was adequate to serve this transformation from monocrop into diversified agriculture.

**OBJECTIVE OF AWUDP**

The Agricultural Water Use and Development Plan (AWUDP) was conceived by the State Legislature to ensure that the plantation irrigation systems affected by plantation closures would be rehabilitated and maintained for future agricultural use. Thus, in 1998 the Legislature enacted Act 101 to provide authority for the AWUDP to become a part of the Hawaii Water Plan on a par with municipal water use and development plans.

This report includes an evaluation of those irrigation systems deemed to be important and viable to Hawaii's growing diversified agriculture industry and existing monocrop industry and an estimation of the acreage and water demand that will be needed to meet such growth.

This report is the first step in meeting the objectives of the AWUDP: (1) to assess and plan for an orderly rehabilitation of former plantation irrigation systems which are considered to be the most important infrastructural need to expand Hawaii's diversified agriculture industry, i.e., IRRIGATION WATER SUPPLY, and (2) to ensure that the irrigation water supply will be reliable and adequate to meet the current and future water requirements of Hawaii's diversified agriculture industry.

**SCOPE OF THIS REPORT**

This report of the AWUDP is composed of two separate and distinct parts. The first part, Sections 1 through IV (*Chapters 1 through 16*), consists of the identification, preservation, and protection of large irrigation systems considered to be important to Hawaii's agriculture industry, including: (1) five select former plantation systems, (2) five HDOA owned and operated systems, and (3) three privately owned and operated systems. All of the 13 irrigation systems are covered in separate chapters, most of which includes an historic description of the original infrastructure, a short narrative of the existing conditions, an assessment of the current concerns and needs, and estimates of costs for improvements and maintenance.

Based upon the assessment, a list of improvements to address system needs was developed. There are two categories of need—capital improvements and maintenance improvements. *Capital improvements* are considered to be those that add and improve the value of the system, whereas *maintenance improvements* are considered to be those that are necessary to maintain operational efficiency and viability of the system. The other factor that sets these two types of improvement apart is that *capital improvements* require professional engineering design and construction by licensed contractors, whereas *maintenance improvements* can be constructed by normal operation and maintenance crews with little or no subcontracting work required. Since capital improvements require additional costs for engineering and environmental studies, such costs were added to construction costs, resulting in a total rehabilitation cost.

The second part of this report, Section V (*Chapters 17 through* 20), consists of identifying each system's sources and water use requirements for Hawaii's expanding diversified agriculture industry. Section V focuses on agricultural water use and related service areas, both present and future. The compilation of existing water uses and sources and the development of water demand forecasts were structured, as much as possible, in conformance with the Hawaii Water Plan and State Water Code.

Section V's principal objective is to forecast agricultural water demand by evaluating the potential needs for diversified crops, current and future. These cropping needs are then used to identify those agricultural land areas where the agricultural industry will likely focus their growing efforts. Assumptions and projections used are based on information from many sources, as this effort is a first-cut attempt to arrive at a comprehensive diversified agriculture cropping and marketing plan. No attempt has ever been made to prepare an agricultural development plan which includes what crops to grow and which markets to serve. This section of the report includes initial discussions concerning the many different segments of Hawaii's agricultural industry, i.e., monocropping, diversified croppings, livestock fodder and seed croppings, horticulture, floriculture, ornamentals, orchards, and exotic tropical fruits. This report discusses established and lesser-known marketing efforts relating to import produce replacement, fresh vegetable niche markets, population expansions, use of locally grown and custom-grown produce for targeted markets, such as the tourism industry.

In order to forecast agricultural water demands, the amounts of cropping needs must first be estimated. Such estimates are then translated into the number of growing acreage required. Thirdly, the acreages are then appropriately assigned to viable irrigation service areas of existing irrigation systems. Finally, the acreages are converted into amount of water required, using established and acceptable water application rates for different crops.

The scope of work in estimating agricultural water use requirements, were limited to the utilization of existing data and information. Due to limited funds and time constraints, no field work was carried out to update and verify such information. Much of the work to obtain information and details of water uses, croppings, existing service areas, and water systems data were taken from existing reports, studies, interviews, newspaper articles, and other readily available sources.

**AUTHORITY**

This July 2004 AWUDP was authorized by and prepared in conformance with Act 101 of the 1998 State Legislature. The Act required the Hawaii Department of Agriculture (HDOA) to:

(1) inventory the irrigation water systems;

(2) identify the extent of rehabilitation needed for each system;

(3) subsidize cost of repair and maintenance of the systems;

(4) establish criteria to prioritize the rehabilitation of the systems;

(5) develop a 5-year program to repair the systems; and

(6) set up a long-range plan to manage the system.

# Chapter 2. SETTING FOR THE PLAN

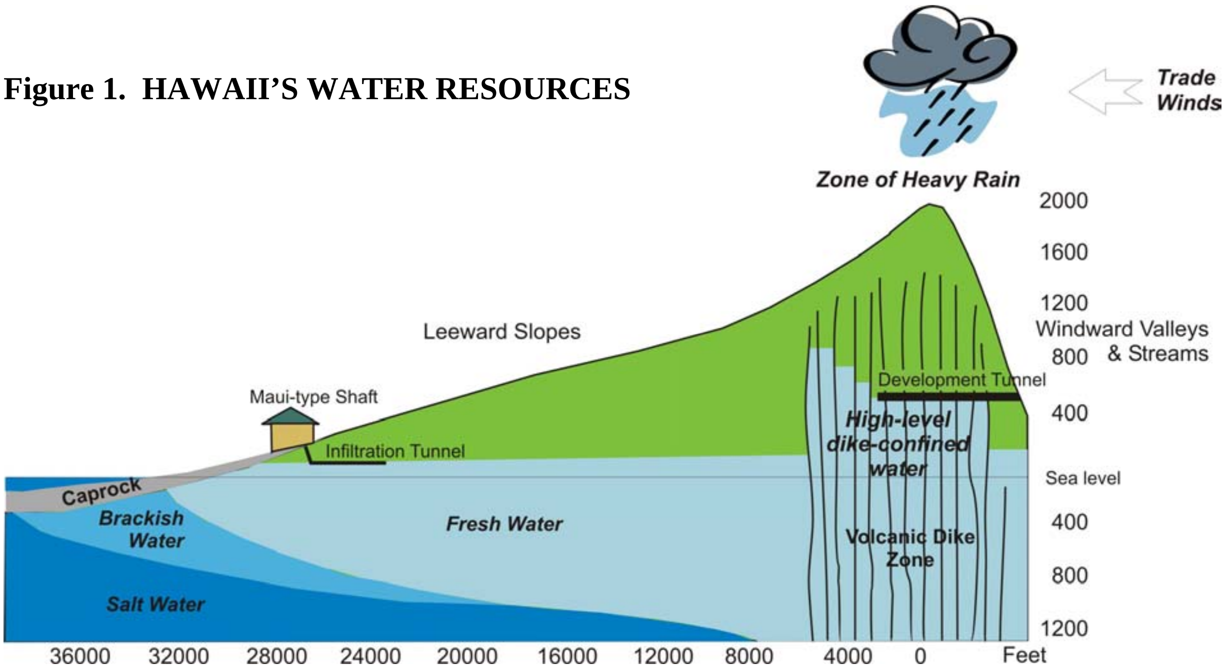
## WATER RESOURCES

The major Hawaiian Islands have mountain slopes over 2,000 ft high and are endowed with up to 300 inches of rainfall a year. Such abundant rainfall is the result of persistent tropical trade winds that strike the islands from the northeast and thereupon release their moisture on “windward” mountains and valley rain forests facing the trade winds (Figure 1). Over geologic time, such large amounts of rainfall have carved the windward or northeast slopes into deep, rugged valleys with perennial streams. On the other hand, the leeward or southwest slopes of the islands have formed less-eroded, fertile, but dry gentle slopes. The abundant occurrence of water resources, both surface water and ground water, rely not only on trade wind rains, but equally on the island’s highly permeable volcanic terrain, which can readily absorb and store rainfall in large groundwater aquifers.

Hawaii streams, the primary source of water for all irrigation systems in Hawaii, are typically very flashy in nature, due not only to their steep profiles and small drainage basins, but also to the intensity of tropical storms. During a rainstorm, a stream especially on the windward side of the island can reach very high rates of flow in a matter of hours and return to normal flows just as rapidly. Aside from the peak, storm-related part of Hawaii’s stream flows, there is a perennial component fed by in-channel springs of “high-level” or “dike-confined” ground water. Such ground water generally occurs in areas where annual rainfall is high and valley streams have eroded deeply into the core of the island, where a number of impermeable volcanic dikes (vertical, thin walls of dense lava) have intruded permeable lava flows. In this setting, mountain rainfall is stored as ground water in compartments of permeable lava flows at high elevations and ultimately discharges as springs throughout sections of a stream’s profile, forming perennial flows.

Ancient Hawaiians developed a number of such perennial streams with diversions and ditches to irrigate and grow taro, a staple crop. Later, sugar growers copied the ancient Hawaiians with their own elaborate and extensive plantation irrigation systems. The use of intake structures to divert perennial low flows and high storm flows, and the use of water-development tunnels to intercept the high-level ground water associated with perennial streams, ultimately gave rise in the late 1800s to the construction of large-scale irrigation systems by sugar plantations. Miles of ditches, tunnels, flumes, and siphons were constructed to transport water primarily to irrigate sugarcane grown on distant arable lands on the dry, sunny, gentle leeward slopes of each major island. A number of these irrigation systems are no longer in use for sugarcane farming, but they continue to be important sources of irrigation water for diversified agriculture.

**Figure 1. HAWAII'S WATER RESOURCES**




During droughts, the sugar plantations relied on groundwater sources, tapping large quantities from lenses of fresh water floating on salt water. Where feasible, irrigation systems included large capacity wells near irrigated fields in low-lying coastal areas. To increase supply, horizontal infiltration tunnels were constructed near sea level with access provided by a vertical or inclined shaft (Figure 1). The first such groundwater shaft was constructed on Maui in the 1890s. These groundwater sources, called Maui-type shafts, continue to serve as supplemental backup irrigation water supplies, especially during droughts.

## CLIMATE AND SOILS

***Climate.*** Hawaii experiences only two seasons: from May through October when weather is warmer and drier, and from October through April when weather is cooler and more cloudy and wet.  Solar energy and length of day are relatively uniform throughout the year and the surrounding ocean provides moist air and keeps temperatures fairly constant without extremes throughout the year.  These conditions contribute to a continuous 12-month growing season.

Moist, northeasterly trade winds are the primary source of Hawaii's abundant rainfall. As trade winds move over mountainous areas, the air expands, cools, and its moisture condenses into clouds and rains which create Hawaii's water resources.

Drought in Hawaii occurs infrequently, but during the last decade has become more persistent due to El Nino and La Nina weather conditions.  These weather conditions affect the ocean temperatures which govern weather fronts and pressure systems and in turn result in failure of the trade winds and development of winter storms.  In the dry leeward agricultural areas, lack of winter storms can result in severe droughts.  For the water-rich windward areas, the interruption of trade winds diminishes rainfall, stream flow and consequently the water supply of irrigation systems.

***Soils.***  Hawaii's soils originate from the weathering (physical and chemical decomposition) of basaltic lavas and volcanic ash, but differ in places due to variations in degree of weathering, drainage, rainfall, etc.  Hawaii's soils have been classified and extensively mapped, using both the obsolete Great Soil Group System and the USDA Soil Conservation Service's comprehensive system of soil classification (National Cooperative Soil Survey Classification).

For cultivation of agricultural crops the soil classified in the following categories are the most suitable and desirable:

- *Oxisols*—occur on old, stable surfaces of relatively flat lands in the lower elevations of the older islands and possess exceptional properties for intensive mechanical cultivation and are considered important agricultural soils in Hawaii.

- *Ultisols*—occur on old, stable surfaces on steeper slopes and at more unstable sections of the higher elevations of the older islands.  These soils possess exceptional properties for intensive mechanical cultivation and are considered important agricultural soils in Hawaii.

- *Mollisols*—occur in moderately dry, well-drained areas and are relatively young soils which develop on lava, alluvium, or coral.  Generally rich in plant nutrients, this soil is also suitable for agricultural cultivation.

## PLANTATION PERIOD (1860s to 1990s)

Although Hawaii's sugar industry started during the 1860s, most of the plantation irrigation systems were developed around the turn of the twentieth century. Large quantities of surface water from perennial streams were diverted by intake structures (see Ave. Flow column in Table 1) into miles-long transmission ditches and tunnels, moving water from the windward side of the islands to the leeward plains, where abundant dry, fertile lands required irrigation to grow sugarcane. Generally, intake structures include a dam across the streambed, an inlet channel, control gates, trash screen, and a connecting tunnel or ditch into the main transmission structure—usually another tunnel or ditch.

**Table 1. PLANTATION DITCH SYSTEMS**

| Plantation and ditches | Date | Ave. Flow (mgd)* | Capacity (mgd) |
|---|---|---|---|
| **KAUAI PLANTATIONS** | | | |
| ***Lihue Plantation Co/East Kauai Water Co.*** | | 140** | |
| Rice Ditch | 1856 | | |
| Lower Lihue Ditch | | | |
| Upper Lihue Ditch | | | |
| Hanamaulu Ditch | ca. 1870 | | |
| Kapaia Ditch | | | |
| Waiahi-Kuia Aqueduct (Koloa Ditch) | 1915 | | 60-90 |
| Waiahi-Iliiliula-N. Wailua ditches | 1926 | | |
| N. Wailua Ditch | | (23) | |
| Stable Storm | | | |
| Hanalei Tunnel | 1926 | (28) | |
| Kaapoko Tunnel | 1928 | | |
| Wailua Ditch | | (14) | |
| Kapahi Tunnel and Makaleha system | 1922-1929 | | |
| ***Makee Sugar Co.*** | | | |
| Anahola, Kaneha, Kapaa ditches | ca 1880-1900 | | |
| ***Grove Farm*** | | 26** | |
| Several small ditches | 1865-1868 | | |
| Halenanahu Ditch | 1884 | | |
| Huleia Ditch | 1893 | | |
| Upper Ditch | 1917 | | |
| Main Ditch (later Lower Ditch) | 1928-1948 | | |
| ***Koloa Sugar Co.*** | | 20** | |
| Dole's "water lead" | 1869 | | |
| Wilcox Ditch | 1885, 1893 | | |
| Mill Ditch | 1902 | | |
| Waita (Koloa) Reservoir | 1906 | | |

| Plantation and ditches | Date | Ave. Flow (mgd)* | Capacity (mgd) |
|---|---|---|---|
| ***McBryde Sugar Co.*** | | 95** | |
| Kamooloa Ditch | 1907 | | |
| Wainiha Powerplant | 1906 | 50 | 65 |
| Pump 3 | ca. 1908 | 34 | |
| Alexander Reservoir | 1932 | 10 | |
| ***Kilauea Sugar Co.*** | | | |
| System of reservoirs and ditches | ca.1880-1900 | | |
| Reservoirs: Kalihiwai, Stone Dam, Puu Ka Ele, Morita, Waiakalua, and Koloko | | | |
| Ditches: Mill, Koolau, Puu Ka Ele, Koloko and Moloaa, Hanalei | | | |
| ***Hawaiian Sugar Co/Olokele Sugar Co.*** | | 100** | |
| Hanapepe Ditch | 1891 | 35 | 42 |
| Olokele Ditch | 1904 | 66 | |
| ***Gay & Robinson*** | | | |
| Koula Ditch Tunnel (Hanonui Tunnel) | 1948 | 40 | |
| ***Waimea Sugar Mill Co.*** | | | |
| Waimea (Kikiaola) Ditch | 1903 | 5 | |
| ***Kekaha Sugar Co.*** | | 50** | |
| Kekaha Ditch | 1907 | 30 | 40 |
| Kokee Ditch | 1927 | 15 | 55 |
| **OAHU PLANTATIONS** | | | |
| ***Waiahole Irrigation Co/Oahu Sugar Co.*** | | 32** | |
| Waiahole Ditch | | 42-27 | 100 |
| ***Waialua Sugar Co.*** | | 30** | |
| Oahu Ditch (Mauka Ditch Tunnel), | 1902 | | |
| Wahiawa, Helemano, Tanada ditches | ca. 1902 | | |
| Opaeula Ditch | 1903 | | |
| Kamananui Ditch | 1904 | | |
| Ito Ditch | 1911 | | |
| ***Kahuku Plantation Co.*** | | 10** | |
| Punaluu Ditch | ca. 1906 | 10 | |
| ***Waimanalo Sugar Co.*** | | | |
| Kailua Ditch | | | |
| Maunawili Ditch | | | |
| **MAUI PLANTATIONS** | | | |
| ***East Maui Irrigation Co.*** | | 160** | 440 |
| (Old) Hamakua Ditch | 1878 | (4) | |
| (Old) Haiku (Spreckels) Ditch | 1879 | | |
| Lowrie Ditch (Lowrie Canal) | 1900 | (37) | 60 |
| New Hamakua Ditch | 1904 | (84) | |
| Koolau Ditch | 1905 | (116) | 85 |
| New Haiku Ditch | 1914 | 25 | 100 |
| Kauhikoa Ditch | 1915 | (22) | 110 |
| Wailoa Ditch | 1923 | (170) | 160-195 |

| Plantation and ditches | Date | Ave. Flow (mgd)* | Capacity (mgd) |
|---|---|---|---|
| ***Wailuku Sugar Co.*** | | 30** | |
| Waihee (Spreckels) Ditch | 1882 | 10-2 | 20 |
| Waihee (Ditch) Canal | 1907 | 27 | |
| Nine other smaller ditches | | | |
| ***Honolua Ranch & Pioneer Mill Co.*** | | 50** | |
| Honokohau Ditch | 1904 | 20 | 35 |
| Honolua (Honokohau) Ditch | 1913 | 30-18 | 50-70 |
| Honokowai Ditch | 1918 | 6 | 50 |
| Kahoma Ditch | | 3 | |
| Kanaha Ditch | | 3.8 | |
| Kauaula Ditch | | 4.5 | 25.5 |
| Launiupoko Ditch | | 0.8 | |
| Olowalu Ditch | | 4 | 11 |
| Ukumehame Ditch | | 3 | 15 |
| **HAWAII PLANTATIONS** | | | |
| ***Kohala Ditch Co.*** | | 30** | |
| Kohala Ditch | 1906 | | |
| Kehena Ditch | 1914 | (6) | |
| ***Hamakua Sugar Co/HIC*** | | 50** | |
| Upper Hamakua Ditch | 1907 | 8 | |
| Lower Hamakua Ditch | 1910 | 30 | 60-45 |

* Average flows are based on the historical record except for those in parentheses, which are from USGS records.
**Estimated average total surface water diverted.

Source: Modified after Wilcox, Carol, 1977.

As the plantations grew, they generally were able to encumber the more productive lands and assure the continued use of their irrigation systems. The monocrop (sugarcane and pineapple) farming industry became a strong economic and political force in Hawaii.

At the peak of the monocrop industry in 1920, approximately 250,000 acres were in production, with irrigation systems diverting an average of 800 mgd (million gallons per day) of water. The plantation irrigation systems provided water not only for irrigation, but also for transportation (of harvested cane), sugar mills, hydropower plants, and plantation villages. The island of Kauai had the most systems (see Table 1), followed by Maui, Oahu, and Hawaii. Because of generally porous soils, large storage reservoirs needed for reliable water supply were not feasible. Consequently, most irrigation systems included only small reservoirs or none at all, in which case diverted stream flows were transmitted directly to sugarcane fields through ditches, tunnels, siphons, and flumes.

***Changes in the Monocrop Industry.*** The monocrop industry (sugarcane and pineapple) was the major contributor to Hawaii's economy during the first half of the twentieth century, but by the late 1950s air travel began to create a new, more lucrative industry—tourism—which did not require the arduous labor of agriculture. Also around this time sugar and pineapple workers were caught up in a labor movement for better working conditions and fair wages. The tourism industry encroached upon agricultural land and infrastructure uses, especially on the neighbor islands. Resort (hotel sites), recreational (golf courses, parks), and public access (parking, water development sites) uses began to erode the large contiguous plantation land holdings.

After World War II, better economic conditions and increased demand for housing resulted in marginal agricultural lands being converted into urban subdivisions. Plantation closures began in the 1970s with most of pineapple plantations closing and sugar plantations merging, shutting down sugar production, or converting to other crops, such as macadamia nuts.

The Land Use Law, Chapter 205, HRS, was enacted in 1961 to provide for orderly development of land in the state. However, the provisions of this law were subjected to broad interpretation which often resulted in decisions unfavorable to agricultural interests. This caused further decline in lands available for true agricultural pursuits by allowing gentlemen farm and certain urban-type uses on agriculturally zoned lands. Nearly 200,000 acres have been reclassified from agriculture since the land-use law was implemented. Such broad interpretation continues and probably will greatly impact the availability of prime agricultural land formerly in monocrops and now idled by plantation closures for conversion into diversified agriculture uses. Land owners and estate trusts with large tracts of fallow sugarcane lands have a unique opportunity to re-evaluate their land use objectives.

The plantations grew sugar and pineapple with the use of extensive irrigation ditch systems that traversed many miles. Records indicate that close to 100 irrigation ditches were built to support the monocrop industry (Table 1). Some of the more prominent systems that were abandoned by plantation closures were: (1) Kohala and Kahena Ditches on the windward slopes of North Kohala, Hawaii, (2) Olaa flume on the eastern slopes of Mauna Loa, Hawaii, (3) Kilauea plantation's system of six ditches on the northern coast of Kauai, (4) Maunawili ditch system on the windward slopes of Oahu (now partially taken over by the

State's Waimanalo Irrigation System), (5) Lanai's irrigation system, (6) Oahu Sugar Co.'s Kalauao-Aiea ditch systems on the slopes above Pearl Harbor, and (7) Kahuku Plantation's system of ditches and wells in northeast Oahu.

By the end of the twentieth century there remained approximately 15 to 20 active ditch systems. Of these remaining systems very few were operating at full capacity due to plantation closure or reduction in the farming activity served by the ditch system. The physical characteristics of these irrigation systems were designed and constructed prior to the enactment of environmental and zoning statutes. Today (2003) it would be nearly impossible to plan, design, and construct similar irrigation systems without enormous effort and cost, making such a project uneconomical.

With the introduction of drip irrigation technology in the early 1970s to replace furrow irrigation of sugarcane, irrigation water requirements for sugarcane were reduced, enough in some instances to sustain plantations short on irrigation water supply. By 1986, major drip irrigation systems were completed at 11 plantations. To protect crops from droughts, the agricultural industry needs to maintain the original capacities of the agricultural water systems.

For Hawaii's agriculture industry the most critical need has always been the availability of reliable irrigation water. Historically, those plantations without irrigation water were at a big disadvantage and often failed or merged with other plantations possessing water.

**POST-PLANTATION PERIOD (1990s to 2003).**

***Collapse of Sugar Industry.*** In 1998, with the collapse of the sugar industry from over 250,000 acres to less than 50,000 acres in production, plantation irrigation systems were abandoned and left to deteriorate. With the lack of maintenance, ditches have been overgrown by vegetation, intake structures have been damaged or clogged, and siphons and flumes have deteriorated. By the late 1990s, government economists, private businesses, and farmers were advocating the development of a new diversified agriculture industry to take the place of the large, corporate sugar plantations. Figure 2 illustrates the contribution to the State's economy from monocrops and diversified agriculture over the last two decades and reflects the deep decline of monocrop revenues.

By 2000, only two sugar plantations (Gay & Robinson on Kauai and Hawaiian Commercial & Sugar Co. on Maui) and three pineapple companies (Maui Land & Pineapple

Co., Dole Company, and Del Monte Corporation on Oahu) were left, with about 35,000 acres in production.

***Diversified Agriculture—A Prime Alternative.*** With fertile volcanic soils, mild climate, prime agricultural lands and irrigation systems made available by sugar plantation closures, and a 12-month growing period, the State of Hawaii has an unparalleled opportunity to support and develop a new and significant diversified agriculture industry. In Hawaii, diversified crops include any agricultural commodity (including orchards, livestock, and poultry) except sugar and pineapple. The diversified crops now being considered for production are on the high-value end of the spectrum, with the potential to produce value-added products such as packaged and specialty items.

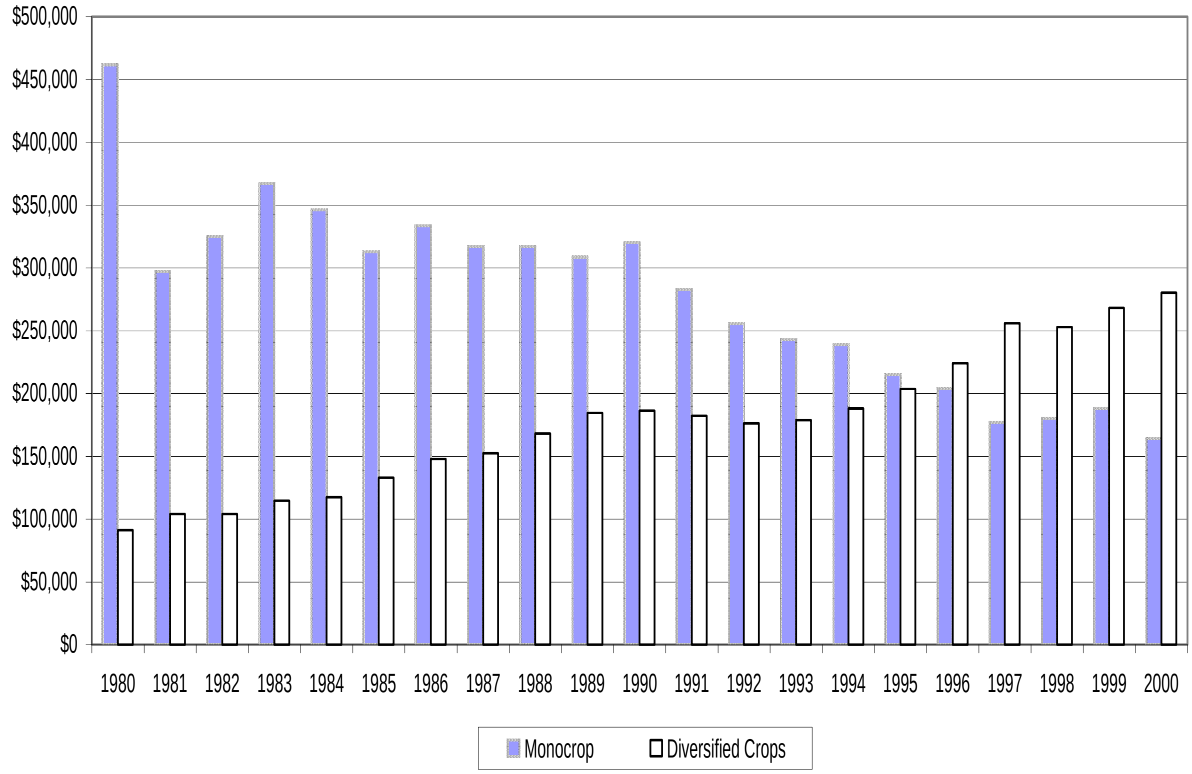
Diversified crops grown in Hawaii for export purposes must be of high value to be competitive because markets are distant and transportation costs are high. With this inherent limitation, other growing options—besides high-value crops—that need to be explored include: (1) growing local crops to replace corresponding imports; (2) pursuing niche markets (specific vegetables and fresh fruits during winter when they are not available from the mainland U.S. or other sources such as Mexico and South America); and (3) growing new or specialty crops (Asian-based crops for immigrant population centers in the United States). In general, any diversified crop grown for export must compete with other producing regions and more importantly must be grown on sufficient acreage to provide an adequate supply throughout the year.

Hawaii imports a majority of the produce it consumes and all of its fresh fruits except for papaya, pineapple, watermelon, and some banana.

Besides local and overseas markets, another potential market for fresh produce is the cruise ship and tourism industry.

By the late 1990s every irrigation system associated with plantation closure became available for conversion into supplying irrigation water for diversified agriculture farming. Concurrently, an almost unlimited amount of prime agricultural lands (former sugarcane fields) also became available for diversified agriculture farming. Most of these lands have agricultural water sources and access roads still in place, making such acreage ideal for small diversified agriculture farms.

**Figure 2. VALUES OF MONOCROP vs DIVERSIFIED CROPS** (1,000 dollars)




Source of Data: Hawaii Agricultural Statistics Service

***Current Developments.*** With the demise of the monocrop industry and plantation closures only two of the six major islands (Kauai and Maui) have a plantation cultural base. The remnants of plantation culture have slowly changed into rural community settings. Nothing remains or is being developed to keep the cohesiveness of plantation-provided housing, utilities, employment, local commerce, etc. This social disruption has caused the younger generation to look for opportunities outside of agri-based vocations, leaving a void in the normal succession of the agricultural labor pool. Agriculture to be viable must now draw upon the urban labor pool or look to immigrants from third world countries for successor generation of farmers.

***Former Sugarcane Lands.*** Former sugar fields now lie fallow with some in "low-level" agricultural uses such as grazing or tree farms. Based upon HDOA data, the State has an estimated 293,600 acres of prime agricultural lands, and since sugar and pineapple were cultivated on these lands, they presumably represent prime agricultural lands. However, according to the 2001 Statistics of Hawaii Agriculture only 66,100 acres were in monocrop cultivation. This indicates that a substantial amount of prime agricultural lands on every major island is now idle and potentially available for transformation into diversified farming (see Table 2).

**Table 2. PRIME AGRICULTURAL LANDS IN HAWAII**

| Island | Classified Prime (acres) | Currently in Monocrop (acres) | Idle and Available |
|---|---|---|---|
| Kauai | 56,000 | 10,600 | 45,400 |
| Oahu | 49,500 | 11,000 | 38,500 |
| Molokai | 11,400 | 0 | 11,400 |
| Maui | 67,900 | 44,500 | 23,400 |
| Hawaii | 108,800 | 0 | 108,800 |
| TOTAL | 293,600 | 66,100 | 227,500 |

Recent and ongoing agricultural land transfers by owners include:

1. Amfac/JMB Hawaii which has sold most of their plantation fee lands at Lihue and Kealia, Kauai, and at Olowalu and Lahaina, Maui;

2. Campbell Estate, which has sold lands at Ewa and Honouliuli, Oahu;

3. Castle & Cook, Inc., which has sold lands at Mililani and Waiawa, Oahu;

4. Grove Farm, Inc., which has sold lands at Nawiliwili and Puhi, Kauai; and

5. A&B, Inc., which has sold lands at Kahului and Wailuku, Maui, and at Kukuiula and Lawai, Kauai.

These lands are being converted into urban and other non-agricultural uses. The sale of prime agricultural lands can easily escalate because of their inherent suitability for urban development, i.e., gentle terrain, deep soils, and dry and sunny climate. Large landowners are not inclined to encumber their lands for long-term agricultural use if the opportunity exists for greater revenue streams through urban development, nor would they want to lose the opportunity to obtain and "land bank" governmental development rights by encumbering their lands with long-term agricultural leases.

***Legal and Environmental Concerns.*** Currently, Hawaii's existing irrigation systems are in a state of flux while the State's agricultural industry is attempting to transform from monocrop cultivation into diversified farming. Several legal (State Supreme Court) and environmental (administrative rules) rulings and decisions regarding water resources have affected the future stability of these irrigation systems to some degree. References include the following: (a) the McBryde-Hanapepe case, relating to surface water, which had a precedent-setting impact concerning surface water and raised the legal question of out-of-watershed transfers of water, (b) enactment of Chapter 174C, HRS, (State Water Code), (c) Reppun case, relating to surface water, which altered the rights to stream diversion, (d) City Mill case, relating to ground water which confirmed the Western Common Law on Correlative Rights, (e) Waiahole contested case which raised the public trust doctrine, (f) the Total Maximum Daily Loads (TMDL) rule, and (g) the pending Water Quality Certification rule.

Generally, the legal implications of these references probably affect in some way directly or indirectly the stability and certainty of operating and maintaining irrigations systems in Hawaii. In some cases, the threat of the regulatory enforcement provisions may deter potential investors, venture capitalist, large farming interests, and especially new or start-up farmers from investing capital and effort into diversified agriculture. These legal decisions and rules have projected the perception that agricultural water in Hawaii is not an easy commodity to acquire, requiring an unpredictable amount of time and effort.

With the recent administrative changes in State government, a greater understanding and appreciation is anticipated of the importance of Hawaii's agricultural industry, particularly diversified agriculture, to the overall interest and well being of the State. Equally important is support from the administration in the preservation and maintenance of the complex agricultural water systems which are the backbone of diversified agriculture. The AWUDP should be the cornerstone of this greater understanding and appreciation.

Persistent droughts and low rainfall periods over the past five years have adversely affected perennial stream flows and depleted high-level groundwater aquifers that supply Hawaii's irrigation systems. In the upper reaches of streams where most of the irrigation systems divert water, the reduction in rainfall has diminished stream flows and recharge to associated dike-confined aquifers. During droughts, soil moisture may be completely depleted in un-irrigated, fallow cane fields, causing dust storms and loss of top soils from wind erosion, as has happened on the western slopes of West Maui at Lahaina and Olowalu after the closure of Pioneer Mill Plantation.

## ASSESSMENT OF HAWAII'S DIVERSIFIED AGRICULTURE POTENTIAL

Diversified agriculture as used in this report is a term that includes all agricultural commodities except sugar and canned pineapple. As indicated elsewhere in this report, Hawaii has the once-in-a-lifetime opportunity to expand its diversified agriculture industry during the current transition from sugar cultivation. With large acreages of prime agricultural lands lying fallow and readily available, a comprehensive plan is needed to avoid conflicts and duplication in diversified crop selection and production, which would be detrimental to farmers’ markets and pricing structures.

***Local Market.*** Hawaii has traditionally imported the majority of the fresh vegetables and fruits it consumes. In many instances these imports can be grown locally and with equal or better quality than imports. However, the produce that is chosen to replace a corresponding import must be grown and marketed year-round in sufficient quantity to meet local market demand. Without this commitment it is difficult for local growers to compete effectively with imported produce. Locally grown crops that have partially succeeded in competing with imports, include watermelons, bananas, watercress, sweet potatoes, fresh corn, and ginger root, according to reports by the Hawaii Department of Agriculture’s Market Analysis and News Branch. The potential for locally grown produce to replace corresponding imports need to be evaluated in terms of the best locations of available sugarcane lands with best growing conditions, i.e., soils, climate, solar radiation, etc. The HDOA report indicates the following produce are currently (2000) imported to Hawaii, but have the potential to be replaced by locally grown crops: asparagus, green beans, broccoli, carrot, lettuce (head), mushroom, dry onion, table potato, squash, avocado, tangerine, lime, lemon, strawberry, and grapefruit.

There is a need for the development of forage and grain feed for the local livestock industry. Certain forage grasses and legumes currently are grown in scattered locations throughout the state, including guinea grass on Molokai, alfalfa on Kauai and Hawaii, feed corn on Hawaii, and field grasses on Hawaii. These forage crops are used to supplement the supply of imported grain feed. Currently, several ranchers on Hawaii and Oahu are cultivating forage grasses for finishing livestock and the results are promising. Using marginal sugarcane lands for pasture grass cultivation with irrigation and fertilization (organic and chemical) could profitably provide improved forage to replace imported feed grain for locally grown beef cattle, while at the same time restoring the scenic greenery once provided by sugarcane fields. Green pastures on upper coastal slopes would provide welcomed open vistas to visitors and residents alike. The major problem with forage grass and hay production in Hawaii is the slow drying process that accompanies the island's high humidity and the high moisture content of locally grown grass.

Based upon recent newspaper articles, Hawaii will experience a build up of military forces which will trigger an increase in Oahu's defacto population. This population increase probably will increase the market for locally grown produce and should be taken into account when planning for agricultural expansion. Expected military buildup includes a new Stryker Brigade for the Army probably at Schofield Barracks on Oahu, a new battleship carrier task force probably based at Pearl Harbor with its aircraft wing based at Kalaeloa, Oahu, and a new B-17 aircraft squadron to be based in Hawaii.

Also, military housing construction currently underway will increase both an opportunity for local produce market expansion and a shortage of construction-related labor which probably will result in an influx of out-of-state workers and their families. This influx should cause an increase in the demand and consumption of locally grown produce.

Along the same line of increased business opportunities for diversified agriculture, the infant Hawaii cruise industry is expected to expand significantly. One cruise line (Norwegian) currently operates out of Hawaii and will be expanding operations in the next couple of years.

The following cruise lines are coming to Hawaii: Princess Cruise Line, Holland America Line and Norwegian Cruise Line (with new ships). Recently there was an agricultural trade show hosting Norwegian purchasing officials. It was reported that these ships need fresh produce and fruit to supply the equivalent of 10 restaurants per ship and serve up to 2,000 passengers daily. This is another opportunity for diversified agriculture expansion.

***Niche Markets.*** Another potentially profitable market for locally grown produce is the new and largely untapped niche or seasonal overseas market. With a 12-month growing season in Hawaii, it is possible to time the growing and marketing of selected high-value or high-demand produce to parts of the U.S. and Canada during their off-season and non-growing periods. However, careful planning and good business sense will be required to successfully establish niche markets due to such factors as marketing, shipping, quarantine regulations, product shelf life, etc. A successful niche market operation probably will also require adequate funding and a detailed market analysis.

In addition to export niche markets, there is potential for local niche markets such as providing resort hotels and upscale restaurants with specialty fresh fruits and ingredients for fresh salads. Success depends on close coordination between the chef's needs and farmer's production capabilities. Some farmers have already successfully entered this niche market.

***Export Markets.*** Expansion of the existing export market and development of new diversified crops for export to the U.S., Canada, Japan, and Hong Kong have great potential. Current export crops include papaya, macadamia nut, fresh pineapple, coffee, seed corn, processed guava, orchids, anthuriums, and a variety of nursery plants. Not all of these export crops are candidates for expansion, but those with potential for expansion include papaya, seed corn, flowers, and nursery plants. Most of these export crops are actively grown on all of the major islands and farmers are knowledgeable and experienced in their production and marketing.

Potential new export crops include Asian fruits and vegetables grown in limited quantities for local consumption and introduced by newly arrived immigrants from southeast Asian countries. Such tropical specialty fruits and vegetables show great promise for export since the approval and construction of irradiation plants in Hawaii. With irradiation treatment, fruits and vegetables can be shipped to the mainland in better condition then when treated conventionally by chemical and heat. A detailed evaluation of a specific produce or herb would be needed to determine if it can be profitably grown in Hawaii.

***Summary.*** There is an urgent need to develop a comprehensive statewide agricultural water use and development plan to bring an orderly sense to the current transitional period following plantation closures. There is no organized effort by any central authority to plan and coordinate the future of the thousands of acres of former sugar and pineapple lands and the complex irrigation systems associated with those lands. Without a concerted effort to bring together every stakeholder to discuss, exchange ideas, and evaluate the situation, these fallow lands and irrigation systems could be taken out of agricultural use forever. It is the State's (Legislature and Executive) responsibility to carry out the mandate of Article XI, Section 3, of the State Constitution, which states:

> "The state shall conserve and protect agricultural lands, promote diversified agriculture, increase agricultural self-sufficiency and assure the availability of agriculturally suitable lands. The Legislature shall provide standards and criteria to accomplish the foregoing. Lands identified by the state as important agricultural lands needed to fulfill the purposes above shall not be reclassified by the state or rezoned by its political subdivisions without meeting the standards and criteria established by the Legislature and approved by a two-thirds vote of the body responsible for the reclassification or rezoning action."

The AWUDP is envisioned as one of the necessary tools, a guide, to be used in carrying out this mandate. Unfortunately, there are no large agribusinesses or related organizations to champion the contributions of Hawaii's agricultural industry to the State's overall well-being. Following the demise of the sugar industry, there remains only the State government, together with Federal and County counterparts, to support and recognize agriculture as one of the State's most important industries.

The AWUDP must first explore all facets of the potential opportunity for diversified agriculture. The AWUDP needs to consider what, where, and how to meet the diversified agriculture demand on the potential needs for irrigation water on those former monocrop lands in diversified agriculture.

With properly planned and coordinated assistance from government, Hawaii could realistically become self-sufficient in producing most of its currently imported food supply, including fresh produce, fish, livestock, and poultry. For this to occur, the State must first adopt a viable agricultural water plan and then implement the improvements to the agricultural water systems which will supply the water needed to sustain a diversified agriculture industry.

# Chapter 3. PLANNING PROCESS

## PURPOSE

The AWUDP has a twofold purpose. The first is to meet the provisions of Act 101, Session Laws of Hawaii 1998 by evaluating those irrigation ditches abandoned by plantation closure by proposing a rehabilitation program, and by providing a long-range management plan. The second is to review and discuss the potential for transitioning from monocrop corporate farming into diversified crop farming along with the potential opportunities available in the new diversified farming.

## LIMITATIONS AND ASSUMPTIONS

Due to limited funds and time, a comprehensive plan could not be completed. Instead, the HDOA has commissioned this initial planning report to meet the provisions of Act 101, as amended.

A comprehensive agricultural water use and development plan would include several components not outlined in Act 101, but considered necessary to adequately meet the HDOA agricultural water planning guidelines and requirements of the Commission on Water Resources Management (CWRM). The CWRM components include the water demand forecast, water demand areas and type, and projections of water demand over the planning period outlined by the CWRM. Studies of these components have not been funded and are not included in this report.

This report has been prepared on a strict time schedule to meet the reporting mandate of Act 101, as amended. With limited funds and time, a second report is planned (mid-2004), which will include interim agricultural water use requirements as outlined in the Commission on Water Resource Management's AWUDP Integration Framework, dated July 2003.

The assumptions made in preparing this report include the following: (1) construction and rehabilitation cost estimate for improvements and maintenance works are estimates only, and are not based on engineering design plans, (2) in most instances no field assessments of the proposed improvements were made, (3) water service areas were based on old plantation field maps provided by the current system operators and were not field checked for accuracy or status, (4) water use rates were taken from information available in the HDOA's files, (5) certain program and management scheduling was based on anecdotal information and experience of the former HDOA administrator handling those HDOA programs, and (6) operations and maintenance estimates were adapted from HDOA's irrigation program operation and maintenance (O&M) costs.

No studies were conducted to determine the effects of soils, terrain, climate, crop suitability, marketing availability, and related factors normally considered in advance agricultural water planning. This was necessitated by limited funds and a short time schedule.

This report covers only those irrigation systems for which information could be gathered in a timely manner. This report includes most of the inventory, assessment, and estimated rehabilitation cost data of 10 systems presented in the U.S. Bureau of Reclamation and HDOA joint report entitled, *Hawaii Water Resources Study, Agricultural Water Systems, September 2003.* Three additional privately owned irrigation systems for which information was voluntarily furnished by their current operators are also included in this report.

## IRRIGATION SYSTEMS NOT STUDIED

Described below are other private irrigation systems that are operational, but were not included within the scope of this report. These systems are listed below for completeness only and should be included in future studies.

<u>Kauai</u>

1. *Kaloko and Puu Ka Ele Ditches* – The former Kilauea Plantation currently operate these two ditches to serve Guava Plantation and surrounding farming regions, including the Kilauea Ag Park Subdivision. This system divert the headwaters of

Kilauea Stream located within the Moloaa Forest Reserve by means of a Reservoir Dam at elevation 395 ft. and was originally used mainly for sugarcane irrigation.

2. *Anahola Ditch* – The former Lihue Plantation originally diverted the headwaters of Anahola and Kealia Streams into Kaneha Reservoir to irrigate the northern section of former Lihue Plantation Company's sugarcane fields. Now under the jurisdiction of the Department of Hawaiian Home Lands, the system basically has been abandoned. The system was studied by Souza, J.N., et al, July 1996.

3. *Upper and Lower Lihue Ditches and por. Waiahi-Iliiliula* Ditch – The former Lihue Plantation Co. Lihue Ditches originally diverted the South Fork of the Wailua River and Hanamaulu Stream into Kapaia Reservoir to serve former Lihue Plantation Company's cane fields in and around Lihue and Hanamaulu. The system is currently being operated by the Lihue Land Company and is maintained by an independent contractor. A portion of the system's water will be fed to a soon-to-be built surface water treatment plant for potable water use by the Kauai Department of Water.

4. *Upper and Lower Haiku Ditches* – The former Grove Farm Plantation diverted the headwaters of Huleia Stream in and around the topographic saddle area between Kilohana Crater and Mount Waialeale. Originally, the system waters were fed into several reservoirs to irrigate the sugarcane fields in Haiku, Puhi, Nawiliwili, and Koloa areas. The system is now owned and managed by the Lihue Land Company, successor to former Grove Farm, Inc. Little information is known about the current condition of the system, portions which are known to be non-operational or abandoned.

5. *Waiaha-Kuia Aqueduct, por. Waiahi-Iliiliula Ditch, and Koloa-Wilcox Ditch* – The former Koloa Plantation diverted water from the southern portion of the same watershed as Grove Farm Plantation, through a series of ditches, tunnel, and small reservoirs into the main storage reservoir at Waita (the largest body of fresh water in the State). The water was used to irrigate the leeward coastal plains in and around Koloa, Poipu, and Lawai. Little is known about the existing condition of the system, but parts of the upstream section of the system may have been abandoned. However, the Waita Reservoir and the downstream part of the system still provide irrigation water to the Koloa and Poipu areas.

6. *Olokele Ditch* – This ditch is still active and is operated and maintained by the Gay and Robinson Plantation, which continues to grow sugarcane and irrigate their fields. Little information is readily available on this system.

<u>Oahu</u>

1. *Oahu Ditch (Wahiawa, Helemano, and Tanaka)* – The former Waialua Sugar Plantation captured and stored the waters of Kaukonahua Stream Watershed by constructing an on-stream dam and reservoir at Wahiawa (Lake Wilson) to irrigate pineapple fields in the Schofield-Wahiawa areas and sugarcane fields on the slopes

above Waialua and Haleiwa. The system is currently operational, but little information is available from the operators. Lake Wilson provides recreational (fresh water fishing) and flood control use and is currently under study for rehabilitation.

2. *Opaeula, Kamananui, and Ito Ditches* – The former Waialua Plantation also maintained an irrigation ditch system to serve their lower Waialua and coastal Mokeulia cane fields. In addition to surface water sources, groundwater wells located mostly in the coastal plain were a major source of water supply. No information is available on the condition of the system.

HAWAII:

1. *Kau Agribusiness Irrigation System* – The former Hawaiian Agricultural Co. developed an irrigation system by using high-level perched water development tunnels within the upper forest reserve areas. This tunnel and ditch system served both the Pahala and Naalehu sections of the sugar plantation. Much of the infrastructure has been abandoned or has deteriorated from neglect and lack of maintenance. There is currently a portion of the system used by Kau Agribusiness Agricultural Park and farmers in the Pahala area.

2. *Kohala Ditch* – The former Kohala Sugar Plantation developed the Kohala Ditch to divert surface waters from the windward streams on the eastern slopes of Kohala Mountain to irrigate sugarcane fields on the coastal slopes of North Kohala. The system is currently used for recreational (Kayak tours) and irrigation purposes and is operated and owned by Chalon, a land development corporation. Little is known of the current condition of the stream diversions and the service areas. Some agricultural uses occur along the coast in and around Hawi that was developed by the Kohala Agricultural Task Force.

3. *Kehena Ditch* – The former Kohala Plantation also built Kehena Ditch which diverted streams in the summit area of Kohala Mountain and conveyed the water to the Kohala Ditch near Hawi. Kehena Ditch was used mainly to irrigate sugarcane fields in the vicinity of Hawi. It is believed that the ditch has been abandoned and little is known of the condition of the diversions or ditches.

Future reports need to identify whether any of these systems are still active and evaluate those meeting the criteria outlined in Act 101, as amended. For privately owned systems, an effort should be made to convince the current owners/operators to have their systems included in the final AWUDP. However, funds for such work were not available.

**FURTHER REQUIRED STUDIES**

The AWUDP, as envisioned, should include a comprehensive study of current and future water demand for agricultural programs and projects based upon careful assessment of the future potential of Hawaii's diversified agricultural industry. A 20-year planning period should also be considered. Further, more consideration should be given to the different rates of consumptive water use for different diversified agriculture crops, such as truck crops, orchard, pasture, etc. Climatic factors, such as rainfall, wind, evaporation, sunlight, etc., also need to be considered at each location and evaluated in determining the water application requirements of individual crops.

The irrigation systems (source, capabilities) and especially their condition need to be updated and field checked as to status of use, zoning, and availability for farming. Further, to facilitate 20-year planning projections, various studies are needed on crop and soil suitability, potential markets, availability of market price support for selected crops, etc.

The agricultural water demand forecasts presented in this report were based primarily upon applied or anecdotal data, rather than data derived from detailed scientific studies, such as soil suitability, crop suitability, climate, terrain limitations, and other limiting physical factors.

The AWUDP utilizes much of the information gathered during the recent Hawaii Water Resources Study by the HDOA and much of the information and details on irrigation system obtained from former sugar plantation maps and data. The service areas of the five select irrigation systems are assumed to still be available for agriculture use; however, adjustments were made if, in the course of the study, it was found that some of the former cane fields were removed from agricultural uses. For the five HDOA operated systems, the service areas were obtained from maps, water customer listings, and data available at the Department of Agriculture. Although some former sugar plantation fields were known to have limited agriculture use, or were fallow, it was assumed that those parcel of lands remained available for return to agricultural use. For completeness and usefulness, the AWUDP will require further studies, inventorying, and field verification and updating of irrigated service areas that were actively being utilized during plantation time. Additional work also is needed to survey current farmers and farming activities.

Future studies will need to take into consideration all these above-mentioned factors and the crop selections will need to be adjusted, taking into account those criteria that will impact the productivity, crop quality, yields, and other marketing factors.  Importantly, the water use estimates and consumptive water use rates for different crops will need to be refined to provide more detailed and accurate water-demand forecasts.

The Agricultural Water Use and Development Plan, as with all long-range plans, will need to be revised from time to time to account for changes resulting from these future, more-intense detailed studies.  With the development of more accurate information on consumptive water-use rates and cropping productivity, it is anticipated that the agricultural water use estimates in the AWUDP will need adjustments and refinements.

# Chapter 4. EAST KAUAI IRRIGATION SYSTEM

## INVENTORY

The East Kauai Irrigation System (EKIS) was built in the 1920s by the Lihue Plantation Co. (LPC) and the East Kauai Water Co. (EKW), which held a water license from the State for all flows in the North Fork of the Wailua River, Kapaa Stream, Anahola Stream, and Hanalei River and their tributaries. The complex system consisted of interconnecting ditches, tunnels, flumes, and reservoirs that collected surface waters from the Hanalei and Wailua Rivers. This system irrigated sugarcane on 6,000 acres in the Kapaa area, 6,500 acres in the Kalepa area (region of the North and South Forks of the Wailua River), and thousands of acres in the Lihue-Hanamaulu area (privately owned area not included in this study). The EKIS included 51 miles of ditches and tunnels, 18 stream intakes, three major reservoirs, and two hydropower plants and the average capacity was 100 to 140 mgd (Map 1).

***Kapaa Section***. The Kapaa section of the EKIS consisted of 22.5 miles of ditches and tunnels and diverted waters from the North Fork of the Wailua River (Wailua Ditch Intake) and Kapaa Stream (Kapaa Stream Intake). From the Wailua Ditch Intake, water moved east via the Wailua Ditch to the Wailua Reservoir (240 MG), and from there, northeast, through a series of tunnels and unlined earthen ditches to the Upper Kapahi Reservoir (30 MG) and the Lower Kapahi Reservoir (25 MG), located in the Kapaa area. From the Kapaa Stream Intake, water moved via ditches to the Upper and Lower Kapahi Reservoirs. Eight separate laterals (unlined earthen ditches) and a number of “Pani” (control) gates directed water from the Wailua Ditch eastward (toward the coast) to the cane fields.

***Kalepa Section.*** The Kalepa section of the EKIS originally diverted Hanalei River water: (1) through the 6,028 ft Hanalei Tunnel, (2) to a tributary of the North Fork of the Wailua River, (3) down the tributary to Stable Storm Intake located at the 700 ft elevation on Wailua River’s North Fork, (4) through Stable Storm Ditch, and (5) to the Hanamaulu Ditch Intake located on Wailua River’s South Fork (Map 1). Further upslope and roughly parallel to the Stable Storm Ditch, the Iliiliula-North Wailua Ditch begins at the Blue Hole Intake (1,100 ft elevation) and diverted headwaters of Wailua River’s North Fork and Iliiliula Stream south to the Upper Waiahi Hydropower Plant and then east to the Lower Waiahi Hydropower Plant. The Lower Waiahi Hydropower Plant was initially built to provide 600 kW of power for mill operations, four small towns, and pumping water. In the late 1930s, its capacity was increased to 800 kW. A second power plant, the Upper Waiahi Hydropower Plant (500 kW), was built upstream at the 1,050 ft elevation.

From the lower power plant, Iliiliula-North Wailua Ditch water flowed east to Wailua River's South Fork. Downstream, the Hanamaulu Ditch Intake diverted flows from both Iliiliula-North Wailua Ditch and Stable Storm Ditch into Hanamaulu Ditch, a series of ditches, tunnels, and wooden flumes which conveyed water east to cane fields in the Kalepa and Hanamaulu-Lihue areas.

***Hanamaulu-Lihue Section.*** In addition to the Hanamaulu Ditch, the cane fields in the Hanamaulu-Lihue area were served by the Upper and Lower Lihue Ditches which diverted water at the Lower Waiahi Hydropower Plant and from the Hanamaulu Ditch, respectively. This section of the original EKIS is located on privately owned land and is not included in this study.

## EXISTING CONDITIONS

The East Kauai Irrigation System, after the closure of the LPC in 2000, continues to be operated as three interrelated sections by two new entities: the East Kauai Water Users' Cooperative (EKWUC), incorporated in March 2001, and the Lihue Land Company (LLC), successor to the Lihue Plantation Co. The principal owners of the system, by virtue of land ownership, are the State of Hawaii and LLC. Some of the distribution and lateral ditches, however, are owned by other entities or in some cases by dual owners.

***Kapaa Section***. The Kapaa section, which includes the Wailua Ditch and Kapaa Stream Intakes, consists of old facilities which are generally in fair condition with a few exceptions. Lateral 8, a transmission ditch from Upper Kapahi Reservoir to Twin Reservoir, traverses a wooded area, exposing the ditch to intruding tree roots and falling leaves and branches. Ditch water losses occur because of eroded earthen banks and a badly corroded section of corrugated metal pipe. The Wailua, Upper Kapahi, and Twin Reservoirs all have control gates with wooden catwalks that are in disrepair or inoperable.

***Kalepa Section***. The Kalepa section, which serves the region between Wailua River's North and South Forks, is fed primarily by Stable Storm Intake, as the Hanalei watershed no longer contributes water due to an un-repaired blockage of the Hanalei Tunnel (blockage not repaired due to an unresolved dispute). Stable Storm Ditch then conveys North Fork water to the South Fork and then to Hanamaulu Ditch. Although Stable Storm Ditch traverses mainly on State lands, its waters must traverse a privately owned (LLC) portion of Hanamaulu Ditch. Presently, an agreement among EKWUC, Department of Land and Natural Resources (DLNR), and LLC allows Stable Storm Ditch water to re-enter the State-owned portion of Hanamaulu Ditch (Map 1). Hanamaulu Ditch is in good condition, with heavy vegetation along most of its length, but it is accessible through abandoned cane fields.

