Hawaii Stormwater Reclamation Appraisal Report

Prepared for

U.S. Department of the Interior
Bureau of Reclamation
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MISSION STATEMENTS

The Mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to tribes and our commitments to island communities.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms and Abbreviations

ALISH	Agricultural Lands of Importance to the State of Hawaii
ASR	aquifer storage recovery
AWWA	American Water Works Association
BASINS	Better Assessment Science Integrating Point and Nonpoint Source
BWS	City and County of Honolulu Board of Water Supply
C-CAP	Coastal Change Analysis Program
CMSWCD	Central Maui Soil and Water Conservation District
DLNR	Department of Land and Natural Resources
DOW	County of Kauai Department of Water
EGIS	Enterprise Geographic Information System
EKIS	East Kauai Irrigation System
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
FAO	Food and Agriculture Organization
FEMA	Federal Emergency Management Agency
FY	fiscal year
GIS	geographic information systems
gpcd	gallons per capita per day
gpd	gallons per day
gpm	gallons per minute
HDOA	Hawaii Department of Agriculture
HDPE	high-density polyethylene
HOLIS	Honolulu Land Information System