## ASSESSMENT OF NEEDS

The EKIS is being maintained adequately by the EKWUC, but facilities are old and show signs of long-term neglect. Most of the control gates and their wooden catwalks and gate boards need to be rehabilitated, replaced, or renovated. Several wooden flumes are badly deteriorated and scheduled to be replaced by HDOA. Unlined reservoirs show signs of siltation and heavy tree root intrusion on the embankments. The concrete rubble masonry diversion dams and intakes have been damaged repeatedly by storm flows, as have their concrete aprons. In some instances, repairs are needed to prevent failure of the diversion structures. The tunnels show spalling from loose rocks and soil at their portals and some work is needed to prevent flow blockage. Wailua Reservoir should be assessed for potential liability and safety before it is used for public fishing, as has been proposed. The reservoir embankment needs to meet dam safety standards if opened for public use.

Most of the system's control gates, ditch service laterals, and "pani" (control) gates need rehabilitation and retrofit to meet the requirement for more precise flow control for diversified agriculture instead of sugarcane irrigation. Sugarcane required large amounts of water for short periods and large, roughly-constructed wooden gates sufficed for flow control. On the other hand, diversified agriculture requires a smaller, more regulated flow of irrigation water, thus impacting the size and type of control gates needed. A more comprehensive evaluation should be conducted to determine whether the existing wooden control gates need to be relocated and rebuilt, and if so, the costs.

The Wailua Ditch, a series of ditches, tunnels, and wooden flumes connecting Wailua Reservoir to Upper Kapahi Reservoir, is in overall good condition. However, all control gates, especially those on the reservoirs, are in need of repair. One wooden flume near Kapaa Stream is in urgent need of repair. The Hanamaulu Ditch, consisting of ditches, tunnels, and flumes, is also in good condition having been in active use since LPC closed in 2000. Some rehabilitation work is needed at the Stable Storm Intake and construction of an access road to the intake is needed because it is remote and accessible only by foot. As mentioned under existing conditions of the Kalepa section, water supply from the State's Stable Storm Intake traverses a section of privately owned land. Because of this uncertain situation, a portion of Hanamaulu Ditch should be replaced in the future with a new by-pass pipeline located entirely on State land to assure service to State lands at Kalepa.

If the EKIS should be allowed to go dry, the reservoirs, ditches, tunnels, and wooden flumes would crack, and be subject to extensive water losses. Consequently, every effort should be made to maintain flows.

Plantation closure has resulted in over 1,400 acres of fallow agricultural land in the Kapaa area and 6,500 acres in the Kalepa area inland of Kalepa Ridge. Land use is slowly evolving to diversified agriculture. New privately owned properties in the Kapaa area that need irrigation water include the Kapaa 382 Property, which is subdivided into 19 agriculture-zoned lots, and the Kapaa 1400 Property, which is planned for agricultural use. These two properties may require about 75 percent of the Kapaa section's water supply.

In the Kalepa area, Hanamaulu Ditch continues to flow and the Department of Land & Natural Resources (DLNR) is preparing an agricultural use master plan for 6,500 acres of State-owned lands. After completion of the plan, the DLNR is expected to issue agricultural land leases. Consequently, the water supply of the Kalepa section of the EKIS will need to be evaluated at that time.

## PROPOSED CAPITAL IMPROVEMENTS

The Hawaii Department of Agriculture's current effort is to maintain the EKIS's interim flows until related land and water use decisions and policies are made by both private land owners and the DLNR. Based upon those decisions, other improvement measures will be identified for future implementation. However, such future activities are beyond the scope of this study.

The improvements listed below address the more pressing needs and problems determined during the system's assessment. Rehabilitation cost estimates include the complexities of engineering design, environmental permitting and clearances, and acquisition of easement.

1. Rehabilitate Lateral 8 Transmission Ditch. Improvements are needed on leaking ditch bank sections and a 40+ feet section of badly corroded corrugated metal pipe. A temporary repair of the 30” corrugated steel pipe was done by insertion of a polyvinyl chloride pipe to allow continued use, but that repair is leaking badly and is also causing the normal flow in the ditch to become obstructed. The repair has changed the gradient of the ditch and has impacted the water delivery characteristics, which need to be fixed.

2. Replace 100+ feet wooden flume on Hanamaulu Ditch. The flume is subject to flooding and sedimentation and has been temporarily repaired with corrugated metal pipe to allow continued use. The flume’s wooden support structure is completely buried and the flume channel is now at ground level. Thus, a future major storm flow may destroy the flume in this dry gulch. Corrective action is needed to clear the storm channel under the flume or replace the flume with a pipe.

3. Rehabilitate Wailua Reservoir, Upper Kapahi Reservoir, Twin Reservoir, and Reservoir 21 (serving Fern Grotto). Rehabilitate wooden access catwalks to control gates and make improvements to bypass gates, and outlet/inlet gates. Most, if not all, of these structures need to be rehabilitated or replaced due to deteriorating materials.

4. Retrofit controls. Most gates were constructed to support sugarcane operations, which required large quantities of water for short periods of time. However, with diversified agriculture, controls are needed to regulate more modest flow. To make this transition, the control, bypass, service laterals, and release gates need to be retrofitted to meet the flow control requirements. Approximately 10 to15 gates will need retrofitting to effectively make the switch.

5. Repair diversion works. Kapaa Stream Intake, Wailua Ditch Intake, Stable Storm Intake, and Hanamaulu Ditch Intake need various improvements to the diversion works (concrete masonry dams and aprons and channel inlet gates).

6. Re-route a portion of Stable Storm Ditch to avoid privately owned lands. The project would involve a new storage reservoir(s) and a new ditch or pipeline alignment. The

existing ditch would need to be redesigned to serve DLNR's master plan for its Kalepa lands and Department of Hawaiian Home Lands' plans for its exchanged Wailua lands.

## PROPOSED MAINTENANCE IMPROVEMENTS

The maintenance projects listed below are needed for the same purpose as discussed above. Although they are not considered capital improvements, they are just as important to the system's integrity and continued operations. As a result, they should be given equal consideration for funding and implementation purposes.

1. Remove root intrusions. Prepare a root intrusion removal program to periodically inspect and remove root intrusions along open ditches and inside tunnel entrances. This will improve efficiency of ditch flows..
2. Access road repairs. Need to repair access road to Wailua Ditch intake by grading and installing sub-base foundation and drainage swales to divert storm runoff from road bed.

## ESTIMATED COSTS

Estimated costs consist of two types: *Rehabilitation costs*, related to capital improvement projects and *maintenance costs*, related to ordinary operations and maintenance work. Capital improvement projects (CIP), as used in this report, are those which add or improve the value of a system. On the other hand, maintenance costs are for work required for efficient operation of a system on a day-to-day basis.

The table below lists the CIP proposed for the EKIS and their total rehabilitation cost. Capital improvement projects require design engineering, a licensed contractor; and other costs. The total cost is defined as the rehabilitation cost.

CAPITAL IMPROVEMENT COSTS
(EKIS)

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Lateral 8 | Demolish 100 LF of 30" CMP; install 100 LF of new 30" CMP; improve ditch bank; and repair lateral 8 siphon inlet | $ 15,000 |
| 2 | Hanamaulu Flume | Demolish wooden flume and salvage; excavate unclassified backfill & buried wooden trestle; backfill earthen ditch; install new reinforced concrete flume; and install concrete flume | 58,000 |
| 3 | Twin Reservoir | Demolish catwalks; install new wooden catwalks and concrete platform; creosote treatment for lumber; and install new control gates | 216,000 |
| 4 | Upper Kapahi Reservoir | Demolish catwalk; install new wooden catwalk and concrete platform; creosote treatment for lumber; and install new control gate | 216,000 |
| 5 | Wailua Reservoir | Demolish catwalk; Install new wooden catwalk and concrete platform; creosote treatment for lumber; install new control gate; and retrofit intake gate structure to main transmission line | 191,000 |
| 6 | Reservoir 21 | Install new control valve | 13,000 |
| 7 | Control Gates | Retrofit approx. 15 control, bypass & release gates | 112,000 |
| 8 | Diversion Works | Renovate diversion works & inlet gates for intakes on Kapaa Stream, Wailua Ditch, Stable Storm Ditch & Hanamaulu Ditch | 100,000 |
| 9 | Stable Storm Ditch | Re-route portion of Stable Storm Ditch onto State land with pipeline & construct lined reservoir | 4,000,000* |
| | | SUBTOTAL | $ 4,921,000 |
| | | Overhead (15%) | 738,000 |
| | | Contingency (8%) | 394,000 |
| | | Profit (10%) | 492,000 |
| | | State general excise tax (4.1667%) | 205,000 |
| | | SUBTOTAL CONSTRUCTION COST | $ 6,750,000 |
| | | Construction mgmt (20%) | 1,350,000 |
| | | Contract admin. (10%) | 675,000 |
| | | Environmental permitting & clearances** | 500,000 |
| | | Design engineering (15%) | 1,012,000 |
| | | Easements acquisition | 100,000 |
| | | **TOTAL REHABILITATION COST** | $10,387,000 |

* Estimate primarily for engineering and survey work
**Estimate based on degree of environmental sensitivity.

The table below lists the maintenance projects proposed for the EKIS and breakdown of maintenance costs required with estimated repair costs. The work can be considered fairly simple to be installed by maintenance crew as part of their routine work schedule.

MAINTENANCE COSTS
(EKIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Prepare root intrusion removal program to periodically inspect and remove root intrusions inside tunnel sections and along open ditches | $ 15,000 |
| 2 | Access road repairs at Wailua Ditch intake by grading and installing sub-base foundation, drainage swales to divert rain storm flows under road bed | 85,000 |
| | Subtotal | $ 100,000 |
| | Design Engineering (15%) | 15,000 |
| | Environmental Permitting & Clearances* | 100,000 |
| | TOTAL MAINTENANCE COST | $ 215,000 |

* Estimate based on degree of environmental sensitivity.

## CRITERIA FOR ESTABLISHING PROJECT PRIORITY

The criteria used to establish the priority of the proposed rehabilitation projects are as follows:

1. Determine which of the proposed rehabilitation improvements will prevent the loss of a critical function of the system i.e. failure of diversion, collapse of tunnel or flume, etc.

2. Evaluate whether the cost of the rehabilitation can be funded within a reasonable period.

3. For the EKIS, meeting the needs and re-establishing service to full-time farmers was a major objective.

4. Improvements that will reduce maintenance work were given higher ranking because this system currently is managed by a single full-time manager.

**FIVE-YEAR PROGRAM - EKIS**

CAPITAL IMPROVEMENT PROJECTS
(EKIS)

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Lateral 8 | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | | |
| 2 | Hanamaulu Flume | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Twin Reservoir | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | |
| 4 | Upper Kapahi Reservoir | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | |
| 5 | Wailua Reservoir | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | | |
| 6 | Reservoir 21 | ▪ request approp. | | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ begin construction | | |
| 7 | Retrofit control, bypass laterals, etc. | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 8 | Repair diversion works, gates, etc. | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction |
| 9 | Re-routing of a portion of Stable Storm Ditch, etc. | | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction |

MAINTENANCE PROJECTS
(EKIS)

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Remove root intrusion, etc. | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | | |
| 2 | Access road repairs, etc. | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | | | |

*See "Maintenance Cost" in Estimated Costs section of this chapter for a detailed description of work.

**LONG-RANGE MANAGEMENT PLAN**

The management of the operations, repairs, and maintenance of the EKIS is currently being carried out by the East Kauai Water Users Cooperative (EKWUC) on an interim basis. This interim maintenance is funded through a special annual appropriation from the State Legislature and administered by the HDOA's Agribusiness Development Corporation. This cooperative was established after the closure of the system's former operator, Lihue Plantation Co., with the assistance of the Agricultural Cooperative Office of the USDA.

The majority of the intakes, reservoirs, tunnels, transmission ditches are located on State-owned lands, as are most of the system's service areas. Sections of the EKIS are still under private ownership and the State and EKWUC have existing operating agreements carried over from the plantation period. When the EKIS is fully organized into a cohesive irrigation district, those related private land parcels should be acquired through an easement purchase agreement or long-term lease.

For the EKIS, the most logical step would be to allow the EKWUC become the successor of the irrigation system's management. The EKWUC has a board of directors and its membership is composed of farmers, ranchers and other water users would give credence to having active water users govern the system (home rule concept).

The cooperative's board could, by mutual consent, have authority for setting water rates and fees, collect and enforce such tariff, control expenditures from revenues generated, and have overall operational control for repairs, maintenance, and service to water users. Currently, there is no statutory authority to give a private entity the authority to assume such a role. Such activity may fall under the Public Utility statutes as purveyor of a public commodity. Further evaluation of this matter should be conducted by the HDOA, possibly under the provisions of Chapter 167, HRS.

Another more pressing issue is the future encumbrance of the lands under the system's infrastructure. There exists no formal encumbrance, i.e., lease or easements which provides access and maintenance rights to any one agency. More important is the liability issue of damage or injury during operation and maintenance. The Department of Land and Natural Resources, the agency responsible for the management of the public lands in the Kalepa area, has not made a decision on the disposition of the irrigation system's facilities because management may shift from DLNR to HDOA, pending the implementation of Act 90, SLH 2003 which authorized transfer of agricultural lease lands to the HDOA. Until this Act is fully implemented, the system's management should remain on an interim basis with the East Kauai Water Users Cooperative.

# Chapter 5. KEKAHA DITCH IRRIGATION SYSTEM

## INVENTORY

The Kekaha Ditch Irrigation System (KEDIS) starts with two intakes at the 850 ft elevation on tributaries of Waimea River in Waimea Canyon. A third intake at the 550 ft elevation on Waimea River itself provides irrigation water for 5,090 acres of cane fields in the flat coastal plains of southwest Kauai (Map 2). The surface water sources were supplemented by pumping several groundwater tunnel sources (Maui-type shafts).

The Kekaha Ditch, also known as the Waimea and the Waimea-Kekaha Ditch, was started in 1906, with 16 miles of ditches, tunnels, flumes, and siphon in Waimea Canyon and four miles in the Kekaha bluffs. Later, the ditch was extended another 8 miles to Polihale. At the 700 ft elevation, the Kekaha Ditch crosses Waimea River from west to east through a penstock to a 1,200 kW hydropower plant on the east side where the system diverts additional water from Waimea River. The ditch water crosses Waimea River again to the west side through a 2,190-ft long steel siphon.

The KEDIS supplied water to Kekaha Plantation and others such as Kikiaola Land Co. and Knudsen Land Co. At Waiawa gulch, a 550 kW hydropower plant utilized a 280-ft drop in the ditch system to boost system water to approximately 500 acres of upland cane fields. In the 1920s, the KEDIS had an average flow of 35 mgd (50 mgd maximum).

The KEDIS consists of approximately 27 miles of ditches, tunnels, steel siphons, and wooden flumes, and two hydropower plants.

## EXISTING CONDITIONS

From the intakes on Koaie and Waiahulu Streams water flows through tunnels on the west side of Waimea Canyon to a 42-inch diameter steel penstock at an elevation of 700 ft. The penstock then crosses under Waimea River to the Waimea Mauka Hydropower Plant on the east bedrock bank at elevation 550 ft.

Just upstream of the hydropower plant, Waimea River water is diverted into a bedrock tunnel which joins with the power plant effluent in a junction tunnel inside the bedrock river bank. The merged flows exit the tunnel into a 10 ft x 10 ft unlined open ditch.

The ditch then follows the east side of Waimea Canyon through a series of tunnels, ditches, and wooden flumes with a slope of 1 inch per 1,000 ft. The tunnels in this steep canyon section of the system are accessible only at “adits” or original construction openings. The ditch is in fairly good condition, but in certain places there are leaks and seepages which provide some return flow to Waimea River. Two wooden flumes have minor leakages and are in fair condition.

The ditch flow crosses from the east to the west side of the Waimea Canyon through a 36-inch diameter steel pipe inverted siphon. The siphon is buried under the river bed in a concrete jacket.

The ditch continues southward in the west wall of Waimea Canyon and near Waimea town turns westward and follows along the steep coastal bluff at the 400 ft elevation. At Waiawa gulch, 1.5 miles west of Kekaha town, ditch flow is dropped 280 ft in a steel penstock to the Waiawa Hydropower Plant. The ditch along the bluff is mostly an unlined 5 ft x 5 ft ditch with several pipe crossings and culverts to carry flows under intersecting roads. The bluff section of the Kekaha Ditch was cut in basalt rock and has been lined in places with concrete to eliminate excessive leakage. Maintenance is high because of rock debris from storm flows over the bluffs.

At the foot of the bluffs, several scattered unlined earthen reservoirs (2 to 5 million gallons) serve as fore bays to filter stations used to provide clear water for drip and sprinkler irrigation.

## ASSESSMENT OF NEEDS

The KEDIS is able to meet current water needs although the system is old and many features need rehabilitation. The unlined ditch along the foot of the coastal basalt bluffs beyond the Waiawa Hydropower Plant (Map 2) requires periodic cleaning of mud and rocks deposited by storm runoff, but there is no road for equipment access.

Deep within Waimea Canyon, the intakes on Koaie and Waihulu Streams show years of damage from storm flows and need rebuilding to assure reliable water flows for the

1,000 kW Waimea Hydropower Plant. Damage to the diversion dams and intake channels should be corrected to prevent failure of the diversion works.

Midway in Waimea Canyon at the penstock fore bay, spillage from the motorized carrier trash rack is corroding the exterior of the penstock. Also, the screw-type bypass valve, used to de-water the penstock, and its catwalk are badly deteriorated.

Approximately a half mile downstream of the junction of the Waimea Hydropower Plant where waters from the Waimea Intake and the power plant exit a tunnel into an open ditch, there is an existing bypass gate valve. This ditch bypass gate needs to be retrofitted with remote control and a flow recorder. When heavy rains occur in the coastal service area, such a remote-controlled gate would permit convenient and timely release of upper system flows back into Waimea River, preventing ditch overflow damage to the lower part of the system.

As the Kekaha Ditch traverses south along the east walls of Waimea Canyon, its alignment passes through a narrow plateau of highly weathered volcanic soil where several wooden flumes have been subjected to falling rocks from adjacent fractured vertical rock faces. Dislodged basalt blocks may completely damage a flume section and catastrophically disrupt ditch flow as has occurred once or twice in the past, according to anecdotal data. The wooden flume sides need relining due to wood rot and the flumes themselves need protection from potential falling rocks.

In the area upstream of the "black pipe" steel siphon, the unlined ditch is susceptible to an exotic aquatic plant (locally called "Amaju"), which grows well in the ditch and impedes flow. The plant, claimed by the locals to be edible, was imported as an aquarium grass plant, which may have become established by inadvertent disposal. The ditch needs regular maintenance to control its growth. In several places, ditch seepage losses support healthy vegetative growth laterally downslope of the ditch, reaching as far as the Waimea River.

The system's control valves and wooden control gates are outdated for the current diversified agriculture uses being planned. Sugarcane required large (10,000 gallons per day per acre), imprecise flows and controls, but now diversified crop operations require smaller (4,000 gallons per day per acre) flows and better controls. The existing valves and control gates should be retrofitted to meet this new requirement. The same rationale for retrofitting applies to reservoir inlet trash screens, outfalls, control gates and valves. Many of the unlined earthen reservoirs need to be cleaned out and lined, but until leases are awarded it is impossible to determine how many reservoirs will be retained in the KEDIS. However, the concern is mentioned as a potential need at some future date. In cases where the reservoir embankments are dams, dam hazard assessments should be conducted to meet existing public safety regulations.

The KEDIS is currently operated and maintained by an informal agricultural coalition under an interim agreement with the State (DLNR). The State (DLNR) plans to transfer its Kekaha lands and management of the KEDIS to HDOA's Agribusiness Development Corporation.

## PROPOSED CAPITAL IMPROVEMENTS

The improvements listed below are needed to continue service to the existing water users of the KEDIS.

1. Waipao Gulch Pipe Crossing. Realign existing 42-inch diameter steel pipe to continue service to Waipao gulch with either a pipe crossing or inverted siphon. The potential site for the new crossing should be moved close to Pump Station No. 1, where access for equipment is readily available. The present crossing is approximately 50 ft long and 15 ft above the gulch floor.

2. Equipment Access Road. Install maintenance road for small construction equipment, along the lower Kekaha Ditch where it intersects with roads, drainage fords, and cattle crossings. The road should be of minimum width to accommodate small construction equipment capable of removing silt, mud, rock, debris, and boulder deposited by heavy runoff.

3. Koaie Stream Intake. Renovate intake on Koaie Stream in Waimea Canyon. Improvements consist of installing trash screens with automatic cleaners, replacing existing manual control gates with remotely operated automatic control gates, and replacing the stream diversion concrete aprons. Maintaining optimum diversion of flows is extremely important to feed the Waimea Hydropower Plant and provide the major portion of ditch flow.

4. Waihulu Stream Intake. Renovate intake on Waihulu Stream in Waimea Canyon. Improvements consist of installing trash screens with automatic cleaners, replacing existing manual control gates with remotely operated automatic control gates, and replacing the stream diversion concrete aprons. Maintaining optimum diversion of flows is extremely important to feed the Waimea Hydropower Plant and provide the major portion of ditch flow.

5. "Black Pipe" Siphon Inlet. Rehabilitate concrete inlet structure of the 42-inch diameter "black pipe" steel siphon on the east bank of Waimea River. The structure is being undermined by leakage at its junction with the ditch and is in danger of failure.

6. Various Control Gates. Retrofitting of control gates involves installing new valves and channeling structures, adding metering devices, and redesigning of existing control facilities. These facilities need to be renovated to meet the requirements for more precise and smaller flow control suited to diversified agriculture, which is different from the more bulk requirements for sugarcane irrigation. The sites are at the following locations: Waimea Mauka fore bay tunnel, Waimea Heights-Menehune Ditch lateral, Pali flumes, near Obake Bridge, and Menehune Ditch junction box. All of these improvements are considered O&M since the improvements do not add value to the system.

7. Pali Flume. In the future, the two wooden flumes that are exposed to falling rocks at the vertical rock face should be replaced with a bypass tunnel. This will eliminate the threat of a catastrophic shutdown of the KEDIS flows.

8. Clean out and install HDPE lining on 14 existing small reservoirs located between Waiawa Hydropower Plant and system terminus at Polihale.

## PROPOSED MAINTENANCE IMPROVEMENTS

The KEDIS improvements listed below reflect needs resulting from neglected maintenance by the sugar plantation in the waning years before closure. Although most of the improvements represent typical operation and maintenance work, if undertaken as a single project, the work could be considered as a system upgrade and thus be qualified as capital improvement. One item, the siphon replacement, will eventually qualify for capital improvement due to deterioration.

1. The open ditch along the bluff at the edge of the Kekaha coastal plain needs cleaning of bottom sediments and ditch banks need clearing. The sections are located at Fields 130–127, 125–123, 119–117, 113, and 631; Pump 3; and at Pali flumes to "black pipe" siphon. The build up of sediments has occurred because of the ditch's exposure to storm runoff and its flat gradient interrupted by many reservoirs inlets which slow flows at these points. It is important to keep the ditch clean as it alleviates overflow flooding and loss of water into the coastal wetland areas, where pumping is required to lower the ground water table to enable crop growth. Again, this work is considered O&M.

2. Although not considered a present need, the black siphon's 42-inch diameter steel pipe will need some work as the upstream section between the Waimea River's east bank and the siphon inlet shows signs of corrosion and deterioration. The scope of this study does not include an engineering evaluation of the siphon.

## ESTIMATED COSTS

Estimated costs consist of two types: *Rehabilitation costs*, related to capital improvement projects and *maintenance costs*, related to ordinary operations and maintenance work. Capital improvement projects (CIP), as used in this report, are those which add or improve the value of a system. On the other hand, maintenance costs are for work required for efficient operation of a system on a day-to-day basis.

The table below lists the CIP proposed for the KEDIS and their total rehabilitation cost. Capital improvement projects require design engineering, a licensed contractor; and other costs. The total cost is defined as the rehabilitation cost.

CAPITAL IMPROVEMENT COSTS
(KEDIS)

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Waipao Gulch Pipe Crossing | Demolish pipe; install pipe supports & 42" HDPE siphon | $ 51,000 |
| 2 | Equipment Access Road(s) | Clear and grub; install pavement (1,000 ft) | 22,000 |
| 3 | Koaie Stream Intake | Install automatic bar screen/cleaner & control gate; install power source, equipment shelter, & concrete apron | 143,000 |
| 4 | Waihulu Stream Intake | Install automatic bar screen/cleaner & control gate; install power source, equipment shelter, & concrete apron | 143,000 |
| 5 | "Black Pipe" Siphon Inlet | Install CRM lining & 20-LF 36-in. HDPE sliplining; replace intake | 100,000 |
| 6 | Various Control Gates | Retrofit control gates with new valves & channel structures; add metering; redesign flow controls at Waimea forebay tunnel, Waimea Heights-Menehune Ditch lateral, Pali flumes, Obake bridge, & Menehune Ditch junction box | 38,000 |
| 7 | Pali Flume | Replace two sections of Pali flumes (80 & 120 ft) with bypass tunnel | 251,000 |
| 8 | Reservoirs | Clean, grade, & install HDPE lining on 14 reservoirs between Waiawa and Polihale | 2,100,000 |
| | | SUBTOTAL | $ 2,848,000 |
| | | Overhead (15%) | 427,000 |
| | | Contingency (8%) | 228,000 |
| | | Profit (10%) | 285,000 |
| | | State general excise tax (4.1667%) | 119,000 |
| | | SUBTOTAL CONSTRUCTION COST | $ 3,907,000 |
| | | Construction mgmt (20%) | 781,000 |
| | | Contract admin. (10%) | 391,000 |
| | | Environmental permitting & clearances* | 1,000,000 |
| | | Design engineering (15%) | 586,000 |
| | | Easements acquisition | 125,000 |
| | | **TOTAL REHABILITATION COST** | $ 6,790,000 |

* Estimate based on degree of environmental sensitivity.

The table below lists the maintenance projects proposed for the KEDIS and breakdown of maintenance costs required with estimated repair costs. The work can be considered fairly simple to be installed by maintenance crew as part of their routine work schedule.

MAINTENANCE COSTS
(KEDIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Clean open ditches of bottom sedimentation and clearing the side banks of growth at sections in fields 130-127, 125-123, 119-117, 113, and 631, at Pump 3, and from Pali flumes to black pipe siphon | $ 102,000 |
| 2 | Repair corrosion, apply protective coating, and repaint black pipe siphon, 42-inch pipe from the inlet end to the east bank of Waimea River | 100,000 |
| | Subtotal | 202,000 |
| | Design Engineering (15%) | 30,000 |
| | Environmental Permitting & Clearance* | 250,000 |
| | TOTAL MAINTENANCE COST | $ 482,000 |

*Estimate based on degree of environmental sensitivity.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. For the KEDIS, the improvements of its water source should have first consideration since they are situated in an environmentally sensitive area.

2. Due to the limited maintenance personnel, give priority to those rehabilitation projects which reduce maintenance workload in the remote sections of the system.

3. Because this system is spread out over long distances, those rehabilitation improvements that provide automation should have higher priority.

4. Due to remoteness and vulnerability to natural forces, those rehabilitation improvements that eliminate the threats should have higher priority.

**FIVE-YEAR PROGRAM – KEDIS**

CAPITAL IMPROVEMENT PROJECTS
(KEDIS)

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Waipao Gulch Pipe Crossing | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction |
| 2 | Maintenance Equipment Access Road(s) (1000 LF) | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction | |
| 3 | Koaie Stream Intake | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 4 | Waihulu Stream Intake | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction | |
| 5 | "Black Pipe" Siphon Inlet in Waimea Canyon | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 6 | Retrofit all control gates, etc. | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction | | |
| 7 | Replace two sections of pali, etc. | ▪ acquire rights-of-way or easements | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 8 | Grade and Line Reservoirs | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction | |

MAINTENANCE PROJECTS
(KEDIS)

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Clean open ditches of bottom, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | | |
| 2 | Repair corrosion, apply protective coating, etc | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ award design & constr. contract | ▪ begin construction | |

*See "Maintenance Cost" in Estimated Costs section of this chapter for a detailed description of work.

## LONG-RANGE MANAGEMENT PLAN

The entire KEDIS is owned by the State and is to be set aside through a Governor's Executive Order to the Agribusiness Development Corporation (ADC), as allowed by Section 171-11, HRS. The ADC is a semi-private corporation administered by a board of directors, attached administratively to the HDOA. Currently the irrigation system is being managed by an informal Agricultural Coalition under an interim agreement with the State (DLNR). The coalition manages former Kekaha Plantation's entire infrastructure operations, which include drainage, hydropower, and road systems. The informal Agricultural Coalition is in the final organizational stage and is composed of parties interested in continuing agricultural pursuits on former Kekaha sugar lands. The interim management contract should be continued until the ADC makes its decision on the disposition of the set aside lands.

Currently the ADC is contemplating its management role for the operations, repairs, and maintenance of the irrigation system's facilities. The ADC does have statutory authority to set, enforce, and collect water rates and fees; further it has all the powers of the State's executive department in accordance with chapter 163D, HRS. There has been no decision made pending the completion of the governors executive order.

The KEDIS is critical to the safety of the Pacific Missile Range Facility because it is a drainage system that prevents flooding of the low-lying agricultural coastal plain surrounding the coastal facility. The agricultural lands and operations provide a buffer zone from urban uses which allows unrestricted aircraft flight operations and off-shore naval research.

The current O&M agreement with the Agricultural Coalition has been funded by a federal appropriation and more recently through an agreement with ADC. There are negotiations underway between ADC, DLNR and the Agricultural Coalition on the future of this maintenance agreement. Until these negotiations are concluded it would premature to suggest a long range management plan.

# Chapter 6. KOKEE DITCH IRRIGATION SYSTEM

## INVENTORY

The Kokee Ditch Irrigation System (KODIS), built by Kekaha Plantation in the 1920s, diverted headwaters of the Waimea River from five tributaries (Map 3). The system started at the edge of the Alakai swamp with the Mohihi Intake at approximately 3,400 ft elevation. With connecting ditch and tunnels, the Mohihi Intake was followed, sequentially, by intakes on Waiakoali, Kawaikoi, Kauaikinana, and Kokee Streams. This mountain water was transported via tunnels and ditches 7 miles to Puu Lua Reservoir at 3,260 ft elevation. The system included 48 tunnels averaging 1,000 ft. each in length (maximum 3,000 ft) and totaling 8 miles. The system also included 18 miles of open ditches. Puu Lua Reservoir, a 260 million gallon earthen dam reservoir and the major storage facility for this system, was finished in the late 1920s. The ditch flow capacity was 55 mgd leading up to the Puu Lua Reservoir, but was only 26 mgd below Puu Lua Reservoir to the Puu Moe Ditch divide.

From the Puu Moe divide, the ditch flow capacity to the 36 MG Kitano Reservoir was 19 mgd and to the 88 MG Puu Opae Reservoir, 7 mgd. The KODIS served only the upland cane fields above the Kekaha coastal plain, utilizing the three storage reservoirs—Puu Lua, Puu Opae, and Kitano.

About one-fourth of the KODIS water was used to irrigate upland fields below Puu Opae Reservoir and the remainder to irrigate the upland fields east of Kokee Road.

## EXISTING CONDITIONS

The KODIS no longer diverts water from Mohihi Stream, since the intake and connecting ditch have been abandoned. This section’s remoteness and high maintenance costs were not cost effective and the water available was not as reliable as the other sources. The Waiakoali Stream Intake is now the high point of the system with water diverted by a concrete dam into an open ditch, a tunnel, and a wooden flume across Kawaikoi Stream. Supported by a wooden trestle, the flume consists of a semi-circular steel trough approximately 200 fe long and about 30 ft over the stream bed. Just upstream of the flume, Kawaikoi Stream is diverted by a natural dam of huge boulders cemented in place that directs flow into a short open ditch and then into a tunnel, joining the flume flows. The Kawaikoi Intake is the KODIS' major source of water.

The third intake is on Kauaikinana Stream which consists of a 15 ft high concrete dam across the stream bed, diverting flows directly into a tunnel. Most of the Kauaikinana Intake flow consists of the combined flows of the Waiakoali and Kawaikoi Intakes which are discharged from a tunnel exiting the stream bank upstream of the intake. The total flows then are conveyed approximately 2.5 miles through a series of tunnels along the rim of Waimea Canyon into the small Kokee watershed where the system's fourth and last intake, a concrete dam, is located on Kokee Stream. The flows enter the Kokee Valley through a series of open ditches.

From the Kokee Intake, a series of tunnels and ditches take the flows through the Canyon's rim onto its western slopes. Most of the ditches and tunnels are well maintained, but the ditches do suffer from frequent vandalism due to the proximity of vacation cabins and a small residential community.

The ditch system continues to Puu Lua Reservoir, which besides storage serves as a public game fishing site. A trout hatchery and fingerling holding pen are located in the reservoir and are managed by the DLNR. The outflow from the reservoir continues to flow near the western rim of Waimea Canyon through a series of ditches and tunnels to the Puu Moe divide.

At Puu Moe divide, the ditch flow is split, with the majority of the flow going to the Kitano Reservoir, which served upland acreages above Waimea. A limited amount of the flow at Puu Moe goes to the Puu Opae Reservoir, which serves only a small area above Mana. The Kitano leg consists of approximately 2 miles of ditches and a couple of tunnels in good condition. The Kitano Reservoir, an unlined cut and fill earthen reservoir, is currently being rehabilitated by HDOA. The Puu Opae leg consists of a smaller ditch, with less flow than the Kitano leg.

The KODIS is currently operated and maintained by an informal agricultural coalition under an interim agreement with the State (DLNR).

## ASSESSMENT OF NEEDS

Since Kekaha Plantation closed in the late 1990s, a significant decrease in ditch flow in both the KEDIS and KODIS has been recorded. This decrease may be due partly to a long running drought or reduced maintenance of the systems. A seepage loss study should be conducted to determine the extent and nature of ditch losses.

There is a need for the following: (1) a detailed survey of all the reservoir capacities, (2) an evaluation of optimum reservoir inflows relative to the current or planned water demand, and (3) installation of flow meters or other measuring devices to record water use for ditch operations.

The KODIS needs some immediate rehabilitation work. The Kawaikoi flume, a 36-inch diameter, semi-circular steel trough supported on a wooden trestle, is badly deteriorated and needs replacement (in July 2003, a section of the flume collapsed and is to be repaired on an emergency basis). The ditches, tunnels, and a 60 ft long, 36-inch diameter wood stave pipe flume named “Halemanu,” experience some sedimentation, small boulder accumulation, and debris from tunnel spalling, but no root intrusions were observed in spite of many trees along the ditches and over the tunnels.

In general, the unlined ditches and tunnels from the headwater intakes to Puu Lua Reservoir are in good condition. Access for maintenance work to most of this section of the system in Waimea Canyon is severely limited.

Puu Lua Reservoir, an unlined earthen reservoir created by an earthen dam across a gulch serves as a storage and public fishing reservoir. Because the earthen dam is old, it should be assessed to determine if it meets dam safety standards. Reservoir outflow is controlled by a 24-inch globe-type valve and discharge piping buried in the dam embankment and accessible by a vertical concrete shaft with manhole on top of the dam. The valve does not operate freely and the concrete shaft weeps from seepages through the dam embankment. The section of ditches and tunnels from Puu Lua Reservoir to the Puu Moe Ditch divide is in good condition and readily accessible for maintenance.

The flow at Puu Moe divide splits between Kitano and Puu Opae Reservoirs. This ditch divide is excavated in deeply weathered, but stable basalt lavas. Severe erosion at the divide is evident and will require correction and new parshall flumes. The Puu Opae Reservoir, an unlined earthen reservoir, needs lining to prevent seepage losses. The 4-mile ditch to Puu Opae Reservoir should be replaced with high-density polyethylene (HDPE) pipe to prevent seepage and evaporation losses.

The Kitano Reservoir, an unlined cut and fill type reservoir, dug into a small ridge, is heavily silted and should be cleaned out and lined to prevent seepage losses, and fenced to prevent public access.

## PROPOSED CAPITAL IMPROVEMENTS

Most of the improvements listed below for the Kokee Ditch Irrigation System are critical as the assessment indicates potential facility failures unless corrected. The system is located in an environmentally sensitive area due to its designation as a critical habitat and environmentally pristine ecosystem (it contains the Waimea Canyon rim and Alakai swamp). The high rehabilitation cost estimates for the improvements provided below reflect this complexity, and are conservative, based on normal cost analysis standards.

1. Reconstruct the Kawaikoi flume. This flume consists of a wooden trestle supporting a 48-inch diameter semi-circular steel trough. Part of the trestle is supported on a huge boulder and movement of the boulder could cause failure of the flume. As observed in March 2003, the semi-circular steel flume is leaking on the bottom in several spots. However, in July 2003, the downstream portion of the flume collapsed and Waiakoali water currently is spilling and lost to the system. Emergency repairs were completed in 2004, consisting of replacing the foundation with steel framing and installing 8-inch HDPE pipe at a cost of $30,000 provided by the ADC. The flume’s capacity needs to be restored as soon as possible and its wooden support structure repositioned onto a firm foundation, possibly as an in-house project.

2. Rehabilitate existing Puu Lua Reservoir outlet pipe and control valve. The outlet pipe lies approximately 110 ft below the top of the dam. A circular concrete shaft with a surface manhole extends from the top of the dam vertically down to a globe-type control valve on the outlet pipe. The concrete shaft joints show signs of water seepage through the reservoir’s embankment and needs to be sealed off. A possible solution is to install an HDPE lining on the upstream face of the embankment. The control valve

is connected to the surface by a steel shaft and is operated by a turning wheel mounted at the top of the concrete manhole. Operation of the valve is difficult as it does not function properly or as tightly as before. The outlet pipe and control valve are critical parts of the reservoir and failure of either could cause dam failure and flooding of coastal developments down slope.

3. Reconstruct Puu Moe Ditch divide. This ditch divide is important to the integrity of the system's operation, and it is where the system's flow is split, controlled, and measured between Kitano and Puu Opae Reservoirs. This divide is narrow and badly eroded in places. Also, the two measuring devices' (steel parshall flumes) accuracy has been adversely affected by erosion and deterioration. This divide should be entirely re-engineered to correct the erosion problem and provide efficient flow control and accurate flow measurement, including data logging. The existing ditch divide is inadequate for its purpose of precisely dividing and accurately measuring the system's flow to Kitano and Puu Opae Reservoirs.

## PROPOSED MAINTENANCE IMPROVEMENTS

With the anticipated reduction in water use from the Kokee Ditch Irrigation System and less cultivated acres on former upland cane fields, the existing capacity may need downsizing. The HDOA has recognized the urgent need for some improvements and is proceeding with them through other funding sources. The potential for alternative uses is greatest for the Kokee system, i.e., hydropower generation, recreational activity (fishing at Puu Lua Reservoir), and stream restoration.

1. Retrofit stream intake aprons, ditch screens, and control gates to meet the change in system flow operations from sugarcane irrigation to diversified agriculture. The current need for reliable, constant ditch flows rather than the bulk flows of the past will require more precise and complete control of flow and distribution.

2. Two improvements are listed for completeness only: (1) cleaning out Kitano Reservoir which is partially silted and (2) replacing the Halemanu wood stave pipe flume (at Halemanu Stream). Improvements of these two structures are planned in 2003 by the HDOA, as authorized by the State Legislature.

## ESTIMATED COSTS

Estimated costs consist of two types: *Rehabilitation costs*, related to capital improvement projects and *maintenance costs*, related to ordinary operations and maintenance work. Capital improvement projects (CIP), as used in this report, are those which add or improve the value of a system. On the other hand, maintenance costs are for work required for efficient operation of a system on a day-to-day basis.

The table below lists the CIP proposed for the KODIS and their total rehabilitation cost. Capital improvement projects require design engineering, a licensed contractor; and other costs. The total cost is defined as the rehabilitation cost.

CAPITAL IMPROVEMENT COSTS
(KODIS)

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Kawaikoi Flume | Demolish flume; install wooden trestle, 48" semi-circular CMP, HDPE lining; structural study | $ 175,000 |
| 2 | Puu Lua Reservoir | Site work; install HDPE lining on dam; pipe burst/24-inch HDPE discharge pipe; install 24-inch globe valve, and flow meter & appurtenances | 144,000 |
| 3 | Puu Moe Ditch Divide | Site work; install new divide, parshall flumes, and flow meters & appurtenances | 47,000 |
| | | SUBTOTAL | $ 366,000 |
| | | Overhead (15%) | 55,000 |
| | | Contingency (8%) | 29,000 |
| | | Profit (10%) | 37,000 |
| | | State general excise tax (4.1667%) | 15,000 |
| | | SUBTOTAL CONSTRUCTION COST | $ 502,000 |
| | | Construction mgmt (20%) | 100,000 |
| | | Contract admin. (10%) | 50,000 |
| | | Environmental permitting & clearances* | 1,000,000 |
| | | Design engineering (12%) | 60,000 |
| | | **TOTAL REHABILITATION COST** | $1,712,000 |

*Estimate based on degree of environmental sensitivity.

The table below lists one maintenance project for the KODIS with a breakdown of related cost estimates. The work can be considered fairly simple to be installed by maintenance crew as part of their routine work schedule.

MAINTENANCE COSTS
(KODIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Retrofit four intake aprons and inlet channels, 6-8 ditch screens, and control gates or valves | $ 90,000 |
| | Subtotal<br>Design Engineering (15%)<br>Environmental Permitting & Clearance*<br><br>TOTAL MAINTENANCE COST | $ 90,000<br>14,000<br>100,000<br><br>$ 204,000 |

*Estimate based on degree of environmental sensitivity.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. For the KODIS, rehabilitation improvements to its water sources are important because they are situated in a very environmentally sensitive and pristine area.

2. Because this system traverses an inhabited recreational area and exposed to public access, it is susceptible to vandalism, and projects that enhance safety is desirable.

3. Projects which reduce maintenance workload should have higher rankings.

**FIVE-YEAR PROGRAM – KODIS**

CAPITAL IMPROVEMENT PROJECTS
(KODIS)

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Kawaikoi Flume | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction |
| 2 | Puu Lua Reservoir | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Puu Moe Ditch Divide | | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction |

MAINTENANCE PROJECTS
(KODIS)

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Retrofit four intake aprons, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | | |

*See “Maintenance Cost” table in Estimated Costs section of this chapter for a detailed description of work.

**LONG-RANGE MANAGEMENT PLAN**

The KODIS facilities are all owned by the State and are to be turned over to the Agribusiness Development Corporation for irrigation system operation purposes from DLNR through a revocable permit authorized under Section 171-59, HRS. The revocable permit will authorize the ADC to operate, repair, maintain, and control the KODIS.

Currently, the ADC is formulating its role in the administration of the revocable permit. The KODIS will serve agricultural water to State-owned lands and homestead lands of the Department of Hawaiian Home Lands (DHHL). Now the State-owned lands will be set aside to the ADC as part of the Kekaha parcel's governor's executive order, and as such may be consolidated into a single function, i.e., land and infrastructures for management purpose. No decisions have been made at this writing.

The KODIS is being operated by the same Agricultural Coalition that operates the KEDIS and under the same maintenance contract awarded by the ADC. This interim management function should continue until ADC makes its final decision on the disposition of the entire former Kekaha Plantation facilities.

A portion of the KODIS is being utilized as a recreational and sport fishing site by DLNR and that function should continue under some mutual agreement with ADC. This recreational use basically involves only the upper reaches of the system, ending at Puu Lua Reservoir which is the main storage reservoir for the system. This use is critical to DLNR's mission which would be justification to maintain current ditch flows in the upper reaches of the system.

The system's intake system lies within an environmentally sensitive and pristine area, and has the great potential for alternative uses, such as recreational fishing, hydropower generation, and flood prevention. With the multiple-use potential, the system's operations and maintenance should remain with a government agency that can assemble or has the authority to direct and coordinate the different disciplines and expertise needed for their common interests and objectives. The system will need separate programs, one for repairs and maintenance and the other for development of alternative use projects, in order to best utilize this public asset.

The long-range management plan should be formulated by an adhoc committee composed of a cross-section of all who would benefit from the system's operation.

# Chapter 7. MAUI LAND AND PINEAPPLE/ PIONEER MILL IRRIGATION SYSTEM

## INVENTORY

The Maui Land and Pineapple Co./Pioneer Mill Irrigation System (MLP/PMIS) originally consisted of three ditch systems: (1) the Honolua-Honokohau Ditch, which diverted water from Honokohau Stream and other sources to irrigate cane fields on the northwestern slopes of West Maui between Lahaina and Kapalua, (2) the Lahainaluna Ditch which conveyed water from Wahikuli Reservoir to serve cane fields south of Lahaina, stretching 4.4 miles to Launiupoko on West Maui's southwestern slopes, and (3) the Wahikuli Ditch which conveyed ditch water from Wahikuli Reservoir to serve lower-slope cane fields along a 2.6 mile stretch north to Puukolii Reservoir. Only the Wahikuli and a portion of the Honolua-Honokohau Ditch systems comprise the existing PMIS (Map 4).

The Honolua-Honokohau Ditch developed most of its water from two West Maui areas: (1) the northwestern slopes (Honokohau, Kaluanui, and Honolua Streams), and (2) the western slopes (Honokowai, Amalu, Kapaloa, and Kahoma Streams). However, the sources of water on the western slopes have been abandoned.

The Lahainaluna Ditch utilized both Honolua-Honokohau Ditch water and surface water sources south of Lahaina (Kanaha, Kauaula, Launiupoko, Olowalu, and Ukumehame Streams). The Honolua-Honokohau and Lahainaluna Ditches were complex irrigation systems comprised of stream intakes, transmission and development tunnels, ditches, flumes, inverted siphons across gulches, hydropower plants, and large-capacity sources of ground water from coastal infiltration galleries, called Maui-type shafts. The Lahainaluna Ditch system was not studied because it is no longer a part of the PMIS and does not meet the criteria of involving State water or land ownership. Only that portion of the Honolua-Honokohau Ditch and Wahikuli Ditch, which remain a part of the current MLP/PMIS, was studied and described in this report.

## EXISTING CONDITIONS

The current (2003) MLP/PMIS no longer includes the Lahainaluna Ditch system or the four western slope sources mentioned above. The MLP/PMIS, today, consists of two major parts: (1) the 7.5 mile "front" or MLP Section located entirely on Maui Land and Pineapple

Company land and originally called the Honolua Ditch, which originally comprised a ditch system, but later replaced by tunnels starting at the Honokohau Stream Intake (840 ft elevation) on the north slope of West Maui, two additional stream intakes (Kaluanui and Honolua), a siphon across Honokahua gulch, and ending with two reservoirs and a ditch to the inlet of Honokowai siphon; and (2) the "back" section, called the Honokohau Ditch, which consists entirely of ditches and several inverted siphons and flumes, starting at the Honokowai siphon inlet and continuing along ground contour to its terminus at Wahikuli Reservoir.

***MLP Section***. The 7.5-mile long MLP Section consists entirely of 6.5 ft x 6.5 ft concrete-lined tunnels and is privately owned and maintained by Maui Land and Pineapple Company (MLP). This section of the MLP/PMIS was not inspected, but is considered to be in good condition (Warren Suzuki, MLP, personal communication). The MLP Section started out as a 30-mgd capacity system of unlined ditches, a flume, and five inverted siphons that were completed in 1904 with intakes at the 700 ft elevation on Honokohau, Kaluanui, and Honolua Streams. The unlined ditch system suffered such great seepage loss and damage from storm runoff debris that it was completely replaced in 1913 with cement-lined tunnels (6.5 miles), inverted siphons and 430 ft of open ditch aligned parallel to the 1904 ditch system. Honolua Ranch, predecessor to MLP, built the 1913 system and sold all of the water to Pioneer Mill for sugarcane. Beginning in 1923, Pioneer Mill spent five years in re-lining the MLP Section with cut stones, while increasing its capacity from 50 to 70 mgd.

By the 1980s, the MLP/PMIS was used by: (1) MLP for irrigation of its pineapple fields at Kapalua and Wahikuli, and its Kapalua Resort (three golf courses and general landscaping), (2) Maui Department of Water Supply for feed water to its Mahinahina municipal water treatment facility, and (3) Pioneer Mill Company for its Kaanapali Resort irrigation needs.

***Honokohau Ditch Section***. Prior to plantation closure, Pioneer Mill Company had built and operated the Honokohau Ditch section which extends from Honokowai siphon to Wahikuli Reservoir, a distance of 3.5 miles. In addition to using water from the Honolua Ditch, Pioneer Mill Company developed water from Honokowai Stream and its Amalu and Kapaloa branches in 1898 and 1918. The intakes and high-level groundwater development tunnels, located at approximately 1525-ft elevation, developed an average of over 6 mgd and were used to irrigate Pioneer Mill Company's upper cane fields.

Amfac/JMB Hawaii, successor to Pioneer Mill Company (which closed in 1996), no longer uses or maintains these three supplemental sources, its coastal Maui-type shaft sources (ground water) at Honokowai, Kahoma, and Wahikuli, or the Lahainaluna Ditch System south of Wahikuli Reservoir, having disposed of its lands which are no longer in agricultural use.

The Honokohau Ditch is lined in places, but mostly unlined, 5 to 8 ft wide, following the topographic contour. The ditch banks are earthen and graded to protect against cross drainage runoff. Steel inverted siphons and flumes consisting of semi-circular steel plates fabricated by the plantation supported on wooden trestles, carry water across gulches and drainage channels. “Pani” (control) gates are scattered along the ditch for releasing irrigation water to fore bays on the down side of the ditch. The fore bays are small unlined earthen reservoirs which provide gravity fed water to filter stations used to provide clear water for drip irrigation.

The Honokohau Ditch terminates at unlined earthen Wahikuli Reservoir (17 MG) where Crater Reservoir (25 MG) and “New” Reservoir (5 MG) are also located (Map 4). “New” Reservoir is a partially lined (cut stone blocks) earthen reservoir that is badly silted, overgrown, and unused. Crater Reservoir occupies a natural volcanic cinder cone crater and receives overflow from Wahikuli Reservoir. Historically, Crater Reservoir has been used to recharge the underlying groundwater aquifer at Pump “M” with surplus water from the system.

***Wahikuli Ditch and Pumps “M”and “K”***. The Wahikuli Ditch, which is concrete-lined and has limited capacity, served some State lands prior to plantation closure, but currently is inactive. The Puukolii Reservoir is the terminus for this ditch.

Pump “M”, a Maui-type groundwater shaft source, which provided up to 10 mgd of supplemental and dry-weather irrigation water to Wahikuli Ditch and Reservoir, is completely shutdown, including its plantation-installed power lines. However, Pump “M” remains an important potential supplemental source of irrigation water during droughts and low-flow periods. No longer in use, Pump “M”, located 700 ft south of Crater Reservoir, consists of a 322-ft deep vertical shaft which extends to the groundwater table. At the bottom of the shaft is a pump room with two 5± mgd pumps which formerly developed ground water from two horizontal infiltration tunnels totaling 3,800 ft in length. Past records show that Pump “M” produced up to 10 mgd of nonpotable irrigation water. Significant groundwater recharge probably occurs through seepage from unlined Crater Reservoir which occupies a permeable volcanic cinder cone.

Pump “K” is a booster pump station located approximately 700 ft northwest of Crater Reservoir and formerly used to boost water from Pump “M” to Wahikuli Ditch and Wahikuli Reservoir.

## ASSESSMENT OF NEEDS

Of all the systems studied, the MLP/PMIS is the most fragmented and unsettled, as to ownership and water use, as explained below. However, the State's interest is based on the agricultural water needs of surrounding State lands and the need to continue scenic greenery on West Maui's western slopes for the tourism industry. The original MLP/PMIS served lands which are now under different ownerships and, as a result, various components have been dismantled and the current system no longer functions as a single unit. Pioneer Mill Company's parent company is in bankruptcy and other partial owners of the MLP/PMIS have no future plans. Consequently, the system's agricultural water uses are of a short-term and interim nature. One of the major problems of the system is the lack of control by a single entity to manage the two sections cohesively for agriculture. An important aspect of the MLP/PMIS is its history of providing the scenic greenery of sugarcane and pineapple fields on the slopes of West Maui, a tourist industry attraction. Without irrigation, brown slopes will mar this popular visitor setting. On several occasions, dust storms have occurred south of Lahaina, resulting from abandoned cane fields.

The MLP Section, owned by Maui Land and Pineapple Company, is in generally good condition, but needs some rehabilitation work. The Honokohau Intake grating, swivel boom, and silt baffle have been damaged by storm flows and Reservoir 140 at Mahinahina gulch needs cleaning out to restore its capacity and re-lining of the banks to reduce seepage losses (Warren Suzuki, MLP, personal communication).

Much of the Honokohau Ditch section (Mahinahina Weir to Wahikuli Reservoir) is still intact; however, the different elements are either not being used, are abandoned, or are in a state of flux (inactive) pending decisions by separate owners on future water uses. Ownership is a major concern and along the ditch itself several partial ownerships could exist. The current inventory determined that the major owners are Amfac/JMB Hawaii (successor to Pioneer Mill Company), Kamehameha Schools (an educational trust), the State of Hawaii, Peter Martin, and MLP.

The Honokohau section is in relatively good condition, although maintenance has been minimal since plantation closure. The ditch will require continued heavy maintenance due to heavy vegetative growth and there is a concern for ditch bank protection from storm runoff erosion and siltation. The siphons and flumes across gulches are in fairly good condition, except for some flumes needing O&M type improvements.

Wahikuli Reservoir is heavily silted and in need of dredging to restore its capacity. The reservoir serves as the hub for distribution of water by gravity to local fields and to

Wahikuli Ditch, if activated, to serve State and private lands at lower elevations. Wahikuli Ditch is concrete-lined, has limited capacity, and crosses one gulch with an inverted polyvinyl chloride pipe siphon in fairly good condition. Puukolii Reservoir is heavily silted and an evaluation needs to be made of the necessity to rehabilitate it.

Currently inactive, "New" Reservoir is badly silted and in need of dredging to restore its capacity. With rehabilitation, "New" Reservoir can provide supplemental storage to Wahikuli Reservoir.

Because the MLP/PMIS has inadequate flows and severally delivers water along its route to MLP's pineapple fields, the County's Mahinahina municipal water treatment plant, and to other scattered users, there often is not sufficient water during low-flow periods for those users on the end of the system. Restoring the capacity of Wahikuli and "New" Reservoirs as well as restoring Pump "M" and booster Pump "K" will alleviate this problem.

There is a need to organize the existing individual ditch users and land owners into a cohesive and formal organization, possibly an irrigation cooperative. The purpose would be two fold: first, to settle the matter of ownership and place the entire system under one entity and secondly, to allow for orderly development of responsibilities for operation and maintenance of the entire irrigation system, from Honokohau Intake to Wahikuli Reservoir.

## PROPOSED CAPITAL IMPROVEMENTS

The assessment indicates a shortage of ditch flows during low rainfall and corresponding high water-use periods. The MLP/PMIS experiences water shortages along its downstream section, especially during drought and low-flow periods. At the same time, a review of existing farming activity reveals there is greater agricultural potential in the downstream section, particularly in the Wahikuli Reservoir area. The improvements listed below are needed to correct both situations by reducing seepage losses, increasing storage capacity, and providing a supplemental/standby groundwater source.

1. Rehabilitate "New" Reservoir. Need to remove accumulation of silt in order to restore reservoir capacity. Install base course, geotextile and HDPE lining.

2. Rehabilitate Wahikuli Reservoir. Need to remove accumulation of silt and sediment in order to restore reservoir capacity. Install base course, geotextile and HDPE lining to reduce seepage losses. Also install new piping and flow control between the reservoirs to allow flow from "New" to Wahikuli Reservoir.

3. Restore Pump "M". Restoration of Pump "M" with three pumps of 1 mgd capacity each would provide a reliable, supplementary source of water during low ditch flow and drought periods to upper and lower State lands. Restoration would involve the following: removing old horizontal pumps and appurtenances and installing new pumps and discharge piping in the existing vertical shaft and installing new pump controls with building and fencing. Restoration would also include reactivation of electric power to the pump site.

4. Restore Pump "K". Restoration of Pump "K" is needed to complement the restoration of Pump "M" by making Pump "M" water available to Wahikuli Ditch and Wahikuli Reservoir which serves upper State lands. Restoration would include downsizing Pump "K" to match the restored pump capacity of Pump "M", installing pump controls, and restoring electrical power to the site.

5. Renovate Honokohau Intake. Honokohau Intake has sustained damage and deterioration from heavy storm flows and its continued function is vital as it is the principal water source for the PMIS. The control gate, known as "Aotaki," needs to be renovated along with silt baffle. Replace intake grating and swivel boom. Install 200 ft concrete channel and control valve.

6. Renovate Reservoir 140. Reservoir 140 located at the Mahinahina weir is a storage reservoir serving State lands at the boundary with MLP. It is badly silted and its existing cut stone lined banks are eroding and causing seepage losses. The reservoir needs to be cleaned out and its stone lined banks replaced with HDPE lining.

7. Restore open ditch. Install lining on Honokohau Ditch banks to prevent erosion and ditch siltation and to lessen high weed/shrub maintenance.

8. Construct cross drainage structures. Construct concrete intake structures at the various transverse drainage channels and inactive ditch systems intercepted by the Honokohau Ditch. There are at least four major ones. The existing improvements used to capture or control the cross drainage storm flows are minimal, not well planned, and therefore are likely to cause siltation and damage to the Honokohau Ditch.

9. Construct reservoirs at stilling basin sites. Increase the storage capacity of the Honokohau Ditch section by constructing and lining 14 new reservoirs on the upslope side of the ditch to capture storm flows at the location of existing stilling basins and cross-connected ditch systems. With increased water use, there will be a need for more

storage capacity along Honokohau Ditch to offset the incremental reduction in system flows as water users scattered along the ditch withdraw water.

10. Replace Wahikuli Ditch. Replace Wahikuli Ditch with pipeline, laterals, and control valves to serve lower State and private agricultural lands situated along the ditch. Because Wahikuli Ditch has limited service areas and crosses some lands that may become non-agricultural in the future, replace ditch with a closed pipeline system.

11. Redesign flow meter recorder at Mahinahina weir, including reconstruction of the enclosure and replacement of the transmission device.

## PROPOSED MAINTENANCE IMPROVEMENTS

The assessment revealed many MLP/PMIS concerns caused by inadequate maintenance during the period when the sugar plantation was experiencing financial difficulties. Normal plantation maintenance would have kept this once extensive and complex irrigation system intact. However, when the plantation closed, different owners of land parcels over which the system traversed, particularly from Wahikuli to Olowalu, destroyed the integrity of the original system and left only the Honolua-Honokohau Ditch section (Kapalua to Wahikuli Reservoir) and the Wahikuli Ditch section (Wahikuli Reservoir to Puukolii Reservoir). These two sections, now called the Pioneer Mill Irrigation System, are not well organized because the State (DLNR) has not made any policy decisions on the future use of its related agricultural lands. The assessment indicates that numerous operation and maintenance type improvements are required to adequately serve water in the area. If these O&M improvements were combined into a single system-wide project, they might be considered as capital improvement (the distinction is meaningful in that capital improvements add/improve value and are funded by bonds, whereas O&M improvements do not and are funded by operating revenues).

There is great potential for reclamation of treated sewage effluent on this system, as indicated by ongoing planning activities with Maui County. For example, commercial establishments have expressed interest in utilizing treated effluent for non-agricultural irrigation.

Suggested maintenance improvements for the MLP/PMIS include:

1. Repair the tunnel cave-in at the Honokowai siphon outlet. This work is considered O&M, but may qualify as capital improvement as it adds or improves the system's value.

2. Remove silt and sediments from Puukolii Reservoir, Honokohau Ditch, and the associated stilling basins scattered along the entire length of the ditch. However, this work is considered to be O&M rather than capital improvements.

3. Replace the semi-circular shaped steel flume across "B-1" gulch. This flume is constructed of steel sections joined together and supported by interlocking steel straps attached to a wood trestle. Based upon anecdotal information, the steel sections and straps were shop fabricated by the former plantation from thin steel sheets and probably are not available as stock items.

4. Inspect root intrusion along the sides and bottom of tunnels at certain locations along the Honolua Ditch section and initiate program for periodic removal of roots and repairing concrete lining damaged by root intrusion.

5. Repaint exterior and check interior of siphons in the Honolua Ditch section to determine if concrete lining is still intact.

## ESTIMATED COSTS

Estimated costs consist of two types: *Rehabilitation costs*, related to capital improvement projects and *maintenance costs*, related to ordinary operations and maintenance work. Capital improvement projects (CIP), as used in this report, are those which add or improve the value of a system. On the other hand, maintenance costs are for work required for efficient operation of a system on a day-to-day basis.

The table below lists the CIP proposed for the MLP/PMIS and their total rehabilitation cost. Capital improvement projects require design engineering, a licensed contractor; and other costs. The total cost is defined as the rehabilitation cost.

CAPITAL IMPROVEMENT COSTS
(MLP/PMIS)

| No. | Item | Needed Improvements | Construction Cost |
|---|---|---|---|
| 1 | "New" Reservoir | Remove silt; install base course, geotextile, and HDPE lining | $ 328,000 |
| 2 | Wahikuli Reservoir | Dewater remove silt; install pipe bypass, base course, geotextile, and HDPE lining; Level II dam hazard assessment | 2,190,000 |
| 3 | Pump "M" (Maui-type shaft) | Remove pump house & pumps; install 3 new pumps, 10" D.I. pipe & 10" HDPE pipe, new building, fence & gate; reactivate electrical service | 265 ,000 |
| 4 | Pump "K" (booster) | Remove pump house & pumps; install 3 new pumps, 10" D.I. pipe & 10" HDPE pipe, new building, fence & gate; reactivate electrical service | 188,000 |
| 5 | Honokohau Intake | Replace grating & swivel boom; renovate silt baffle & Aotaki gate; install 200 ft concrete channel, control gate and valve | 89,000 |
| 6 | Reservoir 140 | Remove silt; repair cut-stone lining; install HDPE lining & bypass pipe | 333,000 |
| 7 | Open Ditch | Install lining (gunite) on sides of ditches through loose earthen sections | 64,000 |
| 8 | Cross Drainages | Construct 4-6 cross drainage structures to bypass storm flows over main ditch & line approach channel | 300,000 |
| 9 | Stilling Basins | Line 14 stilling & cross drainage sites along ditch | 210,000 |
| 10 | Wahikuli Ditch | Replace Wahikuli Ditch with pipeline, laterals, & control valves | 250,000 |
| 11 | Mahinahina Weir | Reconstruct weir, shelter, and telemetry | 50,000 |
| | | SUBTOTAL | $4,267,000 |
| | | Overhead (15%) | 640,000 |
| | | Contingency (8%) | 341,000 |
| | | Profit (10%) | 427,000 |
| | | State General Excise Tax (4.1667%) | 178,000 |
| | | SUBTOTAL CONSTRUCTION COST | $5,853,000 |
| | | Construction mgmt (20%) | 1,171,000 |
| | | Contract admin. (10%) | 585,000 |
| | | Environmental permitting & clearances* | 250,000 |
| | | Design engineering (15%) | 878,000 |
| | | Easement acquisition* | 175,000 |
| | | **TOTAL REHABILITATION COST** | $8,912,000 |

*Estimate based on degree of environmental sensitivity.

The table below lists the maintenance projects proposed for the MLP/PMIS and breakdown of maintenance costs required with estimated repair costs. The work can be considered fairly simple to be installed by maintenance crew as part of their routine work schedule.

MAINTENANCE COSTS
(MLP/PMIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Repair tunnel face cavein at Honokoawai siphon outlet site. | $ 250,000 |
| 2 | Remove silt and sedimentation from bottom of Puukoli, Honokahau ditch sections and six stilling earthen basins. | 175,000 |
| 3 | Replace leaking semi-circular shaped steel flume sections in flume crossing at “B-1” gulch. | 36,000 |
| 4 | Inspect for root intrusion along tunnel sections and initiate periodic root removal program. | 10,000 |
| 5 | Repaint exterior of pipe siphons in Honolua section and conduct interior inspection of pipe siphon to check condition of lining. | 150,000 |
| | Subtotal | $ 621,000 |
| | Design Engineering (15%) | 93,000 |
| | Environmental Permitting & Clearance* | 100,000 |
| | TOTAL MAINTENANCE COST | $ 814,000 |

*Estimate based on degree of environmental sensitivity.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. Due to the uncertainty facing MLP/PMIS’ future, rehabilitation projects which protect the integrity of the system's function is of major importance.

2. As this system does not have a well organized O&M staff, any rehabilitation project that will keep maintenance at a minimum is desirable.

3. This system is critical for maintaining the greenery backdrop on the slopes above the Lahaina-Kapalua visitor destination area, and rehabilitation projects that contribute toward that objective should be given priority.

## FIVE-YEAR PROGRAM – MLP/PMIS

CAPITAL IMPROVEMENT PROJECTS
(MLP/PMIS)

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | New Reservoir | ▪ acquire rights-of-way or easements | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | |
| 2 | Wahikuli Reservoir | ▪ acquire rights-of-way or easements | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Pump “M” (Maui-type shaft) | ▪ acquire rights-of-way or easements | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction |
| 4 | Pump “K” (booster) | ▪ acquire rights-of-way or easements | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction |
| 5 | Honokohau Intake | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction | |
| 6 | Reservoir 140 | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | |
| 7 | Install open ditch lining (gunite) | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 8 | Construct 4-6 cross drainages | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 9 | Construct reservoirs at 14 existing stilling basins | | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 10 | Replace Wahikuli Ditch with pipelines, etc. | | | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction |
| 11 | Renovate Mahinahina Weir | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction | | |

MAINTENANCE PROJECTS
(MLP/PMIS)

| No. | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Repair tunnel face cavein, etc. | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 2 | Remove silt and sedimentation, etc. | ▪ acquire rights-of-way or easements<br>▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Replace leaking semi-circular steel flume, etc. | ▪ acquire rights-of-way or easements | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction |
| 4 | Inspect for root intrusion, etc. | ▪ acquire rights-of-way or easements | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | |
| 5 | Repaint exterior of pipe siphons, etc. | ▪ acquire rights-of-way or easements | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |

*See “Maintenance Cost” in Estimated Costs section of this chapter for a detailed description of work.

## LONG-RANGE MANAGEMENT PLAN

The MLP/PMIS facilities ownership is divided among many different land owners, which is a major concern for the continuity of the ditch's existence, especially the lower or downstream section (between Mahinahina Weir and Wahikuli Reservoir). The upstream section (between the intakes and Mahinahina Weir) is owned and operated by Maui Land and Pineapple Co. and management is not an issue as it is well maintained. Maui Land & Pineapple Co. has expressed no desire to manage the downstream section at this time.

Presently there is no concerted effort to organize a cooperative among those presently using the system. The system is now managed on an interim basis by the surviving firm of bankrupt Amfac/JMB Hawaii. Much of the system's maintenance work is being deferred until firm commitments are developed by the involved land owners.

The continuation of agricultural use of lands in the region is vital to maintaining the greenery backdrop once provided by sugarcane and to preventing pollution of offshore waters. The current water users are not motivated because the sense of urgency is not yet apparent to them. The initial effort to educate and organize an agricultural water system entity should be taken by the largest land owner, DLNR, which has organizational authority under Chapter 174, HRS, or by the HDOA under Chapter 167, HRS, which provides for the establishment and management of water development projects that have public purpose and public benefit.

The MLP/PMIS has multiple-use potential; namely, hydropower generation (the system formerly supported two small hydropower plants), ground water recharge, flood prevention, and recycling treated sewage effluent. However, the major use would still be agriculture and this region could be the test site for selected import replacement. With the region limited to a single highway, limiting the conveyance of goods and services into the area, locally grown diversified agricultural commodities such as eggs, poultry, grass-fed livestock, fresh produce and fruits could offset "imported" items. There needs to be a coordinated effort to bring together farmers and bulk consumer groups (hotels and restaurants) to coordinate supply and demand scheduling, and identifying potential for locally grown agricultural commodities. The long-range management plan should focus on the potential for diversified agricultural farming in the area, rather than on the management of the irrigation system, which will be only a small part of the overall objective of diversified farming for the area. As with the Kokee Ditch Irrigation System, an adhoc committee composed of all existing and potential users of the ditch system should be organized to develop the long-range management plan of the MLP/PMIS.

# Chapter 8.  WAIAHOLE DITCH IRRIGATION SYSTEM

## INVENTORY

The Waiahole Ditch Irrigation System (WDIS), started in 1913 by the Waiahole Water Co., developed both surface water and high-level groundwater sources in the eastern (windward) valleys of Oahu for sugarcane irrigation in the leeward part of the island. The system began at the Kahana Intake (790 ft elevation) in Kahana Valley. From Kahana, the system continued south along the windward cliffs and intercepted in succession (via tunnels and intakes) the headwaters of Waikane and Waiahole Valleys. At Waiahole Valley, the system headed west through the Koolau Mountains via a 7 ft x 7 ft, 2.7-mile long trans-Koolau tunnel to its terminus (Reservoir 155) at Honouliuli, a distance of 22 miles (Map 5). The Waiahole Ditch Irrigation System consisted primarily of tunnels from source to central Oahu (25 tunnels connecting the windward sources, the trans-Koolau Tunnel, followed by 13 transmission tunnels in central Oahu). From central Oahu to Reservoir 155, water was conveyed in concrete-lined ditches and across gulches by inverted siphons.

Beginning in 1925, six high-level groundwater development tunnels were constructed over several years with headings directed into the Koolau Mountain (transverse to connecting tunnels). Only four were productive with Uwau and Waikane I Tunnels being the most productive.

## EXISTING CONDITIONS

In 1970, the Waiahole Water Company, established in 1913, changed its name to Waiahole Irrigation Company, and later became a wholly-owned subsidiary of Amfac/JMB Hawaii, which also owned Oahu Sugar Company. In 1994, Oahu Sugar Company, which used the bulk of WDIS water, closed its plantation operations. In 1999, the WDIS was purchased by the State of Hawaii and is now managed by the HDOA’s Agribusiness Development Corporation, a State agency governed by an appointed board.

The WDIS currently (2003) is a 22-mile long system of tunnels, ditches, and inverted siphons that takes high-level ground water from four windward development tunnels (Kahana, Waikane I and II, and Uwau) and conveys it to the farm areas in central and leeward Oahu. All of the system's 37 stream intakes have been abandoned, but the four groundwater development tunnels have remained unchanged. The system's approximately 15 miles of tunnels (4 development tunnels, 27 windward connecting tunnels, the trans-Koolau tunnel, and 13 tunnels (3.5 miles) extending from the trans-Koolau tunnel to central Oahu) are all in good condition and have never experienced a major cave-in or blockage. From the last tunnel, WDIS water is carried in cement-lined ditches and siphons to Reservoirs 225 and 155.

There are seven inverted siphons (four metal and three wooden) that move Waiahole water across major gulches. Three are located east and four west of Mililani and they total approximately 7,300 ft in length with the longest being 2,034 ft. All of the siphons are supported above ground on concrete cradles. The three wooden siphons, constructed of 4-inch thick redwood staves to form a 60-inch diameter pipe, were recently replaced with a 36-inch HDPE pipe by the HDOA. The four 72-inch diameter steel siphons (Siphons A, B, C, and D), constructed of riveted 5/8-inch thick steel plates with concrete lining, have been in service for 90 years and show signs of external corrosion of varying degree, especially the rivets. The interior conditions of the steel siphons are unknown.

Reservoir 225 (10 MG) and terminal Reservoir 155 (15 MG) are old, unlined earthen reservoirs which are subject to seepage losses and have diminished storage capacity from years of siltation.

Besides the replacement of the three wooden siphons, other recent improvements to the system include a new HDPE-lined 3-MG reservoir and associated pump station to serve Del Monte pineapple fields. On the windward side of the island in Waikane Valley, two release points were installed to meet the State Water Commission's *Decision and Order* to restore windward streams.

The WDIS now has an average daily flow of 28 mgd, although its transmission capacity is 100 mgd.

## ASSESSMENT OF NEEDS

The windward section of the system includes only tunnels: the high-level groundwater development tunnels and connecting transmission tunnels. Access into the transmission tunnels is restricted by a limited number of small openings and a single lane, partially improved access road. Consequently, it is difficult to maintain the windward section of the system.

The Kahana development tunnel, which was bulkheaded about a decade ago by the DLNR in an attempt to restore natural groundwater storage, has the potential of increasing tunnel flow during low-flow periods by releasing high-level ground water stored up during high-flow periods in volcanic dike compartments behind the bulkhead (Figure 1). Further testing is needed to evaluate available storage.

The trans-Koolau tunnel section is in good condition with no reported problems. However, the only means of access through the tunnel is by inflatable raft which has been hampered by lowered water levels due to reduced allocation of windward water.

The open ditch sections (through central and leeward Oahu) that were inspected were in good condition with a few exceptions such as: (1) the roots of trees growing along the ditches have intruded and damaged the side walls, (2) the thin cement lining on the side walls have buckled, cracked, and crumbled, exposing the underlying soil to erosion, and (3) surface runoff from surrounding farm lands have caused heavy siltation and consequent heavy exotic aquatic plant (Amaju) growth along the ditch bottoms, impeding flow.

As the WDIS traverses central and leeward Oahu to its terminus at Reservoir 155 in the Kunia farm area, water is carried across seven moderate to deep gulches via inverted siphons.

Four siphons, consisting of 72-inch diameter pipes constructed of riveted steel panels, cross deep gulches on concrete cradle supports and are badly corroded. Exterior surfaces of the siphons need painting with a protective coating, as most are badly rusted with most, if not all, of the protective coatings gone. One of the concrete cradle supports has been partially undermined by soil erosion (further inspection should be conducted to determine the extent of corrective action needed) and at another, a minor water leak was also observed. Inspection of the siphons’ cement lining by a remote-controlled video camera is recommended.

Earthen Reservoirs 225 and 155 have reduced storage capacities due to buildup of sediments and should be cleaned out. Also, lining the reservoirs with HDPE is recommended to eliminate seepage losses. The embankments of both reservoirs are lined with cut stones which need to be re-grouted. The installation of debris catchers and sediment traps at the reservoir inlets are also recommended to prevent debris from entering and silting the reservoirs. Ramps for equipment access into the reservoirs should also be provided.

Ditch water loss, observed during inspection, occurs in the Garst Seed Co.'s 1,300 ft long supply ditch that connects to the WDIS. The unlined supply ditch, approximately 3 ft deep and 10 ft wide, runs parallel to the Waiahole Ditch before entering their reservoir. Although in relatively good condition, this supply ditch should be replaced with a short lateral directly from the main ditch to the Garst Reservoir to eliminate seepage and evaporation losses.

Portions of the Waiahole Ditch and the reservoirs are on private lands. Therefore, before any improvements are made, easements should be obtained.

All of the ditches are concrete-lined, in relatively good condition, and accessible by vehicle for most of their 10-mile length. Besides water for agriculture, the WDIS provides nonpotable water to the Mililani cemetery, the State's Waiawa prison and farm, and the Mililani golf course. The ditch traverses a heavily urbanized area (Mililani), where problems with urban trash (cans, bottles, small appliances, plastic toys, etc.) and storm runoff debris and sediments cause flow restrictions and blockages.

HDOA's Agribusiness Development Corp. operates and maintains the WDIS with operating and maintenance costs, partially offset by water use revenues. Increasing water rates would be counter-productive because existing water users are having a difficult time with existing rates.

## PROPOSED CAPITAL IMPROVEMENTS

The Waiahole Ditch Irrigation System is the most established of the systems studied relative to water usage and the means by which delivery and connections are provided. Water users have easy access to water supplies with hookups at their property. The system is well organized and operated by State employees with adequate operational support through water sales revenues. The system's water is limited and strictly regulated due to a contested case ruling by the State Commission on Water Resource Management. The opportunity for expansion of agricultural activity is therefore severely restricted, and must be maximized by improving the system's efficiency to ensure water storage and delivery is achieved with minimal water loss. This is reflected in the needed improvements listed below. This system has the best potential for recycling treated effluent and groundwater recharge. The rehabilitation cost estimates include engineering design and environmental permitting and clearance.

1. Rehabilitate four steel inverted siphons (A, B, C, and D). The siphons are important to the part of the system's transmission of water across central Oahu to the farm lands in Kunia. The 72-inch steel siphons are 90 years old and constructed of riveted steel plates, which typically show exterior rusting and corrosion. The interior concrete lining was not inspected, but a wet, leaking section was noted. The exterior of the siphons need to be restored with paint and a protective coating and HDPE pipe needs to be installed inside the steel siphons.

2. Rehabilitate Reservoirs 155 and 225. The reservoirs are partially silted and the cut stone linings on the embankments are partially damaged. Remove sediments and debris, restore cut stone linings and install HDPE lining to minimize seepage losses. Also, install sediment traps and debris screens at the reservoir inlet.

3. Replace Garst Seed Co. Supply Ditch. Replace and abandon 1,300 ft long, 10 ft wide unlined supply ditch to Garst Seed Company Reservoir with a new lined ditch lateral (with parshall flume) directly from the Waiahole ditch to Garst's reservoir, in order to eliminate evaporation and suspected water losses and provide measured water use.

4. Construct two to three new lined reservoirs located on the leeward side of the WDIS to increase system's storage capacity.

## PROPOSED MAINTENANCE IMPROVEMENTS

The system's ability to meet leeward Oahu's irrigation water requirements with dry weather flows has been legally curtailed. Consequently, for system expansion, construction of additional storage capacity will be necessary in order to store excess flows during heavy rain periods.

There is a need to locate ditch water losses or other system leakages and seepages to preserve limited allocations. The improvements needed to meet the above-mentioned concerns include:

1. Survey entire open ditch section. Locate and repair damaged ditch bank linings. Pave or line ditch inverts to stop leakage and prevent aquatic plant "Amaju" growth.

2. Prevent overbank rain runoff and debris from entering open ditches by directing such flows into stilling ponds.

3. Renovate the Kahana bulkhead to control release of stored high-level water during low-flow periods.

4. Use evaporation abatement measures over open ditches and through urbanized section. Consider eliminating selected sections of leeward open ditches with piping, especially near the system terminus.

## ESTIMATED COSTS

Estimated costs consist of two types: *Rehabilitation costs,* related to capital improvement projects and *maintenance costs*, related to ordinary operations and maintenance work. Capital improvement projects (CIP), as used in this report, are those which add or improve the value of a system. On the other hand, maintenance costs are for work required for efficient operation of a system on a day-to-day basis.

The table below lists the CIP proposed for the WDIS and their total rehabilitation cost. Capital improvement projects require design engineering, a licensed contractor; and other costs. The total cost is defined as the rehabilitation cost.

CAPITAL IMPROVEMENT COSTS
(WDIS)

| No. | Item | Needed Improvements | Construction Cost |
|---|---|---|---|
| 1 | Reservoir 155 | • Remove sediment<br>• Install lining<br>• Repair cut stone wall<br>• Repair overflow channel<br>• Construct sediment trap and floating debris screen at inlet<br>• Remove trees along embankment<br>• General site grading | $ 566,000 |
| 2 | Reservoir 225 | • Remove sediment<br>• Install lining<br>• Replace cut stone wall<br>• Construct sediment trap and floating debris screen at inlet<br>• General site grading | 898,000 |
| 3 | Garst Seed Co. Supply Earthen Ditch | • Seal off earthen ditch connection<br>• Reservoir lateral<br>• Backfill earthen ditch | 21,000 |
| 4 | Siphon A | • Slip line with HDPE pipe<br>• Bypass<br>• Headwork modification | 1,054,000 |
| 5 | Siphon B | • See Siphon A | 247,000 |
| 6 | Siphon C | • See Siphon A | 1,538,000 |
| 7 | Siphon D | • See Siphon A | 753,000 |
| 8 | Reservoir | • Construct 2 to 3 lined reservoirs | 600,000 |
| | | SUBTOTAL | $ 5,677,000 |
| | | Overhead (15%) | 852,000 |
| | | Contingency (8%) | 454,000 |
| | | Profit (10%) | 568,000 |
| | | State general excise tax (4.1667%) | 236,000 |
| | | CONSTRUCTION COST | $ 7,787,000 |
| | | Construction mgmt. (20%) | 1,557,000 |
| | | Contract admin. (10%) | 779,000 |
| | | Environmental permitting & clearances* | 50,000 |
| | | Design engineering (7%) | 545,000 |
| | | **TOTAL REHABILITATION COST** | $10,668,000 |

*Estimate based on degree of environmental sensitivity.

The table below lists the maintenance projects proposed for the WDIS and breakdown of maintenance costs required with estimated repair costs. The work can be considered fairly simple to be installed by maintenance crew as part of their routine work schedule.

MAINTENANCE COSTS
(WDIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Inspect and repair damaged ditch sidebanks along entire leeward section from Mililani cemetery to Reservoir 155, pave open ditch inverts and remove aquatic plant growth | $ 250,000 |
| 2 | Install bank diversion bypass swales of storm flows at open field sites with debris removal basins | 55,000 |
| 3 | Reactivate and renovate existing Kahana bulkhead | 50,000 |
| 4 | Conduct study to eliminate evaporation from open ditches and install piping at high losses section of open ditch and through urbanized section of Mililani and Kunai | 150,000 |
| | Subtotal | $ 505,000 |
| | Design Engineering (15%) | 76,000 |
| | Environmental Permitting & Clearance* | 100,000 |
| | TOTAL MAINTENANCE COST | $ 681,000 |

*Estimate based on degree of environmental sensitivity.

***Annual Maintenance Costs.*** This system is now composed of a five-man field crew and office staff. They are administratively attached to the HDOA's Agribusiness Development Corporation (ADC). The Board of Directors sets policy and regulates water rates, but the system is managed by the Executive Director of the Corporation. Latest annual maintenance expenditures (FY 2002-2003) show the budget to be $250,000.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. Because the WDIS traverses an urban area, rehabilitation projects that reduce the system's exposure to urban activity should have priority.

2. Those rehabilitation projects that require modest funding and can more readily be installed should be given preference.

3. Preventing and minimizing system water losses is very critical for the WDIS due to mandates limiting water use. Consequently, rehabilitation projects aimed at reducing or preventing losses should have higher priority.

**FIVE-YEAR PROGRAM - WDIS**

CAPITAL IMPROVEMENTS PROJECTS
(WDIS)

| No | Projects | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Reservoi 155 | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | |
| 2 | Reservoir 225 | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction |
| 3 | Garst Seed Co. Supply Earthen Ditch | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 4 | Siphon A | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction | |
| 5 | Siphon B | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction | |
| 6 | Siphon C | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 7 | Siphon D | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 8 | Construct 2 to 3 new lined reservoirs | ▪ acquire rights-of-way or easements | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | |

MAINTENANCE PROJECTS
(WDIS)

| No. | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Inspect and repair damaged ditch, side banks | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | |
| 2 | Install bank diversion bypass, swales | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | | | |
| 3 | Reactivate and renovate Kahana bulkhead | ▪ acquire rights-of-way or easements | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances<br>▪ award design & constr. contract<br>▪ begin construction | | |
| 4 | Conduct study to eliminate evaporation, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances<br>▪ award design & constr. contract | ▪ begin construction | | | |

*See “Maintenance Cost” in Estimated Costs section of this chapter for a detailed description of work.

## LONG-RANGE MANAGEMENT PLAN

The rulings of the State Supreme Court in the Waiahole contested case have placed a precedent-setting water use limitation on the WDIS. The future expansion of the system will not be possible without greater awareness of the benefits of Hawaii's diversified agriculture industry to the State's well being and its need for agricultural water systems. The status quo of the agricultural use and the availability of Waiahole water during drought or low rainfall periods are severely restricted by the water allocations set by the CWRM.

Although the entire WDIS is neither fully owned nor fully encumbered by the State, the ADC can continue to use and provide the necessary management of the system under a memorandum of agreement with other land owners. The current situation of fully funding operations and maintenance of the system through the use of irrigation revenue collected from water users should remain.

This system will need further upgrades such as additional storage reservoirs and other projects to eliminate water losses from the open ditches, because the water allocations do not take into account the water demand of crops during droughts and natural disasters. Such needed capital improvement projects should be funded from a source other than irrigation revenues. Otherwise, water rates would have to be increased, making it uneconomical for farming. A possible alternative would be issuance of special revenue bonds authorized by the Legislature. The ADC has the ability to issue state bonds, which could be used for this purpose, and it should continue as the system's manager for the long term.

# Chapter 9. LOWER HAMAKUA DITCH IRRIGATION SYSTEM

## INTRODUCTION

This State-owned irrigation system was assessed as part of this study and is fully operational. Because it is an active State-operated system fully funded by HDOA, no inventories of the systems were conducted. The system is managed by the HDOA under authority of Chapter 167, HRS. The system is operated by an irrigation manager and two irrigation system service workers employed by the HDOA. Administrative support is provided by the Department which is governed by the Hawaii Board of Agriculture (HBOA). The HBOA sets policy, approves rules and regulations, and is authorized to establish and enforce water rates. The HBOA is authorized to budget, expend, and contract for capital improvement projects as needed. Operation and maintenance costs of the systems are provided by water use revenues and supplemented with HDOA operating funds; however, capital improvements are financed with State bonds.

## EXISTING CONDITIONS

The Lower Hamakua Ditch Irrigation System (LHDIS) was taken over by the HDOA as a result of the closure of Hamakua Sugar Company. The HDOA has a long-term lease with the land owners. Under the HDOA, the LHDIS is being converted from large-scale sugarcane irrigation to small scale diversified crop farming operations. Without an organized cooperative to manage the system, the HDOA entered into a partnership with the USDA Natural Resources Conservation Service (NRCS) and the Hamakua Soil & Water Conservation District to plan system improvements to meet the needs of new small-scale farming operations. Under Public Law 83-566, Watershed Protection and Flood Prevention Act, two studies were undertaken—the first consisted of a crop suitability analysis and the second prepared a watershed plan. These two reports formed the basis for needed improvements to the system. Funding was provided by the HDOA Capital Improvements Program and construction began in 2000. Construction of the Watershed Plan improvements is being carried out incrementally. Presently, the second of four phases is underway. The watershed plan of improvements is estimated to cost $10,592,000 (1997).

The LHDIS (Map 6) originally diverted the headwaters of four streams in Waipio Valley at the 1,000-ft elevation. The system starts at the Kawainui Intake, followed by the Alakahi and Koiawe Intakes. The Waima Intake, currently inactive, is expected to be reactivated. The collection system is gravity fed through a series of transmission tunnels excavated behind the Waipio Valley cliff face. The tunnels are unlined and carved in basalt lava flows. A tunnel section, located close to the cliff, collapsed a decade ago from an overhead landslide, but has now been replaced with a bypass tunnel.

During plantation days, the distribution of water began at the Kukuihaele Weir where the cliff tunnels end and the ditch system begins. The plantation installed service laterals along the entire length of the gravity flow system that extended approximately 14 miles from Kukuihaele to the terminus, Paauilo Reservoir. Most of these service laterals, which consist entirely of buried pipelines, are still being located by the HDOA. Currently, the system is not fully metered.

There are five reservoirs scattered along the ditch system (Honokaia, Haina, Paauhau, Nobriga, and Paauilo), but two are currently (2003) inactive. In addition, several small ponds serve as fore bays for the service laterals. Due to the length of the system (14 miles) a future requirement would be the construction of additional reservoirs at key locations to increase system storage capacity. The existing reservoirs should be lined and their storage capacity evaluated to meet the needs of new diversified agriculture activity.

Currently, only limited farming activity is taking place along the ditch system as the community is still adjusting to the closure of the Hamakua Sugar Company plantation in 1993. New agricultural activity in the area is still in its infancy due to the State's poor economy, the lack of start-up capital for farming ventures, and the difficulty of farmers to obtain loans or financing without having long-term leases on their farm lands.

## ASSESSMENT OF NEEDS AND PROPOSED IMPROVEMENTS

The following is an assessment of proposed improvements for the LHDIS which was taken from the Lower Hamakua Ditch Watershed Plan prepared in September 1999 by the USDA Natural Resources Conservation Service under the Watershed and Flood

Prevention Act, Public Law 83-566. The Watershed Plan has been approved and accepted by the local project sponsors: HDOA and by the respective local Soil & Water Conservation District in which region the project is located.

***Flume Replacement and Repair.*** The elements of the LHDIS that pose the greatest threat of failure are the flumes and support structures. An examination of the 50 flumes between the Main Weir and Paauilo Reservoir indicated that 24 wooden flumes still exist. The wooden flumes are typically constructed of two-inch thick redwood and their support structures are constructed of four inch by four inch and larger redwood. All of the wooden flumes are in need of repair due to dry rot. Emergency repairs to the flumes have been made using plywood and treated Douglas Fir or similar lumber which has proven to be inferior to the original redwood.

***Ditch Lining Repair and Sediment Removal.*** The severely damaged concrete-lined open ditch sections need to be repaired. While cracking of the lining is extensive, only those sections with broken and missing lining, upheaval, intrusion of roots, significant leakage, or open to sediment sources will be repaired. It is estimated that ten percent of the channel lining needs to be repaired. Removal of sediment from the open ditch sections is needed. Sediment in flumes and tunnels will not be removed unless site is accessible. The deposited sediment depth is estimated to average one foot throughout the system.

***Reservoirs***. Storage of water during nighttime periods will be necessary due to the difficulty in controlling diversion rates during daylight. In short, during the peak demand periods when 14 million gallons per day is needed by farmers and other users, it is expected that most of the demands will take place during the 8 to 12-hour work day. Storage, equivalent to the volume of 12 to 16 hours of ditch flow, will be required if all-day irrigation cycles are to be avoided. At a minimum, 10 MG of storage volume is needed. Additional storage capacity will be needed if a shutdown of the LHDIS for more than a day is needed.

Presently, the four reservoirs of the LHDIS have a combined storage capacity of 31 MG. However, the poor location of the reservoirs on the Paauilo (east) end of the service area leaves much of the project area without water-leveling or storage capability. On the other hand, the farmlots at Honokaia on the west end of the system is a rapidly developing agricultural area without adequate reservoir capacity.

The four existing reservoirs will be used by the LHDIS. A new one-MG reservoir will be installed at Honokaia to serve the new farms. The Paauilo Reservoir will be lined to eliminate seepage losses. Water users will be encouraged to develop reservoir capacity on their farms to ensure adequate water when it is needed.

***Lateral Pipeline Systems.*** Approximately ten lateral distribution systems will be repaired or installed. Many of the lateral systems will incorporate existing pipelines and appurtenances installed during sugarcane cultivation. Sediment ponds and screen filters will be used at each lateral system.

Sixteen lateral systems from the main ditch were used by Hamakua Sugar Co. to irrigate their cane fields. The lateral systems with their filters and screens are still in existence.

***Screening and Filtration.*** A screen filter box or other filtration is needed at each inlet to a lateral system to prevent damaging sediment and floating debris from entering the lateral pipeline system. Some farmers using fine orifice drip systems may need to provide additional filtration on their farms.

***Pipeline Systems and Pressure Regulation.*** Each irrigation subarea will eventually be served by one or more lateral distribution systems which provide water to farmers and ranchers from the LHDIS or one of its reservoirs. Most of the lateral pipeline systems that are currently being used require repair or replacement of components to avoid chronic breakdowns and excessive maintenance. New lateral systems for four subareas will be needed in the short-term future, but other subareas will require more time to be developed and the needed irrigation lateral systems will be installed at a later time. Re-activation of some of the unused lateral systems will also be undertaken.

***Water Meters.*** Water meters will be provided by the LHDIS at the parcel boundary for water users connected to the lateral system and at the ditch takeoff for water users connected directly to the open ditch.

***Intakes.*** Three of the four existing intakes on Waipio Valley streams—Kawainui, Alakahi, and Koiawe—will be reconstructed. The reconstructed intakes will be configured and/or controlled to limit the amount of water diverted to the amount of water demand plus a fraction for seepage, evaporation, and other system losses. System losses are roughly estimated at 3 mgd after the improvements to the system are completed.

The Kawainui Stream diversion will provide operational control over diversion rates for the LHDIS. The Kawainui Stream concrete dam structure will be repaired to fill the structurally threatening void that has developed under the concrete apron. The inlet box will be reconstructed to use a commercially available grating that is angled to be self cleaning. The sand trap will be repaired and fitted with a powered gate that is capable of remote control. The dump gate on the concrete flume will be replaced with a remotely controlled powered gate to control flow in excess of the Hamakua area agricultural water need back into Kawainui Stream.

The intakes at Alakahi and Koiawe Streams will be repaired and reconstructed. Remedial work on access path blockage will also be conducted at each intake to provide adequate visitation access.

***Hakalaoa Falls.*** The construction of a bypass transmission tunnel behind Hakalaoa Falls has been completed and is mentioned for completeness only

***SCADA.*** A Supervisory Control and Data Acquisition (SCADA) system is needed to allow remote data collection and operation of key components of the LHDIS. The data collected by the SCADA system include: flows at the stream diversions, flows at the Main Weir, flows at the lateral systems, storage levels at the reservoirs, and overflow at dump gates. The components that will be controlled by the SCADA system will include the variable diversion gate and sand trap gate at the Kawainui Stream Intake, the dump gate at the Main weir, inlets to the reservoirs, and main gates on the lateral pipeline systems. The use of SCADA to monitor diversion rates at Alakahi and Koiawe Streams will also be considered to comply with the CWRM requirement for water measurement in the system.

The SCADA controls located along the open ditch (for valve actuation and remote terminal unit function) will be connected to the HELCO power supply. Monitoring stations will mainly use solar array and battery unless HECO electrical power is readily available.

The power requirement at the remote Kawainui Stream diversion structure to operate the variable diversion gate, sandtrap gate, flow monitoring gage, and Remote Terminal Unit will be provided by a combination of solar array, and/or micro-hydropower generator and storage batteries. Lack of sufficient sunlight and the variability of stream flows may require both forms of electrical power generation to keep the batteries charged.

A remote relay station will be required for the Kawainui RTU, which does not have line-of-sight access to the Hamakua area. A possible site for the relay station is on the Waipio Valley rim on the ridge between Koiawe and Waima Streams, near the Upper Hamakua Ditch. The site lies within the Conservation District and will be powered by a solar array.

The use of SCADA controls at the Alakahi and Koiawe Intakes was considered, but was not included in the project due to the difficulty of installation and transmission. Manual controls to adjust stream diversion and provide sediment flushing will continue to be used at these intakes.

The Lower Hamakua Ditch Watershed Plan provides for the repair and restoration of LHDIS and effectively addresses the problems of water storage capacity and system reliability. The Plan supports State and County objectives of providing economic opportunities for displaced sugar workers and assisting in the revitalization of the region's economy.

**ESTIMATED COSTS**

CAPITAL IMPROVEMENT COSTS
(LHDIS)

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Land Treatment | Conservation Practices | $1,000,000 |
| 2 | Land Treatment | Technical Assistance | 200,000 |
| 3 | Land Treatment | Waipio Valley Assistance | 100,000 |
| 4 | Ditch | Repair Flume | 1,615,000 |
| 5 | Ditch | Remove Sediment | 191,000 |
| 6 | Ditch | Repair Concrete Lining | 700,000 |
| 7 | Intake | Modify Intakes | 200,000 |
| 8 | System | Install Lateral System | 1,000,000 |
| 9 | Ditch | Install Exclusion Fencing | 170,000 |
| 10 | Intake | Install SCADA System | 500,000 |
| 11 | Waima Intake | Reactivate | 250,000 |
| | | SUBTOTAL | $5,926,000 |
| | | Contingency (20%) | 1,185,000 |
| | | SUBTOTAL CONSTRUCTION COST | $7,111,000 |
| | | Engineering (20%) | 1,422,000 |
| | | Project Admin. (12%) | 853,000 |
| | | Land Rights | 200,000 |
| | | **TOTAL REHABILITATION COST** | $9,586,000 |

Source: Modified after *Lower Hamakua Ditch Watershed Plan and Final EIS, September 1999.*

**Note:** There are no proposed maintenance improvements for the LHDIS, as of this writing.

Presently, the HDOA contracts out the annual maintenance of the system through competitive bidding by qualified firms. Maintenance of the LHDIS will revert back to the HDOA upon completion of the Watershed Project. Administrative and accounting responsibilities are now provided by staff at the main HDOA office. Upon completion of the Watershed Plan, the annual maintenance costs of the LHDIS are estimated in the table below.

ESTIMATED ANNUAL MAINTENANCE COSTS
(LHDIS)

| Item | Units needed | Cost |
|---|---|---|
| PERSONNEL AND FACILITY | | |
| Manager | 1 | $ 75,000 |
| Crew | 3 | 105,000 |
| Clerical | 1 | 25,000 |
| Office and yard | | 30,000 |
| EQUIPMENT (annual cost) | | |
| Pickup Truck | 2 | 8,000 |
| Backhoe | 1 | 10,000 |
| Truck-trailer | 1 | 10,000 |
| Spray truck | 1 | 5,000 |
| Rental | | 10,000 |
| Maintenance and Repair | | 10,000 |
| SUPPLIES | | |
| Herbicide | | 100,000 |
| Office operation | | 8,000 |
| **TOTAL** | | $ 396,000 |

Source: Modified after *Lower Hamakua Ditch Watershed Plan and Final EIS, September 1999.*

## CRITERIA FOR ESTABLISHING PROJECT PRIORITY

The repair, rehabilitation, and/or replacement of components of the LHDIS are to ensure dependable operation of the system. Those components that are in a condition where failure is imminent and can affect the flow in the ditch system will receive highest priority for action. Next priority will be given to components with high rates of water loss. Third priority will be given to elements that will reduce maintenance costs. Special priority will be given to features providing environmental and social benefits, including restoration of the tunnel at Hakalaoa Falls and modification of the Waipio Valley stream diversion structures to partially release stream flow.

**FIVE-YEAR PROGRAM - LHDIS**

SEQUENCE OF INSTALLATION AND SCHEDULE OF OBLIGATIONS (LHDIS)

| Year | Cost Item | Federal & Other Sources |
|---|---|---|
| 1 | **Land Treatment** | |
| | Conservation Practices | $ 250,000 |
| | Accelerated Technical Assistance | 50,000 |
| | Waipio Valley Assistance | 25,000 |
| | **Construction** | |
| | Hakalaoa Falls Tunnel | completed |
| | **Engineering Services** | |
| | Hakalaoa Falls Tunnel | completed |
| | Sediment Removal | 23,000 |
| | Flume Repair | 194,000 |
| | Intakes Modification | 24,000 |
| | Concrete Lining Repair | 84,000 |
| | **Project Administration** | |
| | Hakalaoa Falls Tunnel | completed |
| | **Land Rights** | 200,000 |
| | **TOTAL YEAR 1** | $ 850,000 |
| 2 | **Land Treatment** | |
| | Conservation Practices | $ 250,000 |
| | Accelerated Technical Assistance | 50,000 |
| | Waipio Valley Assistance | 25,000 |
| | **Construction** | |
| | Sediment Removal | 229,000 |
| | Flume Repair | 1,938,000 |
| | Intake Modification | 240,000 |
| | Concrete Lining Repair | 840,000 |
| | **Engineering Services** | |
| | Sediment Removal | 23,000 |
| | Flume Repair | 194,000 |
| | Intake Modification | 24,000 |
| | Concrete Lining Repair | 84,000 |
| | Exclusion Fencing | 20,000 |
| | SCADA | 40,000 |
| | Lateral Systems | 79,000 |
| | **Project Administration** | |
| | Sediment Removal | 28,000 |
| | Flume Repair | 232,000 |
| | Intake Modification | 29,000 |
| | Concrete Lining Repair | 101,000 |
| | **TOTAL YEAR 2** | $ 4,426,000 |

| Year | Cost Item | Federal & Other Sources |
|---|---|---|
| 3 | **Land Treatment** | |
| | Conservation Practices | $250,000 |
| | Accelerated Technical Assistance | 50,000 |
| | Waipio Valley Assistance | 25,000 |
| | **Construction** | |
| | Exclusion Fencing | 204,000 |
| | SCADA | 300,000 |
| | Lateral Systems | 600,000 |
| | **Engineering Services** | |
| | Exclusion Fencing | 20,000 |
| | SCADA | 40,000 |
| | Lateral Systems | 79,000 |
| | Honokaia Reservoir | completed |
| | Paauilo Reservoir Lining | completed |
| | **Project Administration** | |
| | Exclusion Fencing | 25,000 |
| | SCADA | 36,000 |
| | Lateral Systems | 72,000 |
| | **Land Rights** | 200,000 |
| | **TOTAL YEAR 3** | $1,901,000 |
| 4 | **Land Treatment** | |
| | Conservation Practices | $ 250,000 |
| | Accelerated Technical Assistance | 50,000 |
| | Waipio Valley Assistance | 25,000 |
| | **Construction** | |
| | SCADA | 300,000 |
| | Lateral Systems | 600,000 |
| | Honokaia Reservoir | completed |
| | Paauilo Reservoir Lining | completed |
| | **Engineering Services** | |
| | SCADA | 41,000 |
| | Lateral Systems | 82,000 |
| | Honokaia Reservoir | completed |
| | Paauilo Reservoir Lining | completed |
| | **Project Administration** | |
| | SCADA | 36,000 |
| | Lateral Systems | 72,000 |
| | Honokaia Reservoir | completed |
| | Paauilo Reservoir Lining | completed |
| | **TOTAL YEAR 4** | $ 1,456,000 |

Source: Modified after *Lower Hamakua Ditch Watershed Plan and Final EIS, September 1999.*

# Chapter 10. MOLOKAI IRIGATION SYSTEM

## INTRODUCTION

This State-owned irrigation system is assessed as part of this study and is fully operational and because it is an active State-operated system fully funded by HDOA, no inventories of the system was conducted. The Molokai Irrigation System (MIS) is managed by the HDOA under authority of Chapter 167, Hawaii Revised Statutes. The system is operated by an irrigation manager and two irrigation system service workers employed by the HDOA. Administrative support is provided by the Department which is governed by the Hawaii Board of Agriculture (HBOA). The HBOA sets policy, approves rules and regulations, and is authorized to establish and enforce water rates. The HBOA is authorized to budget, expend, and contract for capital improvement projects as needed. Operation and maintenance costs of the systems are provided by water use revenues and supplemented with HDOA operating funds; however, capital improvements are financed with State bonds.

## EXISTING CONDITION

The Molokai Irrigation System's (MIS) sole water source is the Waikolu Valley Watershed. Three intakes divert stream flows at the 1,000 ft elevation into the Molokai Tunnel. And a fourth intake with a pump station at the 800 ft elevation lifts stream flows to the Molokai Tunnel inlet portal (Map 7). Five wells, remotely operated from the office, provide supplemental supply of ground water from the valley, during droughts and low-flow periods. The five-mile long Molokai Tunnel, which conveys water through the mountain by gravity to the central Molokai farms, is the only vehicular access into Waikolu Valley, where diversion works are located in a narrow, V-shaped valley. The intakes become clogged and require frequent maintenance. Electric power for the pumps, controls, etc. is provided by a high voltage line installed on the tunnel roof. This power line is plagued with outages, shorts, and electrical leaks due to high humidity and dampness. Future electrical improvements will be required. The pump and motors also experience frequent problems from short circuits and motor failures. Consequently, adequate access through the tunnel is needed for maintenance.

Water exiting the Molokai Tunnel on the leeward side of the island, is gravity fed through a short length of concrete flume into a 30-inch steel pipeline that extends to the system's terminus, the 1.4 billion gallon Kualapuu Reservoir.

The MIS originally served large-scale pineapple operations, but was converted to serve diversified agriculture after pineapple operations closed in the late 1970s. The system also serves the native Hawaiian homesteads in Hoolehua, a large coffee farm, and a seed corn operation. The intensive diversified farming activity on Molokai which reached a peak during the 1990s has stabilized in recent years, due to the availability of new farming opportunities on the lands left vacant on Oahu and Kauai by sugar plantation closures. Water use at the system has remained constant. The distribution system is composed entirely of gravity-fed pipelines except for a small section of land north of Kualapuu Reservoir where a booster pump and a small steel tank provide sufficient hydraulic pressure.

The system's Waikolu Valley water source has experienced severe droughts over the past few years. Shortage of supply and past water use has kept the system in a conservation mode for the past several years. Additional water sources are needed during droughts and possible sources include brackish water wells and the recycling of sewage effluent. The MIS Water Users Advisory Board has developed potential solutions that need to be implemented. The estimated cost for these improvements is $4,009,000. Another problem for the system is the large size of Kualapuu Reservoir. Its 1.4 billion gallon capacity causes major evaporation losses estimated at 1 mgd. Furthermore, with the low reservoir levels experienced during recent droughts, the bottom 3 to 4 ft of reservoir water (estimated at 7-10 million gallons) are unusable. Preliminary studies conducted by HDOA indicate a mitigating solution by possibly dividing the reservoir into two or more compartments.

The system serves approximately 235 customers with annual water use of 1.224 billion gallons (3.35 mgd) on 3,102 acres. The operation and maintenance of the system is funded from water use revenues and supplemented by HDOA operating funds.

The MIS was planned, designed, and constructed under a special Act of Congress (Reclamation Act of 1954) and the BOR's Small Reclamation Projects Act loan program. The loan has been fully repaid from water revenues.

## ASSESSMENT OF NEEDS

The MIS has experienced severe drought conditions over the past five years. This has depleted the storage reservoir and source supplies of the system. It has been determined that the size of the system's single reservoir is too large because it is difficult to maintain the reservoir water level due to greater losses from evaporation. A study is needed to determine the optimum reservoir size for the system's current operational needs, which has changed since the project was designed.

The system is approaching its project life and needs to begin replacement of its major components. The first is to install a modern up-to-date telemetry system. The present system was based on technology now outmoded. It must schedule the replacement of its moving parts, i.e., gate valves, pumps, electrical wiring, etc.

In order to meet water users' demand, the system must consider the development of additional water sources other than being dependent on its present sole water source in Waikolu Valley.

## PROPOSED CAPITAL IMPROVEMENTS

The HDOA formed an adhoc committee under Chapter 167 to allow water users' input in the development of projects. The committee entitled, "MIS Water Users Advisory Board" assumed the lead in preparing alternatives, accepting input from water users and the public and developing recommendations. The capital improvements discussed below were taken from their report. The purpose of these proposed improvements is to increase water sources to maintain an adequate water level in the 1.4 billion gallon Kualapuu Reservoir.

1. Kawela Stream Diversion. Plans are to capture additional storm flows in Kawela Stream by increasing the height of the dam. Preliminary engineering indicates that a 2 ft high extension of the dam with an 8-inch diameter pipe can divert flows up to 2 mgd. It is estimated that frequent winter storm flows could provide enough additional water supply to justify the estimated construction cost of $4.3 million
2. Activate unused well. There is an existing, unused 12-inch diameter brackish water well located in the upper part of Kaunakakai Gulch which could be activated as a

brackish water source. The salinity of the well water (1300 ppm) is low enough that if mixed with the fresh water in Kualapuu Reservoir it would increase water supply without adversely impacting the utility of the MIS water supply. The well is located approximately 500 to 600 feet from the MIS'main transmission pipeline. The estimated cost to convert the unused well into a production well is estimated at $0.5 million. However, conversion may involve acquisition of the well site by eminent domain and installation of electrical service to the site, in which case the cost escalates to $1.0 million.

3. Waihanau Stream diversion. Renovate the abandoned diversion dam so that only storm flows (not base flows) are diverted into the existing supply pipeline. Storm flows of up to 0.5 mgd would be captured during the winter months, possibly justifying the estimated $1.8 million construction cost.
4. Install a new modern telemetry system to replace the existing antiquated system.

## PROPOSED MAINTENANCE IMPROVEMENTS

1. Convert pumps from electrical to diesel power, except those located in Waikolu Valley. Estimated cost is $0.8 million, however, environmental permitting for diesel fuel storage and handling may increase costs to approximately $1.0 million.
2. Replace mechanical valves, meters, etc., based on an annual schedule of an estimated $100,000 per year for five years.
3. Partition Kualapuu Reservoir (1.4 billion gallons) to an efficient size for current operations.

**ESTIMATED COSTS**

CAPITAL IMPROVEMENT COSTS
(MIS)

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Kawela Stream Diversion | Raise existing diversion dam height two ft. | $ 4,300,000 |
| 2 | Activate Unused Well | Install new well casing.<br>Tap into and extend power line to well site.<br>Install submersible turbine pump & motor.<br>Construct inlet and junction boxes.<br>Install connecting pipeline from well to transmission pipeline. | 1,000,000 |
| 3 | Waihanau Stream Diversion | Renovate Waihanau Stream intake.<br>Construct new inlet box.<br>Install pipeline with junction box to connect onto existing pipeline.<br>Extend pipeline to junction with transmission line. | 1,800,000 |
| 4 | Telemetry System | Install new telemetry system.<br>Connect all system's facility to central control station at office building.<br>Install instruments, computer programs, and appurtenant works.<br>Connect to power sources or install portable power sources. | 750,000 |
| | | SUBTOTAL | $ 7,850,000 |
| | | Overhead (15%) | 1,178,000 |
| | | Contingency (8%) | 628,000 |
| | | Profit (10%) | 785,000 |
| | | State General Excise Tax (4.1667%) | 327,000 |
| | | SUBTOTAL CONSTRUCTION COST | $10,768,000 |
| | | Construction mgmt (20%) | 2,154,000 |
| | | Contract admin. (10%) | 1,077,000 |
| | | Environmental permitting & clearances* | 1,000,000 |
| | | Design engineering (10%) | 1,077,000 |
| | | Easements acquisition | 700,000 |
| | | **TOTAL REHABILITATION COST** | $16,776,000 |

*Estimate based on degree of environmental sensitivity.

MAINTENANCE COSTS
(MIS)

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Remove and dispose of electrical connections and controls.<br>Install new controls, motors, and diesel storage tanks.<br>Convert existing facilities to diesel operation. | $1,000,000 |
| 2 | Locate and test existing valves, meters, etc.<br>Replace those found defective or outdated.<br>Provide replacement inventory of spare parts and materials.<br>Provide testing equipment and maintenance tools. | 100,000 |
| 3 | Construct concrete "curtain" walls inside Kualapuu Reservoir.<br>Construct junction boxes between cells.<br>Reroute inlet pipeline to serve all cells simultaneously. | 1,300,000 |
| | SUBTOTAL | $2,400,000 |
| | Design Engineering (15%) | 360,000 |
| | Environmental Permitting & Clearance* | 250,000 |
| | TOTAL MAINTENANCE COST | $3,010,000 |

*Estimate based on degree of environmental sensitivity.

This system is funded from the revolving special fund within the HDOA's operating budget for the program. The Molokai and Waimea Systems are composed of a three-man field crew, whereas the Waimanalo system is composed of a four-man field crew; the entire accounting and bookkeeping function for the systems are centralized at the main office as is the management of the entire program through the Agricultural Resource Management Division Administrator. The latest actual annual expenditure figures (FY 2001-2002) for this program show the budget to be $1,347,000 which provides operational funding for the program. It is difficult to separate out the maintenance costs for individual systems, at this time, due to time constraints.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. The improvement project that provides the quickest relief for filling the Kualapuu Reservoir should have highest priority.

2. The MIS, with its limited revenue potential, needs to be carefully evaluated with respect to the commitment of funds, since major farming activity has declined.

3. Any rehabilitation project that protects against droughts should have higher priority.

**FIVE-YEAR PROGRAM – MIS**

CAPITAL IMPROVEMENT PROJECTS
(MIS)

| No | Project | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Kawela Stream | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | | ▪ begin construction |
| 2 | Monitor Well | ▪ request approp. | ▪ acquire well site | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract<br>▪ begin construction | |
| 3 | Waihanau Stream | ▪ acquire rights-of-way or easements | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | ▪ begin construction |
| 4 | Install new telemetry system | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |

MAINTENANCE PROJECTS
(MIS)

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Remove and dispose of electrical, etc. | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction |
| 2 | Locate and test existing valves, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Construct concrete, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant<br>▪ obtain environ. permits & clearances | | ▪ award design & constr. contract | | ▪ begin construction |

*See “Maintenance Cost” in Estimated Costs section of this chapter for a detailed description of work.

# Chapter 11. UPCOUNTRY MAUI IRRIGATION SYSTEM

## INTRODUCTION

The Upcountry Maui Irrigation System is currently under development by the HDOA in conjunction with Maui Department of Water Supply (MDWS), the USDA Natural Resources Conservation Services, and the Olinda-Kula Soil and Water Conservation District.

The HBOA will own, construct, and administer the system under Chapter 167, HRS. However under an agreement between the HBOA and the MDWS, MDWS will operate and maintain the system and the HBOA will establish rules and regulations governing the setting, enforcement, collection, and control of water rates for the system.

Administrative support is provided by the Department which is governed by the Hawaii Board of Agriculture (HBOA). The HBOA sets policy, approves rules and regulations, and is authorized to establish and enforce water rates. The HBOA is authorized to budget, expend, and contract for capital improvement projects as needed. Operation and maintenance costs of the systems are provided by water use revenues and supplemented with HDOA operating funds; however, capital improvements are financed with State bonds.

## INVENTORY

The system was started by Maui County in 1912 to serve the water needs of upland region of Olinda and Kula by diverting stream flows from Haipuaena, Puohokamoa, and Waikamoi Streams and their tributaries. It was originally built as a potable water system, but later developed into a dual water system to meet the needs of farms developing along the upcountry Kula region. The stream diversions consisted of inlet boxes located behind low masonry dams and the water was conveyed by pipes and flumes. At Waikamoi, the diverted flows are merged into storage created instream and offstream. These flows were then transmitted via pipeline to reservoirs at Waikamoi, Olinda, Omaopio, Alae, and numerous small capacity tanks located along the distribution pipeline route. At the twin Waikamoi Reservoirs inflows are piped from 6 streams which are located on the western side of the watershed. The total storage capacity was less than 50 MG, which was inadequate during low-rainfall or high-irrigation periods.  The collection system is currently operated and maintained by the Maui Department of Water Supply under agreements between the East Maui Irrigation Co. and the County of Maui.

The transmission portion of the system was improved by increasing the pipe size which allowed greater capacity for distribution, and by constructing new twin 50 MG reservoirs at Kahakapao which alleviated the problem of inadequate storage capacity.  However, current major problems for Kula farmers include:  (1) inadequate distribution capacity, (2) inadequate downstream storage capacity, and (3) the high cost of having to use treated potable water.

The Upcountry Maui Irrigation System when completed, will provide Kula farmers with a source of cheaper untreated surface water by bypassing the treated municipal water supply with a parallel pipeline system.  The use of untreated water by the Upcountry Maui Irrigation System will result in greatly reduced water rates for farmers.  The gravity-fed system, a project authorized under Public Law 83-566,  will tap into the Kahakapao Reservoir located upstream of the County's Olinda Water Treatment Plant (Map 8).  The system will serve farm lands well known for growing world-famous Maui onions, beautiful protea flowers, giant carnations, persimmons, and wine grapes.

Approximately 2 miles of the planned 10-mile long 24-inch pipeline has been installed and the next construction phase is expected to start in summer 2003.

When completed, the Upcountry Maui Irrigation System will serve existing truck crop farms and possibly some large acreage of pineapple.  However, because the surface water sources are susceptible to droughts, additional storage capacity or alternate supplemental sources, i.e., recycled or reuse of water, needs to be studied.  The adequacy of the system's reservoir capacity, especially along its downstream end, also should be further evaluated.

## ASSESSMENT OF NEEDS

The assessment of needs presented below was taken from the Upcountry Maui Watershed Final Plan prepared in 1997 by the USDA Natural Resources Conservation Service under the Watershed and Flood Prevention Act, Public Law 83-566.  The Watershed Plan has been approved and accepted by the local project sponsors, the HDOA and the respective local Soil & Water Conservation District in which region the project is located.

The Watershed Plan has been developed to meet the Federal and Sponsors' objectives of developing viable agricultural industry by providing adequate and consistent agricultural water supply.

The major concern is that the existing system cannot provide adequate supply to meet water demands during low rainfall periods. The system is unable to make optimum use of the water resources available in the region because portions of the collection system, transmission, and storage components are not adequately sized to permit capture, storage, and conservation of storm flows during abundant periods of rainfall. The existing system was built in a piece-meal fashion as both municipal and agricultural water users increased over the years, resulting in the current system.

The existing system utilizes surface water sources; and, therefore, it must conform with the federal Clean Water Act, which increases the cost of providing potable water for municipal users, but unnecessarily so for agricultural users. The system's transmission pipelines are inadequate to meet the irrigation needs of farmers on the downstream end of the system. Also, storage capacity is inadequate to meet peak irrigation demands.

The Watershed Plan meets national and state objectives of developing viable agricultural businesses by providing adequate and reliable water supply for farming use.

## PROPOSED CAPITAL IMPROVEMENTS

The Upcountry Maui Irrigation System will include a total of 49,500 ft or 9.4 miles of distribution pipeline that will be installed from the Olinda Water Treatment Plant to Keokea. The pipeline will begin at the 4,120 ft elevation at the Maui County Water Treatment Plant and drop to the 3,100 ft elevation at its terminus. The ductile iron or high density polyethylene distribution pipeline will vary in diameter from 18 inches to eight inches, as shown in the following table, "Proposed Pipeline." Approximately 12 acres of easements across private parcels will be acquired. The pipeline will be buried along most of its length. Thirteen crossings of gulches are identified. Most crossings will be designed as elevated trestles. This pipeline will be dedicated to nonpotable water use.

An unpaved, 10 ft wide access road will be installed along the distribution pipeline alignment. The access road will join existing gulch crossings located closely, or otherwise will be constructed as grade crossings across dry gulches. Measures will be taken to minimize erosion potential due to the roadway. Upon completion, there will be two separate water systems, both sharing the same water source.

Nine lateral systems for the service areas of Olinda, Kimo Road, Crater Road, Pulehuiki/Kamehameiki, Kealahou, Waiakoa, Kaonoulu, Waiohuli, and DHHL/Keokea will be installed (see following table, “Capital Improvement Costs”). Lateral pipeline lengths will vary from 3,800 ft to 19,850 ft. High density polyethylene pipe sizes will vary from eight inches to two inches in diameter. The pipelines will be buried within the existing road rights-of-way where possible. Approximately 4.8 acres of private land easements will be acquired. Sublateral pipelines will connect the water system to farmer-supplied meters at the farm boundaries.

PROPOSED PIPELINE*
Upcountry Maui Irrigation System, Hawaii

| Pipeline Segment | Nominal Diameter (in.) | Segment Length (ft.) | Flow Cap. (gpm)** |
|---|---|---|---|
| Main Distribution Pipeline | | | |
| 0+00 to 165+00 | 18 | 16,500 | 2,660 |
| 165=00 to 257+00 | 16 | 9,200 | 2,100 |
| 257+00 to 287+00 | 14 | 2,900 | 1,600 |
| 286+00 to 323+00 | 12 | 3,700 | 1,330 |
| 323+00 to 387+00 | 10 | 6,400 | 950 |
| 387+00 to 495+00 | 8 | 10,800 | 610 |
| Olinda Road Lateral | | | |
| 0+00 to 98+00 | 3 | 9,800 | 100 |
| Kimo Road Lateral | | | |
| 0+00 to 198+50 | 8 | 19,850 | 610 |
| Crater Road Lateral | | | |
| 0+00 to 124+00 | 4 | 12,400 | 170 |
| Pulehuiki/Kamehameiki Lateral | | | |
| 0+00 to 86+00 | 3 | 8,600 | 100 |
| Sub Lateral | | | |
| 87+00 to 152+50 | 2 | 6,650 | 50 |
| Kealahou Lateral | | | |
| 0+00 to 86+86+80 | 8 | 8,680 | 610 |
| Waiakoa Lateral | | | |
| 0+00 to 47+00 | 6 | 4,700 | 360 |
| Kaonoulu Lateral | | | |
| 0+00 to 75+00 | 6 | 7,500 | 360 |
| Waiohuli Lateral | | | |
| 0+00 to 32+80 | 4 | 3,280 | 170 |
| Keokea/DHHL Lateral | | | |
| 0+00 to 164+00 | 6 | 16,400 | 360 |

* All pipe is High Density Polyethylene, 160 psi, SDR 11. March 1997
**5 feet per second flow velocity.
Source: Modified after *Final Watershed Plan, Environmental Impact Statement, Upcountry Maui Watershed, March 1997.*

## PROPOSED MAINTENANCE IMPROVEMENTS

The Upcountry Maui Irrigation System is currently under development and no infrastructure has been installed yet, except for 12,000 ft of 36" pipeline (Map 8). No maintenance improvements are contemplated for at least the next four to five years and consequently no cost estimate for maintenance is provided.

An irrigation district will be established under Chapter 167, HRS, to operate the system. The policy, regulations, and water-rate control will be set by the HDOA. However, the County of Maui's Department of Water Supply will maintain the system under a maintenance agreement to be entered into upon completion of all the improvements under the watershed plan.

## ESTIMATED COSTS

This project began construction in 2000 and approximately 12,000 ft. of 36" D.I. pipeline of the main transmission line has already been installed.

CAPITAL IMPROVEMENT COSTS
Upcountry Maui Irrigation System (Revised March 1997)

| No. | Improvement | Total Cost |
|---|---|---|
| 1 | Mobilization | $ 53,000 |
| 2 | Main Pipeline (HDPE) | 2,365,000 |
| 3 | Lateral Pipeline (HDPE) | 1,849,000 |
| 4 | Sublateral Pipeline (HDPE) | 89,000 |
| 5 | Road Crossings | 32,000 |
| 6 | Gulch Crossings | 137,000 |
| 7 | Access Road | 1,274,000 |
| | SUBTOTAL | $ 5,799,000 |
| | Contingency (20%) | 1,160,000 |
| | TOTAL CONSTRUCTION | $ 6,959,000 |
| | Engineering Services (15%) | 1,044,000 |
| | Project Administration (15%) | 1,044,000 |
| | Real Property | 227,000 |
| | TOTAL REHABILITATION COST | $ 9,274,000 |

Source: Modified after *Final Watershed Plan, Environmental Impact Statement, Upcountry Maui Watershed, March 1997.*

## CRITERIA FOR ESTABLISHING PROJECT PRIORITY

Although the priorities have been enumerated and adopted in the watershed plan there is some flexibility to alter the order of installation based on the availability of revenue producing potential. Any improvement that can provide revenue on a timely basis should be given consideration.

## FIVE-YEAR PROGRAM

Attached is a table showing a 3-year installation program with funding. However, funds are subject to availability of legislative appropriations (both State and Federal).

SCHEDULE OF WATERSHED IMPROVEMENTS INSTALLATION*
Upcountry Maui Irrigation System

| Year | Item | Total |
|---|---|---|
| 1 | Main Pipeline | $ 552,000 |
| | Gulch Crossings | 25,000 |
| | Access Road | 115,000 |
| | Total | $ 692,000 |
| 2 | Mobilization | $ 41,000 |
| | Main Pipeline | 3,264,000 |
| | Lateral Pipelines | 383,000 |
| | Sublateral Pipelines | 16,000 |
| | Gulch Crossings | 189,000 |
| | Access Road | 1,377,000 |
| | Paved Road Crossings | 5,000 |
| | Total | $5,275,000 |
| 3 | Demobilization | $ 41,000 |
| | Lateral Pipelines | 2,552,000 |
| | Sublateral Pipelines | 122,000 |
| | Access Road | 497,000 |
| | Paved Road Crossings | 45,000 |
| | Total | $3,257,000 |
| | TOTAL | $9,224,000 |

*Price Base 1996
Source: Modified after *Final Watershed Plan, Environmental Impact Statement, Upcountry Maui Watershed, March 1997*

# Chapter 12. WAIMANALO IRRIGATION SYSTEM

## INTRODUCTION

The Waimanalo Irrigation System, a State-owned and operated system that is fully operational, is included as part of this report. Because the system is an active State-operated system fully funded by HDOA, no inventory of the system was conducted. The system is managed by the HDOA under authority of Chapter 167, Hawaii Revised Statutes. The system is operated by an irrigation manager and two irrigation system service workers employed by the HDOA. Administrative support is provided by the Department which is governed by the Hawaii Board of Agriculture (HBOA). The HBOA sets policy, approves rules and regulations, and is authorized to establish and enforce water rates. The HBOA is authorized to budget, expend, and contract for capital improvement projects as needed. Operation and maintenance costs of the systems are provided by water use revenues and supplemented with HDOA operating funds; however, capital improvements are financed with State bonds.

## EXISTING CONDITIONS

The Waimanalo Irrigation System's water source is located in the Maunawili Valley watershed with intakes located on Maunawili, Ainoni, and Makawao Streams (Map 9). The collection system within the valley is composed mainly of open unlined ditches, pipe siphons, and tunnels which are susceptible to heavy siltation, tree root intrusion, and heavy vegetative growth due to high rainfall (approximately 100 inches a year). Because access to most of the collection system is by four wheel drive vehicles, system maintenance is labor intensive.

The proposed improvements below were taken from the Waimanalo Watershed Final Plan prepared in 1981 by the USDA Natural Resources Conservation Service under the Watershed and Flood Prevention Act, Public Law 83-566. The Watershed Plan has been approved and accepted by the local project sponsors, the HDOA, and the respective local Soil & Water Conservation District in which region the project is located.

The Waimanalo Irrigation System is in fairly good condition and is presently undergoing improvements based on the Waimanalo Watershed Plan, prepared by the USDA NRCS.

The system's gravity-fed ditch flows are transported from Maunawili Valley to Waimanalo Valley through a short unlined tunnel (Aniani Nui Tunnel). A short ditch directs water from the Aniani Nui Tunnel exit into a network of pipelines which connect to the Waimanalo farming community and a 60 MG earthen reservoir lined with HDPE. This new 60 MG reservoir replaces several small reservoirs and serves as the distribution point for the system and was constructed with federal assistance under the watershed project

The original ditch distribution system was recently replaced with ductile iron pipe and water meters, under the watershed project. However, many of the system's distribution laterals are inactive due to family farm closures in which the younger generation does not continue farming. On the other hand, since the Vietnam War, southeastern Asian immigrants with farming backgrounds have taken over many vacated farming operations. Currently (2003), the Waimanalo Irrigation System has 164 accounts with an annual water use of 146,226,964 gallons (0.4 mgd) over 1,170 acres.

The plan will improve agricultural water management through modernizing the antiquated irrigation water delivery system; recycle treated sewage effluent for irrigation; preserve and enhance environmental quality of Waimanalo valley by retaining prime and important farmland in agriculture; protecting and preserving historic value of the ditch; and improve health and aesthetics by providing adequate solid waste collection sites. Also part of the local sponsors' action was to acquire the fee water rights and to upgrade the water collection system in Maunawili Valley.

## PROPOSED CAPITAL IMPROVEMENTS

The Watershed Plan has the objective of accelerating assistance to all system water users. The Plan's improvements include a storage reservoir, 15.7 miles of distribution pipeline, a separate treated sewage effluent lift pump and reservoir, and a transmission pipeline. Accelerated technical assistance would be provided to water users in converting from sprinkler and drip irrigation and in designing cultivation practices to minimize nematode problems. Bananas would be irrigated at 50 percent of the computed water requirement for June to September, and the number of acres irrigated would be maximized.

Water from the Maunawili watershed would be taken from the tunnel outlet at Aniani Nui Ridge and piped to the reservoir near the mauka end of Mahailua Street. The reservoir would be a deep, off-channel, 60 MG excavated structure with an embankment 40 feet high. A gravity-fed pipeline (with some supplementary pumping required) would deliver water from the reservoir to water users. The treated sewage effluent would be pumped from the Waimanalo sewage treatment plant to a storage reservoir at the site of the existing Wing-King Reservoir.

Installation of improvements would provide high quality Waimanalo Irrigation System water under pressure to 1,134 acres, including 79 acres previously irrigated with municipal system water. An additional 68 acres would be supplied with treated sewage effluent. The Waimanalo Agricultural Park will also be provided an irrigation system. As a result, the agricultural productivity and the rural character of Waimanalo Valley could be strengthened. The agricultural use of important Waimanalo farmland will be able to continue, by irrigating with treated sewage effluent. Problems with solid waste disposal may continue to be a problem.

**Note:** At this writing, most of the improvements in the Watershed Plan have been installed with the remaining improvements pending, due to financial constraints.

## PROPOSED MAINTENANCE IMPROVEMENTS

1. Routine replacement of slide gates on reservoir and control structures, pumps and motors, trash/debris racks, valves, vents, pressure relief valves, meters, flow control devices are required at 25-year increments.

2. Routine maintenance of Aniani Nui Tunnel, i.e., remove root intrusion and debris and line tunnel entrances.

3. Abandoned open ditches should be sealed and returned to original condition and subsequently release easement rights to owners.

**ESTIMATED COSTS**

CAPITAL IMPROVEMENT COSTS
Waimanalo Irrigation System

| No. | Item | Improvements | Construction Cost* |
|---|---|---|---|
| 1 | | Land Treatment | $ 616,000 |
| 2 | Maunawili Source | Improve Water Collection System | 500,000 |
| 3 | Reservoir | Install Irrigation Pipeline System | completed |
| 4 | Ditch | Install Irrigation Pipeline System | completed |
| 5 | Ditch | Modify Old Irrigation Ditch | 50,000 |
| 6 | Sewage | Construct Sewage Effluent Pumps, Pipeline System and Storage Reservoir | 410,000 |
| 7 | Waste Mgmt | Install Solid Waste Collection Sites | completed |
| 8 | Reservoirs | Restore three abandoned reservoirs | 750,000 |
| | | SUBTOTAL | $ 2,326,000 |
| | | Overhead (15%) | 349,000 |
| | | Contingency (8%) | 186,000 |
| | | Profit (10%) | 233,000 |
| | | State General Excise Tax (4.1667%) | 97,000 |
| | | SUBTOTAL CONSTRUCTION COST | $ 3,191,000 |
| | | Construction mgmt (20%) | 638,000 |
| | | Contract admin. (10%) | 319,000 |
| | | Environmental permitting & clearances** | 1,000,000 |
| | | Design engineering (10%) | 319,000 |
| | | Easements acquisition | 25,000 |
| | | **TOTAL REHABILITATION COST** | $ 5,492,000 |

* Price base 1981.
**Estimate based on degree of environmental sensitivity.
Source: Modified after *Final Watershed Plan and Environmental Impact Statement, Waimanalo Watershed, December 1981*

The Waimanalo Watershed project began construction in 1992 and several structural measures outlined in the watershed agreement have been installed and are operational. These completed projects include: The 60 MG Waimanalo Reservoir, pipeline connecting Aniani

Nui Tunnel to the reservoir, pipeline (replacing open water distribution ditches), and improvements to limited sections of the Maunawili collection systems.

Due to financial constraints and higher priorities of other more critical watershed projects, construction activity for this project is currently pending. Furthermore, due to community and public concerns raised, some improvements may need to be processed through environmental clearance again.

MAINTENANCE COSTS
Waimanalo Irrigation System

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Replace reservoir gate's control structure, pumps, motors, valves, racks, flow controls, etc., annually | $ 50,000 |
| 2 | Routine maintenance Aniani Nui Tunnel | 100,000 |
| 3 | Distribution ditches now abandoned in service areas returned to original condition and cancel easements | 150,000 |
| | SUBTOTAL | $ 300,000 |
| | Design Engineering (15%) | 45,000 |
| | Environmental Permitting & Clearance* | 1,000,000 |
| | TOTAL MAINTENANCE COST | $ 1,345,000 |

*Estimate based on degree of environmental sensitivity.

The annual maintenance costs of the system are funded from a revolving special fund within the HDOA's operating budget and are not individually earmarked. The Molokai and Waimea systems each has a three-man field crew, whereas the Waimanalo system has a four-man field crew; and the entire accounting and bookkeeping function for the systems are centralized at the main office as is the management of the entire program through the Agricultural Resource Management Division Administrator. The latest actual annual expenditure figures (FY 2001-2002) for this program show the budget to be $1,347,000, which provides operational funding for the program. Due to time constraints, individual maintenance costs were not separated out.

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. For the Waimanalo Irrigation System, most of the watershed improvements have been constructed, but the remaining projects need consideration in order to complete the plan.

2. The capital improvement projects that can result in increasing the revenue stream should have higher priority.

**FIVE-YEAR PROGRAM**

The planned sequence for installing the structural improvements during the first year includes: (1) design and construction of the pipeline from Aniani Nui Ridge Tunnel to the 60 MG storage reservoir, (2) construction of the 60 MG Reservoir, (3) construction of the 1.5 MG sewage effluent reservoir, and (4) initial construction of the delivery systems. Construction during the second year will include construction of the delivery systems and the solid waste disposal sites. Of the above list, only (3) remains.

The planned sequence for installing land treatment would be phased over several years with the first two years concentrating on preparation of those lands now being developed for agricultural use. The conversion from sprinkler to drip irrigation and development of contour furrow irrigation for the sewage effluent will be delayed until the new delivery systems are near completion. This sequence should provide the least disruption of the cropping operations and farm production. The table below presents the five-year planned project installation and funding needed. The schedule is subject to availability of appropriations from the State and Federal governments. This watershed project is in its final stages of installation.

FIVE-YEAR REPAIR PROGRAM
Waimanalo Irrigation System

| Year | Measure | Total Funds |
|---|---|---|
| 1 | Reservoirs & Pipelines | completed |
| | Water Collection System | $ 500,000 |
| | Land Treatment | 160,000 |
| 2 | Complete Reservoirs, Pipelines & Solid Waste Sites | completed |
| | Land Treatment | 160,000 |
| 3 | Contracted Technical Assistance | 20,000 |
| | Land Treatment | 160,000 |
| 4 | Land Treatment | 153,000 |
| | TOTAL | $ 1,153,000 |

Source: Modified after *Final Watershed Plan and Environmental Impact Statement, Waimanalo Watershed, December 1981*

MAINTENANCE PROJECTS
Waimanalo Irrigation System

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Replace reservoir gate's control, etc. | | ▪ conduct prelim. eng. & select consultant ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | | ▪ begin construction | ▪ ongoing |
| 2 | Restore abandoned reservoirs, etc. | | ▪ request approp. ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | | ▪ begin construction |
| 3 | Clean and clear Maunawili, etc. | | ▪ request approp. | | ▪ conduct prelim. eng. & select consultant ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract ▪ begin construction |
| 4 | Reoutine maintenance, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | | ▪ begin construction | | |
| 5 | Distribution ditches now abandoned, etc. | ▪ request approp. ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances ▪ award design & constr. contract | ▪ begin construction | ▪ cancel easements | ▪ return land to owners | |

*See "Maintenance Cost" in Estimated Costs section of this chapter for a detailed description of work.

# Chapter 13.  WAIMEA IRRIGATION SYSTEM

## INTRODUCTION

The Waimea Irrigation is a State-owned (HDOA) system.  Because it is an active, fully operational State-operated system, no inventory of the system was conducted.  The system is managed and fully funded by the HDOA under authority of Chapter 167, Hawaii Revised Statutes.  The system is operated by an irrigation manager and two irrigation system service workers employed by the HDOA.  Administrative support is provided by the HDOA which is governed by the Hawaii Board of Agriculture (HBOA).  The HBOA sets policy, approves rules and regulations, and is authorized to establish and enforce water rates.  The HBOA is authorized to budget, expend, and contract for capital improvement projects as needed. Operation and maintenance costs of the systems are provided by water use revenues and supplemented with HDOA operating funds; however, capital improvements are financed with State bonds.

## EXISTING CONDITIONS

The Waimea Irrigation System serves the farmers in Lalamilo and Puukapu.  The system's water sources are the summit watersheds of Kohala Mountain starting with Kawainui and followed by Kawaiki, Alakahi, and Koiawe Streams (Map 10).  The diverted flows from intakes on these streams are channeled into a series of open ditches and tunnels, called the Upper Hamakua Ditch, which was originally constructed to collect Kohala Mountain water for use along the Hamakua coast.  However, in 1948, the ditch system was returned to the then Territory of Hawaii.  Later, the lower end of the collection system was re-aligned and diverted into a new concrete-lined 60 MG reservoir at Waimea.

The Waimea Reservoir is supplemented by the 100 MG Puu Pulehu Reservoir, recently rehabilitated with HDPE lining by the HDOA.   This is a twin-celled reservoir that collects the excess flows from the Upper Hamakua Ditch for use during drought periods.  The region is prone to droughts lasting 3 to 5 months.  Puu Pulehu Reservoir water can be transferred to the Waimea Reservoir via a booster pump and connecting pipeline.   There is sufficient storage to maintain an average service flow in the system for approximately 100 irrigation days.

The system distributes water from Waimea Reservoir, via pipelines, to serve farm lands up to 6.5 miles away. The distribution system is pressurized and completely metered at each service lateral. Currently (2003), the system has 117 water service accounts drawing 330,847,000 gallons annually (0.906 mgd) on 587 acres. The distribution pipelines vary in size from 6 to 24 inches and passes through several populated areas, impacting maintenance work. The Waimea Irrigation System has been operational since the early 1970s and supports a stable agricultural community and has been continuously improved under the HDOA's capital improvements program.

## ASSESSMENT OF NEEDS

A study conducted several years ago to assess the needs of the system forms the basis for proposed capital improvements by the HDOA (1989). System improvements have also been planned under authority of Public Law 83-566, with an approved watershed plan awaiting appropriations. The planned improvements presented under the project title, "Waimea-Paauilo Watershed Plan," will increase the storage capacity of the system and allow for expansion of water uses. This assessment below was taken from the Watershed Plan prepared by the USDA Natural Resources Conservation Service. The Watershed Plan has been approved and accepted by the local project sponsors: The HDOA and the respective local Soil & Water Conservation District in which region the project is located.

The plan's objectives are to: (1) provide improved water conveyance efficiency of the existing transmission ditch system, (2) add another major storage reservoir for increase capacity, and (3) expand service to provide livestock drinking water by installing new distribution pipelines.

The efficiency of the transmission system will be achieved by eliminating seepage losses along sections of the ditch by installing bypass pipelines. The storage capacity of the entire system needs to be increased by lining existing reservoirs to eliminate water losses through leakages and add one new reservoir. The plan calls for constructing delivery systems for livestock water through a series of new pipelines that will distribute water to remote pasture lands. This will increase domestic water availability in the system and reduce the need to develop new domestic water sources.

The watershed plan was developed to meet both the national objective of increasing the economic value of national output of goods and services and achieving the Sponsors' objective to improve agricultural water management.

The major problem of the Waimea Irrigation System is insufficient agricultural water caused by inadequate collection, storage and distribution facilities. Excessive seepage losses occurring along the existing transmission ditches cause deterioration of the linings, tunnels and flumes.

The system's existing storage capacity is inadequate for meeting irrigation water demand during frequent dry periods and for effective application of water to diversified crops. Furthermore, the region served by the Waimea Irrigation System is the heart of the cattle industry, but the system lacks a supplemental livestock water system for low or drought periods.

## PROPOSED CAPITAL IMPROVEMENTS

The Watershed Plan selected by the Sponsors includes livestock water. It will complement the ongoing land treatment program of the Conservation District and provides improved water conveyance efficiency of the Upper Hamakua Ditch, reservoir storage for irrigation and livestock water, and irrigation and livestock water distribution systems.

Capital improvements proposed in the Watershed Plan include:

1. A 133 MG storage reservoir (Waimea II Reservoir) to supplement the existing two reservoirs,

2. A 30-inch diameter supply pipeline to convey water from the existing Upper Hamakua Ditch collection system to the proposed 133 MG reservoir, and

3. Improvements to the upper reaches of the Ditch system.

The collection system which presently uses sections of natural stream channels will be improved with 8,000 ft of by-pass pipeline segments. Required right-of-way for the by-pass pipeline amounts to 5.5 acres. The 30-inch supply pipeline, most of which is located adjacent to an existing road, will require an additional 1.8 acres for use of the road.

The proposed 133 MG Waimea II Reservoir will be constructed on Department of Hawaiian Home Lands pasture land. A compacted earthfill dam with maximum height of 65 ft and crest length of 1,450 ft is to be constructed using fill material excavated from the reservoir and adjacent area. The reservoir will be lined with high density polyethylene plastic. A geofabric and polyethylene drainage grid under the liner is proposed. The embankment will include a chimney drain and principal and emergency spillways. The reservoir will be filled by the supply pipeline from the Upper Hamakua Ditch. The principal spillway inlet structure is an SCS standard covered riser and the outlet structure is an impact basin. A 30-inch diameter reinforced concrete cylinder pipe is considered to convey flows from inlet to outlet structure. The emergency spillway will be grassed with a reinforced concrete crest control structure. Maximum reservoir storage during passage of this storm is 136.5 MG. Minor clearing of brush and small trees will be required within the 34.7 acres of pasture land for which land rights will be required. A total of two acres clearing is estimated.

The existing Lalamilo irrigation delivery system will be expanded with 21,800 ft of pipeline. Pumps will be installed to supplement gravity pressure as needed during peak demand periods. Approximately 900 ft of 24-inch diameter ductile iron pipe and 20,900 ft of polyvinyl chloride pipe, 14-inch to 4-inch diameter, will be installed. Required right-of-way is 4.8 acres.

A separate livestock water distribution system will be constructed. Total length of the livestock water pipeline is 184,400 ft. Use of high-density polyethylene (HDPE) pipe ranging in diameter from 6-inch to ¾-inch is proposed. Electric and diesel pumps will be used to provide water to elevations beyond the reach of gravity. Storage tanks and ponds will satisfy demand fluctuation and will limit hours of pumping required. This will allow for periods of electrical failure, repairs and other shutdowns. A sequential control system will automate pump operation. Total required right-of-way is 174.1 acres including temporary right-of-way of 84.5 acres. Estimated capital costs are shown in the following table.

## PROPOSED MAINTENANCE IMPROVEMENTS

The Waimea Irrigation System was converted from the remnants of the Upper Hamakua Ditch Irrigation System to serve the Lalamilo Farm Lots in Kamuela. The system is rapidly approaching its project life and should begin replacement of its valves, meters, equipment, and the 60 MG reservoir should be cleared of accumulated sediments. A system assessment conducted in 1986 recommended several improvements (Division of Water & Land Development, DLNR, Report R77). Estimated maintenance costs are shown in the *Maintenance Costs* table.

1. Replace valves, meters, pumps, and other equipment. These should be phased in over a period of several years at $50,000 per year.

2. Convert two existing pumps from electrical to diesel power.

3. Install a new telemetry system to control and monitor water flows within the system.

4. Clean and remove sediment from 60 MG Waimea Reservoir and install automated gauging recorder and weather station.

**ESTIMATED COSTS**

CAPITAL IMPROVEMENT COSTS
Waimea Irrigation System

| No. | Item | Improvements | Construction Cost |
|---|---|---|---|
| 1 | Upper Hamakua Ditch Improvement | UHD By-pass Pipelines | $ 517,000 |
| | | UHD to Waimea II Reservoir Supply Pipeline | 747,000 |
| 2 | Waimea II Reservoir | Construct Lined Reservoir | 6,019,000 |
| 3 | Irrigation Water Distribution System | Lalamilo Addition | 249,000 |
| | | DHHL Additions | 622,000 |
| | | Waimea II to Existing Mainline | 159,000 |
| 4 | Livestock Water Distribution System | Main, Group 2, E, E-1 | 540,000 |
| | | Group 1 | 37,000 |
| | | Group 3 | 318,000 |
| | | Group 5 | 298,000 |
| | | Group 7 | 36,000 |
| | | Group 9 | 107,000 |
| 5 | Pumps | Convert two elect. pumps to diesel | 100,000 |
| 6 | Telemetry System | Install new system to control & monitor flows | 500,000 |
| | SUBTOTAL | | $10,249,000 |
| | Overhead (15%) | | 1,537,000 |
| | Contingency (8%) | | 820,000 |
| | Profit (10%) | | 1,025,000 |
| | State general excise tax (4.1667%) | | 427,000 |
| | SUBTOTAL CONSTRUCTION COST | | $14,058,000 |
| | Construction mgmt (20%) | | 2,812,000 |
| | Contract admin. (10%) | | 1,406,000 |
| | Environmental permitting & clearances* | | 1,000,000 |
| | Design engineering (12%) | | 1,687,000 |
| | **TOTAL REHABILITATION COST** | | $20,963,000 |

*Estimate based on degree of environmental sensitivity. The cost has been revised to reflect additional costs from original NRCS' estimates.

Source: Modified after *Watershed Plan and Environmental Assessment, Waimea-Paauilo Watershed, September 1989*

MAINTENANCE COSTS
Waimea Irrigation System

| No. | Description of Work | Repair Costs |
|---|---|---|
| 1 | Replacement of valves, meters, pumps and other equipment phased in over five years at annual increments | $ 50,000 |
| 2 | Clean and remove sediment from 60 MG Waimea Reservoir and install automated gauging recorder and weather station | 250,000 |
| | SUBTOTAL | $ 300,000 |
| | Design Engineering (15%) | 45,000 |
| | TOTAL MAINTENANCE COST | $ 345,000 |

The operation and maintenance costs of the Waimea Irrigation System are funded from the revolving special fund within the HDOA's operating budget for all of its systems. Individual system expenditures are not available for this report. The system has a four-man field crew and is administered from the main office through the Agricultural Resource Management Division Administrator. The latest annual expenditure figures (FY 2001-2002) for all five HDOA systems was $1,347,000. Upon completion of the watershed plan improvements, the estimated annual additional maintenance costs are as shown in the table below.

ESTIMATED ANNUAL ADDITIONAL MAINTENANCE COST*
Waimea Irrigation System

| Item | Operation & Maintenance |
|---|---|
| Upper Hamakua Ditch Improvement | |
| UHD By-pass Pipelines | $ 4,000 |
| UHD to Waimea II Reservoir Supply Pipeline | 6,000 |
| SUBTOTAL | $ 10,000 |
| Storage | |
| Waimea II Reservoir | $ 24,000 |
| Irrigation Water Distribution System | |
| Lalamilo Addition | $ 9,000 |
| DHHL Additions | 28,000 |
| Waimea II to Existing Mainline | 1,000 |
| SUBTOTAL | $ 38,000 |
| Livestock Water Distribution System | |
| Main, Group 2, E, E-1 | $ 5,000 |
| Group 1 | 1,000 |
| Group 3 | 4,000 |
| Group 5 | 4,000 |
| Group 7 | 1,000 |
| Group 9 | 1,000 |
| SUBTOTAL | $ 16,000 |
| GRAND TOTAL | $ 88,000 |

*Price Base: 1987
Source: Modified after *Watershed Plan and Environmental Assessment, Waimea-Paauilo Watershed, September 1989*

**CRITERIA FOR ESTABLISHING PROJECT PRIORITY**

1. The priority for the capital improvements have been determined and agreed by the parties to the watershed plan.

2. Certain capital improvement projects that deal with providing adequate storage should have higher priority because without the extra storage the effectiveness of the plan's objective will be difficult to implement.

3. Any improvements that will increase revenues from increased water sales, should have higher priority.

**FIVE-YEAR PROGRAM**

The table below shows the schedule of improvements to be installed under the Waimea-Paauilo Watershed Plan, together with funding obligations, and is subject to availability of future legislative appropriations (both State and Federal).

SCHEDULE OF WATERSHED IMPROVEMENTS INSTALLATION

Waimea Irrigation System

| Year | Item | Total |
|---|---|---|
| 1 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | UHD By-Pass Pipelines | $ 40,000 |
| | UHD-Waimea II Res. Sup. PL | 58,000 |
| | Waimea II Reservoir | 60,000 |
| | Project Administration | |
| | UHD By-Pass Pipelines | 3,000 |
| | UHD-Waimea II Res. Sup. PL | 5,000 |
| | Waimea II Reservoir | 7,000 |
| | SUBTOTAL | $ 173,000 |
| 2 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Waimea II Reservoir | $ 60,000 |
| | UHD By-Pass Pipelines | 10,000 |
| | UHD-Waimea II Res. Sup. PL | 10,000 |
| | Project Administration | |
| | UHD By-Pass Pipelines | 7,000 |
| | UHD-Waimea II Res. Sup. PL | 10,000 |
| | Waimea II Reservoir | 77,000 |
| | LAND RIGHTS | |
| | UHD By-Pass Pipelines | 1,000 |
| | UHD-Waimea II Res. Sup. PL | 3,000 |
| | Waimea II Reservoir | 34,000 |
| | SUBTOTAL | $ 212,000 |

| Year | Item | Total |
| --- | --- | --- |
| 3 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | UHD By-Pass Pipelines | $ 17,000 |
| | UHD-Waimea II Res. Sup. PL | 28,000 |
| | Waimea II Reservoir | 343,000 |
| | Project Administration | |
| | UHD By-Pass Pipelines | 20,000 |
| | UHD-Waimea II Res. Sup. PL | 29,000 |
| | Waimea II Reservoir | 39,000 |
| | Irrigation Dist. System | 13,000 |
| | FINANCIAL ASSISTANCE | |
| | UHD By-Pass Pipelines | 416,000 |
| | UHD-Waimea II Res. Sup. PL | 600,000 |
| | LAND RIGHTS | |
| | Irrigation Dist. System | 7,000 |
| | SUBTOTAL | $ 1,512,000 |
| 4 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Waimea II Reservoir | $ 309,000 |
| | Irrigation Dist. System | 112,000 |
| | Project Administration | |
| | UHD By-Pass Pipelines | 3,000 |
| | UHD-Waimea II Res. Sup. PL | 5,000 |
| | Waimea II Reservoir | 225,000 |
| | Irrigation Dist. System | 7,000 |
| | FINANCIAL ASSISTANCE | |
| | Waimea II Reservoir | 4,827,000 |
| | SUBTOTAL | $ 5,488,000 |
| 5 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Irrigation Distribution System | $ 20,000 |
| | Livestock Water Distribution System | 5,000 |
| | Project Administration | |
| | Waimea II Reservoir | 39,000 |
| | Irrigation Distribution System | 40,000 |
| | Livestock Water Distribution System | 15,000 |
| | FINANCIAL ASSISTANCE | |
| | Irrigation Distribution System | 824,000 |
| | LAND RIGHTS | |
| | Livestock Water Distribution System | 157,000 |
| | SUBTOTAL | $ 1,100,000 |

| Year | Item | Total |
| --- | --- | --- |
| Future Year 6 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Livestock Water Distribution System | $ 132,000 |
| | Project Administration | |
| | Irrigation Distribution System | 7,000 |
| | Livestock Water Distribution System | 8,000 |
| | SUBTOTAL | $ 147,000 |
| Future Year 7 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Livestock Water Distribution System | $ 10,000 |
| | Project Administration | |
| | Livestock Water Distribution System | 31,000 |
| | FINANCIAL ASSISTANCE | |
| | Livestock Water Distribution System, Main, E, E-1, Groups 1,3 | 650,000 |
| | SUBTOTAL | $ 691,000 |
| Future Year 8 | TECHNICAL ASSISTANCE | |
| | Engineering | |
| | Livestock Water Distribution System | $ 5,000 |
| | Project Administration | |
| | Livestock Water Distribution System | 20,000 |
| | FINANCIAL ASSISTANCE | |
| | Livestock Water Distribution System, Groups 5,7,9 | 301,000 |
| | SUBTOTAL | $ 326,000 |
| Future Year 9 | TECHNICAL ASSISTANCE | |
| | Project Administration | |
| | Livestock Water Distribution System | $ 2,000 |
| | SUBTOTAL | $ 2,000 |
| | **GRAND TOTAL** | $ 9,651,000 |

*Price Base: 1988
Source: Modified after *Watershed Plan and Environmental Assessment, Waimea-Paauilo Watershed, September 1989*

MAINTENANCE PROJECTS
Waimea Irrigation System

| No | Project* | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 | Future Years |
|---|---|---|---|---|---|---|---|
| 1 | Replacement of valves, etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | ▪ ongoing |
| 2 | Convert two existing pumps, etc. | | ▪ request approp.<br>▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |
| 3 | Install a new telemetry system, etc. | | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | | ▪ award design & constr. contract<br>▪ begin construction |
| 4 | Clean and remove sediment from , etc. | ▪ request approp. | ▪ conduct prelim. eng. & select consultant | ▪ obtain environ. permits & clearances | ▪ award design & constr. contract | ▪ begin construction | |

*See “Maintenance Cost” in Estimated Costs section of this chapter for a detailed description of work.

# Chapter 14. EAST MAUI IRRIGATION SYSTEM

## INVENTORY

The East Maui Irrigation System remains intact and continues to supply irrigation water for Hawaiian Commercial & Sugar Co. (HC&S) agricultural operations in central Maui. The East Maui Irrigation Co, Ltd operates the system with 18 employees. The company maintains and repairs 74 miles of 355 stream diversions, 50 miles of tunnels, 16 steel siphons, and 7 storage reservoirs and 62 miles of unpaved access roads.

There are four main transmission ditches: Wailoa Ditch, 195 mgd capacity; New Hamakua Ditch, 100 mgd capacity; Lowrie Ditch, 70 mgd capacity; and Haiku Ditch, 70 mgd capacity.

In 1898, immediately after acquiring HC&S, Alexander & Baldwin started the Lowrie Ditch, which started in the rain forest of Kailua in Makawao district. The ditch had two sources. The first source was a reservoir at Papaaea that was fed by two 5 to 6-mile ditches and the second source was Kailua stream where the diversion intercepted the source of the older Haiku Ditch and ran parallel to that ditch. The Lowrie Ditch, a 22-mile system with a capacity of 60 mgd, was three-fourths open ditch and included these elements: 74 tunnels for a total of 20,850 ft, the longest being 1955 ft; 19 flumes for a total length of 1965 ft; and 12 siphons with a total length of 4,760 ft, the biggest being 250 feet deep at Halehaku gulch. The Lowrie Ditch, by means of inverted siphons, ended at the 475-ft elevation, 257 ft above the Haiku Ditch.

The Koolau Ditch was the next big project built in 1904-1905. The Koolau Ditch extended the water collection system another 10 miles eastward toward Hana, around the Koolau Range to Makapipi, in 1904. This ditch traveled through more difficult terrain than most other systems and it presented greater logistical problems. In all, ten mountain streams were intercepted. There were 7.5 miles of tunnel and 2.5 miles of open ditch and flume. The 38 tunnels, all dug out of solid rock, were 8 ft wide and 7 ft high. In length they averaged 1,000 ft: the shortest was 300 ft and the longest 2,710 ft.

The New Haiku Ditch was completed in 1914 with a capacity of 100 mgd. It was mostly tunnel, partially lined, with a length of 54,044 ft. Kauhikoa Ditch was completed in 1915 with a capacity of 110 mgd and a length of 29,910 ft. Wailoa Ditch was started in 1918 and finished in 1923. Mostly tunnel, all lined, with a length of 51,256 ft, Wailoa Ditch had an original capacity of 160 mgd, later increased to 195 mgd.

East Maui Irrigation System's water collection system originally had 388 intakes, 24 miles of ditch, 50 miles of tunnels, and 12 inverted siphons as well as numerous small feeders, dams, intakes, pipes, and flumes. The water source was primarily surface runoff from a total watershed area of 56,000 acres. Of this watershed, East Maui Irrigation Co. owned 18,000 acres—the 38,000-acre balance belonged to the State of Hawaii.

The East Maui Irrigation Co. controlled all the surface water to HC&S supplied through the East Maui Irrigation System. Ground waters were controlled by HC&S itself.

By 1931, HC&S was able to pump 144 mgd of ground water. HC&S also received water from the West Maui Irrigation System through the Waihee Canal and Spreckels Ditch through agreements with Wailuku Sugar Co.

**EXISTING CONDITIONS**

| | |
|---|---|
| Ownership & Management: | The East Maui Irrigation System is owned and managed by the East Maui Irrigation Co., Ltd., a wholly owned subsidiary of Alexander & Baldwin, Inc. |
| Employment: | 18 full-time employees |
| Average Delivery: | 165 million gallons per day (mgd) |
| Delivery Capacity: | • Wailoa Ditch 195 mgd<br>• New Hamakua Ditch 100 mgd<br>• Lowrie Ditch 70 mgd<br>• Haiku Ditch 70 mgd<br>Total Capacity 435 mgd |
| Miles of Ditches: | 74 miles of aqueduct of which 50 miles are tunnel. |
| Miles of Roads: | 62 miles of private four-wheel drive jeep access roads to facilitate maintenance and repair of ditch system. |
| Reservoirs: | Seven reservoirs with a total capacity of 274 million gallons. |

Intakes: 355 registered stream diversions ranging from 1” diameter pipes to permanent concrete structures that can divert up to 75 mgd.

Siphons: 13 steel siphons ranging from 42 to 72 inches in diameter.

Watershed Area: 50,000 acres of which 33,000 acres are leased from the State of Hawaii.

Water Users:
- Hawaiian Commercial & Sugar Co.
- Maui County Department of Water Supply
- Maui Pineapple Company

**ASSESSMENT OF NEEDS**

For this report, no assessment of the needs and concerns were conducted due to time constraints and limited funds. No proposed improvements are included for the same reason. Future studies will be directed toward a detailed evaluation of this system.

The staff of employees conduct normal maintenance which consists of road and trail maintenance, ditch and tunnel cleaning, brush and tree removal, and minor repairs to stream intakes, etc. Storm damage repairs require special or urgent attention because storms usually threaten the physical integrity of system, although they occur infrequently (over a period of several years). No estimates of costs for maintenance or capital improvement were prepared for this report due to time constraints and limited funds.

# Chapter 15. KAUAI COFFEE IRRIGATION SYSTEM

## INVENTORY

The original plantation irrigation system was conceived and constructed by McBryde Sugar Co. over a period extending from the early 1900s to the 1930s. The plantation acreage extended from Hanapepe eastward through Eleele, Kalaheo, Lawai and into Koloa covering 20,000 acres. Due to its leeward location the McBryde plantation did not have access to sufficient surface water, so it developed ground water sources near Hanapepe River and numerous storage reservoirs (estimated at 800 MG) to augment system water supply. In order to economically pump water to storage reservoirs and fields, McBryde plantation needed a cheap electric power source. A massive undertaking built the Wainiha Hydropower Plant, 35 miles away tapping into northern Kauai's abundant windward surface water sources in the Wainiha watershed. McBryde's Wainiha Power Plant is the earliest hydroelectric power plant of any significant size built in Hawaii—and to this day remains the largest in annual power production. Power from Wainiha plant was transmitted the 35-mile distance to Hanapepe by means of a power line that traversed across Wainiha, Lumahai, and Hanalei Valleys; up the ridge mauka of Kalihiwai to the mountain divide between Kalihiwai and Wailua; onward toward Lihue; and passing between Haiku and Lawai to Hanapepe. At its peak, the Wainiha hydropower plant provided up to 57,000 volts, more than adequate for plantation needs. The plant had three generators, pelton wheels with exciters, transformers and a switchboard.

McBryde plantation had access to the Wahiawa watershed, which includes the Kanaele Swamp. Determined to build a reservoir to capture the runoff from this watershed, McBryde started the Alexander Reservoir in 1928, although conditions for water storage were not generally ideal in Hawaii. The only Hawaii plantations that developed any substantial water storage capacity were McBryde and Koloa plantations on Kauai and Wailua Sugar Co. on Oahu.

A second hydropower plant was built by McBryde when the Alexander Dam and Reservoir were built, storing water from Wahiawa Stream. The dam was 120 ft high and 620 ft long and it provided adequate hydraulic differential to power 1100 kW generator at Kalaheo. All this hydroelectric power, together with steam power from burning mill bagasse waste combined, resulted in excess power which was sold.

Pump 3 was one of four pump stations that tapped both in and under the Hanapepe River (three of them have since been abandoned). Pump 3 was uniquely successful in water production. At Pump 3, a vertical shaft descends 90 ft to a pump room. Forty feet below that, a network of skimming tunnels was built, beginning in 1908. The tunnel essentially intercepted an underground river. Pump 3 is recharged by surface water diverted from Hanapepe River. The main pump at No. 3 tapped surface flows of Hanapepe River and the underlying groundwater aquifer. A vertical shaft descends 130 ft below river bed with skimming tunnels, one of these skimming tunnels intercepted a huge "underground river." Although there were four pump stations originally, only Pump 3 could sustain adequate capacity. When McBryde's cost of running its coal-burning steam pumps proved prohibitive, the company turned to cheaper energy sources—specifically hydroelectric power and burning bagasse for fuel. The center of the power grid was at Pump 3.

After plantation closure, the Kauai Coffee Irrigation System presently consists of Pump 3 Ditch and Alexander Dam Ditch. The system is composed of tunnels, siphons, flumes and open ditches. System water flows southward from Alexander Reservoir, fives miles to the junction of Pump 3 Ditch near Umi Reservoir; and also eight miles eastward from Hanapepe Valley floor to the storage reservoir (Luawai near Lawai). Still surviving are eight storage reservoirs (Elua 80 MG, Mau 26 MG, Elma 27 MG, Hukiwai 16 MG, Kapa 18 MG, Ioleau 39 MG, Umi 7 MG, and Luawai 9 MG). The system is operated and maintained by a crew from McBryde Sugar Co.

## EXISTING CONDITIONS

Ownership: McBryde Sugar Co., a wholly owned subsidiary of Alexander & Baldwin, Inc.

Management: Kauai Coffee Company, Inc.

Ditches:
- Alexander Dam ditch system, owned in entirety by McBryde Sugar Co.
- Pump 3 ditch system, owned in entirety by McBryde Sugar Co.

Average Delivery: 27 million gallons per day (mgd)

Delivery Capacity:
- Alexander Dam – 15 mgd
- Pump 3 Ditch – 18 mgd

Total Capacity 33 mgd

| | | |
|---|---|---|
| Miles of Ditches: | (infrastructure include tunnels, siphons, aqueducts, etc.) | |
| | • Alexander dam: from Alexander dam to Pump 3 ditch - | 5 miles |
| | • Pump 3: from Hanapepe Valley to Luawai Reservoir (Lawai) | 8 miles |
| | Total | 13 miles |

No. of Major Intakes: Two

Area of Watershed: 8,000 acres

Water Users:
- Kauai Coffee Co.
- National Tropical Botanical Gardens
- Syngenta Seed Co.
- Dekalb Seed Co.
- Pioneer Seed Co.
- Hanapepe Valley Taro Growers use 5 mgd not included in the 27 mgd average delivery

Reservoirs:
- Alexander Dam: 810 MG (services Kalaheo Hydroelectric)
- Elua Reservoir: 80 MG
- Mau Reservoir: 26 MG
- Elima Reservoir: 27 MG
- Hukiwai Reservoir: 16 MG
- Kapa Reservoir: 18 MG
- Ioleau Reservoir: 39 MG
- Umi Reservoir: 7 MG
- Luawai Reservoir: 9 MG

▪ Total Maximum Storage Capacity: 1,032 MG

**ASSESSMENT OF NEEDS**

Due to time constraints and limited funds, no assessment of the system's needs was conducted. Future studies will include a detailed evaluation of this system, including an assessment of improvements needed. Consequently, no cost estimates for improvements or maintenance were prepared for this report.

# Chapter 16. WEST MAUI IRRIGATION SYSTEM

## INVENTORY

Subsequent to plantation closure, the original system has been down-sized to two operational ditches: Waihee Ditch, 70 mgd capacity, and Spreckels Ditch, 50 mgd capacity. The ownership of these two ditches are shared by Wailuku Agribusiness Co. Inc. (successor to Wailuku Sugar Co.) and Alexander & Baldwin, Inc. Now called the West Maui Irrigation System, the system is operated and maintained jointly by Wailuku Agribusiness Co. and Hawaiian Commercial & Sugar Co. There are seven surface water diversions and approximately 17 miles of ditches which support agricultural operations on the western side (Iao Valley) of the Maui isthmus.

The former Wailuku Sugar Co. took over Waihee Plantation in 1895, at which time Spreckels' 1882 Waihee Ditch became the source of conflict and legal action between Wailuku Sugar Co. and Mr. Spreckels of HC&S.

Subsequently, but before legal resolution, HC&S was acquired by new owners who shared a common interest with Wailuku Sugar Co. in a proposal to construct a second ditch to divert Waihee Stream flows at a higher elevation. The terms of the agreement (made permanent with exchanges of fee title almost 25 years later) were that HC&S would get five-twelfths of the new upper-level " Waihee Canal" water and one-half of the older Waihee Ditch (Spreckels) water. With these issues resolved, Wailuku Sugar Co. undertook the construction of Waihee Canal.

The Waihee Canal (also called Waihee Ditch) was started in 1905 and completed in 1907. This 50-mgd capacity ditch tapped Waihee Stream at the 650 ft elevation, just below Aliele Falls. Its 10.62 mile length included 22 tunnels, totaling 16,539 ft; 39 flumes totaling 2,764 ft; 35,549 ft of open, cement-lined ditch; and a 1,253 ft long, 3 ft diameter siphon across Iao Valley. Ditch grade averaged 2.5 ft per 1,000 ft. The longest tunnel (2,246 ft) was especially challenging because much of it penetrated through hard close-grained rock.

The old Wailuku Sugar Co. ditch names, it must be noted, are particularly confusing. In recent times, the newer ditch (formerly Waihee Canal) is now referred to as the Waihee Ditch, whereas the older ditch is now called the Spreckels Ditch (formerly Waihee Ditch).

Adding confusion is another Spreckels Ditch (formerly Haiku Ditch) belonging to the East Maui Irrigation System.

By 1913, Wailuku Sugar Co. was irrigating entirely from mountain sources. Besides the major ditches mentioned herein, the company had nine other smaller ditches; two on Waiehu Stream, five on Wailuku Stream in Iao Valley (the largest was Maniania Ditch), and two on Waikapu Stream (South Side and Palolo Ditches). Some of these ditches have been abandoned or consolidated. Wailuku Sugar Co. ended sugar production in 1988.

**EXISTING CONDITIONS**

Ownership:
- Wailuku Agribusiness Co., Inc. (WAB)
- Alexander & Baldwin, Inc. (A&B)

Management: Wailuku Agribusiness and Hawaiian Commercial & Sugar Co. A maintenance crew of 4 to 5 persons maintains the West Maui Irrigation System.

Ditches:
sections.
- Waihee—owned in fee by WAB with perpetual easements in some.
- Spreckels—owned in fee by WAB with perpetual easements in some sections from Waihee Stream to South Waiehu Stream. A&B owns in fee from South Waiehu Stream to HC&S reservoirs 73 and 74.

Average Delivery: 45 million gallons per day (mgd)

Delivery Capacity:
- Waihee Ditch – 70 mgd
- Spreckels Ditch – 50 mgd
- Total Capacity 100 mgd

Miles of Ditches:

| | Miles |
|---|---|
| • Waihee Ditch (from Waihee Valley to Hopoi Chute) | 6.06 |
| • Waihee Ditch (from Hopoi Chute to WAB Reservoir 99) | 4.47 |
| Total ……………………………........... | 10.53 |
| • Spreckels Ditch (from Waihee Valley to South Waiehu intake) | 3.30 |
| • Spreckels Ditch (from South Waiehu intake to HC&S Res. 73/74) | 3.44 |
| Total ……………………………………. | 6.74 |
| ■ Total Waihee and Spreckels ……………………………….. | 17.27 |

No. of Major
Intakes: Seven

Watershed
Area: 13,500 acres

Water Users: Hawaiian Commercial & Sugar Co.
Sandalwood Golf Course
Maui Tropical Plantation
Maui Pineapple Company
Maui Department of Water Supply
Various landowners for agricultural purposes
Kuleanas (4.5 mgd of uses not included in the 45 mgd average delivery)

Allocation of
Water: Per June 23, 1924 Agreement:

- Waihee Ditch—5/12 HC&S, 7/12 WAB from Waihee Stream to Hopoi Chute Ditch
- Spreckels Ditch—50/50 HC&S and WAB from Waihee Stream to South Waiehu Stream, 100% HC&S from South Waiehu Stream to Reservoirs 73 and 74

**ASSESSMENT OF NEEDS**

Due to time constraints and limited funds, no assessment of the system's needs was conducted. Future studies will include a detailed evaluation of this system, including an assessment of improvements needed. Consequently, no cost estimates for improvements or maintenance of the system were prepared for this report.

# Chapter 17.  AGRICULTURAL WATER PLANNING GUIDELINES

The planning of State agricultural water projects which involves improvements to infrastructure of existing irrigation systems, such as surface water source developments and rehabilitation, reservoir construction and rehabilitation, reactivation of groundwater pump stations, replacement of pipelines and flumes, restoration of ditches, etc., are affected by a comprehensive and complex set of regulations, administrative rules, and public review processes.

Described in this chapter are Federal, State, and County regulations which will likely impact any farming operation and its economic viability and, therefore, which need to be considered in planning any agricultural water development or improvement project.  The permitting process under these regulations may be involved and time consuming, and may entail commitment of major financial resources before construction can begin.  It takes very little adversity or uncertainty in the process of permitting or compliance to affect the economics of farming.

***County Zoning.***  There are four Counties in the State, each consisting of a major island except for the County of Maui which is composed of three islands.  Each County has its own zoning ordinance which determines the allowable land uses within each County.  A County, through its governing body, the County Council, can change land-use zoning of individual parcels of land.  However, such change normally occurs through a lengthy process and involves an entire County sub-district leading to adoption of a development plan for a sub-district.  Adoption of a development plan requires several votes of the Council, each of which involves an extensive public review period.

Irrigation system service areas which are already zoned for agricultural use do not require land reclassification and consequent lengthy and difficult County review process. Therefore, it is imperative that first consideration be given to those agricultural water development or improvement projects which serve land parcels which are zoned for agricultural use.

***State Environmental Impact Statement Law (Chapter 343, HRS).***  The State of Hawaii has enacted strict environmental regulations to protect and preserve its unique natural beauty and island setting under Hawaii Administrative Rules, Chapter 11-200, which governs the requirements and process for the preparation and review of Environmental Assessments

(EA) and Environmental Impact Statements (EIS). Any projects or activity which anticipates the use of public lands or public funds are first required to conform with Chapter 343 and 11-200. For complex projects, the impacts to be considered must include the cumulative long-term effects on native Hawaiian cultural and religious practices, particularly those that are customary and traditional.

Any project or activity which involves the use of Federal lands or funds must also conform to the National Environmental Policy Act (NEPA). This Federal environmental regulation outlines the process necessary to obtain consent for the implementation of the project or activity. Federal EA's and EIS's for irrigation water projects also need to consider the impacts on drainage, flood control, and water resources because of their close relationship.

Whenever a project needs to meet the requirements of both State and Federal statutes, it is acceptable to prepare a joint report and conduct concurrent public review and processing in accordance with the respective government levels and regulatory requirements.

***State Land Use Districts.*** Agricultural water development or improvement projects located within a State designated Agricultural District are not subject to regulation by the respective counties. In this report, all agricultural water-related projects discussed are limited to those service areas which have a State land classification of Agriculture, in order to avoid regulatory overview by County agencies. However, the State Land Use Commission is authorized to change land-use classifications which can impact any agricultural water project during the course of its development.

***State Water Code.*** Regarding water use (including agricultural use), the State Water Code (Chapter 174C, HRS) authorizes the Commission on Water Resource Management (CWRM) to regulate water use by designating areas for water management in accordance with Sections 174C-41 through 63. The criteria for designating a "water management area" by the CWRM for regulation of groundwater use are enumerated in Section 174C-44 of the State Water Code and Section 13-171-7 of the Hawaii Administrative Rules (HAR). Similarly, the criteria for designation by the CWRM of a "water management area" for the regulation of surface water use are enumerated in Section 174C-45, HRS, and Section 13-171-8, HAR. In such designated "water management areas", the CWRM regulates, by means of permits, all water uses (including agricultural use) derived by withdrawal, diversion, or impoundment, excepting domestic consumption by individual users, and, as a result of the Waiahole Case (Waiahole, 94, Haw.) must consider the public trust doctrine in weighing competing instream and offstream uses (including agricultural use) and issuing water use permits. The Waiahole

Case possibly could lead to difficulty and uncertainty in the future processing of water use permits for existing agricultural water systems in designated water management areas.

Currently, the State's Waiahole Ditch Irrigation System on Oahu and Molokai Irrigation System on Molokai are the only systems located in designated water management areas; and therefore, subject to water use regulations. These two viable irrigation systems serve very important agricultural regions of the State.

Regarding water sources, whether in a designated water management area or not, the CWRM under the State Water Code regulates stream channel alterations, stream diversion works, well constructions, and pump installations; all by means of permits. The regulatory process involved in obtaining such permits can in some cases be lengthy, difficult, and uncertain. On the other hand, irrigation system repairs (such as flume replacement) which do not involve the construction of a new or expanded diversion works or flume supports in stream channels are generally not regulated. The CWRM also has the authority and obligation to set instream flow standards.

***Clean Water Act.*** The Clean Water Act is a federal law relating to the environmental protection of the nation's water resources. The Act 's provisions are burdensome to agricultural water use and development because they strictly regulate the development, use, and disposition of irrigation water. Of the Act's many requirements, three relate directly to agricultural water project planning—these are Sections 303(d), 401 and 404 outlined below.

Section 401 of the Clean Water Act is known in Hawaii as the "Water Quality Certification (WQC) Requirement." It is administered by the State Department of Health and it is a regulation that controls any construction or operation of water facilities resulting in any discharge into the navigable waters of the U.S. Since the State is composed of islands, almost every agricultural water project may potentially cause discharges to enter the ocean, making it mandatory to go through the WQC permitting process. The WQC permit application entails engineering work to comply with the law which a "lay" farmer cannot meet without a professional consultant. The preparation of the application and the regulatory review process involves lengthy public participation and it can take up to a year to obtain a permit. Meeting the requirements of Section 401 is costly and prohibitive for small farmers or farming ventures without capital.

Section 404 of the Clean Water Act, less stringent than Section 401, can adversely impact any planning for agricultural water projects. This provision requires another permit from the U.S. Army Corps of Engineers for any activity which may cause discharges of dredged or fill material into waters of the United States.  Hawaii being an island state, any work on irrigation systems which may cause a discharge of sediment into the ocean would require a permit.

Section 303(d) of the Clean Water Act relates to any work conducted in any stream or stream segment that is on the list of “impaired waters.”  The effect on planning for agricultural water projects is significant if the stream or stream segment is so listed because such projects must meet state water quality standards for which total maximum daily load (TMDL) analyses must be prepared for that stream.  Until a TMDL analysis is completed, such an agricultural project is delayed.

***Endangered Species Act.*** The Endangered Species Act, a federal law, is unlimited in its designation of critical habitats, which could pose serious obstacles in the planning of agricultural water development projects.  Most sources of water supply for irrigation systems are from stream diversions in the higher elevations or upper reaches of watersheds, where the habitats of threatened and endangered plants and animals are also located.  Every major island in Hawaii has at least one critical habitat designation covering thousands of acres in upper forest and range lands of major stream watersheds.  For any irrigation water development activity conducted within these designated habitats, great effort and financial expenditures are required to develop best management plans (BMP) to protect and preserve the habitat.  However, developing such plans is not a simple task because sufficient data on the life cycle or living habits of many of the endangered species in the designated habitat do not exist.  Therefore, it is very difficult to develop a BMP because of insufficient knowledge of what to protect and what habitat to preserve.  Almost all of Hawaii’s irrigation system's water sources are situated within or are a part of these designated critical habitat areas.

# Chapter 18. AWUDP RELATIONSHIP TO HAWAII WATER PLAN

## OVERVIEW OF HAWAII WATER PLAN

The Hawaii Water Plan is a comprehensive water plan composed of eight separate documents. These documents include, in alphabetical order, the following:

- Agricultural Water Use and Development Plan (AWUDP)
- Four County Water Use and Development Plans (Hawaii, Maui, Kauai, and Oahu)
- State Water Projects Plan (SWPP)
- Water Quality Plan (WQP)
- Water Resource Protection Plan (WRPP)

Each of the above Plans is an individual stand-alone planning document dealing with different programs and aspects of water resources in Hawaii. The State Water Code defines the interrelationships among these Plans, but it is beyond the scope of this report to present the details of the intricate relationships.

The CWRM has overall responsibility for the Hawaii Water Plan and its authority is provided in Chapter 174C, Hawaii Revised Statutes, which mandates the Commission to prepare, update, and implement the Hawaii Water Plan. The responsibility for preparation of the Agricultural Water Use and Development Plan belongs to the State Board of Agriculture whose authority is provided in Act 101, Session Laws of Hawaii 1998. Act 101 states that the AWUDP shall provide for:

- A master inventory of irrigation water systems,
- Identification of system rehabilitation needs, costs and sources of funding for repair and maintenance,
- Development of prioritization criteria and a 5-year program for system repairs,
- Set up of a long-range plan to manage the systems, and
- Incorporation of the AWUDP into the SWPP per CWRM coordination.

## STATEWIDE FRAMEWORK FOR UPDATING HAWAII WATER PLAN

As stated above, the updating function has been laid out in detail by the Commission in its report, *Statewide Framework for Updating the Hawaii Water Plan, February 2000*. This report outlines the process and duties of the different agencies responsible for the preparation and updating of the individual plans mentioned above. The Framework report recommends that certain guidelines and planning elements be made common in each Plan, in order to maintain uniformity and cohesiveness among all of the Plans. The Framework Report mandates certain requirements, as outlined in the following paragraphs, in accordance with the State Water Code.

## INTEGRATED RESOURCES PLANNING ELEMENTS

In addition to the provisions of Act 101, SLH 1998, the Framework report recommends additional planning elements for the AWUDP. The pertinent recommendations listed below are excerpted from the Framework report:

> *Recommended Plan Elements*
>
> The effort described above is identified in the Act as a "master irrigation inventory plan" and should therefore be considered as an initial step in the development of a comprehensive Agricultural Water Use and Development Plan. The additional steps that would need to be taken to complete a comprehensive AWUDP should include the following:
>
> 1) Based on existing statewide agricultural land uses, assess the existing agricultural water irrigation needs of each of the counties.
>
> 2) Based on long-term agricultural crop development plans, develop a range of future agricultural irrigation water needs for each of the counties, including projected agricultural water demands of the DHHL.
>
> 3) Based on the information from the WRPP and the "master irrigation inventory plan," identify existing sources for irrigation water and assess any shortfalls or excess capacities in existing irrigation systems.

4) Identify options for development of additional and alternative irrigation water sources.

5) Identify options for conserving irrigation water and/or managing the uses to reduce the total irrigation water demand.

6) Develop strategies encompassing both demand management and resource development options.

*Integrated Resource Planning Elements*

To provide consistency and coordination between the State Water Projects Plan and the County Water Use and Development Plan, the following elements of the Integrated Resource Planning approach should be followed in the preparation of the AWUDP:

a) *Demand Forecast* – The AWUDP shall include a range of forecasts of the amount of water required over the planning horizon. The DOA shall develop forecasts for multiple scenarios that are necessary or appropriate in the development of the State Water Projects Plan and the County Water Use and Development Plans. Among the scenarios are the base case scenario (a scenario based on the most likely assumptions), a high-growth scenario, and a low-growth scenario. Forecasts shall be based on yearly increments for the first 5 years. Thereafter, forecasts shall be based on 5-year increments to the year 2020. The DOA is encouraged to extend their forecasts beyond the year 2020, particularly when the forecasts for the initial 20-year period indicates that the limits of particular resources are within reach.

b) *Water System Profiles* – The AWUDP shall include a thorough description of current supplies, major conveyance facilities and storage reservoirs, re-use programs, and conservation programs that are currently in operation. This description shall also include resources, if any, to which the State, county, or private agricultural entities have made commitments. The ability of the current (and, if applicable, committed) system to meet future demands should be explored.

c) *Resource Development Options* – As applicable, the AWUDP shall address the following types of resource options:

- <u>Supply sources</u>, including both surface-water and ground-water supplies and various combined uses of the two. The issue of inter-basin transfers should be examined, with due regard to the environmental and cultural impacts in the basin of origin.

- Transmission and other infrastructure, including, but not limited to, major conveyance, treatment, and pumping facilities to relieve existing or anticipated constraints on effectively utilizing existing supplies.

- Storage facilities, to take advantage of annual, seasonal, daily, or diurnal variations in demands and/or available supplies.

- Conservation programs for agricultural water users. Conservation options should be considered as carefully as supply and facility options as to their ability to achieve objectives. In particular, the estimates for future program participation, costs, and savings should be enumerated and explained. As used here, the term "conservation programs" also includes conservation-oriented rate designs.

- Direct and indirect use of reclaimed wastewater for irrigation uses. Such options must be consistent with federal, state, and county laws and regulations.

d) *Source Development Plan* – The AWUDP must include a source development plan based upon selected resource options. The plan shall be divided into three periods as follows:

Near-term (initial 5 years): For this period, the source development plan must detail all of the actions that need to take place to accommodate the projected agricultural water demands anticipated for the initial 5-year time frame. A near-term implementation schedule and a detailed description of each action shall be presented. This schedule shall reflect the anticipated timing and sequencing of all near-term actions. The schedule shall also include expected supply-side capacity additions and demand-side program penetration levels by year. Near-term actions may include, but are not limited to, pre-design, design, construction, obtaining financing, information-gathering, staff hiring, execution of initial conservation program phases, and additional stakeholder and public involvement activities. The 5-year plan should also include estimates of incremental annual capital and operating costs.

Medium-term (subsequent 5 years): The source development plan for the medium-term will require less detail, and should focus on major decision points and actions such as plan reassessments, and other actions that may require substantial advance preparation. Precise scheduling and sequencing of events is not critical. However, such information will need to be developed as part of subsequent updates to the AWUDP.

Long-term (final 10 years): The long-term source development plan should serve to highlight major events that are anticipated in the final portion of the planning period. It is expected that detailed information may not be available for long-term plans, however, available data should be identified and sufficiently described.

A number of the excerpted items listed above could not be addressed in this report due to the availability of funds and time constraints and should be dealt with later when additional funds become available. It is also noted that the "recommended" plan elements extend beyond the scope of Act 101's master inventory irrigation plan and normal irrigation water system operations, requiring assessments more difficult and complex than for municipal potable water systems. Furthermore, the development of multiple scenarios, while more or less straightforward for municipal water system operations, is less so for crop development planning, agricultural crop production, and irrigation system operations. Also, existing State environmental laws (Chapter 343), court precedence (Hanapepe case), and County policies (some Departments of Water Supply are reluctant to allow reuse of treated wastewater over prime aquifers) make it extremely difficult through lengthy proceedings and uncertainty associated with the environmental review process to consider inter-basin transfer of agricultural water or the use of reclaimed wastewater for agricultural use (the State Department of Health Administrative Rules allow use of R-1 treated water for irrigation, but in general R-1 water is too expensive to produce solely for agricultural use without some government subsidy or assistance).

## CONSISTENCY WITH WATER RESOURCE PROTECTION PLAN

The CWRM's responsibility is to comport all of the interrelated Plans with each other and to ensure consistency among the SWPP, the WRPP and the WQP. In order to provide such uniformity and resolve conflicts, the Framework Report recommended that the following elements shall be included:

1) *Consistency with the WRPP* – The AWUDP shall comport with the provisions of the Water Resource Protection Plan and should utilize the ground-water hydrologic units and surface-water hydrographic units designated statewide by the CWRM for the presentation of data and analyses.

2) *Current and Future Demand Forecasts* – The AWUDP should evaluate current and future water demands for agricultural programs and projects statewide to insure orderly authorization and development of existing water resources. The AWUDP shall consider a twenty-year projection period for analysis purposes. The review of all existing and contemplated agricultural projects shall be based upon water consumption guidelines and water demand unit rates used by the CWRM for the purposes of its water permit application review process. All projects should indicate the following information, at a minimum:

    a) Type of project;
    b) Source of water;
    c) Existing uses;
    d) Contemplated uses;
    e) System capacity;
    f) Location/Tax Map Key (TMK);
    g) Project schedule;
    h) Quality of water needed;
    i) Basis for water demand projects (e.g. area, units, etc.); and
    j) Primary source development plan for the project(s).

3) *Water demand-forecasting techniques* – The forecasts developed by the DOA should identify the significant demand determinants used by the agency which may include but are not limited to:

    a) The data, the sources of data, the assumptions, and the analysis upon which the forecast is based;

    b) The relative sensitivity of the forecasts to changes in assumptions and varying conditions;

> c) The procedures, methodologies, and models used in the forecast, together with the rationale underlying the use of such procedures, methodologies, and models.
>
> The approach used by the DOA in their forecasts should be based on sufficient historical data and at a minimum should result in high, medium, and low forecasts of average day demands. Additional forecasts of annual, seasonal, and peak-day system demands, as may be necessary, should be based upon forecasted average day demands. The validity and reliability of the approach used by the DOA must be demonstrated and the agency must be prepared to discuss unexplained variation in demand.

Not all of the excerpted items listed above could be addressed in this report due to the availability of funds and time constraints that should be dealt with later when additional funds become available.

## RESOURCES STRATEGIES

The subject of resource strategies is not covered in this report of the Agricultural Water Use and Development Plan, but rather is left for later review and direction by the Department of Agriculture as the matter does require certain policy and administrative decisions. The Framework Report outlines the requirements and decisions that are needed and are excerpted below:

> 5) *Resource Strategies* – The resource and facility options that are identified by the DOA in the AWUDP must be combined into resource strategies and integrated with the county strategies. A resource strategy is defined as: *A flexible sequence of supply, infrastructure, storage, and conservation program additions intended to meet agricultural water needs over the planning period.* The DOA must be prepared to develop alternative strategies and to evaluate each strategy against the other. During the update of each county's WUDP, the DOA's strategies should be re-evaluated based upon county specific objectives and measurable criteria developed under the prescribed IRP process. The final product of this step should result in a manageable number of strategies within the WUDP from which a final recommendation will be selected.

6) *Uncertainties* – The DOA should consider future uncertainties in the development of resource strategies. Source development strategies should provide for future contingencies that may arise in the face of particular outcomes. Sensitivity analysis of strategies developed by the DOA should be performed to evaluate the sensitivity of forecasts and outcomes to various future scenarios.

7) *Updating* – The responsibility for maintaining, monitoring, and updating the AWUDP document resides with the DOA. However, it is recommended that agricultural stakeholders annually update project information in order to monitor demand forecasts and implementation of water development strategies. The DOA should establish a mechanism for regular review of existing, planned, and proposed water resources to meet projected agricultural requirements.

# Chapter 19. EXISTING WATER USE AND SOURCES

## MONTHLY WATER USE DATA

Existing water use data for current diversified agriculture operations are sparse, since most irrigation systems in Hawaii were built and utilized primarily for sugarcane or pineapple cultivation, without any metering or monitoring of water use. Since plantation closures in the mid-1990s the five former plantation irrigation systems selected for study in this report (East Kauai, Kekaha Ditch, Kokee Ditch, Maui Land and Pineapple/Pioneer Mill, and Waiahole Ditch) have remained largely unused for diversified farming, providing little, if any, useful water use data on diversified agriculture operations, except for the Waiahole Ditch System on Oahu with only a few years of records.

Three of the five HDOA irrigation systems (Molokai, Waimanalo, and Waimea), have years of metered monthly diversified agriculture water use records, as well as acreages served. The most recent eight years of record (1995-2002) are shown in Appendices A, B, and C. The HDOA's Lower Hamakua Ditch and Upcountry Maui systems were acquired in recent years and do not have adequate metered records for water use rate analysis. Of the three HDOA systems with metered water use records, only the Lalamilo section of the Waimea System, located on the island of Hawaii, as the most representative of diversified agriculture operations by full-time farmers, has metered water use and acreage served data suitable for determining water use rates for diversified agriculture farming. On the other hand, the acreage served by the Molokai and Waimanalo systems have not been fully utilized for diversified farming operations or operated entirely by full-time farmers, i.e., farming as their primary livelihood. The water use records of these two and other systems should be considered in future studies.

The three private systems (East Maui, Kauai Coffee, and West Maui) are currently used for monocrops (sugarcane, pineapple, and coffee) and, therefore, do not meter nor have water use data relating to diversified agriculture.

## IRRIGATION WATER USE RATE (DIVERSIFIED CROPS)

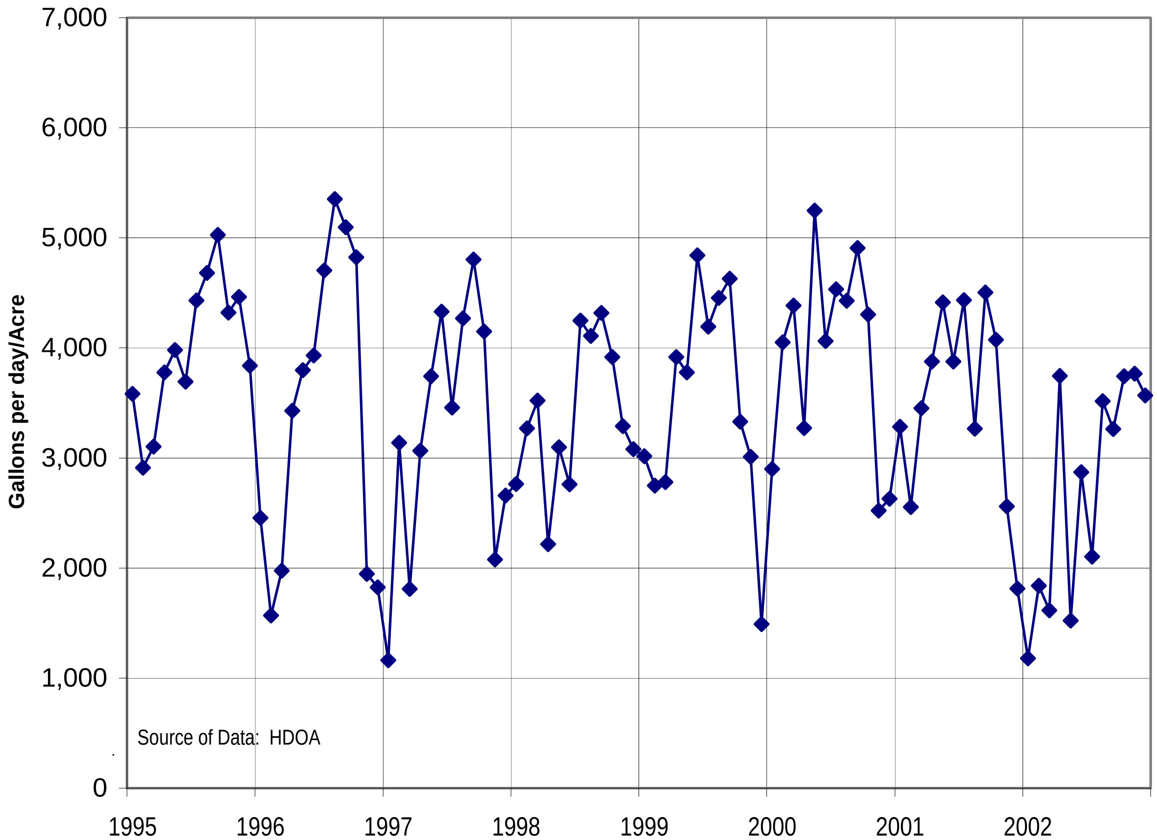
Fortunately, the Lalamilo Section of the HDOA's Waimea Irrigation System has many years of monthly records of metered water use related to consistent farming operations by full-time farmers of diversified crops on a total of 280 acres, from which can be derived reliable monthly irrigation water use rates needed for forecasting diversified agriculture water demand. However, only the most recent eight years of record (1995-2002) were made available for the rate analysis (see Appendix C). The monthly metered irrigation water use (gallons per day/acre) shown in Table 3 were calculated from the records shown in Appendix C by dividing the monthly metered water use by the number of acres irrigated. The monthly data in Table 3 was then plotted in Figure 3 to illustrate the wide variation (1,500 gpd/acre to 4,500 gpd/acre) in water use from winter months to summer months, as compared to a more uniform pattern of municipal water use.

**Table 3. MONTHLY METERED IRRIGATION WATER USE (1995-2002)**
**Lalamilo Section (280 acres served), Waimea Irrigation System**
**(in Gallons Per Day/Acre)**

| Year | Jan. | Feb. | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Avg Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1995 | 3,584 | 2,912 | 3,102 | 3,778 | 3,981 | 3,693 | 4,430 | 4,680 | 5,027 | 4,321 | 4,463 | 3,838 | 3,984 |
| 1996 | 2,455 | 1,569 | 1,976 | 3,428 | 3,798 | 3,932 | 4,705 | 5,353 | 5,096 | 4,825 | 1,947 | 1,825 | 3,409 |
| 1997 | 1,162 | 3,139 | 1,811 | 3,067 | 3,742 | 4,329 | 3,457 | 4,270 | 4,804 | 4,150 | 2,078 | 2,660 | 3,222 |
| 1998 | 2,762 | 3,269 | 3,522 | 2,216 | 3,099 | 2,761 | 4,248 | 4,110 | 4,317 | 3,917 | 3,289 | 3,080 | 3,383 |
| 1999 | 3,017 | 2,749 | 2,781 | 3,918 | 3,778 | 4,841 | 4,192 | 4,455 | 4,629 | 3,330 | 3,009 | 1,490 | 3,516 |
| 2000 | 2,900 | 4,050 | 4,384 | 3,272 | 5,248 | 4,062 | 4,534 | 4,427 | 4,909 | 4,303 | 2,521 | 2,630 | 3,937 |
| 2001 | 3,284 | 2,555 | 3,451 | 3,875 | 4,414 | 3,877 | 4,433 | 3,266 | 4,503 | 4,074 | 2,559 | 1,812 | 3,509 |
| 2002 | 1,179 | 1,840 | 1,616 | 3,746 | 1,524 | 2,870 | 2,103 | 3,516 | 3,263 | 3,743 | 3,767 | 3,568 | 2,728 |
| Average | 2,543 | 2,760 | 2,830 | 3,413 | 3,698 | 3,796 | 4,013 | 4,260 | 4,569 | 4,083 | 2,954 | 2,613 | 3,461 |
| High | 3,584 | 4,050 | 4,384 | 3,918 | 5,248 | 4,329 | 4,705 | 5,353 | 5,096 | 4,825 | 4,463 | 3,838 | |
| Low | 1,162 | 1,569 | 1,616 | 2,216 | 1,524 | 2,761 | 2,103 | 3,266 | 3,263 | 3,330 | 1,947 | 1,490 | |

Source of Data: HDOA

**Figure 3. MONTHLY IRRIGATION WATER USE RATES (1995-2002)**
**Lalamilo Section (280 acres served), Waimea Irrigation System**




For planning purposes, the average values of water use calculated for the 8-year period are somewhat more useful and are included in Table 3 and plotted in Figure 4 which shows that the monthly water application rate at the Lalamilo diversified agriculture farm lots ranges from an 8-year average low of approximately 2,500 gpd/acre during the winter months of December and January to an approximately 4,600 gpd/acre average high during the late summer month of September. This wide range bears out the assumptions referred to in previous chapters of this report that diversified agricultural water use is highly variable from month to month and obtaining reliable average values is difficult without long term records. As can be seen in Table 3 and Figure 4, over the 8-year period (1995-2002) the monthly metered irrigation water use rate for year-round diversified agriculture farming at the Lalamilo Farmlot Subdivision averaged 3,461 gpd/acre. This 8-year average rate of approximately 3,461 gpd/acre, calculated by the authors, is considered a reliable value for use in planning or forecasting irrigation water demand for Hawaii's diversified agriculture industry. The 3,461 gpd/acre average rate and monthly averages shown in Figure 4 are based upon records of metered water use (Appendix

C) for diversified farm operations on dedicated farm lots under climatic conditions found at Lalamilo, which are somewhat typical of other irrigation systems such as Waiahole, Upcountry Maui, Kekaha, and Kokee Ditches. It must be noted that irrigation system losses (including evaporation) are extraneous to metered water use and, therefore, do not affect the calculated water use rate. System water losses are a separate matter and were not analyzed due to time constraint, but should be considered in future studies.

**Fig. 4. EIGHT-YEAR AVERAGE, HIGH, & LOW MONTHLY WATER USE RATES**
**Lalamilo Section (280 acres served), Waimea Irrigation System**

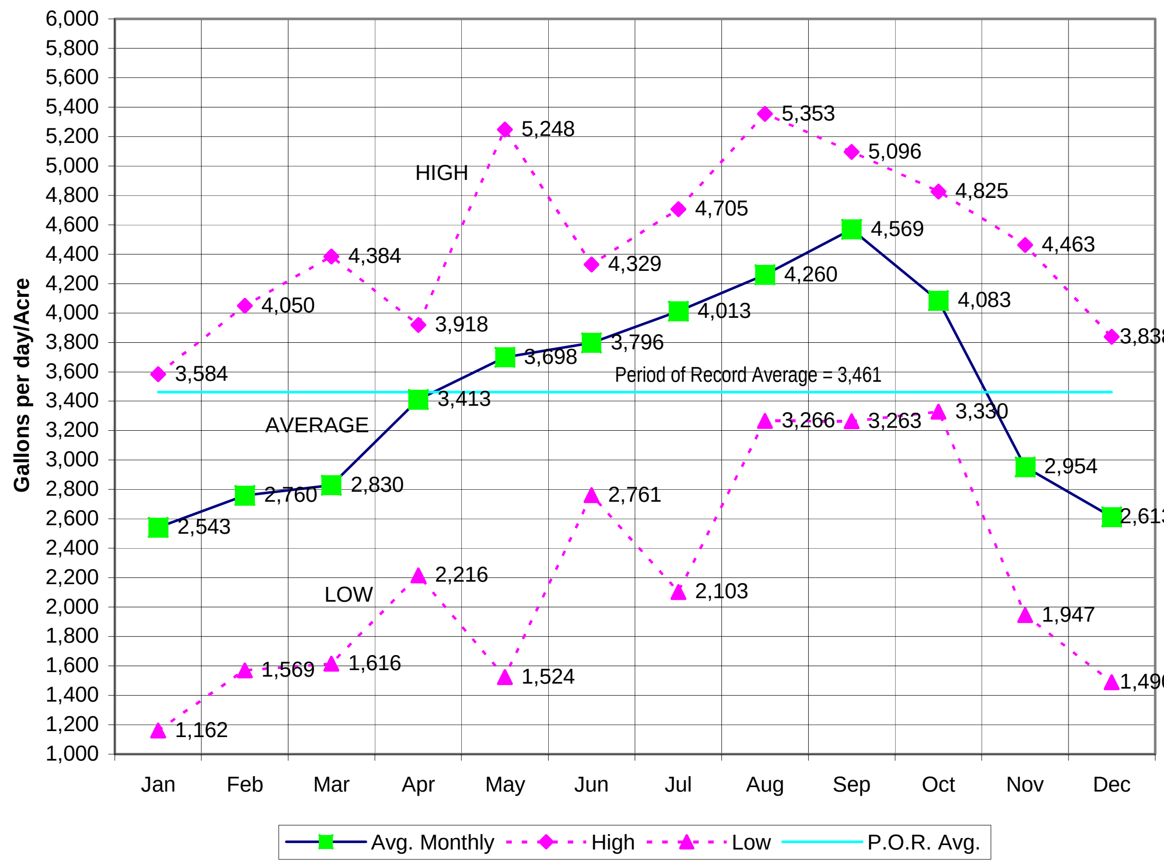



Table 4 lists irrigation water use rates for individual crop types which have been used by the HDOA's Agricultural Resource Management Division (ARMD) and Agricultural Planning Office as guideline values for agricultural project planning and design during the period 1985-2001. The guideline irrigation water use rates in Table 4 were compiled from many undocumented sources and from field agents of the HDOA and the Cooperative Extension Service of the University of Hawaii by ARMD's Irrigation Program Administrator and HDOA's Planning Office.

**Table 4. HDOA IRRIGATION WATER USE GUIDELINES**

| Crop | Water Use Rate (gpd/acre) | Crop | Water Use Rate (gpd/acre) |
|---|---|---|---|
| Alfalfa/Corn (feed & forage) | 7,700 | Orchids | 3,700 |
| Aquaculture | 145,000 | Papaya | 5,000 |
| Dendrobium | 4,000 | Passion Fruit | 10,000 |
| Field crops (grass & seed) | 6,700 | Pineapple | 1,350 |
| Foliage Plants | 4,000-6,000 | Protea | 2,000-2,500 |
| Forage Crops | 7,400 | Sugarcane (drip) | 6,700 |
| Guava | 4,400 | Sugarcane (furrow) | 10,000 |
| Leafy Vegetables (drip) | 4,050 | Taro (Asian) | 4,000-8,000 |
| Leafy Vegetables (sprinkler) | 5,400 | Taro (dryland) | 5,400 |
| Macadamia Nuts | 4,400 | Taro (wetland) | 80,000-100,000 |
| Nursery (potted plants) | 6,000 | Vegetables | 6,700 |

Source of Data: Unpublished data compiled from various sources by the HDOA, Agricultural Resources Management Division, Irrigation Program Administrator and Planning Office, Office of Chairperson, 1985 – 2001.

## SYSTEMS, SOURCES, AND WATER USE

The 13 thirteen irrigation systems covered in this report are summarized (in terms of their infrastructure, water sources, supply capabilities, storage capacities, potential service areas, and water uses) in Appendices D-1 to D-13. These items were selected to meet the CWRM's Framework Report relating to "Water System Profiles" and "Forecasts" recommendation (see Chapter 18). The data were gathered from published and unpublished reports, tables, maps, correspondence, and anecdotal data from government and private personnel. Verification and field checking of the data were beyond the scope of work for this report, but it is anticipated that future work will be needed to complete this and other phases of work for the Agricultural Water Use and Development Plan. The water sources currently being utilized by the 13 irrigation systems are nearly all from surface water sources, i.e., intakes or diversions on streams. Some of the irrigation systems have ground water sources, which were practical during plantation days when surplus electrical power was available from mill operations, but which are no longer economically viable sources of water supply. Ownership of the active surface water sources is referenced to tax map keys, or to tax map plat numbers in cases where a cluster of sources fall within different parcels of the same tax map plat.

The water supply capabilities of each irrigation system are listed by their major infrastructure features including diversion or intake capacities, ditch or pipeline transmission capacities, and storage capacities. As used in this report, the water supply of each system is considered to be the rated carrying capacity of the transmission pipeline or ditch.

The former plantation irrigation systems provided water not only for agricultural purposes, but also for non-agricultural uses such as domestic needs, mill operations, and hydropower generation. Except for the East Maui System which continues to be used for sugarcane irrigation, current use of many former plantation systems has shifted from sugarcane to diversified agriculture. Secondary water uses continue to include domestic purposes, hydropower generation, and landscape irrigation. The water use shown in Appendix D are not actual measured quantities (except as noted), but estimates based upon anecdotal data from system operators or calculated from the acreage served multiplied by the previously used irrigation water application rate of 2,500gpd/acre. The uses of the systems listed in Appendix D are those presently known, but not field checked. Development of a more accurate and complete data base on existing water use and acreage irrigated will require a significant amount of field work and survey of farmers for current information on actual acreages farmed, types of crops grown, estimate or metering of amounts of water used, and estimates or measurements of irrigation water application rates. Estimates of system operational and unaccounted for water losses are also field data that will need to be collected to determine overall system water demand, as opposed to net water demand delivered to system users. In addition, evaporation losses from open ditches and reservoirs will need to be evaluated. These losses need to be quantified as "system losses" for each individual irrigation system. Large open bodies of water can evaporate a significant quantity of water, as studies indicate that the 1.4 billion-gallon Kualapuu Reservoir on Molokai loses one million gallons of water per day.

In Appendix D, under the column heading of "potential service area", the acreage listed represents the irrigable land area for which each irrigation system was originally designed to serve (see respective irrigation systems maps), and also the maximum amount of land potentially suitable for diversified agriculture farming and irrigation.

The overall sparseness of data compiled in Appendix D clearly indicates the need for future field work to conduct a comprehensive analysis of agricultural existing water use, water demand forecasts, and source development needs and options over a 20-year planning period as envisioned for the HDOA's Agricultural Water Use and Development Plan set within the Hawaii Water Plan Framework guidelines of the CWRM.

# Chapter 20.  AGRICULTURAL WATER DEMAND FORECAST

## PLANNING CONSIDERATIONS

***Potential New Diversified Crops.*** Former sugarcane fields now lying fallow or being used on an interim basis for alternative uses, such as cattle grazing, are a great resource for establishing new diversified crops not yet grown on any significant commercial level in Hawaii.  Among the most promising new crops are the traditional fresh greens and herbs consumed by Hawaii's Asian immigrant population.  The following is a list of potential new crops:  Vietnamese mints (sprigs), bottle gourd, Thai taro root, green papaya, lemon grass, silk squash, winged asparagus bean, palm sugar, amarath spinach, shallot bulb, gai lan broccoli, durian fruit, Bac Ha or Khoon (zuiki), garlic chive flower, black-eyed pea pods, parsley roots, Kaffir leaves, Hadun/Madun, Kha or galangal and chayote squash.

There is some interest in expanding the existing seed crop (corn) industry to growing other seed crops such as sorghum, barley, sunflower, grasses, and legumes (soy beans and peas).  Some market analyses indicate that fresh tropical specialty fruits (rambutan, cherimoya, lychee, etc.) have great potential for market expansion both in Hawaii and the U.S. mainland. The market for these new crops should be developed within the State until sufficient information and demand can be established through contacts with U.S. mainland or other overseas marketing areas.  The consumptive water demands required to grow these crops should be determined through research or anecdotal data from actual farming.

***Niche and Off-Season Market Development.*** With a year-round growing season, certain fresh vegetables and fruits can be grown in Hawaii to meet niche or off-season markets for export.  For example, some pilot shipments have already proven successful such as the export of locally grown fresh green beans and bell peppers to Canada during the winter season; locally grown fresh strawberries for local hotel restaurants in the spring and winter seasons; and locally grown fresh fruits (avocado, mango, and navel orange) for local as well as west coast markets.  Aquaculture is yet another possibility which has proven feasible for the use of low-lying former sugarcane lands (Kahuku on Oahu and Kekaha on Kauai).

The niche and off-season markets exist throughout the U.S. and Canada, but the marketing development effort isn't readily apparent without more capital investment and time. The coordination needed for the growing, packing, shipping, and selling requires a multidisciplined effort not possible through a single entity. But such markets have significant potential for expansion of Hawaii's agriculture industry.

This report also considered annual specialty event markets which generate a spiked, but significant demand for fresh fruits, vegetables, and flowers. These occasions include St. Patrick's Day (*cabbage*), Halloween (*pumpkin*), Secretary's Day (*flowers and restaurant produce*), Christmas (*fruit baskets*), New Year's (*flowers and produce*), Easter (*flowers for cemetery*), Mother's Day (*flowers and restaurant produce*), graduation season (*leis, flowers, party produce*), etc. These spiked demand for fresh fruits, vegetables, and flowers were not factored directly into estimates for additional acreage needed for diversified agriculture.

For this report, the diversified crops selected for expansion were determined by comparing diversified crops currently grown in Hawaii with the market demand for those produce in selected mainland cities. The agricultural acreages needed for expansion were determined from farm values and crop yields per acre reported in the Statistics of Hawaii Agriculture publication prepared by the HDOA-HASS and USDA National Agricultural Statistic Service. Water requirements for the additional acreages were based on the 3,400 gpd/acre irrigation water use rate developed in Chapter 19 for diversified agriculture.

***Import Replacement Crops.*** The most logical way to expand Hawaii's agriculture industry is to focus on the replacement of the large quantities of vegetables and fruits now being imported into the State from overseas (primarily U.S. mainland, South America, and Australia). With the availability of large tracts of former sugarcane lands throughout the State, large irrigation systems widely scattered throughout the State, and an all-season growing climate; now is the perfect time and opportunity to expand Hawaii's diversified agriculture industry. This report has evaluated the data from the Hawaii Agricultural Statistics Service's "Unloads of Fresh Fruits and Vegetables to Oahu in 2003" (Appendix E) and "Market Supply: Imports vs. Local, 1984-2001" (Figures 5a and 5b, Appendix F). The graphs in Figure 5a and 5b indicate the shortfall of locally grown fruits and vegetable supply to the total market supply. After carefully considering such factors as ease of crop production in Hawaii, market feasibility (ease of packaging and shipping), and experienced local farmers with growing the crop, the following diversified crops were determined to have the best potential for replacement of imported produce:

Asparagus
Banana, Cavendish
Bean, green
Bean, long
Broccoli
Burdock
Cabbage, Chinese
Cabbage, red
Cantalope
Carrot
Cauliflower
Celery
Corn, sweet
Cucumber
Dasheen
Eggplant, round
Garlic
Ginger Root
Grapefruit
Grapes, table
Leek
Lemon
Lettuce, head
Lettuce, other
Lettuce, red
Lettuce, Romaine
Lime
Lotus Root
Mango
Onion, dry
Onion, green
Orange
Parsley, American
Parsley, Chinese
Pea, Sugar Snap
Peanut
Pepper, hot
Pepper, sweet
Persimmon
Potato, chips
Potato, sweet
Potato, table
Radish
Spinach, American
Squash
Squash, Kabocha
Strawberry
Tangerine
Tomato
Tomato, plum
Watermelon, seedless
Yam Bean Root

**Figure 5a. FRESH VEGETABLES MARKET SUPPLY: Imported vs. Locally Grown**

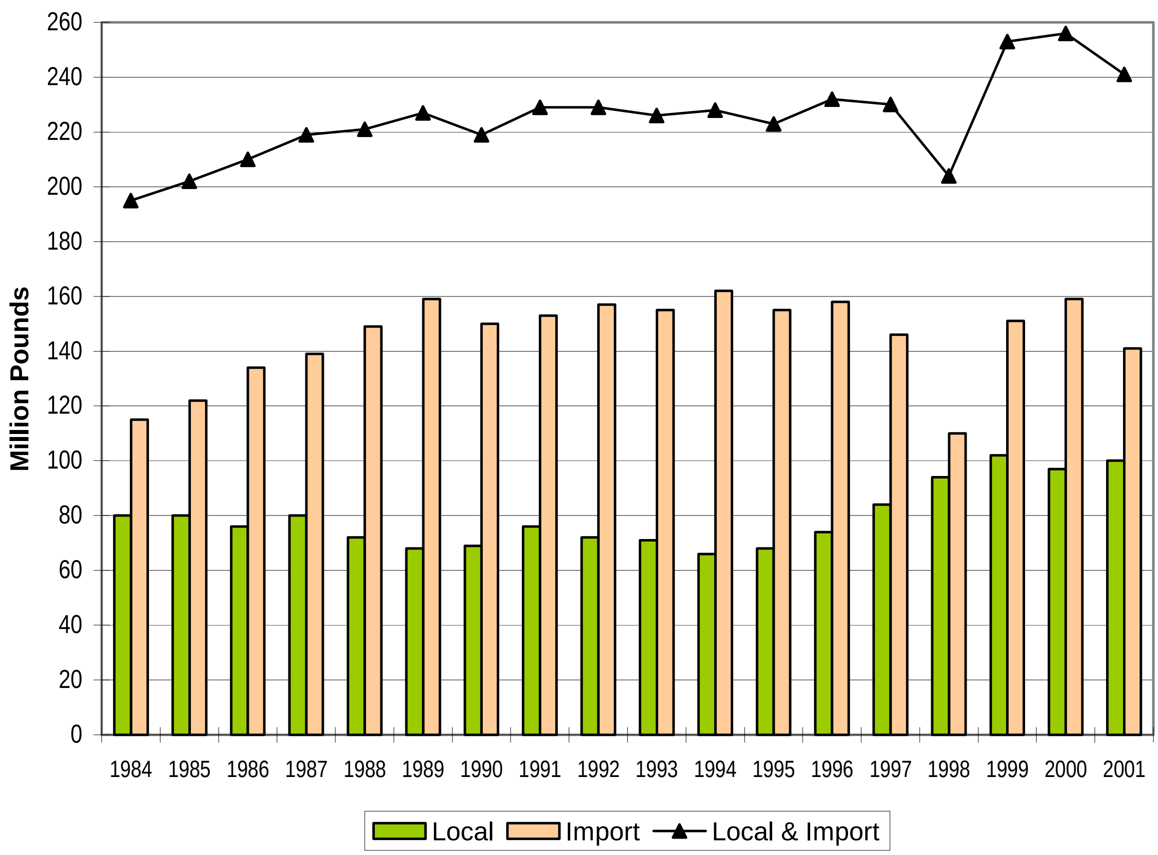
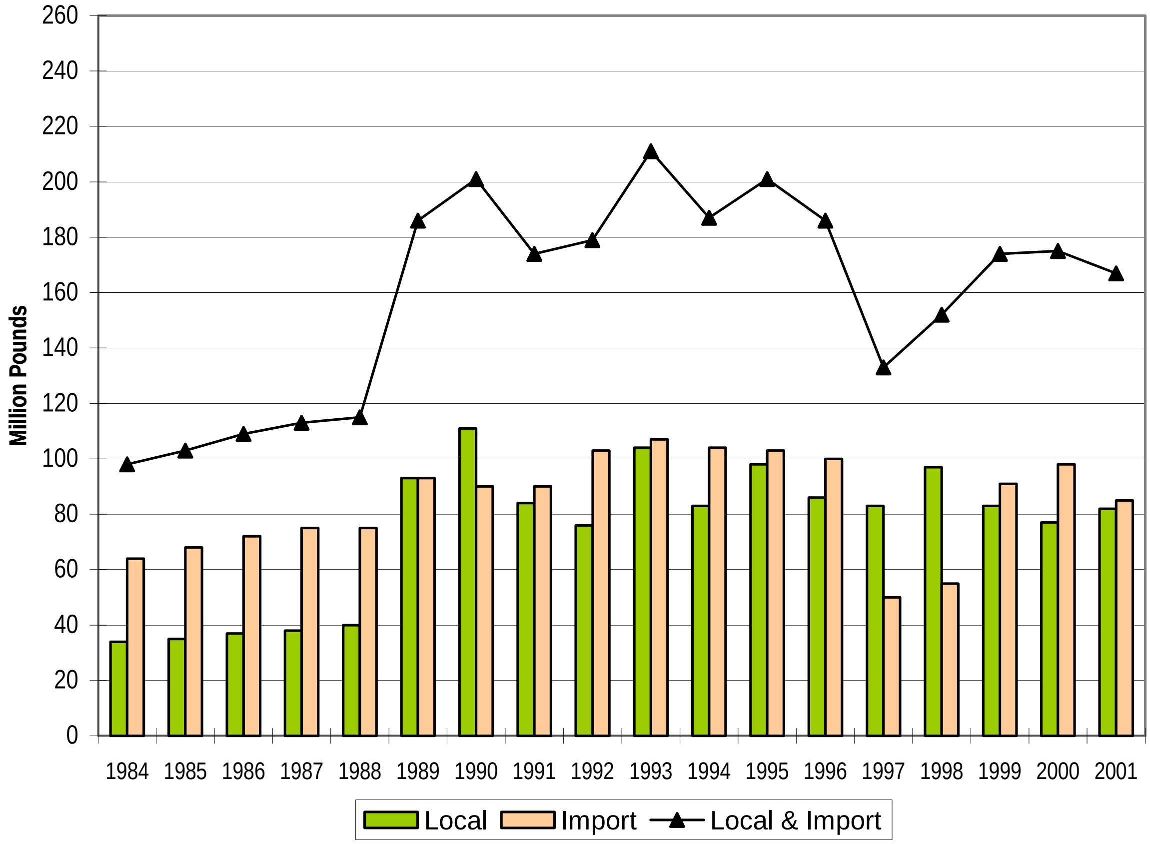


**Figure 5b. FRESH FRUITS MARKET SUPPLY: Imported vs. Locally Grown**




Because the marketing program of the above crops is not developed, it is conceptualized that croppings begin in incremental phases. The initial start-up phase would be to open irrigable agricultural plots in small increments of 15 to 20-acre size for each crop and to allocate acreages to all the islands with irrigation systems studied in this report. The goal would be to achieve an overall 5 to 10 percent replacement of imported produce in the initial period and at least 40 percent over the 20-year forecast period.

It is noted that for fruits the shortfall or import replacement potential isn't as large as that for fresh vegetables. The reason for this is that several locally grown fruit crops, i.e., pineapple, papaya, and macadamia nut include significant exports. However, when these exports are discounted, shortfalls are more evident.

Development of a plan to export fresh fruits and other agricultural commodities overseas is a more difficult task. Presently, the following commodities are exported:

| | |
|---|---|
| Fresh Pineapple | Protea |
| Seed Corn | Variety of potted nursery plants |
| Papaya | Processed Guava |
| Orchid | Macadamia Nut |
| Anthurium | Limited quantities of various |
| Ginger Root | flowers/fruits |

Since export markets for these commodities already exist, it would be more feasible to concentrate initial efforts to increase diversified agriculture exports on the above commodities until the diversified agriculture industry can find entrepreneurs willing to invest in the development of new markets for other fresh produce and fruits.

For export of fruits and commodities, this report suggests a target goal of increasing exports during the initial period by 5% to 10% for the following selected crops:

Seed Crops (corn, grains, and grasses)
Papaya
Specialty tropical fruits
Potted nursery plants.

***Economic Supply and Demand Analysis.*** For decades, consumption of fresh vegetables and fruits in Hawaii has followed national trends. However, with strides in modern technology the freshness and preservation of fresh fruits and produce have improved to the extent that consumption is greater, more frequent, and over longer periods. Refrigeration, vacuum packaging, and certain value-added processes such as freezing and sun-drying have made produce more easily adapted in every day menus which translates into greater demand. All of the proposed crop developments discussed in previous paragraphs above need to be converted into forecastable demand. The initial attempt to convert forecast demand was to select each crop development activity directly into demand acreages. However, inadequate data and records prevented this approach. The final methodology used in this plan is described later in this Chapter under the section, “Methodology for Estimating Agricultural Water Use.” As might be expected, the farm value and acreage of diversified agriculture in Hawaii shows an increasing trend with a corresponding increase in population (Figure 6, Appendix G). This relationship together with the market supply data in Appendix F and the per capita consumption of fresh fruits and vegetables data in Appendix H were used in this report to forecast the rate of increased demand in Hawaii’s diversified agriculture and to estimate the diversified farm acreage that would be needed to meet such demand, based upon a projected increase in population. The growing interest in a healthy life style, fitness, and wellness favors an increasing consumption of fresh fruits and vegetables which is reflected in the graph in

Appendix H.  This increased health-associated need for greater quantities of fresh fruits and vegetables, coupled with that associated with the projected increase in population (Table 5) are the basis for forecasting increase in Hawaii's diversified agriculture farm value of 3% to 5% annually.  There is a logical relationship between increase in farm value and increase in cultivated acreage which can be used to calculate the additional acreage needed by assuming that the past growth rate in farm value will continue through the 20-year planning period.

Although the additional acreage needed to accommodate the increase in fresh vegetable and fresh fruit demand based on maintaining the past growth rate is not as significant as the acreage based on import replacement, it needs to be accounted for in this plan.  The methodology for determining the additional acreage requirement based on the past growth rate in farm value is discussed later in this report.

**Figure 6.  FARM VALUES OF DIVERSIFIED AGRICULTURE IN HAWAII 1984-2001**

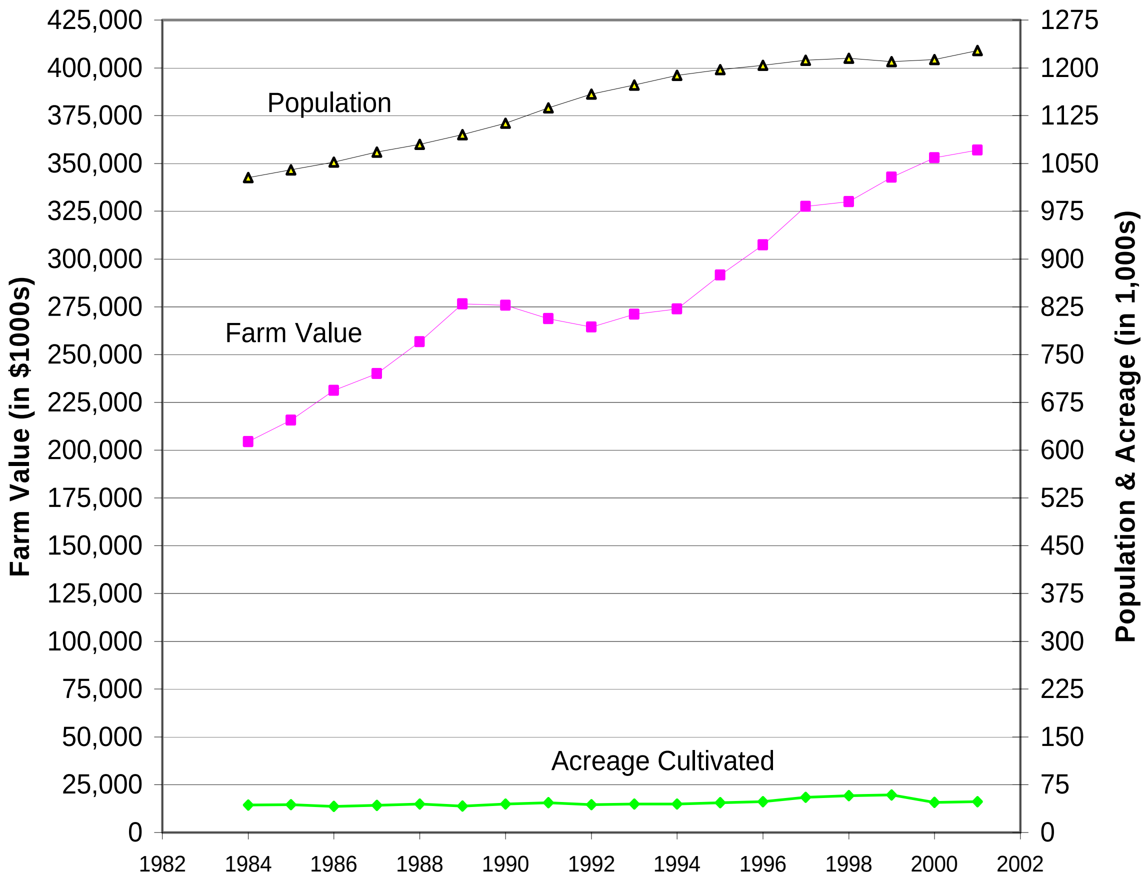


**Table 5. RESIDENT POPULATION PROJECTIONS BY COUNTIES: 1998 to 2025**

| Year | State Total | City & County of Honolulu | Other Counties | | | |
|---|---|---|---|---|---|---|
| | | | Total | Hawaii | Kauai | Maui* |
| Resident Population (1,000s):** | | | | | | |
| 1998 | 1190.5 | 868.2 | 322.3 | 143.6 | 56.7 | 122.1 |
| 2000 | 1197.3 | 872.9 | 324.4 | 144.6 | 57.2 | 122.6 |
| 2005 | 1236.1 | 895.6 | 340.5 | 151.4 | 60.5 | 128.6 |
| 2010 | 1291.1 | 929.2 | 361.9 | 159.6 | 65.8 | 136.4 |
| 2015 | 1349.1 | 964.8 | 384.3 | 168.3 | 72.0 | 144.0 |
| 2020 | 1406.2 | 999.4 | 406.0 | 176.9 | 78.7 | 151.2 |
| 2025 | 1461.6 | 1029.8 | 431.8 | 187.7 | 85.4 | 158.7 |
| Percent of State Population: | | | | | | |
| 1998 | 100% | 72.9% | 27.1% | 12.1% | 4.8% | 10.3% |
| 2000 | 100 | 72.9 | 27.1 | 12.1 | 4.8 | 10.2 |
| 2005 | 100 | 72.5 | 27.5 | 12.2 | 4.9 | 10.4 |
| 2010 | 100 | 72.0 | 28.0 | 12.4 | 5.1 | 10.6 |
| 2015 | 100 | 71.5 | 28.5 | 12.5 | 5.3 | 10.7 |
| 2020 | 100 | 71.1 | 28.9 | 12.6 | 5.6 | 10.8 |
| 2025 | 100 | 70.5 | 29.5 | 12.8 | 5.8 | 10.9 |

* Includes Kalawao.

**The resident population is defined as the number of person whose usual place of residence is in an area, regardless of physical location on the estimate or census date. It includes military personnel stationed or homeported in the area but excludes persons of local origin attending school or in military service outside the area.

Source: Hawaii State Department of Business, Economic Development & Tourism, Population and Economic Projects for the State of Hawaii to 2025 (Website 2004)

***Recent Developments.*** Economic developments, not related to the normal population growth rate, have recently been announced and reported by government and military officials and the news media. Various planned activities, which are scheduled to begin within the next three to ten years, will result in increased demand for fresh fruits and vegetables. Some of the activities are discussed below for completeness, but were not included in the forecast. However, future updates of this Plan may have access to pertinent data on these developments.

The recently announced passenger cruise ship activity in Hawaii will create a new market for very large quantities of fresh produce. According to published news articles the three cruise lines Princess, Holland America, and Norwegian will serve Hawaii. Indications are that each cruise ship will have a capacity of up to 2,000 passengers and a maximum crew of up to 800. This may require fresh fruits and vegetables amounting to the equivalent need of up to 10 restaurants added to the Hawaii market. Norwegian Cruise Lines plans to home port up to four new cruise ships in Hawaii. Such plans, if realized, could translate into an equivalent annual population of 240,000 persons (2,000 passengers + 500 crew members x 4 ships x 24 cruises per year).

Military housing and defense construction will escalate in the next two to five years, such that construction and skilled trade workers will need to be imported from out of state. Estimates are that Hawaii may need up to 65,000 construction workers of which presently there is only 25,000 locally available. Consequently, up to 40,000 workers may need to be imported. Some of the imported workers will probably bring dependents and this might double or triple the 40,000 figure. However, the duration of their stay will be short and may encompass only a small portion of the planning period.

A build-up of military forces in Hawaii has been announced. The U.S. Army plans to station a Stryker Brigade in Hawaii, the U.S. Air Force plans to station a squadron of C-17 aircraft at Hickam, and the U.S. Navy is contemplating home porting an Aircraft Carrier Battle Group at Pearl Harbor with its Air Wing to be stationed somewhere in the State. The above three deployments of military personnel to Hawaii is estimated to increase Hawaii's population by 18,930 persons (Stryker, 810; C-17 squadron, 500; and Aircraft Carrier Battle Group, 5,000 with an estimated average of two dependents per person). Development of Ford Island into a rest and recreation base is currently underway and may contribute further to the military population by an estimated 1,000 persons. Altogether, the deployment of military personnel and development of Ford Island amounts to an increase in population of 19,930. This anticipated increase in Hawaii's population is also expected to increase the demand for fresh fruits and vegetables.

For this report, the anticipated population increase based on the above activity was not included in the acreage requirements for the 20-year planning period.

The growth of Hawaii's tourism industry is not expected to result in a large increase in demand for fresh fruits and vegetables over current use, but some consideration is needed in forecasting long-term (10 and 20 year) requirements for fresh produce. For this report the visitor count growth rate was not taken into account, but should be included in future updates of the AWUDP.

***Future of Monocrop Industry.*** Pineapple will experience a shift from canned to fresh fruit sales. Fresh pineapple will remain one of the main export crops of Hawaii's diversified agriculture industry. With ample agricultural acreage available from former sugarcane lands, expansion of Hawaii's fresh pineapple crop is anticipated, especially on Oahu and Maui where large pineapple companies already exist. Additional acreages have been added in some areas, namely, Kunia and Wahiawa on Oahu and Lahaina on Maui. However, research to determine market and acreage requirements for fresh pineapple was not included in the scope of this report, but should be considered in the future when funds become available.

Sugarcane cultivation is now confined to only two growers, both with mill operations. On Kauai, Gay & Robinson, Inc. has added approximately 4,000 acres to its operations by re-opening old fields on the slopes above Kekaha, once utilized by the former Kekaha Sugar Plantation. On Maui, Hawaiian Commercial & Sugar Co., is the other remaining sugar operation. Enactment in 2004 of a new Hawaii Statute authorizing the use of Ethanol as a mixture with gasoline to be used as motor vehicle fuel will have great impact on the potential growth for sugarcane cultivation. Studies, research, and experiments conducted by several separate groups indicate sugarcane processing can be adapted to maximize the production of fermentable sugars, i.e., glucose, fructose, sucrose and xylose. This is done by utilizing all byproducts from processing sugarcane, such as molasses, bagasse, and "left in the field" cane stock. Estimates of the acreage needed for a 25 MG per year ethanol plant range from 7,600 to 15,300 acres of sugarcane (U.S. Department of Energy, Hawaiian Sugar Plantations Association and State sponsored trail plantings for the Biomass to Energy project).

Based on the assumption that ethanol production and use will become viable in Hawaii, the world sugar market, national sugar subsidy, and current sugar prices; there is potential for some increase in sugarcane cultivation within the 20-year planning period. In future updates of the Plan, this should be evaluated in the water demand forecast.

## METHODOLOGY FOR ESTIMATING AGRICULTURAL WATER USE

***HDOA Irrigation Water Use Guidelines.*** Prior to the Waiahole Contested Case, agricultural water planning relied on pre-determined water use rates as described below. Table 4 in Chapter 19 lists the consumptive irrigation water use rates for selected crops and grasses that have been compiled and used by the Hawaii Department of Agriculture's Agricultural Resource Management Division (ARMD) and Agricultural Planning Office since 1985. Most of the guideline values in Table 4 reflect the unique growing conditions of Hawaii's volcanic soils and tropical climate and were used to calculate agricultural water use, in instances where water records were unavailable, by multiplying the rate times the acreage in cultivation.

The ARMD has also developed irrigation water use rates in its program of planning and developing irrigation systems and agricultural parks. Such water use rates serve as an engineering tool to estimate irrigation water demand for agricultural development projects and for preliminary engineering design of source developments, transmission pipelines, storage reservoirs, and other related facilities. The two values used by the ARMD include:

- Preliminary project planning (for water source development): 5,000 gpd/acre
- Preliminary design of irrigation facilities (for sizing pipes and reservoirs): 2,500 gpd/acre

These two values have been used in the past to do preliminary planning of agricultural water projects and to develop capital improvement program (CIP) budgets for legislative purposes. The HDOA water use guidelines shown above and in Table 4 are included in this report as optional data and for completeness. However, the Supreme Court rulings in the Waiahole Case set new precedent which basically invalidated previously set water duties, for instance when water use permit involves streamflows in designated water management areas. In order to meet this new precedent regarding agricultural water duty, existing metered irrigation water use data needed to be analyzed to arrive at a useable agricultural water duty for diversified agriculture in order to complete the Plan's long-term water use forecasts. As presented in Figures 3 and 4, HDOA's irrigation water use data was used to arrive at the water duty as described below. Currently, the Supreme Court's acceptable water duty for diversified agriculture is 2,500 gpd/acre and this is reflected in Appendices D-1 through D-13 which cover existing water uses.

***Determining Irrigation Water Use Rate (Diversified Agriculture).*** One of the most practical and effective methods of estimating agricultural water use is to measure the amount of irrigation water applied to a crop or general group of crops, such as meant by the term "diversified crops" and "diversified farming" under actual conditions of the farmed land and routines of the farmer. Contrary to past irrigation practices in Hawaii, agricultural water use is more and more being metered as irrigation system improvements are carried out and as required by system operators and the State Water Code. With the keeping of monthly records of metered water use and the corresponding acreage irrigated, sufficient data is being collected in which the rate of application of irrigation water, expressed as gallons per day per acre (gpd/ac), can be determined, especially for diversified agriculture farming. In fact, the HDOA-operated irrigation systems have accumulated many years of such monthly records, as mentioned in Chapter 19; and an analysis of the Lalamilo Section of the Waimea Irrigation

System where farming of diversified crops by dedicated, full-time farmers has continued for many years, a reliable average value (based upon eight years of records) of **3,400 gpd/acre** (rounded from 3,461) was determined to be the application rate of irrigation water use for diversified crop farming at Lalamilo (for details refer to Figures 3 and 4). Farming of diversified crops, such as at Lalamilo, involves active cultivation of the land in growing a commercial crop throughout the crop's growing cycle, which, depending on the crop, may include several harvesting cycles during a calendar year. Portions of the land may be rotated out of cultivation and left unirrigated for a short period of time as part of routine farming activities. The figure, 3,400 gpd/acre, is the best available estimate for diversified crop farming in Hawaii. Consequently, it was used in forecasting agricultural water demand in this report and should be used until refined by future records and analyses. The figure, 3,400 gpd/acre, is tempered by an acceptable level of conservation practices, including the HBOA administrative rules governing HDOA irrigation systems' conservation action, the HDOA's metering, and the monitoring of individual farm water connections and billings. Unlike unmetered water use by Hawaii's former monocrop growers, conservation of water by most farmers today is inherent in the metered cost of water. Currently, the cost of agricultural water use is 33½ cents per 1,000 gallons for HDOA operated systems.

***Determining Agricultural Acreage Required.*** Based upon the goals and objective discussed in this Chapter, the additional acreage required for diversified agriculture was determined as the second step in forecasting agricultural water demand for the 20-year planning period. However, due to time constraint and limited funds, the methodology used to estimate the additional acreage required to meet Hawaii's future diversified agriculture needs was limited to an analysis of three factors: (1) annual population projections, (2) replacing imported fresh vegetables and fruits, and (3) maintaining past growth rate of farm values. Data and information obtained from the Hawaii Agricultural Statistics annual publications and various reports by HASS and HDOA were used in developing the methodology.

In this report, the planning period for water demand forecasts begins with the year 2001 because the various baseline data used for calculating and forecasting were available only up to 2001, whereas the various data for 2002 and 2003 were missing, consisted of estimates, or subject to updating, which made it difficult to obtain a reliable baseline to the year 2003 from which to begin the planning period. Thus, the initial five-year planning period includes the years 2001 to 2006 in annual increments; the second 5-year period, 2007 to 2011; the third 5-year period, 2012 to 2016; and the fourth 5-year period 2017 to 2021. In the initial 5-year period, expansion is forecasted or anticipated to grow at a slow to moderate pace. A period of adjustment is assumed wherein there would be little cohesiveness, organizational effort, or agricultural activity among irrigation water users, and wherein many false starts and crop experimentations might occur. Difficulties in financing farm activities and locating people interested in farming are also two major factors which might delay any quick or start-up farming developments during this initial period.

The additional acreage requirement for diversified agriculture (based on annual population projections) for the 20-year planning period was derived in several steps. First, using available data shown in Appendix G, an average rate of population increase for the 5-year period (1997-2001) was calculated and used to project the annual population for the 20-year planning period (see Table 5). Secondly, the 5-year (1997-2001) per capita consumption data of fresh fruits and vegetables shown in Appendix H was used to project the per capita consumption of fresh fruits and vegetables for the 20-year planning period and based on the annual population projections, the annual fresh fruit and vegetable consumption in pounds were obtained. Thirdly, to convert annual consumption (pounds per capita) to the additional acreage required based on population (see Table 6a), the fresh fruit and vegetable yield (pounds/acre) data in Appendices J and K were used. The assumption is made that increased consumption of fresh fruits and vegetables occurs with increased population.

The additional acreage requirement for diversified agriculture (based on import replacement) shown in Table 6a was derived using the data in Figures 5a and 5b to obtain import replacement (in pounds) and using Appendices J and K (yield in pounds/acre) to determine the additional acreage required for import replacement.

The additional acreage requirement (based on maintaining the past growth rate in diversified agriculture) was derived by using the 1997-2001 average rate of increase of farm values shown graphically in Figure 6 (red line) and the corresponding farm acreages shown in Appendix G to calculate the annual growth rate over the 20-year planning period. The additional acreage required (based on maintaining past growth rate of farm value) assumes that future consumptions of fresh fruits and vegetables will continue to grow at the same rate as in the past. Authors assumed that maintaining past growth rate in farm value will need some new acreages over the 20-year planning period. It may, in some cases, overlap the acreages that were projected on the basis of import replacement and population.

It is impractical to assume for planning purposes, that 100 percent of the imported supply of produce can be replaced by locally grown crops. One of the main reasons for this is that not all crops can be produced economically and marketed on a competitive basis with oversea sources. For example, a large market for a particular crop, like carrots and potatoes, would dictate the pricing. Also, certain crops may be unsuitable for import replacement due to their unique drawbacks; for example hay is difficult to dry due to Hawaii's humidity, and fruits such as peaches and plums are prone to disease (such as fruit fly infestation) related to Hawaii's tropical climate. All of such factors were taken into account and adjustments made in the calculations and estimates of the acreage requirements shown in Table 6a.

In Table 6a, the estimates of additional acreage that will be needed to meet Hawaii's diversified agriculture needs during the 20-year planning were broken down into two categories based upon a "best case" scenario and a "worst case" scenario. These two scenarios were developed to provide consistency with the CWRM's framework element for forecasting agricultural water demand for multiple scenarios as outlined in Chapter 18. As stated earlier, not all of Hawaii's imported fresh fruits and vegetables can be replaced by locally grown supply. Therefore, the best case scenario was conservatively based upon the current percentage of the total market supply that is currently met by locally grown crops of fresh fruits and vegetables (see Appendix I). This percentage is based on the assumption that many fresh fruits and vegetables, although having a local demand as an import, may not be competitively grown locally. For the worst case scenario, a review of studies by others on continued development of farming shows that status quo operations generally range between 10 and 20 percent. Again, taking the conservative approach, 10% was assumed for the worst case scenario.

**Table 6a. ADDITIONAL AGRICULTURAL ACREAGE NEEDED, 20-YEAR PERIOD**

| Planning Period | Scenario % | Acres | | | |
|---|---|---|---|---|---|
| | | Based on Population | Based on Import Replacement | Based on Maintaining Past Growth Rate | Total |
| 1st Year | Best (40%) | 1,138 | 0 | 310 | 1,448 |
| | Worst (10%) | 282 | 0 | 74 | 356 |
| 2nd Year | Best (40%) | 1,138 | 0 | 310 | 1,448 |
| | Worst (10%) | 282 | 0 | 74 | 356 |
| 3rd Year | Best (40%) | 1,138 | 670 | 310 | 2,118 |
| | Worst (10%) | 282 | 168 | 74 | 524 |
| 4th Year | Best (40%) | 1,138 | 670 | 310 | 2,118 |
| | Worst (10%) | 282 | 168 | 74 | 524 |
| 5th Year | Best (40%) | 1,138 | 1,340 | 310 | 2,788 |
| | Worst (10%) | 292 | 335 | 74 | 701 |
| 2nd 5-Yr. | Best (40%) | 4,680 | 2,010 | 1,548 | 8,238 |
| | Worst (10%) | 1,170 | 503 | 387 | 2,060 |
| 3rd 5-Yr. | Best (40%) | 4,936 | 2,010 | 1,548 | 8,494 |
| | Worst (10%) | 1,234 | 503 | 387 | 2,124 |
| 4th 5-Yr. | Best (40%) | 4,864 | 2,680 | 1,548 | 9,092 |
| | Worst (10%) | 1,216 | 670 | 387 | 2,273 |

The estimated agricultural acreage available to meet the forecasted increase in diversified agriculture for each of the 13 irrigation systems included in this report is shown in Table 6b. The available acreage was derived by estimating the lands currently being utilized by each individual system as a percent of the known total acres formerly served. The in-use acreage data was taken from Appendices D-1 through D-13. In these appendices the existing water use shown in the last column was logically based on the currently acceptable water duty of 2,500 gpd/acre.

**Table 6b. AGRICULTURAL ACREAGE AVAILABLE**

| Irrigation System | Total Acres | Acreage in Use | | Unused Acreage |
|---|---|---|---|---|
| | | Estimated Percent | Acres | |
| East Kauai | 5,922 | 40 | 2,369 | 3,553 |
| Kekaha Ditch | 6,566 | 60 | 3,940 | 2,626 |
| Kokee Ditch | 3,519 | 72 | 2,527 | 992 |
| Pioneer Mill* | 3,533 | 30 | 1,060 | 2,473 |
| Waiahole Ditch | 6,270 | | 1,569** | 4,701 |
| Lower Hamakua Ditch | 4,765 | nd | na | |
| Molokai | 9,885 | | 3,102** | 6,783 |
| Upcountry Maui | 1,751 | nd | na | |
| Waimanalo | 1,601 | | 1,177** | 424 |
| Waimea | 1,367 | | 550** | 817 |
| East Maui | 33,026 | 70 | 23,118 | 9,908 |
| Kauai Coffee | 4,698 | 50 | 2,349 | 2,349 |
| West Maui | 5,400 | 60 | 3,240 | 2,160 |

* Does not include Maui Land & Pineapple Co. figures.
**Actual use.
nd – no data
na – not applicable

***Determining Agricultural Water Demand.*** The third and final step to estimating agricultural water demand for diversified crop farming is simply to multiply the acreage required by the irrigation water application rate of 3,400 gpd/acre. It is assumed that the amount of water applied is based upon good farming practices to meet only the consumptive needs for plant growth and upon good conservation practices encouraged by the economic cost of the water. Consequently, the figure of 3,400 gpd/acre is considered to be a practical consumptive water use rate which does not include irrigation system water losses. Irrigation system water losses, which would require a comprehensive field investigation of flow measurements and analyses, have not been studied by the HDOA.

## WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE

The additional acreage required for diversified agriculture farming for the 20-year planning period was estimated for the State as a whole (see Table 6a). Then, based on the estimated acreage available (see Table 6b), the acreage total and corresponding agricultural water demand forecasts were divided among the individual islands and irrigation systems over the 20-year planning period as shown in Tables 6c and 7a to 7e. The AWUDP is intended to be used to: (1) rehabilitate the irrigation systems, (2) provide a plan for future expansion of the systems to meet the forecasted water demand, and (3) fulfill the obligation to comport with the Hawaii State Water Plan. However, because a majority of the acreages assigned in Tables 7a to 7e are privately owned and controlled, these tables and the AWUDP as a whole can serve only as a guide rather than a plan until forecasted acreage and allotments are accepted and adopted by the affected private land owners. The forecasted acreage and associated water demand presented in Tables 7a through 7e reflect incremental increases for the specified periods. For example, each acreage shown is the acreage required for the year and scenario under which it is listed and is in addition to the existing acreage in cultivation.

Although the research and analyses conducted in this report were constrained by time and availability of funds, the authors believe that the calculated results presented in Tables 7a to 7e are reasonable estimates of the forecasted acreages during the 20-year planning period. Acreage forecasts for specific diversified crops were not within the scope of this report. Instead, the acreage forecasts were for diversified agriculture as a whole, based upon population projections, partial replacement of imported produce with locally grown produce, and maintaining farm value growth in diversified agriculture.

**Table 6c. ASSIGNMENT OF ADDITIONAL ACREAGE (in acres)**

| Year | Scenario | Maui (10%) | Kauai (40%) | Molokai (5%) | Hawaii (20%) | Oahu (25%) | Total (100%) |
|---|---|---|---|---|---|---|---|
| 1st | Worst | 36 | 132 | 18 | 72 | 89 | 356 |
| | Best | 145 | 580 | 72 | 290 | 362 | 1,448 |
| 2nd | Worst | 36 | 132 | 18 | 72 | 89 | 356 |
| | Best | 145 | 580 | 72 | 290 | 362 | 1,448 |
| 3rd | Worst | 52 | 209 | 26 | 104 | 130 | 524 |
| | Best | 181 | 797 | 106 | 414 | 530 | 2,118 |
| 4th | Worst | 52 | 209 | 26 | 104 | 130 | 524 |
| | Best | 212 | 797 | 106 | 414 | 530 | 2,118 |
| 5th | Worst | 70 | 280 | 35 | 140 | 175 | 701 |
| | Best | 279 | 1,115 | 139 | 558 | 697 | 2,788 |
| 5-Year Planning Periods | | | | | | | |
| 2nd | Worst | 206 | 824 | 103 | 412 | 515 | 2,060 |
| | Best | 524 | 3,295 | 412 | 1,648 | 2,060 | 8,238 |
| 3rd | Worst | 212 | 850 | 106 | 424 | 530 | 2,124 |
| | Best | 849 | 3,378 | 425 | 1,688 | 2,125 | 8,494 |
| 4th | Worst | 227 | 909 | 114 | 454 | 568 | 2,273 |
| | Best | 909 | 3,636 | 455 | 1,818 | 2,273 | 7,544 |

Note: Acreage assigned to available service areas of the irrigation systems included in this report. Any unassigned acreages included under “Other Private Irrigation System Not Covered.”

The overall forecasted acreages were arbitrarily allocated on a weighted basis by island and then by individual irrigation systems. It is important to note that there are several other private irrigation systems that have not been included in this report and consideration should be given to assigning some of the forecasted acreage requirements to such irrigation systems in a future report. In allocating overall forecasted acreage requirements to the different islands and irrigation systems, the authors took several factors into consideration: (l) climate and growing conditions (wind and solar radiation), (2) proximity to transportation facilities and market, (3) availability of water, (4) availability of irrigable agricultural land, and (5) personal knowledge of the various irrigation systems. Some acreage allowance was made under “unassigned” category in Tables 7a and 7b. Not taken into account is the availability of willing farmers, marketing conditions, transportation and shipping conditions, and pricing. This report provides a snapshot of the potential growth and irrigation water needs of the diversified agriculture industry in Hawaii, based upon current knowledge and conditions.

However, due to the uncertainty of economic conditions and policy changes in the years ahead, the forecasts are subject to change. Consequently, this AWUDP report is a dynamic document which must be viewed and used as a basis for highlighting the needs and guiding the growth and development of Hawaii's diversified agriculture industry.

Based upon the goals and objectives developed under the planning considerations section of this chapter, the acreage forecasts were calculated for the State as a whole. The sum of these acreages was then allocated among the 13 irrigation systems included in this report. However, before assigning the acreages to individual irrigation systems, each system was given a cursory evaluation to determine whether or not it was capable of supporting the assigned acreages. Adequate prime agricultural lands are shown in the "idle and available" column of Table 2. In addition to the physical characteristics of the irrigation system, the system's service areas (location, terrain, climate, etc.) were also considered for crop suitability. Lastly, the irrigation system's capacity was reviewed to assure that the assigned crops could be supplied with adequate irrigation water.

## Table 7a. WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE
## Island of Kauai

| | Initial 5-year Planning Period | | | | | | | | | | Second 5-year Period | | Third 5-year Period | | Fourth 5-year Period | | 20-Year Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First Year | | Second Year | | Third Year | | Fourth Year | | Fifth Year | | | | | | | | | |
| Irrigation System | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) |
| **ISLAND OF KAUAI** | | | | | | | | | | | | | | | | | | |
| Worst Case | 132 | 0.45 | 132 | 0.45 | 209 | 0.71 | 209 | 0.71 | 280 | 0.95 | 824 | 2.80 | 850 | 2.89 | 909 | 3.09 | 3,545 | 12.05 |
| Best Case | 580 | 1.97 | 580 | 1.97 | 797 | 2.71 | 797 | 2.71 | 1,115 | 3.79 | 3,295 | 11.20 | 3,398 | 11.55 | 3,636 | 12.36 | 14,198 | 48.27 |
| | | | | | | | | | | | | | | | | | | |
| **1. Kekaha Ditch** | | | | | | | | | | | | | | | | | | |
| Worst Case | 50 | 0.17 | 0 | | 50 | 0.17 | 50 | 0.17 | 86 | 0.29 | 200 | 0.68 | 350 | 1.19 | 300 | 1.02 | 1,086 | 3.69 |
| Best Case | 150 | 0.51 | 150 | 0.51 | 250 | 0.85 | 250 | 0.85 | 400 | 1.36 | 800 | 2.72 | 1,362 | 4.63 | 409 | 1.39 | 3,771 | 12.82 |
| **2. Kokee Ditch** | | | | | | | | | | | | | | | | | | |
| Worst Case | 30 | 0.10 | 52 | 0.18 | 50 | 0.17 | 30 | 0.10 | 50 | 0.17 | 200 | 0.68 | 200 | 0.68 | 200 | 0.68 | 812 | 2.76 |
| Best Case | 180 | 0.61 | 180 | 0.61 | 147 | 0.50 | 147 | 0.50 | 150 | 0.51 | 200 | 0.68 | 188 | 0.64 | 0* | | 1,192 | 4.05 |
| **3. Kauai Coffee** | | | | | | | | | | | | | | | | | | |
| Worst Case | 0 | | 30 | 0.10 | 30 | 0.10 | 50 | 0.17 | 44 | 0.15 | 124 | 0.42 | 100 | 0.34 | 109 | 0.37 | 487 | 1.66 |
| Best Case | 50 | 0.17 | 50 | 0.17 | 100 | 0.34 | 100 | 0.34 | 155 | 0.53 | 1,000 | 3.40 | 1,000 | 3.40 | 0* | | 2,455 | 8.35 |
| **4. East Kauai** | | | | | | | | | | | | | | | | | | |
| Worst Case | 52 | 0.18 | 50 | 0.17 | 79 | 0.27 | 79 | 0.27 | 100 | 0.34 | 300 | 1.02 | 200 | 0.68 | 300 | 1.02 | 1,160 | 3.94 |
| Best Case | 200 | 0.68 | 200 | 0.68 | 300 | 1.02 | 300 | 1.02 | 410 | 1.39 | 1,295 | 4.40 | 848 | 2.88 | 0* | | 3,553 | 12.08 |
| **5. Unassigned** | | | | | | | | | | | | | | | | | | |
| Worst Case | | | | | | | | | | | | | | | 0 | | 0 | |
| Best Case | | | | | | | | | | | | | | | 3,227 | 10.97 | 3,227 | 10.97 |

Note: Water Use = acreage x 3,400 gpd/acre.
Acreages shown are additional, not cumulative.

All available acreage assigned.

## Table 7b. WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE
## Island of Oahu

| | Initial 5-year Planning Period | | | | | | | | | | Second 5-year Period | | Third 5-year Period | | Fourth 5-year Period | | 20-Year Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First Year | | Second Year | | Third Year | | Fourth Year | | Fifth Year | | | | | | | | | |
| Irrigation System | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) |
| **ISLAND OF OAHU** | | | | | | | | | | | | | | | | | | |
| Worst Case | 89 | 0.30 | 89 | 0.30 | 130 | 0.44 | 130 | 0.44 | 175 | 0.6 | 515 | 1.75 | 530 | 1.80 | 568 | 1.93 | 2,226 | 7.57 |
| Best Case | 362 | 1.23 | 362 | 1.23 | 530 | 1.80 | 530 | 1.80 | 697 | 2.37 | 2,060 | 7.00 | 2,125 | 7.23 | 2,273 | 7.73 | 8,939 | 30.39 |
| | | | | | | | | | | | | | | | | | | |
| **1. Waiahole Ditch** | | | | | | | | | | | | | | | | | | |
| Worst Case | 50 | 0.17 | 50 | 0.17 | 80 | 0.27 | 80 | 0.27 | 100 | 0.34 | 415 | 1.41 | 459 | 1.56 | 568 | 1.93 | 1,802 | 6.13 |
| Best Case | 302 | 1.03 | 302 | 1.03 | 430 | 1.46 | 430 | 1.46 | 597 | 2.03 | 2,060 | 7.00 | 580 | 1.97 | 0* | | 4,701 | 15.98 |
| **2. Waimanalo** | | | | | | | | | | | | | | | | | | |
| Worst Case | 39 | 0.13 | 39 | 0.13 | 50 | 0.17 | 50 | 0.17 | 75 | 0.26 | 100 | 0.34 | 71 | 0.24 | 0* | | 424 | 1.44 |
| Best Case | 60 | 0.20 | 60 | 0.20 | 100 | 0.34 | 100 | 0.34 | 100 | 0.34 | 0* | 0.00 | 0* | 0.00 | 0* | | 420 | 1.43 |
| **3. Unassigned** | | | | | | | | | | | | | | | | | | |
| Worst Case | | | | | | | | | | | | | 0 | | 0 | | 0 | |
| Best Case | | | | | | | | | | | | | 1,545 | 5.25 | 2,273 | 7.73 | 3,818 | 12.98 |
| | | | | | | | | | | | | | | | | | | |

Note: Water Use = acreage x 3,400 pd/acre.
Acreages shown are additional, not cumulative
All available acreage assigned.

## Table 7c. WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE
## Island of Molokai

| Irrigation System | Initial 5-year Planning Period | | | | | | | | | | Second 5-year Period | | Third 5-year Period | | Fourth 5-year Period | | 20-Year Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First Year | | Second Year | | Third Year | | Fourth Year | | Fifth Year | | | | | | | | | |
| | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) |
| **ISLAND OF MOLOKAI** | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| **1. Molokai** | | | | | | | | | | | | | | | | | | |
| Worst Case | 18 | 0.06 | 18 | 0.06 | 26 | 0.09 | 26 | 0.09 | 35 | 0.12 | 103 | 0.35 | 106 | 0.36 | 114 | 0.39 | 446 | 1.52 |
| Best Case | 72 | 0.24 | 72 | 0.24 | 106 | 0.36 | 106 | 0.36 | 139 | 0.47 | 412 | 1.40 | 425 | 1.45 | 455 | 1.55 | 1,787 | 6.08 |

Note: Water Use = acreage x 3,400 gpd/acre.
Acreages shown are additional, not cumulative.

## Table 7d. WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE
## Island of Maui

| Irrigation System | Initial 5-year Planning Period | | | | | | | | | | Second 5-year Period | | Third 5-year Period | | Fourth 5-year Period | | 20-Year Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First Year | | Second Year | | Third Year | | Fourth Year | | Fifth Year | | | | | | | | | |
| | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) |
| **ISLAND OF MAUI** | | | | | | | | | | | | | | | | | | |
| Worst Case | 36 | 0.12 | 36 | 0.12 | 52 | 0.18 | 52 | 0.18 | 70 | 0.24 | 206 | 0.70 | 212 | 0.72 | 227 | 0.77 | 891 | 3.03 |
| Best Case | 145 | 0.49 | 145 | 0.49 | 181 | 0.62 | 212 | 0.72 | 279 | 0.95 | 824 | 2.80 | 849 | 2.89 | 909 | 3.09 | 3,544 | 12.05 |
| | | | | | | | | | | | | | | | | | | |
| **1. Pioneer Mill** | | | | | | | | | | | | | | | | | | |
| Worst Case | 36 | 0.12 | 36 | 0.12 | 30 | 0.10 | 30 | 0.10 | 40 | 0.14 | 100 | 0.34 | 100 | 0.34 | 50 | 0.17 | 422 | 1.43 |
| Best Case | 100 | 0.34 | 100 | 0.34 | 60 | 0.20 | 90 | 0.31 | 100 | 0.34 | 200 | 0.68 | 300 | 1.02 | 400 | 1.36 | 1,350 | 4.59 |
| **2. West Maui** | | | | | | | | | | | | | | | | | | |
| Worst Case | 0 | | 0 | | 22 | 0.07 | 22 | 0.07 | 20 | 0.07 | 50 | 0.17 | 50 | 0.17 | 50 | 0.17 | 214 | 0.73 |
| Best Case | 45 | 0.15 | 45 | 0.15 | 60 | 0.20 | 62 | 0.21 | 80 | 0.27 | 200 | 0.68 | 200 | 0.68 | 200 | 0.68 | 892 | 3.03 |
| **3. East Maui** | | | | | | | | | | | | | | | | | | |
| Worst Case | 0 | | 0 | | 0 | | 0 | | 0 | | 50 | 0.17 | 50 | 0.17 | 100 | 0.34 | 200 | 0.68 |
| Best Case | 0 | | 0 | | 61 | 0.21 | 60 | 0.20 | 79 | 0.27 | 400 | 1.36 | 300 | 1.02 | 260 | 0.88 | 1,160 | 3.94 |
| **4. Upcountry Maui** | | | | | | | | | | | | | | | | | | |
| Worst Case | 0 | | 0 | | 0 | | 0 | | 10 | 0.03 | 6 | 0.02 | 12 | 0.04 | 27 | 0.09 | 55 | 0.19 |
| Best Case | 0 | | 0 | | 0 | | 0 | | 20 | 0.07 | 24 | 0.08 | 49 | 0.17 | 49 | 0.17 | 142 | 0.48 |
| | | | | | | | | | | | | | | | | | | |

Note: Water Use = acreage x 3,400 gpd/acre.
Acreages shown are additional, not cumulative.

## Table 7e. WATER DEMAND FORECAST FOR DIVERSIFIED AGRICULTURE
## Island of Hawaii

| Irrigation System | Initial 5-year Planning Period | | | | | | | | | | Second 5-year Period | | Third 5-year Period | | Fourth 5-year Period | | 20-Year Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | First Year | | Second Year | | Third Year | | Fourth Year | | Fifth Year | | | | | | | | | |
| | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) | Service Area (ac) | Use (mgd) |
| **ISLAND OF HAWAII** | | | | | | | | | | | | | | | | | | |
| Worst Case | 72 | 0.24 | 72 | 0.24 | 104 | 0.35 | 104 | 0.35 | 140 | 0.48 | 412 | 1.40 | 424 | 1.44 | 454 | 1.54 | 1,782 | 6.06 |
| Best Case | 290 | 0.99 | 290 | 0.99 | 414 | 1.41 | 414 | 1.41 | 558 | 1.9 | 1,648 | 5.60 | 1,688 | 5.74 | 1,818 | 6.18 | 7,120 | 24.21 |
| | | | | | | | | | | | | | | | | | | |
| **1. Lower Hamakua Ditch** | | | | | | | | | | | | | | | | | | |
| Worst Case | 36 | 0.12 | 36 | 0.12 | 64 | 0.22 | 64 | 0.22 | 80 | 0.27 | 212 | 0.72 | 274 | 0.93 | 304 | 1.03 | 1,070 | 3.64 |
| Best Case | 250 | 0.85 | 250 | 0.85 | 314 | 1.07 | 314 | 1.07 | 358 | 1.22 | 1,448 | 4.92 | 1,488 | 5.06 | 1,818 | 6.18 | 6,240 | 21.22 |
| **2. Waimea** | | | | | | | | | | | | | | | | | | |
| Worst Case | 36 | 0.12 | 36 | 0.12 | 40 | 0.14 | 40 | 0.14 | 60 | 0.2 | 200 | 0.68 | 150 | 0.51 | 150 | 0.51 | 712 | 2.42 |
| Best Case | 40 | 0.14 | 40 | 0.14 | 100 | 0.34 | 100 | 0.34 | 200 | 0.68 | 200 | 0.68 | 200 | 0.68 | 0* | | 880 | 2.99 |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | |

Note: Water Use = acreage x 3,400 gpd/acre.
Acreages shown are additional, not cumulative.

All available acreage assigned.

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# APPENDICES

## Appendix A
## MONTHLY WATER USE AND ACREAGE SERVED
## Molokai Irrigation System

**1995**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| January | 145,277,000 | 3,279 | 1,429 |
| February | 80,323,000 | 3,343 | 858 |
| March | 159,595,000 | 3,314 | 1,553 |
| April | 105,090,000 | 3,331 | 1,052 |
| May | 164,032,000 | 3,331 | 1,589 |
| June | 282,699,000 | 3,331 | 2,829 |
| July | 195,922,000 | 3,342 | 1,891 |
| August | 186,399,000 | 3,379 | 1,779 |
| September | 149,778,000 | 3,362 | 1,485 |
| October | 145,587,000 | 3,362 | 1,397 |
| November | 125,072,000 | 3,365 | 1,239 |
| December | 126,226,000 | 3,365 | 1,210 |
| **Total** | 1,866,000,000 | | |

**1996**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| January | 64,098,000 | 3,395 | 609 |
| February | 86,551,000 | 3,395 | 879 |
| March | 71,214,000 | 3,395 | 677 |
| April | 110,014,000 | 3,395 | 1,080 |
| May | 142,652,000 | 3,395 | 1,355 |
| June | 126,268,000 | 3,395 | 1,240 |
| July | 124,700,000 | 3,382 | 1,189 |
| August | 122,141,000 | 3,382 | 1,165 |
| September | 113,964,000 | 3,382 | 1,123 |
| October | 139,007,000 | 3,382 | 1,326 |
| November | 51,231,000 | 3,382 | 505 |
| December | 79,006,000 | 3,382 | 754 |
| **Total** | 1,230,846,000 | | |

**1997**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| January | 51,230,000 | 3,382 | 489 |
| February | 95,565,000 | 3,358 | 1,016 |
| March | 70,022,000 | 3,358 | 673 |
| April | 95,500,000 | 3,358 | 948 |
| May | 118,591,000 | 3,358 | 1,139 |
| June | 115,576,000 | 3,358 | 1,147 |
| July | 186,806,000 | 3,260 | 1,848 |
| August | 165,381,000 | 3,298 | 1,618 |
| September | 178,215,000 | 3,298 | 1,801 |
| October | 131,144,000 | 3,298 | 1,283 |
| November | 96,681,000 | 3,298 | 977 |
| December | 99,681,000 | 3,298 | 975 |
| **Total** | 1,404,392,000 | | |

**1998**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| January | 80,301,000 | 3,271 | 792 |
| February | 126,288,000 | 3,267 | 1,381 |
| March | 111,516,000 | 3,269 | 1,100 |
| April | 113,273,000 | 3,269 | 1,155 |
| May | 149,147,000 | 3,236 | 1,487 |
| June | 187,876,000 | 3,236 | 1,935 |
| July | 209,827,000 | 3,236 | 2,092 |
| August | 175,456,000 | 3,236 | 1,749 |
| September | 216,003,000 | 3,153 | 2,284 |
| October | 175,907,000 | 3,155 | 1,799 |
| November | 101,004,000 | 3,121 | 1,079 |
| December | 134,045,000 | 3,109 | 1,391 |
| **Total** | 1,780,643,000 | | |

## Appendix A (Cont'd)
## Molokai Irrigation System

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1999** | | | |
| January | 83,354,000 | 3,106 | 866 |
| February | 102,894,000 | 3,104 | 1,184 |
| March | 148,307,000 | 3,104 | 1,541 |
| April | 139,617,000 | 3,106 | 1,498 |
| May | 237,113,000 | 3,108 | 2,461 |
| June | 173,117,000 | 3,108 | 1,857 |
| July | 151,351,000 | 3,106 | 1,572 |
| August | 206,324,000 | 3,129 | 2,127 |
| September | 199,834,000 | 3,105 | 2,145 |
| October | 171,051,000 | 3,075 | 1,794 |
| November | 180,465,000 | 3,079 | 1,954 |
| December | 111,374,000 | 3,079 | 1,167 |
| **Total** | 1,904,801,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2000** | | | |
| January | 116,339,000 | 3,079 | 1,219 |
| February | 123,564,000 | 3,079 | 1,384 |
| March | 158,892,000 | 3,079 | 1,665 |
| April | 89,917,000 | 3,079 | 973 |
| May | 131,217,000 | 3,079 | 1,375 |
| June | 134,495,000 | 3,079 | 1,456 |
| July | 134,828,000 | 3,065 | 1,419 |
| August | 146,907,000 | 3,065 | 1,546 |
| September | 119,668,000 | 3,065 | 1,301 |
| October | 134,706,000 | 3,065 | 1,418 |
| November | 100,528,000 | 3,069 | 1,092 |
| December | 120,707,000 | 3,069 | 1,269 |
| **Total** | 1,511,768,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2001** | | | |
| January | 122,274,000 | 3,069 | 1,285 |
| February | 120,228,000 | 3,069 | 1,399 |
| March | 79,744,000 | 3,024 | 851 |
| April | 86,477,000 | 3,107 | 928 |
| May | 166,033,000 | 3,105 | 1,725 |
| June | 97,277,000 | 3,105 | 1,044 |
| July | 138,502,000 | 2,992 | 1,493 |
| August | 144,095,000 | 3,100 | 1,499 |
| September | 121,859,000 | 3,100 | 1,310 |
| October | 128,646,000 | 3,100 | 1,339 |
| November | 95,311,000 | 3,102 | 1,024 |
| December | 69,405,000 | 3,069 | 730 |
| **Total** | 1,369,851,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2002** | | | |
| January | 100,746,000 | 3,102 | 1,048 |
| February | 66,433,000 | 3,102 | 765 |
| March | 80,707,000 | 3,102 | 839 |
| April | 84,663,000 | 3,102 | 910 |
| May | 84,036,000 | 3,102 | 874 |
| June | 110,214,000 | 3,102 | 1,184 |
| July | 122,943,000 | 3,102 | 1,278 |
| August | 136,345,000 | 3,102 | 1,418 |
| September | 143,483,000 | 3,102 | 1,542 |
| October | 97,501,000 | 3,102 | 1,014 |
| November | 68,964,000 | 3,102 | 741 |
| December | 97,454,000 | 3,102 | 1,013 |
| **Total** | 1,193,489,000 | | |

# Appendix B
## MONTHLY WATER USE AND ACREAGE SERVED
## Waimanalo Irrigation System

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1995** | | | |
| January | 4,912,000 | 1,083 | 146 |
| February | 4,471,000 | 1,083 | 147 |
| March | 3,955,000 | 1,083 | 118 |
| April | 7,729,000 | 1,083 | 238 |
| May | 12,637,000 | 1,083 | 376 |
| June | 12,412,000 | 1,085 | 381 |
| July | 12,849,968 | 1,085 | 382 |
| August | 20,483,994 | 1,085 | 609 |
| September | 16,232,964 | 1,085 | 499 |
| October | 14,328,816 | 1,085 | 426 |
| November | 5,691,700 | 1,085 | 175 |
| December | 5,327,900 | 1,085 | 158 |
| **Total** | 121,031,342 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1996** | | | |
| January | 2,416,900 | 1,085 | 72 |
| February | 4,412,400 | 1,085 | 140 |
| March | 6,229,700 | 1,085 | 185 |
| April | 11,589,279 | 1,085 | 356 |
| May | 13,755,284 | 1,085 | 409 |
| June | 11,027,417 | 1,085 | 339 |
| July | 11,027,417 | 1,085 | 328 |
| August | 10,879,848 | 1,085 | 323 |
| September | 27,259,416 | 1,085 | 837 |
| October | 18,589,228 | 1,085 | 553 |
| November | 18,716,979 | 1,085 | 575 |
| December | 3,931,300 | 1,085 | 117 |
| **Total** | 139,835,168 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1997** | | | |
| January | 5,441,100 | 1,085 | 162 |
| February | 15,299,300 | 1,085 | 504 |
| March | 10,617,200 | 1,085 | 316 |
| April | 5,326,448 | 1,085 | 164 |
| May | 7,752,631 | 1,085 | 230 |
| June | 5,215,977 | 1,085 | 160 |
| July | 12,571,125 | 577 | 703 |
| August | 16,993,532 | 577 | 950 |
| September | 16,126,407 | 577 | 932 |
| October | 9,752,682 | 577 | 545 |
| November | 8,424,400 | 577 | 487 |
| December | 3,288,600 | 577 | 184 |
| **Total** | 116,809,402 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1998** | | | |
| January | 6,491,200 | 583 | 359 |
| February | 12,406,136 | 583 | 760 |
| March | 13,644,448 | 576 | 764 |
| April | 12,921,021 | 576 | 748 |
| May | 7,027,752 | 576 | 394 |
| June | 8,637,508 | 580 | 496 |
| July | 16,460,084 | 1,139 | 466 |
| August | 16,417,376 | 1,139 | 465 |
| September | 17,613,073 | 1,142 | 514 |
| October | 13,593,328 | 1,142 | 384 |
| November | 5,246,500 | 1,153 | 152 |
| December | 5,141,426 | 1,155 | 144 |
| **Total** | 135,599,852 | | |

**Appendix B (Cont'd)**
**Waimanalo Irrigation System**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 1999** | | | |
| January | 2,446,694 | 1,164 | 68 |
| February | 8,086,000 | 1,165 | 248 |
| March | 11,238,536 | 1,155 | 314 |
| April | 15,481,990 | 1,150 | 449 |
| May | 14,789,305 | 1,155 | 413 |
| June | 24,530,986 | 1,159 | 706 |
| July | 9,652,542 | 1,144 | 272 |
| August | 15,220,070 | 1,144 | 429 |
| September | 16,614,516 | 1,148 | 482 |
| October | 9,770,952 | 1,178 | 268 |
| November | 7,277,408 | 1,137 | 213 |
| December | 4,542,432 | 1,147 | 128 |
| **Total** | 139,651,431 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2000** | | | |
| January | 7,179,022 | 1,147 | 202 |
| February | 10,662,908 | 1,129 | 326 |
| March | 16,415,020 | 1,129 | 469 |
| April | 8,220,516 | 1,138 | 241 |
| May | 17,595,548 | 1,135 | 500 |
| June | 21,393,616 | 1,148 | 621 |
| July | 20,191,868 | 1,176 | 554 |
| August | 16,225,292 | 1,176 | 445 |
| September | 12,927,128 | 1,176 | 366 |
| October | 11,577,428 | 1,176 | 318 |
| November | 5,741,400 | 1,176 | 163 |
| December | 7,259,236 | 1,176 | 199 |
| **Total** | 155,388,982 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2001** | | | |
| January | 9,611,948 | 1,176 | 264 |
| February | 8,604,056 | 1,176 | 261 |
| March | 12,649,120 | 1,176 | 347 |
| April | 15,025,360 | 1,176 | 426 |
| May | 14,700,932 | 1,176 | 403 |
| June | 15,051,008 | 1,176 | 427 |
| July | 19,605,540 | 1,164 | 543 |
| August | 12,071,824 | 1,164 | 335 |
| September | 9,162,600 | 1,164 | 262 |
| October | 12,176,100 | 1,164 | 337 |
| November | 14,017,800 | 1,164 | 401 |
| December | 7,635,800 | 1,164 | 212 |
| **Total** | 150,312,088 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|
| **■ 2002** | | | |
| January | 7,251,300 | 1,155 | 203 |
| February | 6,901,500 | 1,155 | 213 |
| March | 10,609,900 | 1,170 | 293 |
| April | 13,139,200 | 1,180 | 371 |
| May | 12,502,700 | 1,170 | 345 |
| June | 21,152,700 | 1,170 | 603 |
| July | 19,600,500 | 1,167 | 542 |
| August | 16,473,300 | 1,186 | 448 |
| September | 20,614,900 | 1,173 | 586 |
| October | 15,732,800 | 1,168 | 435 |
| November | 9,644,100 | 1,171 | 275 |
| December | 10,163,700 | 1,177 | 279 |
| **Total** | 163,786,600 | | |

# Appendix C
# MONTHLY WATER USE AND ACREAGE SERVED
# Waimea Irrigation System

## Lalamilo Section

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1995** | | | | **■ 1996** | | | |
| January | 31,107,000 | 280 | 3,584 | January | 21,308,000 | 280 | 2,455 |
| February | 22,829,000 | 280 | 2,912 | February | 12,742,000 | 280 | 1,569 |
| March | 26,922,000 | 280 | 3,102 | March | 17,156,000 | 280 | 1,976 |
| April | 31,737,000 | 280 | 3,778 | April | 28,797,000 | 280 | 3,428 |
| May | 34,554,000 | 280 | 3,981 | May | 32,969,000 | 280 | 3,798 |
| June | 31,020,000 | 280 | 3,693 | June | 34,130,000 | 280 | 3,932 |
| July | 38,451,000 | 280 | 4,430 | July | 40,836,000 | 280 | 4,705 |
| August | 40,623,000 | 280 | 4,680 | August | 46,460,000 | 280 | 5,353 |
| September | 42,228,000 | 280 | 5,027 | September | 42,806,000 | 280 | 5,096 |
| October | 37,505,000 | 280 | 4,321 | October | 41,882,000 | 280 | 4,825 |
| November | 37,491,000 | 280 | 4,463 | November | 16,353,000 | 280 | 1,947 |
| December | 33,317,000 | 280 | 3,838 | December | 15,841,000 | 280 | 1,825 |
| **Total** | 407,784,000 | | | **Total** | 351,280,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1997** | | | | **■ 1998** | | | |
| January | 10,084,000 | 280 | 1,162 | January | 24,145,000 | 282 | 2,762 |
| February | 24,609,000 | 280 | 3,139 | February | 25,810,000 | 282 | 3,269 |
| March | 15,717,000 | 280 | 1,811 | March | 30,786,000 | 282 | 3,522 |
| April | 25,764,000 | 280 | 3,067 | April | 18,747,000 | 282 | 2,216 |
| May | 32,477,000 | 280 | 3,742 | May | 27,095,000 | 282 | 3,099 |
| June | 36,361,000 | 280 | 4,329 | June | 23,359,000 | 282 | 2,761 |
| July | 30,330,000 | 283 | 3,457 | July | 37,139,000 | 282 | 4,248 |
| August | 37,596,000 | 284 | 4,270 | August | 35,933,000 | 282 | 4,110 |
| September | 40,931,000 | 284 | 4,804 | September | 36,521,000 | 282 | 4,317 |
| October | 36,538,000 | 284 | 4,150 | October | 34,246,000 | 282 | 3,917 |
| November | 17,705,000 | 284 | 2,078 | November | 27,824,000 | 282 | 3,289 |
| December | 23,250,000 | 282 | 2,660 | December | 26,922,000 | 282 | 3,080 |
| **Total** | 331,362,000 | | | **Total** | 348,527,000 | | |

**Appendix C (Cont'd)**

## Waimea Irrigation System, Lalamilo Section

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| ■ **1999** | | | | ■ **2000** | | | |
| January | 26,372,000 | 282 | 3,017 | January | 25,528,000 | 284 | 2,900 |
| February | 21,707,000 | 282 | 2,749 | February | 33,357,000 | 284 | 4,050 |
| March | 24,314,000 | 282 | 2,781 | March | 38,597,000 | 284 | 4,384 |
| April | 33,146,000 | 282 | 3,918 | April | 27,538,000 | 284 | 3,232 |
| May | 33,025,000 | 282 | 3,778 | May | 46,201,000 | 284 | 5,248 |
| June | 40,957,000 | 282 | 4,841 | June | 34,609,000 | 284 | 4,062 |
| July | 36,778,000 | 283 | 4,192 | July | 39,918,000 | 284 | 4,534 |
| August | 39,080,000 | 283 | 4,455 | August | 38,979,000 | 284 | 4,427 |
| September | 39,296,000 | 283 | 4,629 | September | 41,828,000 | 284 | 4,909 |
| October | 29,006,000 | 281 | 3,330 | October | 37,888,000 | 284 | 4,303 |
| November | 25,369,000 | 281 | 3,009 | November | 21,480,000 | 284 | 2,521 |
| December | 13,119,000 | 284 | 1,490 | December | 23,152,000 | 284 | 2,630 |
| **Total** | 362,169,000 | | | **Total** | 409,075,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| ■ **2001** | | | | ■ **2002** | | | |
| January | 28,913,000 | 284 | 3,284 | January | 10,376,000 | 284 | 1,179 |
| February | 20,317,000 | 284 | 2,555 | February | 14,634,000 | 284 | 1,840 |
| March | 30,383,000 | 284 | 3,451 | March | 14,224,000 | 284 | 1,616 |
| April | 33,012,000 | 284 | 3,875 | April | 31,915,000 | 284 | 3,746 |
| May | 38,859,000 | 284 | 4,414 | May | 13,421,000 | 284 | 1,524 |
| June | 33,028,000 | 284 | 3,877 | June | 24,452,000 | 284 | 2,870 |
| July | 39,030,000 | 284 | 4,433 | July | 18,513,000 | 284 | 2,103 |
| August | 28,756,000 | 284 | 3,266 | August | 30,958,000 | 284 | 3,516 |
| September | 38,363,000 | 284 | 4,503 | September | 27,800,000 | 284 | 3,263 |
| October | 35,869,000 | 284 | 4,074 | October | 32,949,000 | 284 | 3,743 |
| November | 21,800,000 | 284 | 2,559 | November | 32,091,000 | 284 | 3,767 |
| December | 15,956,000 | 284 | 1,812 | December | 31,412,000 | 284 | 3,568 |
| **Total** | 364,286,000 | | | **Total** | 282,745,000 | | |

## Appendix C (Cont'd)
## MONTHLY WATER USE AND ACREAGE SERVED
## Waimea Irrigation System

### Hawaiian Homes

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1995** | | | | **■ 1996** | | | |
| January | 1,851,000 | 95 | 629 | January | 1,469,000 | 97 | 447 |
| February | 2,043,000 | 95 | 768 | February | 999,000 | 106 | 325 |
| March | 1,490,000 | 95 | 506 | March | 1,114,000 | 106 | 339 |
| April | 1,126,000 | 95 | 395 | April | 1,027,000 | 106 | 323 |
| May | 988,000 | 97 | 329 | May | 1,207,000 | 106 | 367 |
| June | 684,000 | 97 | 235 | June | 1,172,000 | 106 | 357 |
| July | 804,000 | 97 | 267 | July | 1,212,000 | 106 | 369 |
| August | 1,095,000 | 97 | 364 | August | 1,207,000 | 106 | 367 |
| September | 2,163,000 | 97 | 743 | September | 2,208,000 | 106 | 694 |
| October | 1,293,000 | 97 | 430 | October | 2,987,000 | 106 | 909 |
| November | 1,467,000 | 97 | 504 | November | 829,000 | 106 | 261 |
| December | 2,029,000 | 97 | 675 | December | 716,000 | 106 | 218 |
| **Total** | 17,033,000 | | | **Total** | 16,147,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1997** | | | | **■ 1998** | | | |
| January | 502,000 | 106 | 153 | January | 1,499,000 | 106 | 456 |
| February | 1,004,000 | 106 | 338 | February | 1,364,000 | 106 | 460 |
| March | 553,000 | 106 | 168 | March | 1,764,000 | 102 | 558 |
| April | 865,000 | 106 | 272 | April | 303,000 | 102 | 99 |
| May | 1,259,000 | 106 | 383 | May | 322,000 | 102 | 102 |
| June | 1,063,000 | 106 | 334 | June | 173,000 | 102 | 57 |
| July | 885,000 | 106 | 269 | July | 317,000 | 102 | 100 |
| August | 1,597,000 | 106 | 486 | August | 592,000 | 102 | 187 |
| September | 1,561,000 | 106 | 491 | September | 662,000 | 102 | 216 |
| October | 1,655,000 | 106 | 504 | October | 536,000 | 102 | 170 |
| November | 744,000 | 106 | 234 | November | 901,000 | 106 | 283 |
| December | 793,000 | 106 | 241 | December | 600,000 | 106 | 183 |
| **Total** | 12,481,000 | | | **Total** | 9,033,000 | | |

**Appendix C (Cont'd)**
**Waimea Irrigation System, Hawaiian Homes**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1999** | | | | **■ 2000** | | | |
| January | 936,000 | 115 | 263 | January | 595,000 | 153 | 125 |
| February | 478,000 | 115 | 148 | February | 1,276,000 | 153 | 288 |
| March | 1,079,000 | 133 | 262 | March | 1,354,000 | 153 | 285 |
| April | 1,179,000 | 133 | 295 | April | 583,000 | 153 | 127 |
| May | 1,616,000 | 143 | 365 | May | 938,000 | 153 | 198 |
| June | 1,978,000 | 145 | 455 | June | 1,261,000 | 153 | 275 |
| July | 999,000 | 144 | 224 | July | 1,357,000 | 153 | 286 |
| August | 1,322,000 | 151 | 282 | August | 1,099,000 | 153 | 232 |
| September | 2,037,000 | 153 | 444 | September | 1,918,000 | 153 | 418 |
| October | 1,414,000 | 153 | 298 | October | 1,735,000 | 153 | 366 |
| November | 375,000 | 153 | 82 | November | 765,000 | 153 | 167 |
| December | 556,000 | 153 | 117 | December | 1,594,000 | 153 | 336 |
| **Total** | 13,969,000 | | | **Total** | 14,475,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 2001** | | | | **■ 2002** | | | |
| January | 1,977,000 | 153 | 417 | January | 592,000 | 160 | 119 |
| February | 1,015,000 | 153 | 237 | February | 565,000 | 160 | 126 |
| March | 1,106,000 | 153 | 233 | March | 718,000 | 160 | 145 |
| April | 1,285,000 | 153 | 280 | April | 1,423,000 | 160 | 296 |
| May | 2,100,000 | 153 | 443 | May | 906,000 | 160 | 183 |
| June | 2,030,000 | 153 | 442 | June | 1,410,000 | 170 | 276 |
| July | 3,059,000 | 160 | 617 | July | 586,000 | 170 | 111 |
| August | 1,363,000 | 160 | 275 | August | 5,955,000 | 180 | 1,067 |
| September | 1,024,000 | 160 | 213 | September | 2,692,000 | 180 | 499 |
| October | 2,463,000 | 160 | 497 | October | 1,739,000 | 186 | 302 |
| November | 1,185,000 | 160 | 247 | November | 1,374,000 | 186 | 246 |
| December | 568,000 | 160 | 115 | December | 1,210,000 | 186 | 210 |
| **Total** | 19,175,000 | | | **Total** | 19,170,000 | | |

# Appendix C (Cont'd)
# MONTHLY WATER USE - Waimea Irrigation System

## Puukapu Section

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1995** | | | | **■ 1996** | | | |
| January | 3,335,000 | 123 | 875 | January | 3,886,000 | 128 | 979 |
| February | 4,263,000 | 123 | 1,238 | February | 1,587,000 | 128 | 428 |
| March | 2,796,000 | 123 | 733 | March | 1,230,000 | 128 | 310 |
| April | 1,744,000 | 128 | 454 | April | 1,118,000 | 128 | 291 |
| May | 1,868,000 | 128 | 471 | May | 3,479,000 | 128 | 877 |
| June | 2,175,000 | 128 | 566 | June | 3,913,000 | 128 | 986 |
| July | 2,232,000 | 128 | 563 | July | 4,237,000 | 127 | 1,076 |
| August | 1,760,000 | 128 | 444 | August | 6,377,000 | 127 | 1,620 |
| September | 5,184,000 | 128 | 1,350 | September | 6,449,000 | 127 | 1,693 |
| October | 4,579,000 | 128 | 1,154 | October | 6,921,000 | 127 | 1,758 |
| November | 4,442,000 | 128 | 1,157 | November | 1,430,000 | 129 | 370 |
| December | 6,102,000 | 128 | 1,538 | December | 951,000 | 129 | 238 |
| **Total** | 40,480,000 | | | **Total** | 41,578,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| **■ 1997** | | | | **■ 1998** | | | |
| January | 590,000 | 129 | 148 | January | 3,768,000 | 129 | 942 |
| February | 2,605,000 | 129 | 721 | February | 4,320,000 | 129 | 1,196 |
| March | 515,000 | 129 | 129 | March | 3,136,000 | 129 | 784 |
| April | 4,045,000 | 129 | 1,045 | April | 214,000 | 129 | 55 |
| May | 3,392,000 | 129 | 848 | May | 190,000 | 129 | 48 |
| June | 3,813,000 | 129 | 985 | June | 1,147,000 | 129 | 296 |
| July | 1,741,000 | 129 | 435 | July | 563,000 | 129 | 141 |
| August | 5,528,000 | 129 | 1,382 | August | 800,000 | 129 | 200 |
| September | 5,060,000 | 129 | 1,307 | September | 967,000 | 129 | 250 |
| October | 5,323,000 | 129 | 1,331 | October | 1,098,000 | 129 | 275 |
| November | 631,000 | 129 | 163 | November | 1,465,000 | 129 | 379 |
| December | 2,590,000 | 129 | 648 | December | 1,432,000 | 129 | 358 |
| **Total** | 35,833,000 | | | **Total** | 19,100,000 | | |

**Appendix C (Cont'd)**
**Waimea Irrigation System, Puukapu Section**

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| ■ **1999** | | | | ■ **2000** | | | |
| January | 1,924,000 | 129 | 481 | January | 1,682,000 | 129 | 421 |
| February | 884,000 | 129 | 245 | February | 3,766,000 | 129 | 1,007 |
| March | 1,141,000 | 129 | 285 | March | 3,671,000 | 129 | 918 |
| April | 2,089,000 | 129 | 540 | April | 968,000 | 129 | 250 |
| May | 4,372,000 | 129 | 1,093 | May | 2,372,000 | 129 | 593 |
| June | 5,219,000 | 129 | 1,349 | June | 3,903,000 | 129 | 1,009 |
| July | 3,942,000 | 129 | 986 | July | 5,784,000 | 129 | 1,446 |
| August | 3,267,000 | 129 | 817 | August | 2,650,000 | 129 | 663 |
| September | 3,973,000 | 129 | 1,027 | September | 3,131,000 | 129 | 809 |
| October | 3,020,000 | 129 | 755 | October | 2,953,000 | 129 | 738 |
| November | 900,000 | 129 | 233 | November | 1,192,000 | 129 | 308 |
| December | 879,000 | 129 | 220 | December | 4,468,000 | 129 | 1,117 |
| **Total** | 31,610,000 | | | **Total** | 36,540,000 | | |

| Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) | Month | Water Use (gallons) | Acreage Served | Water Use (gpd/ac) |
|---|---|---|---|---|---|---|---|
| ■ **2001** | | | | ■ **2002** | | | |
| January | 6,133,000 | 129 | 1,534 | January | 1,084,000 | 129 | 271 |
| February | 3,413,000 | 129 | 945 | February | 1,001,000 | 133 | 269 |
| March | 2,439,000 | 129 | 610 | March | 1,547,000 | 133 | 375 |
| April | 2,886,000 | 129 | 746 | April | 4,154,000 | 133 | 1,041 |
| May | 4,077,000 | 129 | 1,020 | May | 1,622,000 | 133 | 393 |
| June | 3,599,000 | 129 | 930 | June | 1,880,000 | 133 | 471 |
| July | 4,922,000 | 129 | 1,231 | July | 298,000 | 133 | 72 |
| August | 1,378,000 | 129 | 345 | August | 2,590,000 | 133 | 628 |
| September | 2,411,000 | 129 | 623 | September | 3,771,000 | 143 | 879 |
| October | 4,077,000 | 129 | 1,020 | October | 3,876,000 | 143 | 874 |
| November | 1,888,000 | 129 | 488 | November | 5,025,000 | 143 | 1,171 |
| December | 820,000 | 129 | 205 | December | 2,529,000 | 143 | 570 |
| **Total** | 38,043,000 | | | **Total** | 29,377,000 | | |

## Appendix D-1. EAST KAUAI IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Kauai

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **EAST KAUAI** | | pfc | pfc | 473 | 295 | tbd | 5,922 | dva | 2,369 | 5.9 |
| **INTAKE** | | | | | | | | | | |
| Blue Hole (N. Fork, Wailua) | 3-9-01 | 17 | 59 | tbd | - | - | | | | |
| Stable Storm (N. Fork, Wailua) | tbd | 17 | pfc | tbd | - | - | | | | |
| Hanamaulu (S. Fork, Wailua) | tbd | 21 | pfc | tbd | - | - | | | | |
| Wailua (el. 462) | tbd | 10 | pfc | tbd | - | - | | | | |
| Kapaa (el. 377) | tbd | pfc | pfc | tbd | - | - | | | | |
| Hanalei Tunne (el. 1210) | abd | 17 | 36 | 42 | - | | | | | |
| **DITCH** | | | | | | | | | | |
| Iliiliula-North Wailua (el. 1070) | tbd | 12 | 15 | 57 | - | pfc | | | | |
| Stable Storm | tbd | 17 | pfc | 69 | - | pfc | | | | |
| Hanamaulu (el. 430) | tbd | 21 | 32 | 26 | - | pfc | | | | |
| Wailua | tbd | 10 | pfc | 26 | - | pfc | | | | |
| Kapahi | tbd | 10 | 88 | 88 | - | pfc | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Wailua | tbd | | | | 240 | | | | | |
| Aahoaka | tbd | | | | abd | | | | | |
| Aii | tbd | | | | una | | | | | |
| Reservoir 21 | tbd | | | | una | | | | | |
| Upper Kapahi | tbd | | | | 30 | | | | | |
| Lower Kapahi | tbd | | | | 25 | | | | | |
| Twin | tbd | | | | una | | | | | |
| House | abd | | | | nd | | | | | |

* Based on currently accepted 2,500 gpd/acre.

pfc - pending field check
dva - diversified agriculture
tbd - to be determined
abd - abandoned
una - unavailable
nd - no data

## Appendix D-2. KEKAHA DITCH IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Kauai

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **KEKAHA DITCH** | | 56 | tbd | 104 | 95 | pfc | 6,566 | dva, hydro | 3,695 | 9.2 |
| **INTAKE** | 1-5-01 | 40 | 104 | pfc | | | | | | |
| Koaie | pfc | pfc | tbd | pfc | - | - | | | | |
| Waiahulu | pfc | pfc | tbd | pfc | - | - | | | | |
| Waimea | pfc | pfc | tbd | | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Field 4 | tbd | | | | 8 | | | | | |
| Waiawa | tbd | | | | 9 | | | | | |
| Field 12 | tbd | | | | 4 | | | | | |
| Field 23 | tbd | | | | 10 | | | | | |
| Mana | tbd | | | | 25 | | | | | |
| Field 37 | tbd | | | | 7 | | | | | |
| Field 38 | tbd | | | | 1 | | | | | |
| Field H | tbd | | | | 9 | | | | | |
| Field 68 | tbd | | | | 2 | | | | | |
| Field L | tbd | | | | 4 | | | | | |
| Field N | tbd | | | | 14 | | | | | |
| Field 36 | tbd | | | | 2 | | | | | |
| | | | | | | | | | | |

* Based on currently accepted 2,500 gpd/acre.
tbd - to be determined
pfc - pending field check
dva - diversified agriculture
hydro - hydropower

## Appendix D-3. KOKEE DITCH IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Kauai

| System Infrastructure | | System Capabilities | | | | | Potential Service Area (acre) | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | | Type | Service Area (acre) | Water Use (mgd)* |
| **KOKEE DITCH** | | tbd | tbd | 105 | 361 | pfc | 3,519 | dva, sugar, recr | 2,527 | 6.3 |
| **INTAKE** | 1-4-01 | 55 | 105 | pfc | - | - | | | | |
| Mohihi | pfc | abd | pfc | | - | - | | | | |
| Waiakoli | tbd | tbd | pfc | | - | - | | | | |
| Kawaikoi | tbd | tbd | pfc | | - | - | | | | |
| Kauaikinana | pfc | tbd | pfc | | - | - | | | | |
| Kokee | pfc | tbd | pfc | | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Puulua | tbd | | | | 262 | | | | | |
| Kitano | tbd | | | | 63 | | | | | |
| Puuopae | tbd | | | | 36 | | | | | |
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* Based on currently accepted 2,500 gpd/acre.

tbd - to be determined

pfc - pendin field che

dva - diversified agriculture

recr - recreational

**Appendix D-4. MAUI LAND & PINEAPPLE/PIONEER MILL IRRIGATION SYSTEM, SOURCE, AND WATER USE, Island of Maui**

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **MAUI LAND & PINEAPPLE/ PIONEER MILL** | na | 20 | 42 | pfc | 48 | tbd | 3,533 | dva, pine, mun, lscp | 1,060** | 2.6** |
| **INTAKE** | | | | | | | | | | |
| Honokohau (el. 825) | 4-1-01 | 34 | tbd | pfc | - | - | | | | |
| Kaluanui | 4-1-01 | 1 | tbd | pfc | - | - | | | | |
| Honolua | 4-2-01 | 3 | tbd | pfc | - | - | | | | |
| Pump M | 5-2-21 | 5 | 10 | pfc | - | - | | | | |
| Crater Res. | 5-2-21 | pfc | pfc | pfc | - | - | | | | |
| **DITCH** | | | | | | | | | | |
| Honolua | tbd | 50 | 70 | pfc | - | tbd | | | | |
| Honokohau | tbd | 35 | 42 | 18 | - | tbd | | | | |
| Wahikuli | tbd | 5 | 10 | pfc | - | tbd | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Reservoir 140 | tbd | | | | pfc | | | | | |
| Field 3 | tbd | | | | pfc | | | | | |
| B-1 | tbd | | | | 0.5 | | | | | |
| New | abd | | | | 5 | | | | | |
| Wahikuli | tbd | | | | 17 | | | | | |
| Crater Res. | tbd | | | | 25 | | | | | |
| Puukolii | tbd | | | | pfc | | | | | |

* Based on currently accepted 2,500 gpd/acre.
** Does not include Maui Land and Pineapple

pfc - pending field check
tbd - to be determined
dva - diversified agriculture
pine - pineapple
mun - municipal
lscp - landscape irrigation
abd - abandoned

## Appendix D-5. WAIAHOLE DITCH IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Oahu

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **WAIAHOLE DITCH** | | 28 | 114 | 193 | pfc | 233 | 6,270 | dva, pine, lscp | 1,569 | 5.49** |
| **INTAKE** | | | | 100 | - | | | | | |
| Kahana | 5-1-01 | 6 | pfc | 6 | - | - | | | | |
| Waikane I | 4-8-14 | 4 | pfc | 4 | - | - | | | | |
| Waikan II | 4-8-14 | 1 | pfc | 1 | - | - | | | | |
| Uwau Development | 4-8-14 | 12 | pfc | 12 | - | - | | | | |
| Pump | 4-8-13 | abd | pfc | 2 | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Reservoir 225 | tbd | | | | pfc | | | | | |
| Garst | tbd | | | | pfc | | | | | |
| Reservoir 155 | tbd | | | | pfc | | | | | |
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* Based on currently accepted 2,500 gpd/acre.
**Metered data
pfc - pending field check
dva - diversified agriculture
pine - pineapple
lscp - landscape irrigation
abd - abandoned
tbd - to be determined

**Appendix D-6. LOWER HAMAKUA DITCH IRRIGATION SYSTEM, SOURCE, AND WATER USE, Island of Hawaii**

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **LOWER HAMAKUA** | | 66 | pfc | tbd | tbd | pfc | 4,765 | dva | nd | nd |
| **INTAKE** | | 71 | 106 | | - | | | | | |
| Kawainui (el. 1037) | pfc | 19 | pfc | tbd | - | - | | | | |
| Alakahi | pfc | 8 | pfc | tbd | - | - | | | | |
| Koiawe | pfc | 4 | pfc | tbd | - | - | | | | |
| Waima | abd | abd | abd | tbd | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Honokaia | tbd | | | | 1 | | | | | |
| Haina | tbd | | | | tbd | | | | | |
| Paauhau | tbd | | | | tbd | | | | | |
| Nobriga | tbd | | | | tbd | | | | | |
| Paauilo | tbd | | | | tbd | | | | | |
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* Based on currently accepted 2,500 gpd/acre.

pfc - pending field check

tbd - to be determined

dva - diversified agriculture

nd - no data

abd - abandoned

## Appendix D-7. MOLOKAI IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Molokai

| System Infrastructure | | System Capabilities | | | | | Potential Service Area (acre) | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | | Type | Service Area (acre) | Water Use (mgd)* |
| **MOLOKAI** | | 8 | 41 | 36 | 1,400 | pfc | 9,885 | dva | 3,102 | 3.27** |
| **INTAKE** | | | | | | | | | | |
| Waikolu 1 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Waikolu 2 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Waikolu 3 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Well 22 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Well 23 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Well 5 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Well 6 | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Waikolu Pump | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| Tunnel | 6-01-01 | pfc | pfc | tbd | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Kualapuu | tbd | | | | 1,400 | | | | | |
| Lihi Pali Tank | tbd | | | | 0.25 | | | | | |
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* Based on currently accepted 2,500 gpd/acre.

**Metered data

pfc - pending field check

dva - diversified agriculture

tbd - to be determined

## Appendix D-8. UPCOUNTRY MAUI IRRIGATION SYSTEM, SOURCE, AND WATER USE, Island of Maui

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **UPCOUNTRY MAUI** | | 3 | tbd | pfc | 130 | pfc | 1,751 | dva | nd | nd |
| **INTAKE** | | | | | | | | | | |
| Haipuaena | 2-4-16 | (1) | 5 | tbd | - | - | | | | |
| Waikamoi | 1-1-01 | (3) | pfc | tbd | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Waikamoi | tbd | | | | 30 | | | | | |
| Kahakapao | tbd | | | | 100 | | | | | |

* Based on currently accepted 2,500 gpd/acre.
tbd - to be determined
pfc - pending field check
dva - diversified agriculture
nd - no data

## Appendix D-9. WAIMANALO IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Oahu

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **WAIMANALO** | | tbd | tbd | tbd | 60 | tbd | 1,601 | dva | 1,177 | 0.45** |
| **INTAKE** | | | | | | | | | | |
| Maunawili | tbd | pfc | tbd | tbd | - | - | | | | |
| Ainoni | tbd | pfc | tbd | tbd | - | - | | | | |
| Makawao | tbd | pfc | tbd | tbd | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Maunawili | abd | | | | abd | | | | | |
| Kailua | abd | | | | abd | | | | | |
| Waimanalo | tbd | | | | 60 | | | | | |
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* Based on currently accepted 2,500 gpd/acre.
**Metered data
tbd - to be determined
dva - diversified agriculture
abd - abandoned

## Appendix D-10. WAIMEA IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Hawaii

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **WAIMEA** | | 10 | 21 | pfc | 160 | pfc | 1,367 | dva | 550 | 0.91** |
| **INTAKE** | | | | | | | | | | |
| Kawainui (el. 4042) | tbd | pfc | pfc | tbd | - | - | | | | |
| Kawaiki (el. 4020) | tbd | pfc | 33 | tbd | - | - | | | | |
| Alakahi | tbd | pfc | pfc | tbd | - | - | | | | |
| Koiawe | tbd | pfc | pfc | tbd | - | - | | | | |
| Waima | tbd | pfc | pfc | tbd | - | - | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Waimea | tbd | | | | 60 | | | | | |
| Puu Pulehu | tbd | | | | 100 | | | | | |
| Lalamilo | abd | | | | abd | | | | | |
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* Based on currently accepted 2,500 gpd/acre.
**Metered data
pfc - pending field check
dva - diversified agriculture
tbd - to be determined
abd - abandoned

## Appendix D-11. EAST MAUI IRRIGATION SYSTEM, SOURCE, AND WATER USE
### Island of Maui

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **EAST MAUI** | | pfc | 284 | pfc | 274 | pfc | 33,026 | dva, sugar | 23,118 | 155 |
| **INTAKE** | | | | | | | | | | |
| 355 diversions | na | 75 | na | na | na | na | | | | |
| **DITCH** | | | | | | | | | | |
| Koolau | 1-2-04 | 55 | 75 | 111 | - | tbd | | | | |
| Spreckels | 1-1-01 | 30 | 97 | 133 | - | tbd | | | | |
| New Hamakua | tbd | 54 | 116 | 65 | - | tbd | | | | |
| Hamakua | 1-1-01 | 65 | 181 | 39 | - | tbd | | | | |
| Wailoa | 1-1-01 | 110 | 195 | 126 | - | tbd | | | | |
| Haiku | 2-9-14 | 45 | 209 | 65 | - | tbd | | | | |
| Kauhikoa | | 71 | 106 | una | - | tbd | | | | |
| Lowrie | 2-9-14 | 45 | 116 | 45 | - | tbd | | | | |
| **RESERVOIR** | | | | | | | | | | |
| 7 unnamed reservoirs | na | | | | 274 | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

* Based on currently accepted 2,500 gpd/acre.
pfc - pending field check
dva - diversified agriculture
na - not applicable
tbd - to be determined
una - unavailable

## Appendix D-12. KAUAI COFFEE IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Kauai

| System Infrastructure | | System Capabilities | | | | | Potential Service Area (acre) | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation System | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | | Type | Service Area (acre) | Water Use (mgd)* |
| **KAUAI COFFEE** | | pfc | 95 | pfc | 1,032 | pfc | 4,698 | dva | 2,349 | 5.9 |
| **DITCH** | | | | | | | | | | |
| Pump 3 | 1-8-05 | 35 | pfc | 18 | - | pfc | | | | |
| No. 2 Reservoir | tbd | pfc | pfc | tbd | - | pfc | | | | |
| **RESERVOIR** | | | | | 1,032 | | | | | |
| Alexander | 2-4-09 | | | 15 | 810 | | | | | |
| Elima | tbd | | | | 27 | | | | | |
| Elua | tbd | | | | 80 | | | | | |
| Mau | tbd | | | | 26 | | | | | |
| Ipuolono | tbd | | | | | | | | | |
| Kapa | tbd | | | | 18 | | | | | |
| Umi | tbd | | | | 7 | | | | | |
| Hukiwai | tbd | | | | 16 | | | | | |
| Ioleau | tbd | | | | 39 | | | | | |
| Luawai | tbd | | | | 9 | | | | | |
| | | | | | | | | | | |
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* Based on currently accepted 2,500 gpd/acre.
pfc - pending field check
dva - diversified agriculture
tbd - to be determined

# Appendix D-13. WEST MAUI IRRIGATION SYSTEM, SOURCE, AND WATER USE
## Island of Maui

| System Infrastructure | | System Capabilities | | | | | | Existing Water Use | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Irrigation Systemn | TMK | Ave. Water Supply (mgd) | Max. Diversion (mgd) | Transmission (mgd) | Storage (MG) | Distribution (mgd) | Potential Service Area (acre) | Type | Service Area (acre) | Water Use (mgd)* |
| **WEST MAUI** | | tbd | pfc | pfc | pfc | pfc | 5,400 | dva, pine | 3,240 | 8.1 |
| **INTAKE (7 not all listed)** | | | | | | | | | | |
| Waihee (el. 620) | 3-2-14 | 27 | 72 | 54 | - | - | | | | |
| Iso-Manania | tbd | 20 | pfc | pfc | - | - | | | | |
| Waikapu (el. 1140) | 3-5-03 | 3 | 5 | pfc | - | - | | | | |
| Waiehu (el. 840) | tbd | 12 | pfc | pfc | - | - | | | | |
| **DITCH** | | | | | | | | | | |
| Spreckels (el. 440) | tbd | 10 | 50 | pfc | - | tbd | | | | |
| Waihee | tbd | 27 | 70 | pfc | - | tbd | | | | |
| Iao-Waikapu | tbd | tbd | | pfc | - | tbd | | | | |
| **RESERVOIR** | | | | | | | | | | |
| Waiale (HCS #73 and #74) | tbd | | | | tbd | | | | | |
| Field 99 | tbd | | | | tbd | | | | | |
| Mill | tbd | | | | tbd | | | | | |
| Field 97 | tbd | | | | tbd | | | | | |
| Field #14 | tbd | | | | | | | | | |
| | | | | | | | | | | |
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| | | | | | | | | | | |

* Based on currently accepted 2,500 gpd/acre.
tbd - to be determined
pfc - pending field check
dva - diversified agriculture
pine - pineapple

## Appendix E. UNLOADS OF FRESH FRUITS AND VEGETABLES TO OAHU IN 2003

| | Receipts Within State (pounds) | | | | | State | | Grand |
|---|---|---|---|---|---|---|---|---|
| Commodity | Hawaii | Maui | Kauai | Molokai | Oahu | Total | Mainland | Total |
| Apple | | | 160 | | | 160 | 9,072,772 | 9,072,932 |
| Apricot | | | | | | | 107,114 | 107,114 |
| Artichoke | | | | | | | 226,357 | 226,357 |
| Asparagus | | 66 | | | | 66 | 1,529,907 | 1,529,973 |
| Atemoya | 548 | | 1.992 | | | 2,537 | | 2,537 |
| Avocado | 377,369 | 6,425 | 43,314 | 810 | 516 | 428,434 | 1,151,027 | 1,579,461 |
| Banana, apple | 2,159,465 | 30,080 | 280 | | 254,323 | 2,444,148 | 640 | 2,444,788 |
| Banana, cave | 8,253,839 | 11,700 | 4,240 | 320 | 1,640,578 | 9,910,677 | 8,018,483 | 17,929,160 |
| Banana, spec | 42,497 | | | | 18,100 | 60,597 | 53,781 | 114,378 |
| Basil | | | | | 27,651 | 27,651 | 28,907 | 30,548 |
| Beans, green | 7,520 | 302,701 | 2,570 | | 47,891 | 360,682 | 357,345 | 718,027 |
| Beans, long | 2,550 | | | | 37,853 | 40,403 | 38,110 | 74,513 |
| Beans, specialty | | 50 | | | 1,075 | 1,125 | 26,223 | 27,348 |
| Berries, other | 157 | | | | | 157 | 452,261 | 452,418 |
| Bittermelon | | | | | 43,151 | 43,151 | 45,257 | 88,408 |
| Broccoli | | 1,560 | | | 6,920 | 8,480 | 4,416,190 | 4,424,670 |
| Broccoli, process | | | | | | | 5,175 | 5,175 |
| Burdock | 25,409 | | | | | 25,409 | 66,011 | 91,420 |
| Cabbage, Chi | 4,205,705 | 472,176 | | 1,850 | 208,485 | 4,888,216 | 721,325 | 5,609,541 |
| Cabbage, gre | 704,860 | 2,881,765 | 2,500 | 1,600 | 2,340,634 | 5,931,359 | 1,738,777 | 7,670,136 |
| Cabbage, kai | 111,815 | 14,855 | | 840 | 125,462 | 252,972 | 17,351 | 270,323 |
| Cabbage, other | | 140 | | | 750 | 890 | 60,367 | 61,257 |
| Cabbage, pak | 360 | 2,000 | | | 247,605 | 249,965 | 61,824 | 311,789 |
| Cabbage, process | | | | | | | 53,962 | 53,962 |
| Cabbage, red | 67,030 | 53,550 | | | 82,572 | 203,152 | 110,368 | 313,520 |
| Caimito | | | 12 | | | 12 | | 12 |
| Carrot | | | | | | | 8,522,113 | 8,522,113 |
| Cauliflower | | 1,609 | | | | 1,609 | 843,318 | 844,927 |
| Celery | 70,585 | 19,990 | 1,100 | 110 | 300 | 92,085 | 4,077,113 | 4,169,198 |
| Cherimoy | 400 | | | | | 400 | 1,715 | 2,115 |
| Cherry | | | | | | | 1,971,006 | 1,971,006 |
| Chestnut | | | | | | | 26,379 | 26,379 |
| Citrus, other | 665 | | | | 175 | 840 | 64,754 | 65,594 |
| Corn, sweet | 20,572 | 7,288 | 118,596 | | 85,053 | 231,509 | 1,061,930 | 1,293,439 |
| Cucumber | 62,937 | 40,233 | | 2,075,540 | 49,065 | 2,227,775 | 202,398 | 2,430,173 |
| Cucumber, English | | | | | | | 117,676 | 117,676 |
| Cucumber, Japanese | | | | | 758,777 | 758,777 | 13,173 | 771,950 |
| Daikon, Chine | 24,960 | | | | 172,217 | 197,197 | | 197,197 |
| Daikon, Japar | 992,485 | 4,500 | | 440 | 3,641 | 1,001,066 | 5,374 | 1,006,440 |
| Daikon, Korea | 700,450 | 29,850 | | | 2,500 | 732,800 | | 732,800 |
| Daikon, proce | 13,500 | | | | | 13,500 | 800 | 14,300 |
| Dasheen | | 10 | | | | 10 | 64,855 | 64,865 |
| Durian | 196 | | | | | 196 | | 196 |
| Eggplant, long | 2,060 | 1,135 | | | 251,756 | 254,951 | 176,301 | 431,252 |
| Eggplant, rour | 11,355 | 67,115 | | | 43,668 | 122,138 | 181,106 | 303,244 |
| Endive/Escarole | | | | | | | 127,866 | 127,866 |
| Fruit, other | 315 | | | | | 315 | 123,571 | 123,886 |

| | Receipts Within State (pounds) | | | | | State | | Grand |
|---|---|---|---|---|---|---|---|---|
| Commodity | Hawaii | Maui | Kauai | Molokai | Oahu | Total | Mainland | Total |
| Fruit, tropical | 20,163 | 15 | 50 | | 1,777 | 22,005 | 89,016 | 111,021 |
| Garlic | | | | | 300 | 300 | 1,041,372 | 1,041,672 |
| Ginger Root | 826,898 | 124 | 10,280 | | 1,200 | 838,502 | 215,243 | 1,053,745 |
| Grape | | | | | | | 6,282,476 | 6,282,476 |
| Grapefruit | 120 | 90 | | | | 210 | 1,355,014 | 1,355,224 |
| Greens, orient | 556 | | | | 165,495 | 166,051 | 76,985 | 243,036 |
| Greens, other | 7,076 | 1,210 | | | 1,840 | 10,126 | 286,986 | 297,112 |
| Guava, proces | 1,529,617 | | 83,877 | | | 1,613,494 | 137 | 1,613,631 |
| Herbs & Spice | 489 | 14,470 | 180 | 8,678 | 39,719 | 63,536 | 55,416 | 118,952 |
| Kiwi | | | | | | | 311,193 | 311,193 |
| Leek | | 50 | | | | 50 | 124,285 | 124,335 |
| Lemon | 2,550 | | | | | 2,550 | 2,865,405 | 2,867,955 |
| Lettuce, head | 2,500 | | | | | 2,500 | 7,487,783 | 7,490,283 |
| Lettuce, Manc | 12,708 | | | | 161,876 | 174,584 | | 174,584 |
| Lettuce, other | | 840 | 140 | | 6,503 | 7,483 | 169,054 | 176,537 |
| Lettuce, process | | | 9,702 | | | 9,702 | 5,909,150 | 5,918,852 |
| Lettuce, red/g | 376,660 | 9,820 | | 2,760 | 7,960 | 397,200 | 2,158,824 | 2,554,024 |
| Lettuce, speci | 7,393 | 90 | 90 | | 27,693 | 35,266 | 630,001 | 665,267 |
| Lime | 33,173 | 80 | 180 | | 207 | 33,640 | 900,851 | 934,491 |
| Longan | 5,228 | | 10,081 | | 22 | 15,331 | 3,185 | 18,516 |
| Lotus Root | 30 | | | | 5,727 | 5,757 | 52,368 | 58,125 |
| Luau Leaf | 1,212 | | | | 74,300 | 75,512 | 1,340 | 76,852 |
| Lychee | 14,494 | | 5,600 | | 105 | 20,199 | 77,101 | 97,300 |
| Mandarin | | | | | | | 341,805 | 341,805 |
| Mango | 710 | 5,005 | 500 | 2,330 | 110,287 | 118,832 | 798,680 | 917,512 |
| Melon, Cantaloup | | | 683 | | 196,160 | 196,843 | 5,844,880 | 6,041,723 |
| Melon, Honeydew | | | 337 | | 93,996 | 94,333 | 1,893,538 | 1,987,871 |
| Melon, other | | | | | 1,540 | 1,540 | 222,451 | 223,991 |
| Melon, seedless Watermelon | | | 85,173 | | | 85,173 | 1,536,374 | 1,621,541 |
| Melon, Watermelon | | | 156,150 | | 6,535,863 | 6,692,013 | 344,599 | 7,036,612 |
| Mushroom | | | | | | | 1,039 | 1,039 |
| Mushroom, button | | | | | | | 2,675,896 | 2,675,896 |
| Mushroom, sp | 2,914 | | | | | 2,914 | 483,578 | 486,492 |
| Nectarine | | | | | | | 1,713,077 | 1,713,077 |
| On Choy | | | | | 50,726 | 50,726 | 96 | 50,822 |
| Onion, dry | 5,250 | 587,250 | 2,000 | | 31,330 | 625,830 | 11,235,066 | 11,860,896 |
| Onion, green | | 1,300 | | | 47,171 | 472,471 | 175,219 | 647,690 |
| Onion, specialty | | | | | | | 108,579 | 108,579 |
| Orange | 129,920 | 265 | | | | 130,185 | 12,007,899 | 12,138,084 |
| Papaya | 14,372,915 | 2,337 | 132,486 | 58,917 | 943,526 | 15,510,181 | 3,616 | 15,513,797 |
| Papaya, proce | 74,357 | | | | | 74,357 | | 74,357 |
| Parsley, American | | 120 | | | 75,211 | 75,331 | 72,546 | 147,877 |
| Parsley, Chinese | | 180 | | | 60,791 | 60,971 | 52,257 | 114,228 |
| Passion Fruit | | | | | | | 148 | 148 |
| Pea, Chinese | | | | | | | 251,239 | 251,239 |
| Pea, sugarsnap | | | | | | | 108,656 | 108,656 |
| Peach | | | | | | | 1,901,027 | 1,901,027 |
| Peanut | 250 | | | | | 250 | 95,861 | 96,111 |
| Pear | | | | | | | 2,454,586 | 2,454,586 |
| Pepper, hot | 536 | | | | 2,510 | 3,046 | 257,953 | 260,999 |

| Commodity | Receipts Within State (pounds) Hawaii | Maui | Kauai | Molokai | Oahu | State Total | Mainland | Grand Total |
|---|---|---|---|---|---|---|---|---|
| Pepper, swee | 3,148 | 2,230 | | | 1,221,943 | 1,227,321 | 1,553,168 | 2,780,489 |
| Persimmon | 730 | 1,930 | | | | 2,660 | 1,169,626 | 1,172,286 |
| Pineapple | 23,200 | 1,475,832 | 16,275 | | 13,027,504 | 14,542,811 | 3,851 | 14,546,662 |
| Plum | | | | | | | 1,197,828 | 1,197,828 |
| Potato, chipper | | | | | | | 11,865,107 | 11,865,107 |
| Potato, table | | 100 | | | | 100 | 19,003,509 | 19,003,609 |
| Pumpkin | 2,150 | | | | 226,470 | 228,620 | 84,914 | 313,534 |
| Radish | 125 | 485 | | | 19,866 | 20,476 | 10,162 | 30,638 |
| Rambutan | 42,110 | | 15,078 | | | 57,188 | | 57,188 |
| Romaine | 262,625 | 51,250 | | 1,450 | 17,673 | 332,998 | 6,246,570 | 6,579,568 |
| Roots, other | 460 | 1,600 | | 16,450 | | 18,510 | 200,297 | 218,807 |
| Soybean | | | | | 11,079 | 11,079 | 1,050 | 12,129 |
| Spinach, American | | 136 | | | 1,475 | 1,611 | 1,437,782 | 1,439,393 |
| Spinach, Chinese | | | | | | | 30 | 30 |
| Sprouts | | | | | 12,034 | 12,034 | 35,003 | 47,037 |
| Squash, hechima | | | | | 4,583 | 4,583 | 1,233 | 5,816 |
| Squash, hyotan | | | 240 | | 69,090 | 69,330 | 20,425 | 89,755 |
| Squash, Italia | 14,930 | 459,725 | 725 | 875 | 124,995 | 601,250 | 884,967 | 1,486,217 |
| Squash, kabo | 5,497 | | | | 66,810 | 72,307 | 112,649 | 184,956 |
| Squash, other | 2,050 | 150 | 1,005 | | 347 | 3,552 | 766,406 | 769,958 |
| Squash, togan | | | | | 14,214 | 14,214 | 105 | 14,319 |
| Starfruit | 75 | 95 | 2,300 | | | 2,470 | 12,375 | 14,845 |
| Strawberry | | 135,784 | | | | 135,784 | 2,855,383 | 2,991,167 |
| Sweet Potato | 1,344,195 | 15,111 | 160 | 597,955 | | 1,957,421 | 1,033,408 | 2,900,829 |
| Tangelo | 3,000 | 125 | | | | 3,125 | 78,955 | 82,080 |
| Tangerine | 4,740 | | | | | 4,740 | 1,119,778 | 1,124,518 |
| Taro | 64,430 | | | | | 64,430 | 492,816 | 557,246 |
| Taro, chipper | 119,350 | | | | | 119,350 | 101,971 | 221,321 |
| Taro, process | 115,177 | 25,695 | 2,333,461 | | 2,330 | 2,476,663 | | 2,476,663 |
| Tomato | 613,454 | 13,417 | 702 | | 5,350,145 | 5,977,718 | 1,297,561 | 7,275,279 |
| Tomato, other | | 250 | 144 | | 79,852 | 80,246 | 487,130 | 567,376 |
| Tomato, plum | 775 | 77,810 | | | 288,225 | 366,810 | 390,330 | 757,140 |
| Unavailable | | | | | | | 550 | 550 |
| Unspecified | 111,255 | 10,890 | 35,098 | 360 | 2,296 | 159,899 | 14,897,805 | 15,057,704 |
| Vegetables, o | 8851 | 219 | | | 11,784 | 20,854 | 151,424 | 172,278 |
| Vegetables, process | | | | | 2,265 | 2,265 | 167,160 | 169,425 |
| Watercress | | | | | 174,019 | 174,019 | 31,894 | 205,913 |
| Yam Bean Ro | 3,330 | | | | | 3,330 | 62,444 | 65,774 |
| All Commoditi | 38,032,980 | 6,844,878 | 3,075,471 | 2,771,285 | 35,823,552 | 86,974,173 | 188,390,498 | 275,243,655 |

Source of Data: HDOA, Market News Branch

## Appendix F. MARKET SUPPLY: IMPORTS VS. LOCAL, 1984-2001

| Year | Fresh Fruits (pounds) | | | Fresh Vegetables (pounds) | | | Grand Total |
|---|---|---|---|---|---|---|---|
| | Import | Local | Total | Import | Local | Total | |
| 1984 | 64,318,000 | 34,330,000 | 98,648,000 | 114,508,000 | 79,530,000 | 194,038,000 | 292,686,000 |
| 1985 | 68,083,000 | 35,180,000 | 103,263,000 | 121,602,000 | 79,630,000 | 201,232,000 | 304,495,000 |
| 1986 | 72,253,000 | 36,650,000 | 108,903,000 | 134,084,000 | 76,215,000 | 210,299,000 | 319,202,000 |
| 1987 | 75,139,000 | 38,375,000 | 113,514,000 | 139,485,000 | 80,120,000 | 219,605,000 | 333,119,000 |
| 1988 | 75,221,000 | 40,095,000 | 115,316,000 | 149,251,000 | 72,335,000 | 221,586,000 | 336,902,000 |
| 1989 | 92,896,000 | 93,220,000 | 186,116,000 | 159,003,000 | 68,150,000 | 227,153,000 | 413,269,000 |
| 1990 | 89,753,000 | 111,195,000 | 200,948,000 | 149,638,000 | 68,945,000 | 218,583,000 | 419,531,000 |
| 1991 | 90,018,000 | 83,641,000 | 173,659,000 | 153,130,000 | 76,305,000 | 229,435,000 | 403,094,000 |
| 1992 | 102,863,000 | 75,948,000 | 178,811,000 | 156,938,000 | 72,240,000 | 229,178,000 | 407,989,000 |
| 1993 | 107,157,000 | 103,789,000 | 210,946,000 | 155,434,000 | 71,400,000 | 226,834,000 | 437,780,000 |
| 1994 | 103,506,000 | 83,058,000 | 186,564,000 | 161,935,000 | 65,955,000 | 227,890,000 | 414,454,000 |
| 1995 | 102,551,000 | 98,365,000 | 200,916,000 | 154,557,000 | 67,750,000 | 222,307,000 | 423,223,000 |
| 1996 | 99,744,000 | 86,224,000 | 185,968,000 | 158,036,000 | 74,125,000 | 232,161,000 | 418,129,000 |
| 1997 | 49,518,000 | 82,793,000 | 132,311,000 | 145,657,000 | 83,550,000 | 229,207,000 | 361,518,000 |
| 1998 | 54,864,000 | 96,960,000 | 151,824,000 | 110,247,000 | 93,806,000 | 204,053,000 | 355,877,000 |
| 1999 | 90,883,000 | 83,431,000 | 174,314,000 | 150,874,000 | 102,350,000 | 253,224,000 | 427,538,000 |
| 2000 | 98,396,000 | 77,456,000 | 175,852,000 | 159,250,000 | 97,370,000 | 256,620,000 | 432,472,000 |
| 2001 | 85,347,000 | 81,585,000 | 166,932,000 | 141,420,000 | 100,410,000 | 241,830,000 | 408,762,000 |

Source of Data: HDOA/HASS

## Appendix G. FARM VALUE OF DIVERSIFIED AGRICULTURE IN HAWAII, 1984-2001

| Year | Farm Value ($1000s) | Acreage (acres) | Population (1000s) |
|---|---|---|---|
| 1984 | $ 204,389 | 43,300 | 1,028 |
| 1985 | 215,719 | 43,400 | 1,040 |
| 1986 | 231,197 | 40,900 | 1,052 |
| 1987 | 240,012 | 42,500 | 1,068 |
| 1988 | 256,660 | 44,700 | 1,080 |
| 1989 | 276,438 | 41,500 | 1,095 |
| 1990 | 275,789 | 44,800 | 1,113 |
| 1991 | 268,707 | 47,000 | 1,137 |
| 1992 | 264,427 | 43,800 | 1,159 |
| 1993 | 271,074 | 44,600 | 1,173 |
| 1994 | 273,826 | 44,600 | 1,188 |
| 1995 | 291,632 | 46,600 | 1,197 |
| 1996 | 307,329 | 48,500 | 1,204 |
| 1997 | 327,484 | 55,000 | 1,212 |
| 1998 | 329,886 | 57,900 | 1,215 |
| 1999 | 342,846 | 58,700 | 1,210 |
| 2000 | 352,870 | 47,100 | 1,213 |
| 2001 | 356,935 | 48,600 | 1,227 |

Source of Data: HDOA/HASS and DBEDT

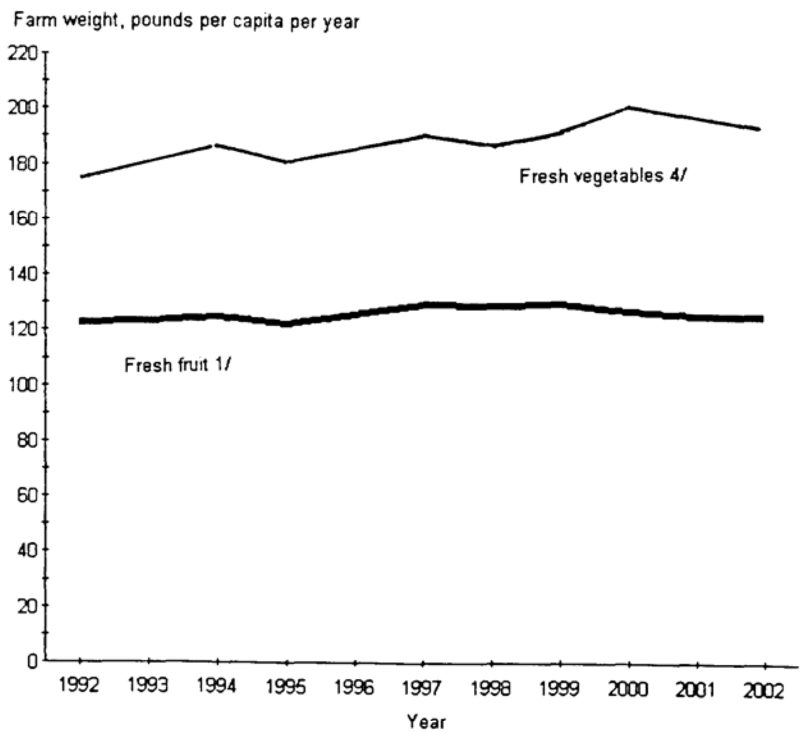
# Appendix H. PER CAPITA CONSUMPTION OF FRUITS AND VEGETABLES

Farm weight, pounds per capita per year

| Year | Fresh fruit 1/ | Fruit for processing 2/ | Total fruit 3/ | Fresh vegetables 4/ | Vegetables for processing 5/ | Total vegetables 3/ | Total fruit and vegetables 3/ |
|---|---|---|---|---|---|---|---|
| 1992 | 122.8 | 159.5 | 282.3 | 173.9 | 220.7 | 394.6 | 676.9 |
| 1993 | 123.5 | 157.4 | 280.8 | 180.7 | 226.5 | 407.2 | 688.1 |
| 1994 | 124.9 | 154.2 | 279.1 | 186.5 | 226.3 | 412.8 | 691.9 |
| 1995 | 122.5 | 161.0 | 283.6 | 180.9 | 226.3 | 407.2 | 690.8 |
| 1996 | 126.2 | 157.2 | 283.3 | 185.9 | 231.6 | 417.4 | 700.8 |
| 1997 | 129.4 | 161.1 | 290.6 | 190.1 | 227.9 | 418.0 | 708.6 |
| 1998 | 128.8 | 155.3 | 284.1 | 186.5 | 226.4 | 412.9 | 697.0 |
| 1999 | 129.6 | 162.7 | 292.3 | 191.3 | 222.4 | 413.7 | 706.0 |
| 2000 | 127.2 | 159.9 | 287.1 | 200.4 | 224.7 | 425.2 | 712.3 |
| 2001 | 125.4 | 147.4 | 272.8 | 196.7 | 216.5 | 413.2 | 686.0 |
| 2002 | 125.6 | 146.0 | 271.7 | 193.4 | 218.6 | 412.0 | 683.6 |

1/ Includes apples, apricots, avocados, bananas, cherries, cantaloupe, cranberries, grapes, grapefruit, honeydew, kiwifruit, lemons, limes, mangoes, nectarines, oranges, papayas, peaches, pears, pineapples, plums, prunes, strawberries, tangelos, tangerines, temples, and watermelon.
2/ Includes apples, apricots, blackberries, boysenberries, cherries, cranberries, dates, figs, grapes, grapefruit, lemons, limes, loganberries, nectarines, olives, oranges, peaches, pears, pineapples, plums, prunes, raspberries, strawberries, tangelos, tangerines, temples, and other miscellaneous fruit and berries.
3/ Calculated from unrounded data.
4/ Includes artichokes, asparagus, snap beans, broccoli, cabbage, carrots, cauliflower, celery, sweet corn, cucumbers, eggplant, endive, escarole, garlic, head lettuce, romaine and leaf lettuce, mushrooms, onions, bell peppers, potatoes, radishes, spinach, sweetpotatoes, and tomatoes.
5/ Includes asparagus, lima beans, snap beans, beets, broccoli, cabbage, carrots, cauliflower, sweet corn, cucumbers, dry edible beans and peas, lentils, mushrooms, onions, green peas, chile peppers, potatoes, spinach, tomatoes, and other miscellaneous vegetables.
Source: USDA/Economic Research Service.

RUNID=151046645 ReportType=2




Source: http://www.ers.usda.gov/data/foodconsumption/RERUN.ASP?CommodityPick=050101... 10/14/2004

## Appendix I. LOCALLY GROWN SHARE OF HAWAII AGRICULTURE MARKET

| | Fresh Fruits | Fresh Vegetables |
|---|---|---|
| U.S. Department of Agriculture, Economic Research Service (2001) | 11 crops locally grown out of 27 imported, or 40.7% | 12 crops locally grown out of 25 imported, or 48% |
| Hawaii Agricultural Statistics Service (2001) | 55,230* lbs. locally grown out of 140,577* total supply, or 39.2% | 91,910* lbs. locally grown out of 223,330* total supply, or 41.1% |
| Average | 40% | 44.5% |

*Data taken from Appendix F and adjusted by authors.

Source of Data: USDA/ERS, *Food Consumption (per Capita) Data System.*
USDA, *Statistics of Hawaii Agriculture, 2001, Market Supply: Fresh Fruits & Vegetables.*

**Appendix J. YIELD PER ACRE FOR SELECTED HAWAII FRESH FRUITS**
**(in 1,000 lbs.)**

| Crop* | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
|---|---|---|---|---|---|---|
| Specialty Tropical Fruits | 4.7 | 2.9 | 2.4 | 2.3 | 1.6 | 2.78 |
| Avocado | 2.0 | 2.1 | 2.6 | 2.9 | 2.6 | 2.44 |
| Banana | 14.4 | 14.8 | 17.3 | 19.9 | 18.8 | 17.04 |
| Lemon | n/a | n/a | n/a | n/a | n/a | 2.3 |
| Lime (1991-1995) | 1.5 | 2.2 | 2.2 | 2.4 | 3.0 | 2.26 |
| Mango (1999-2001) | n/a | n/a | 1.9 | 2.1 | 1.3 | 1.77 |
| Orange, navel (1984-1986) | 5.8 | 3.4 | 4.5 | n/a | n/a | 4.57 |
| Orange, tangerine (1991-1995) | 5.0 | 1.5 | 2.1 | 1.9 | 2.5 | 2.60 |
| Seed Crops (1998-2002) | 1.4 | 1.6 | 1.4 | 1.6 | 1.9 | 1.58 |
| Forage/Feed (1991-1995) | 8.6 | 15.3 | 6.9 | 9.4 | 10.6 | 10.16 |

*For crops showing years in parenthesis, the average is based on these years, inasmuch as these crops are actively grown, but no data is available since then.

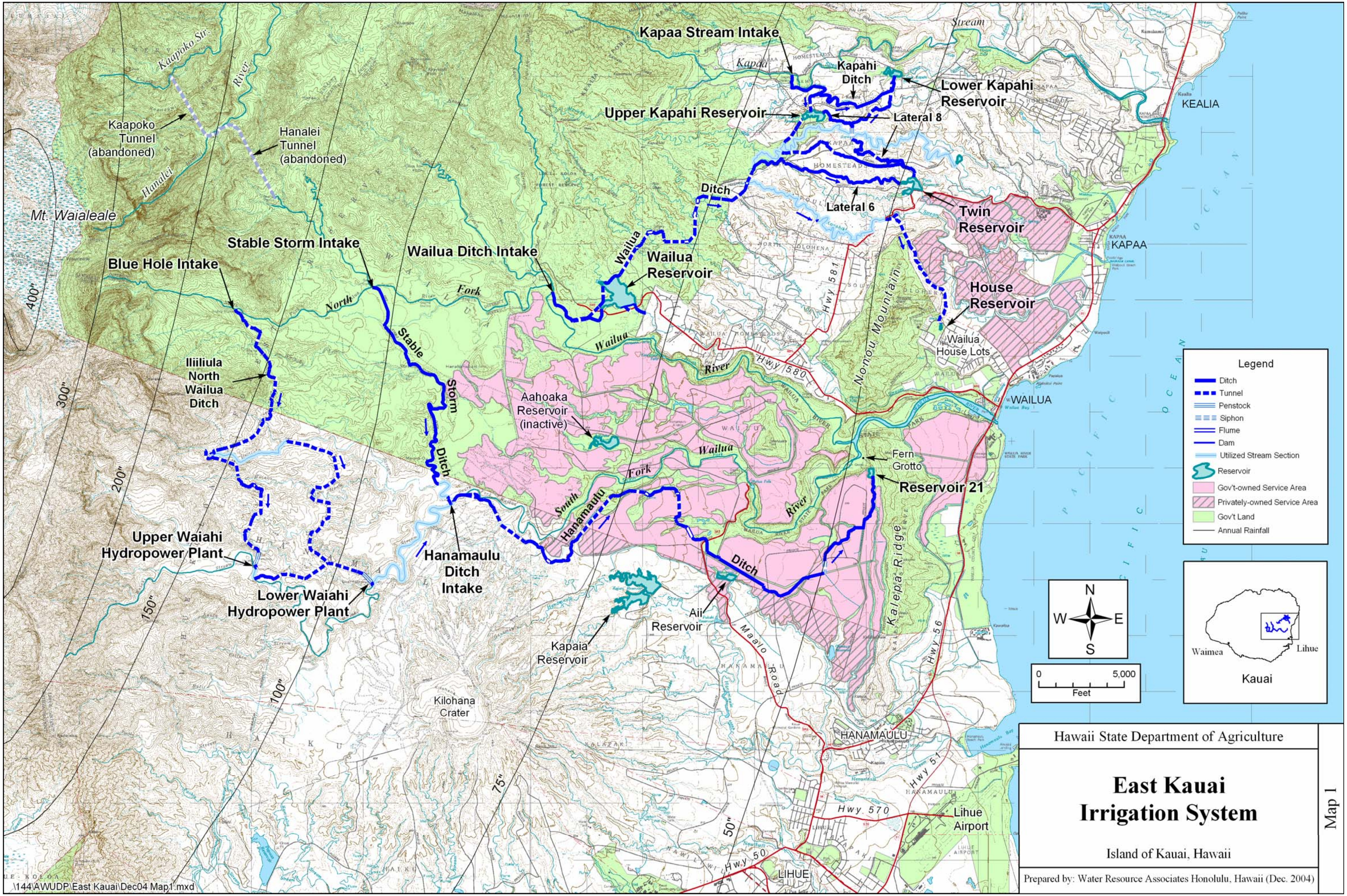
Source of Data: HDOA/HASS, Statistics of Hawaii Agriculture

**Appendix K. YIELD PER ACRE FOR SELECTED HAWAII FRESH VEGETABLES (in 1,000 lbs.)**

| Crop* | 1997 | 1998 | 1999 | 2000 | 2001 | Average |
|---|---|---|---|---|---|---|
| Beans, snap | 5.4 | 4.5 | 5.0 | 5.7 | 5.2 | 5.16 |
| Bittermelon | 9.0 | 10.0 | 13.8 | 15.0 | 16.7 | 12.90 |
| Broccoli | 3.2 | 3.2 | 4.0 | 4.0 | 3.5 | 3.58 |
| Burdock | 14.7 | 13.2 | 12.5 | 12.0 | 10.0 | 12.48 |
| Cabbage, Chinese | 19.7 | 20.8 | 22.7 | 22.5 | 21.9 | 21.52 |
| Cabbage, head | 20.0 | 25.5 | 26.0 | 27.0 | 25.0 | 24.70 |
| Cabbage, mustard | 10.0 | 10.7 | 11.4 | 11.5 | 12.3 | 11.18 |
| Carrots (1991-1995) | 15.0 | 12.5 | 10.0 | 10.0 | 12.0 | 11.90 |
| Cauliflower (1994-199u8) | 12.0 | 13.3 | 12.0 | 13.3 | 13.0 | 12.72 |
| Celery | 25.0 | 26.0 | 26.0 | 22.0 | 23.0 | 24.40 |
| Corn, sweet | 3.1 | 2.8 | 3.8 | 5.5 | 4.3 | 3.90 |
| Cucumber | 12.5 | 12.5 | 12.3 | 14.3 | 14.3 | 13.18 |
| Daikon | 11.4 | 10.0 | 9.0 | 8.9 | 9.7 | 9.80 |
| Dasheen (1993-1997) | 21.4 | 15.7 | 18.6 | 14.3 | 19.0 | 17.80 |
| Eggplant | 18.8 | 21.7 | 21.4 | 24.0 | 20.0 | 21.18 |
| Ginger Root | 44.0 | 50.0 | 46.0 | 50.0 | 50.0 | 48.00 |
| Lettuce, head | 11.0 | 10.0 | 8.8 | 8.7 | 8.6 | 9.42 |
| Lettuce, Romaine (1995-1999) | 9.2 | 9.7 | 11.5 | 15.0 | 11.2 | 11.32 |
| Lotus Root (1987-1991) | 4.1 | 6.3 | 9.0 | 6.7 | 7.5 | 6.72 |
| Onions, dry | 9.2 | 13.0 | 11.0 | 12.6 | 18.0 | 12.76 |
| Onions, green | 9.0 | 8.3 | 8.9 | 10.0 | 11.7 | 9.58 |
| Parsley (1988-1992) | 12.4 | 11.2 | 12.8 | 12.0 | 11.0 | 11.88 |
| Peas, Chinese (1993-1997) | 5.0 | 5.0 | 5.0 | 5.0 | 5.0 | 5.00 |
| Peppers, green | 10.0 | 17.6 | 15.0 | 14.0 | 14.8 | 14.28 |
| Potato, sweet | 10.0 | 10.0 | 8.5 | 9.6 | 8.2 | 9.26 |
| Pumpkin | 6.9 | 11.0 | 10.0 | 11.3 | 11.4 | 10.12 |
| Radish | 10.7 | 10.0 | 8.7 | 10.0 | 10.0 | 9.88 |
| Squash, oriental | 12.0 | 16.0 | 20.0 | 24.0 | 25.0 | 19.40 |
| Squash, Italian | 7.0 | 8.8 | 10.6 | 12.2 | 11.3 | 9.98 |
| Taro, Chinese | 5.0 | 3.3 | 3.7 | 5.0 | 10.0 | 5.40 |
| Tomato | 30.0 | 34.0 | 40.0 | 33.0 | 30.2 | 33.44 |
| Watermelon | 20.0 | 20.0 | 20.0 | 22.5 | 20.2 | 20.54 |

*For crops showing years in parenthesis, the average is based on these years, inasmuch as these crops are actively grown, but no data is available since then.

Source of Data: HDOA/HASS, Statistics of Hawaii Agriculture



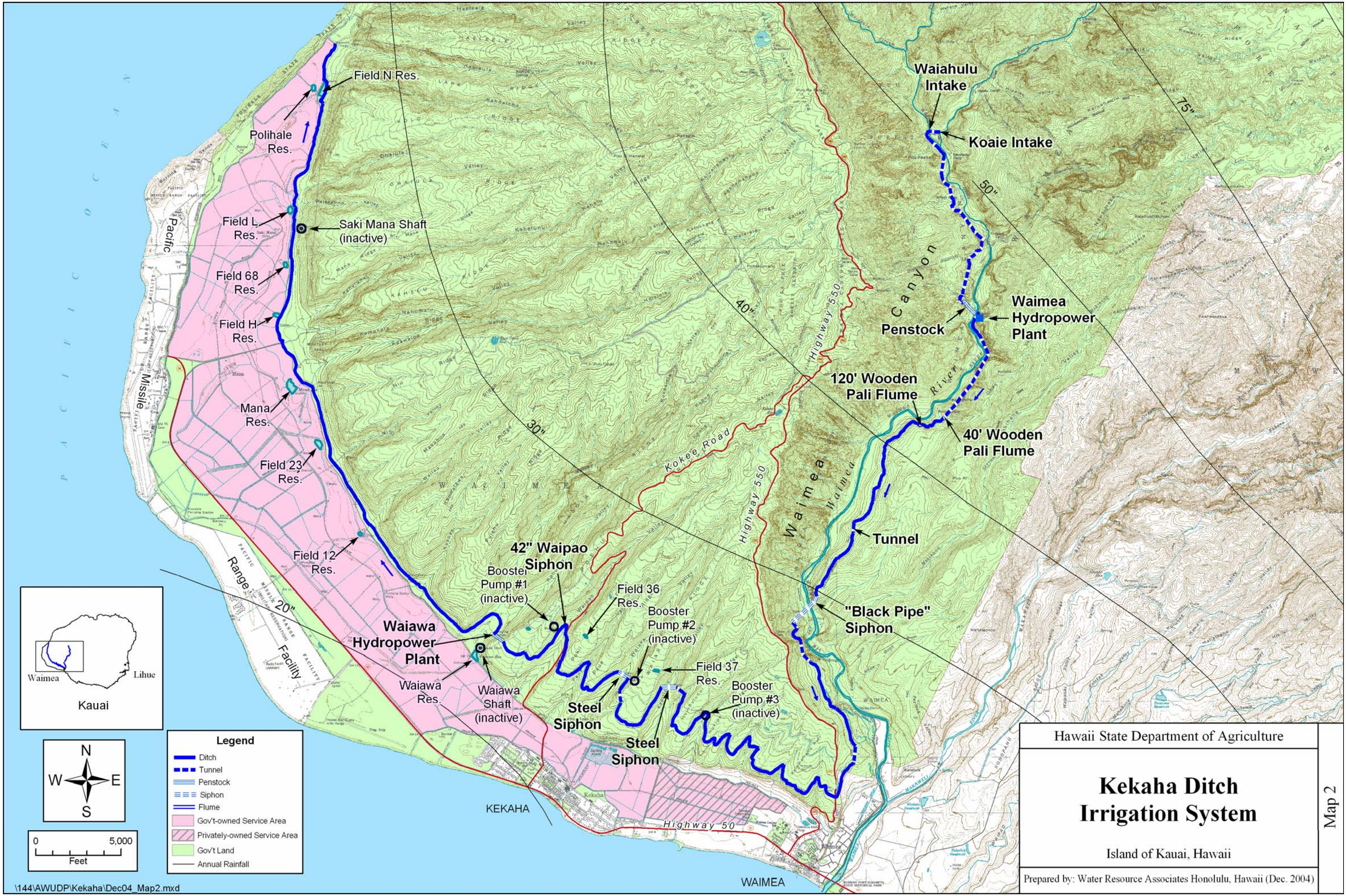

Hawaii State Department of Agriculture

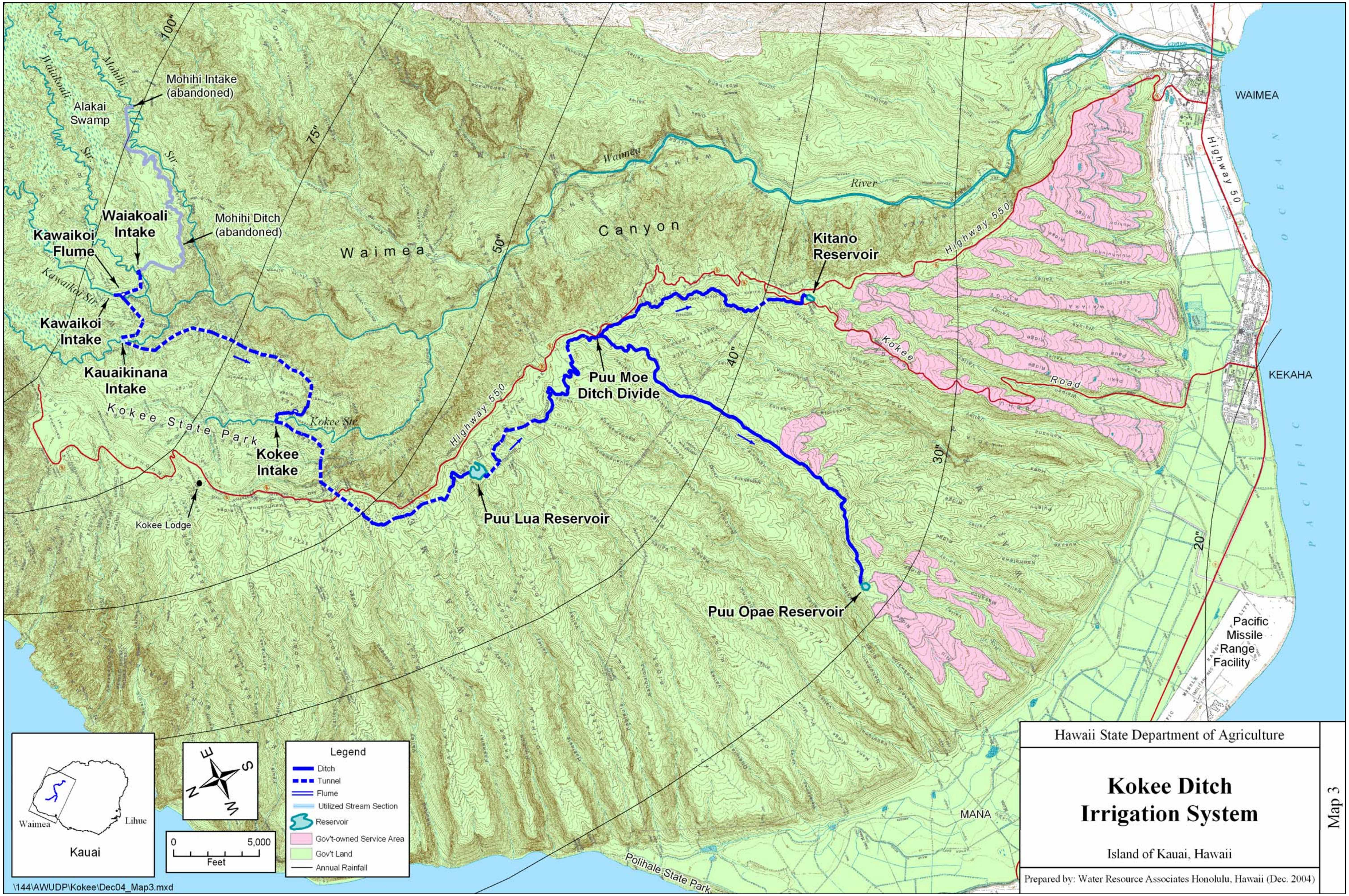
# East Kauai Irrigation System

Island of Kauai, Hawaii

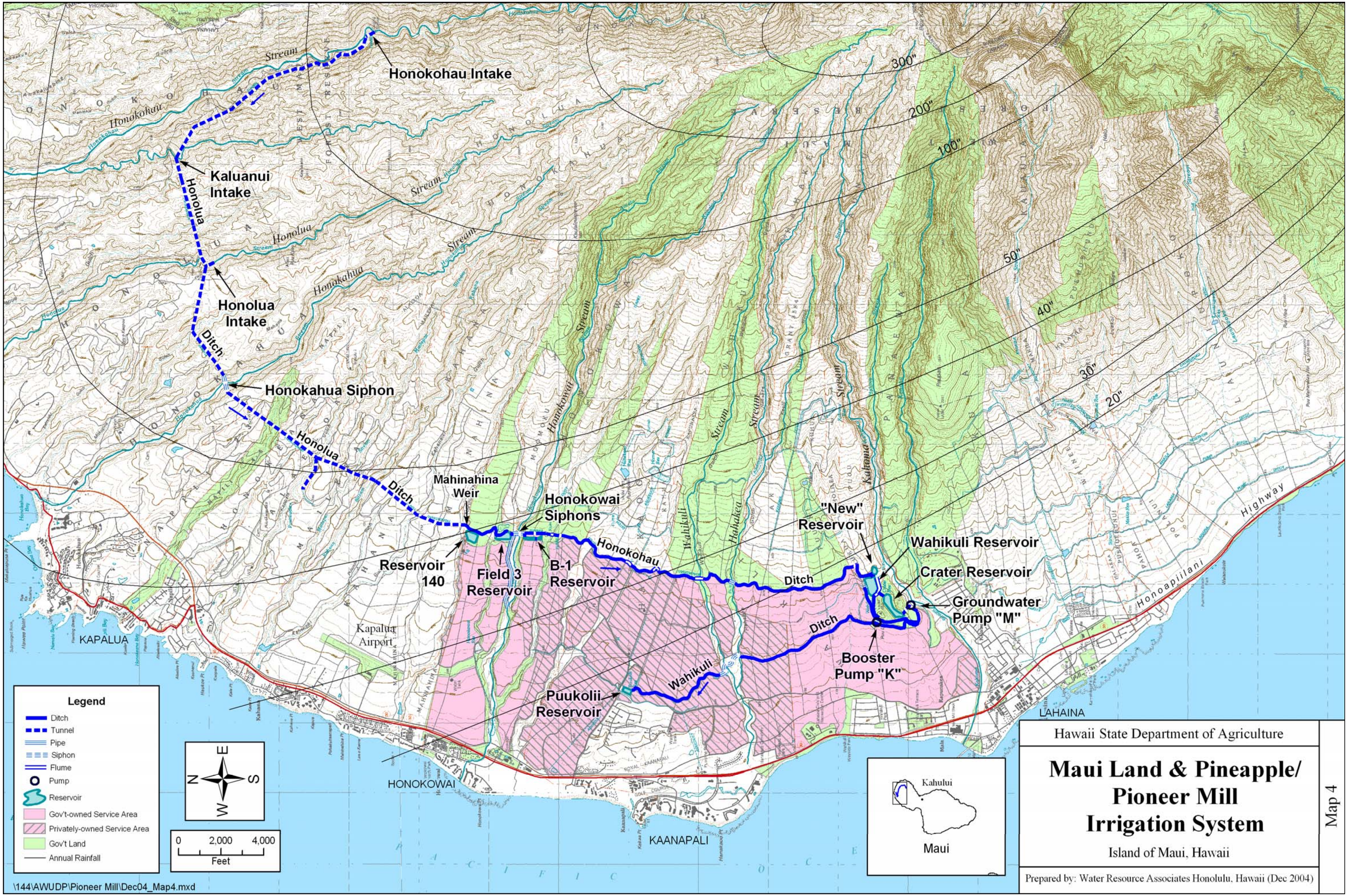
Map 1

Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)

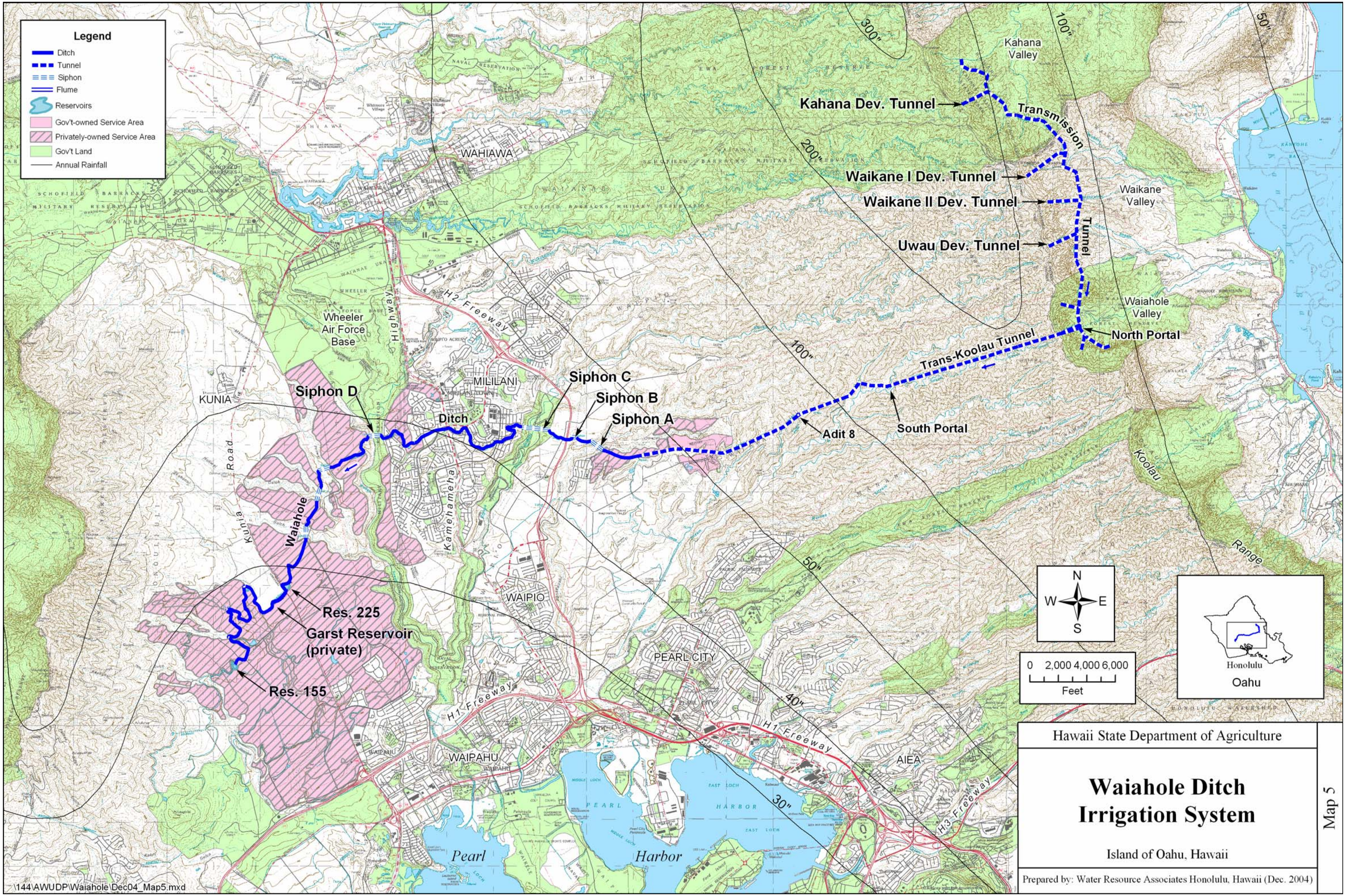

Field N Res.
Polihale Res.
Field L Res.
Saki Mana Shaft (inactive)
Field 68 Res.
Field H Res.
Mana Res.
Field 23 Res.
Field 12 Res.
Waiahulu Intake
Koaie Intake
Waimea Hydropower Plant
Penstock
Canyon
120' Wooden Pali Flume
40' Wooden Pali Flume
Tunnel
"Black Pipe" Siphon
42" Waipao Siphon
Booster Pump #1 (inactive)
Field 36 Res.
Booster Pump #2 (inactive)
Field 37 Res.
Booster Pump #3 (inactive)
Waiawa Hydropower Plant
Waiawa Res.
Waiawa Shaft (inactive)
Steel Siphon
Steel Siphon
Kokee Road
Highway 550
Highway 50
Waimea
Pacific Missile Range Facility
PACIFIC OCEAN
KEKAHA
WAIMEA
20"
30"
40"
50"
75"
Waimea
Lihue
Kauai
N
W
E
S
0
5,000
Feet
Legend
Ditch
Tunnel
Penstock
Siphon
Flume
Gov't-owned Service Area
Privately-owned Service Area
Gov't Land
Annual Rainfall
Hawaii State Department of Agriculture
Kekaha Ditch Irrigation System
Island of Kauai, Hawaii
Map 2
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)
\144\AWUDP\Kekaha\Dec04_Map2.mxd



Mohihi Intake (abandoned)
Alakai Swamp
Waiakoali Str.
Mohihi Str.
100"
75"
50"
40"
30"
20"
Mohihi Ditch (abandoned)
Waiakoali Intake
Kawaikoi Flume
Kawaikoi Str.
Kawaikoi Intake
Kauaikinana Intake
Kokee State Park
Kokee Str.
Kokee Intake
Kokee Lodge
Waimea Canyon
Waimea River
Highway 550
Puu Moe Ditch Divide
Puu Lua Reservoir
Kitano Reservoir
Kokee Road
Puu Opae Reservoir
WAIMEA
Highway 50
PACIFIC OCEAN
KEKAHA
Pacific Missile Range Facility
MANA
Polihale State Park
Waimea
Lihue
Kauai
N
E
S
W
0
5,000
Feet
Legend
Ditch
Tunnel
Flume
Utilized Stream Section
Reservoir
Gov't-owned Service Area
Gov't Land
Annual Rainfall
\144\AWUDP\Kokee\Dec04_Map3.mxd
Hawaii State Department of Agriculture
Kokee Ditch Irrigation System
Island of Kauai, Hawaii
Map 3
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)



Honokohau Intake
Kaluanui Intake
Honolua
Honolua Intake
Ditch
Honokahua Siphon
Honolua
Ditch
Mahinahina Weir
Honokowai Siphons
Reservoir 140
Field 3 Reservoir
B-1 Reservoir
Honokohau
Ditch
"New" Reservoir
Wahikuli Reservoir
Crater Reservoir
Groundwater Pump "M"
Booster Pump "K"
Ditch
Wahikuli
Puukolii Reservoir
300"
200"
100"
50"
40"
30"
20"
Stream
Honokohau
Honolua
Honokahua
Honokowai
Wahikuli
Hahakea
Kahoma
Kapalua Airport
KAPALUA
HONOKOWAI
KAANAPALI
LAHAINA
Honoapiilani
Highway
Legend
Ditch
Tunnel
Pipe
Siphon
Flume
Pump
Reservoir
Gov't-owned Service Area
Privately-owned Service Area
Gov't Land
Annual Rainfall
N
E
S
W
0
2,000
4,000
Feet
Kahului
Maui
Hawaii State Department of Agriculture
Maui Land & Pineapple/
Pioneer Mill
Irrigation System
Island of Maui, Hawaii
Map 4
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec 2004)
\144\AWUDP\Pioneer Mill\Dec04_Map4.mxd




Hawaii State Department of Agriculture

# Waiahole Ditch Irrigation System

Island of Oahu, Hawaii

Map 5

Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)

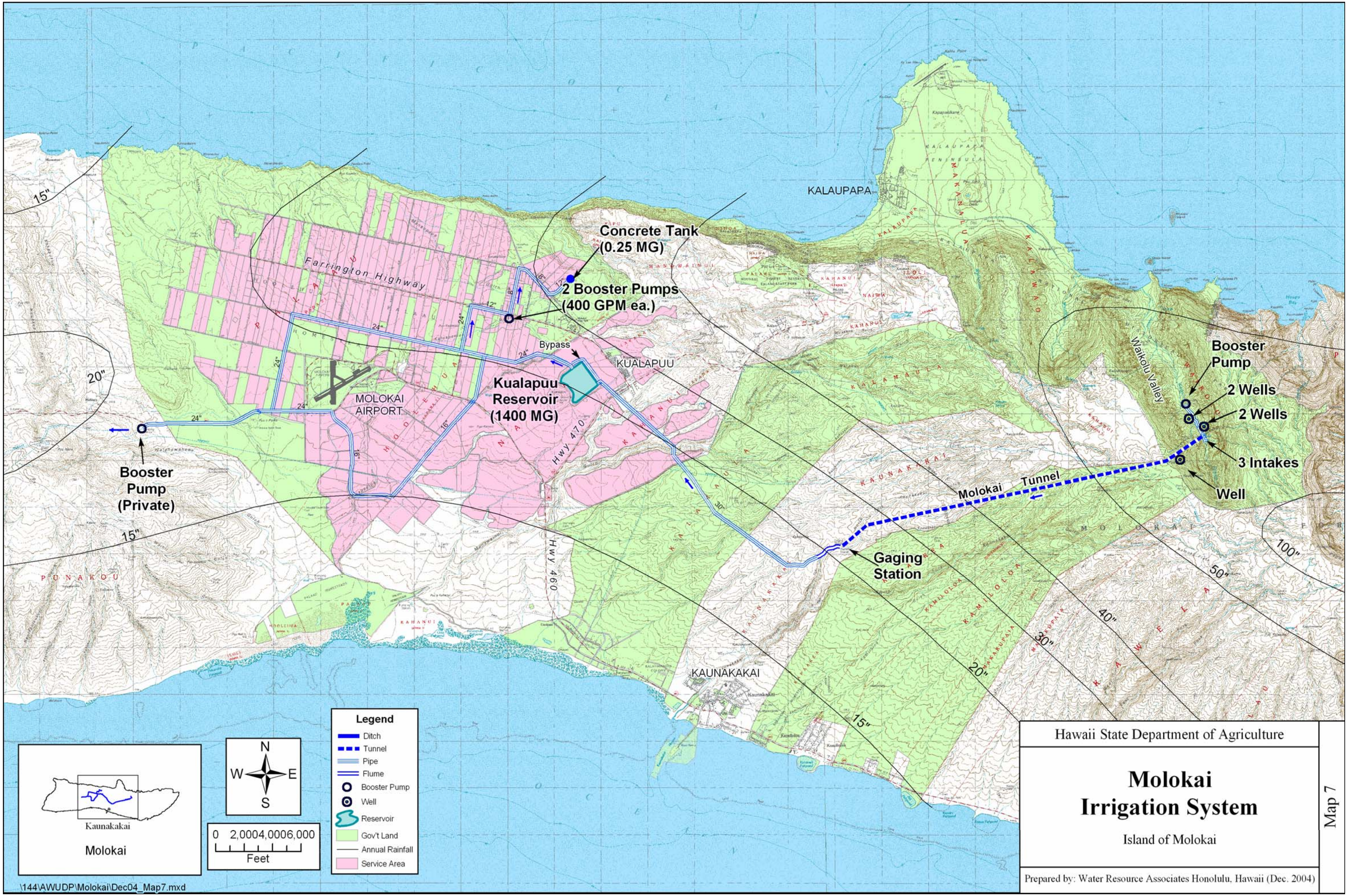

Hawaii State Department of Agriculture

# Lower Hamakua Ditch Irrigation System

Island of Hawaii

Map 6

Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)



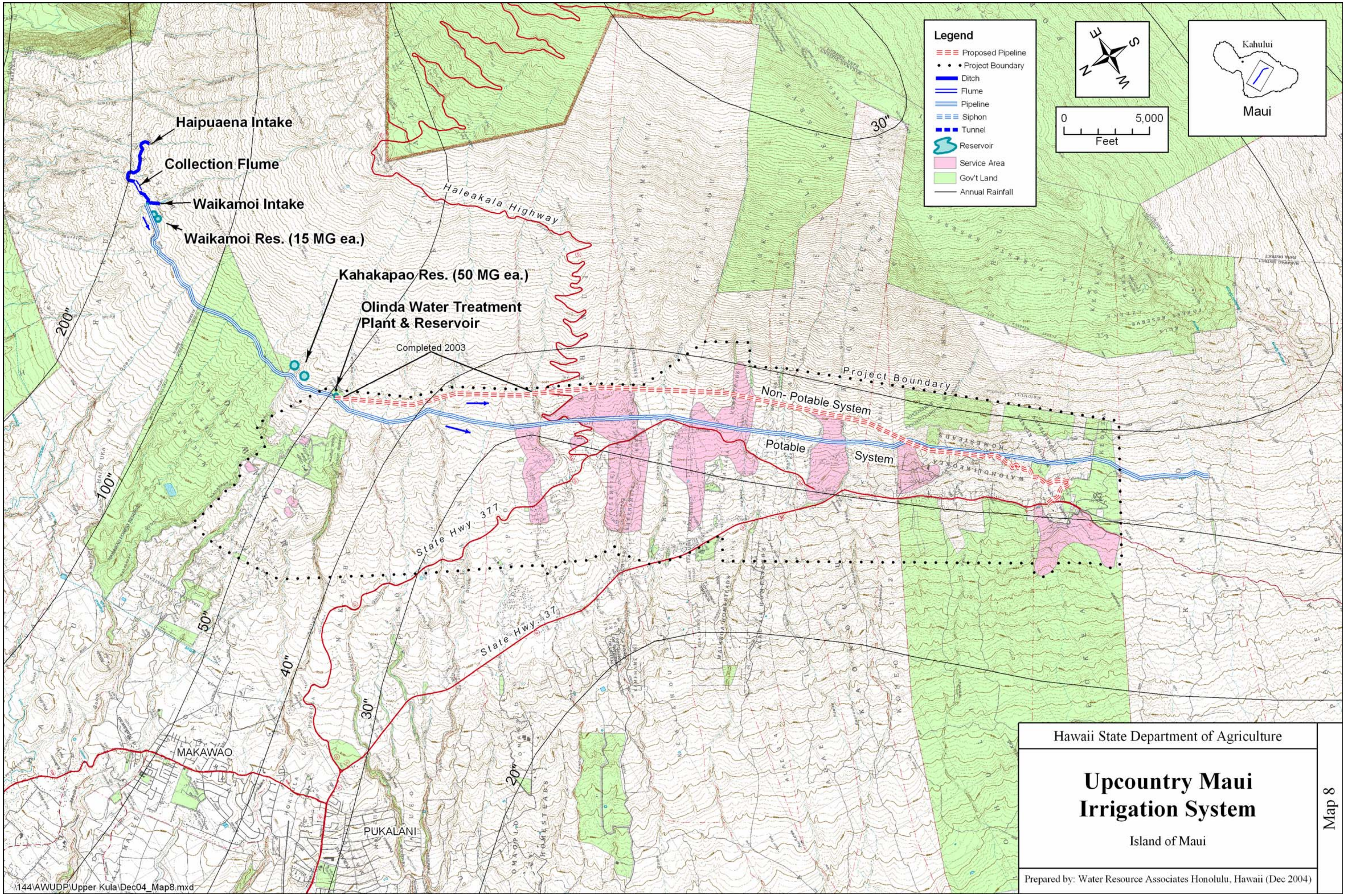

Hawaii State Department of Agriculture

# Molokai Irrigation System

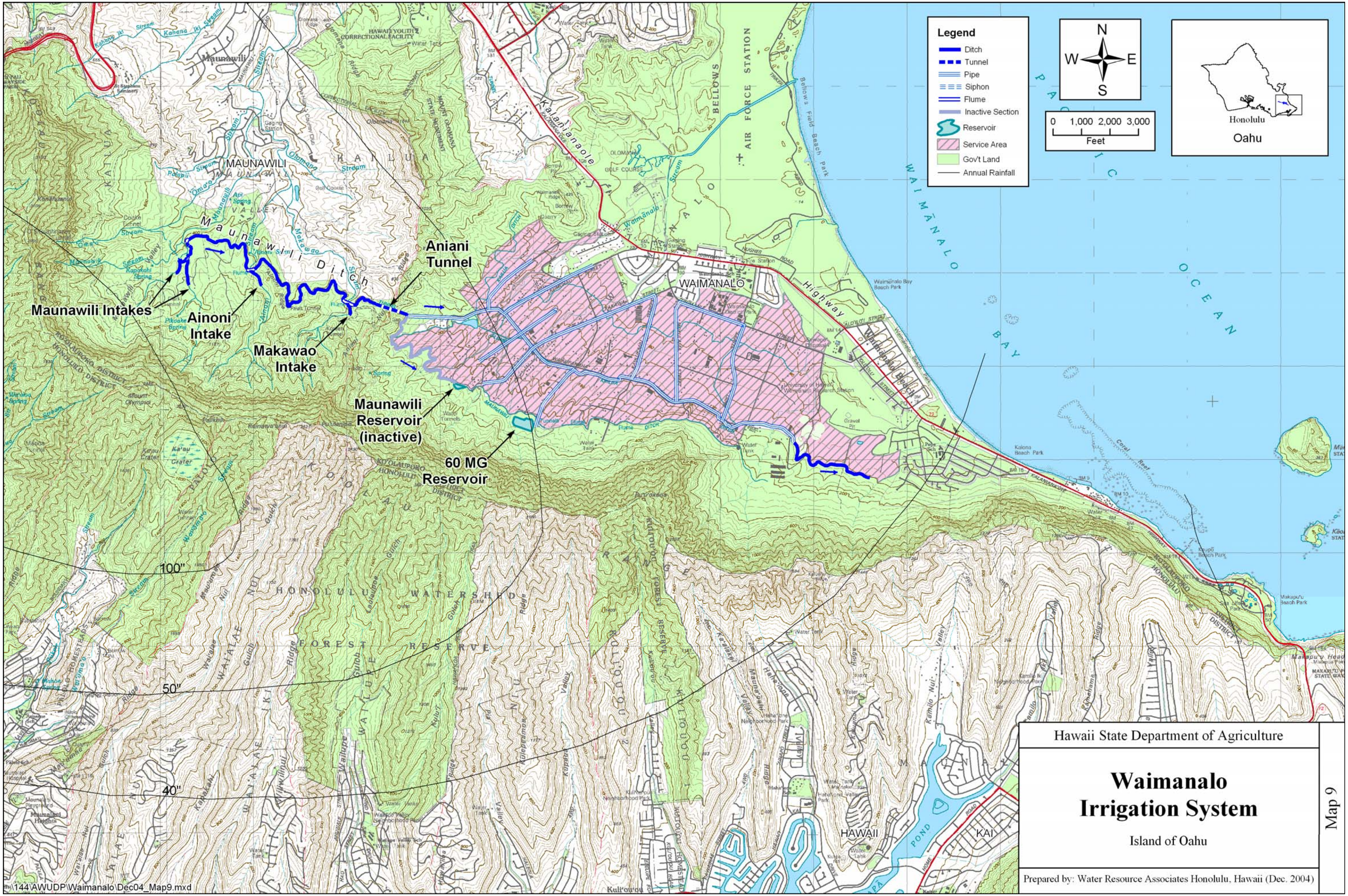
Island of Molokai

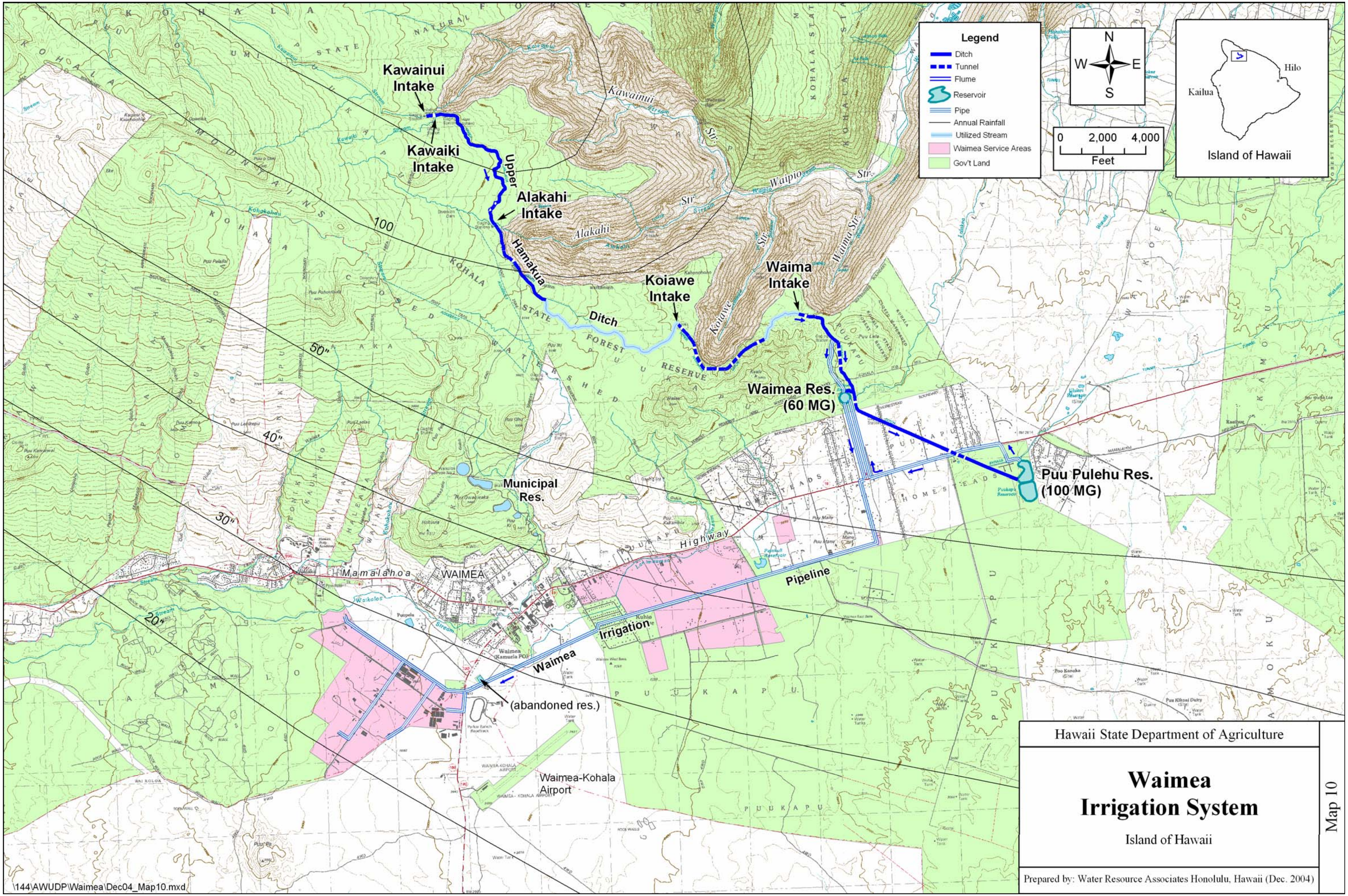
Map 7

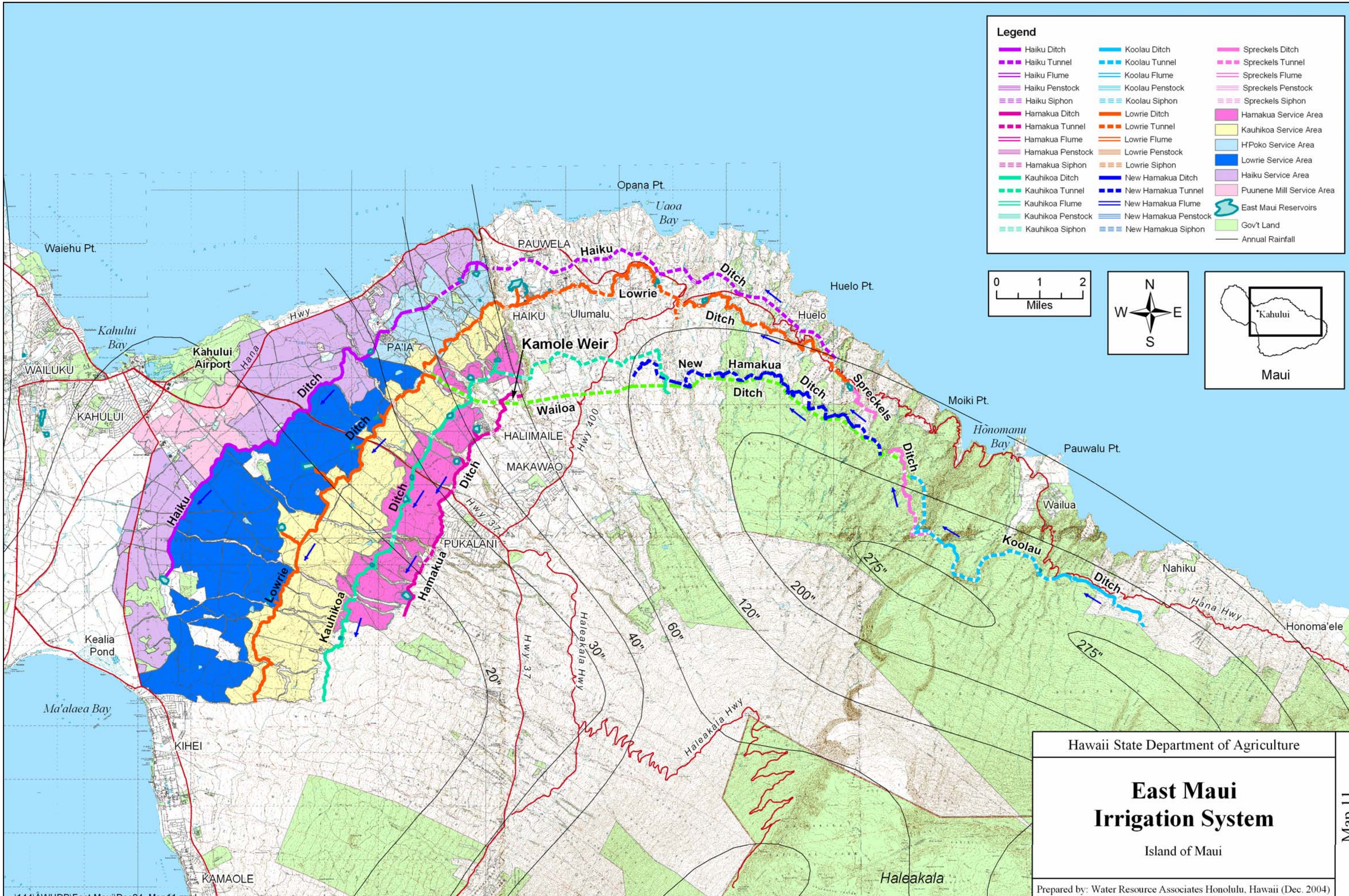
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)

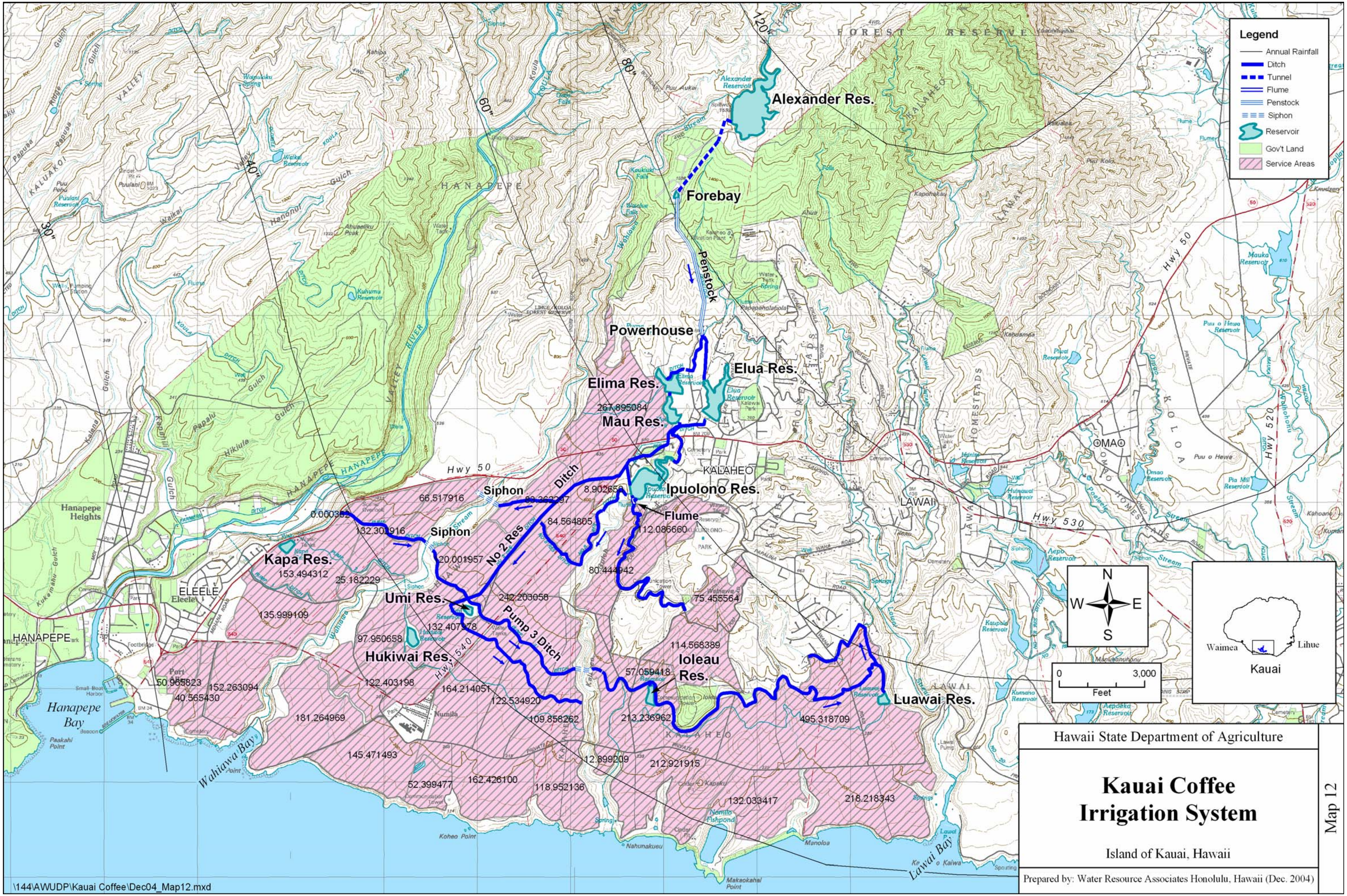


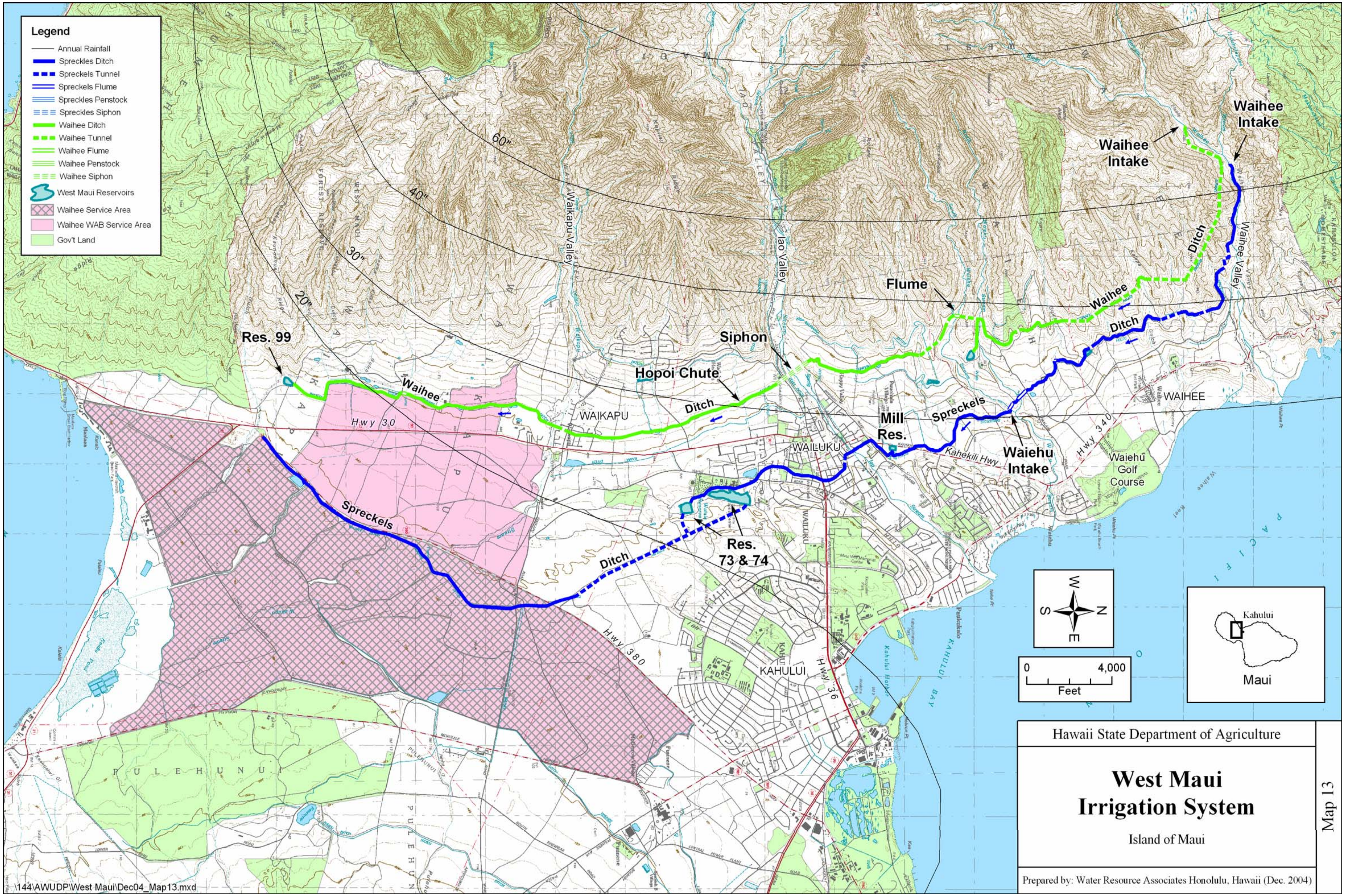
Legend
Proposed Pipeline
Project Boundary
Ditch
Flume
Pipeline
Siphon
Tunnel
Reservoir
Service Area
Gov't Land
Annual Rainfall
0 5,000
Feet
Kahului
Maui
Haipuaena Intake
Collection Flume
Waikamoi Intake
Waikamoi Res. (15 MG ea.)
Kahakapao Res. (50 MG ea.)
Olinda Water Treatment
Plant & Reservoir
Completed 2003
Haleakala Highway
Project Boundary
Non- Potable System
Potable
System
State Hwy. 377
State Hwy. 37
MAKAWAO
PUKALANI
200"
100"
50"
40"
30"
20"
30"
\144\AWUDP\Upper Kula\Dec04_Map8.mxd
Hawaii State Department of Agriculture
Upcountry Maui
Irrigation System
Island of Maui
Map 8
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec 2004)


Legend
Ditch
Tunnel
Pipe
Siphon
Flume
Inactive Section
Reservoir
Service Area
Gov't Land
Annual Rainfall
N
W
E
S
0 1,000 2,000 3,000
Feet
Honolulu
Oahu
Maunawili Ditch
Aniani Tunnel
Maunawili Intakes
Ainoni Intake
Makawao Intake
Maunawili Reservoir (inactive)
60 MG Reservoir
MAUNAWILI
WAIMANALO
Kalanianaole Highway
BELLOWS AIR FORCE STATION
PACIFIC OCEAN
WAIMANALO BAY
HONOLULU WATERSHED FOREST RESERVE
KOOLAU RANGE
HAWAII
KAI
100"
50"
40"
Hawaii State Department of Agriculture
Waimanalo Irrigation System
Island of Oahu
Map 9
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)
144 AWUDP Waimanalo Dec04_Map9.mxd


Legend
Ditch
Tunnel
Flume
Reservoir
Pipe
Annual Rainfall
Utilized Stream
Waimea Service Areas
Gov't Land
N
W
E
S
0
2,000
4,000
Feet
Hilo
Kailua
Island of Hawaii
Kawainui Intake
Kawaiki Intake
Upper
Alakahi Intake
Hamakua
Ditch
Koiawe Intake
Waima Intake
Waimea Res. (60 MG)
Puu Pulehu Res. (100 MG)
Municipal Res.
100
50"
40"
30"
20"
Mamalahoa
Highway
WAIMEA
Pipeline
Irrigation
Waimea
(abandoned res.)
Waimea-Kohala Airport
Hawaii State Department of Agriculture
Waimea Irrigation System
Island of Hawaii
Map 10
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)
144\AWUDP\Waimea\Dec04_Map10.mxd


Legend
Haiku Ditch
Haiku Tunnel
Haiku Flume
Haiku Penstock
Haiku Siphon
Hamakua Ditch
Hamakua Tunnel
Hamakua Flume
Hamakua Penstock
Hamakua Siphon
Kauhikoa Ditch
Kauhikoa Tunnel
Kauhikoa Flume
Kauhikoa Penstock
Kauhikoa Siphon
Koolau Ditch
Koolau Tunnel
Koolau Flume
Koolau Penstock
Koolau Siphon
Lowrie Ditch
Lowrie Tunnel
Lowrie Flume
Lowrie Penstock
Lowrie Siphon
New Hamakua Ditch
New Hamakua Tunnel
New Hamakua Flume
New Hamakua Penstock
New Hamakua Siphon
Spreckels Ditch
Spreckels Tunnel
Spreckels Flume
Spreckels Penstock
Spreckels Siphon
Hamakua Service Area
Kauhikoa Service Area
H'Poko Service Area
Lowrie Service Area
Haiku Service Area
Puunene Mill Service Area
East Maui Reservoirs
Gov't Land
Annual Rainfall
0 1 2
Miles
N
W
E
S
Kahului
Maui
Opana Pt.
Uaoa Bay
Waiehu Pt.
PAUWELA
Haiku
Ditch
Lowrie
Ditch
Huelo Pt.
Huelo
HAIKU
Ulumalu
Kahului Bay
Kahului Airport
Hwy
Hana
PA'IA
Kamole Weir
New
Hamakua
Ditch
Spreckels
Ditch
WAILUKU
Ditch
Wailoa
Ditch
Moiki Pt.
KAHULUI
Ditch
HALIIMAILE
Hwy 400
Honomanu Bay
Pauwalu Pt.
MAKAWAO
Ditch
Ditch
Hwy 37
Wailua
Haiku
PUKALANI
Koolau
Ditch
Hamakua
Lowrie
Nahiku
275"
200"
Hana Hwy
Honoma'ele
120"
Kealia Pond
Kauhikoa
Haleakala Hwy
30"
40"
60"
275"
Hwy 37
20"
Ma'alaea Bay
Haleakala Hwy
KIHEI
KAMAOLE
Haleakala
\144\AWUDP\East Maui\Dec04_Map11.mxd
Hawaii State Department of Agriculture
East Maui Irrigation System
Island of Maui
Map 11
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)


Legend
Annual Rainfall
Ditch
Tunnel
Flume
Penstock
Siphon
Reservoir
Gov't Land
Service Areas
Alexander Res.
Forebay
Penstock
Powerhouse
Elua Res.
Elima Res.
Mau Res.
Ipuolono Res.
Flume
Ditch
Siphon
Siphon
No 2 Res
Kapa Res.
Umi Res.
Pump 3 Ditch
Hukiwai Res.
Ioleau Res.
Luawai Res.
FOREST RESERVE
HANAPEPE
Hanapepe Heights
HANAPEPE
ELEELE
Hanapepe Bay
Wahiawa Bay
Lawai Bay
KALAHEO
LAWAI
OMAO
Hwy 50
Hwy 530
Hwy 520
Hwy 540
30"
40"
60"
80"
120"
267.895084
66.517916
83.263297
8.902659
0.000352
132.302916
84.564805
112.086660
20.001957
80.444942
153.494312
25.182229
242.203058
75.455564
135.999109
132.407378
97.950658
114.568389
57.059418
50.955823
152.263094
40.565430
122.403198
164.214051
122.534920
109.856262
213.236962
495.318709
181.264969
145.471493
12.899209
212.921915
52.399477
162.426100
118.952136
132.033417
218.218343
N
W
E
S
0
3,000
Feet
Waimea
Lihue
Kauai
Hawaii State Department of Agriculture
Kauai Coffee Irrigation System
Island of Kauai, Hawaii
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)
Map 12
\144\AWUDP\Kauai Coffee\Dec04_Map12.mxd


Legend
Annual Rainfall
Spreckles Ditch
Spreckels Tunnel
Spreckels Flume
Spreckles Penstock
Spreckles Siphon
Waihee Ditch
Waihee Tunnel
Waihee Flume
Waihee Penstock
Waihee Siphon
West Maui Reservoirs
Waihee Service Area
Waihee WAB Service Area
Gov't Land
60"
40"
30"
20"
Waikapu Valley
Iao Valley
Waihee Valley
Waihee Intake
Waihee Intake
Ditch
Waihee
Flume
Ditch
Siphon
Hopoi Chute
Res. 99
Waihee
Ditch
WAIKAPU
Hwy 30
Mill Res.
Spreckels
WAILUKU
Kahekili Hwy
Waiehu Intake
Hwy 340
WAIHEE
Waiehu Golf Course
Spreckels
Ditch
Res. 73 & 74
Hwy 380
KAHULUI
Hwy 36
KAHULUI BAY
PULEHUNUI
W
N
S
E
0
4,000
Feet
Kahului
Maui
Hawaii State Department of Agriculture
West Maui Irrigation System
Island of Maui
Map 13
Prepared by: Water Resource Associates Honolulu, Hawaii (Dec. 2004)
\144\AWUDP\West Maui\Dec04_Map13.mxd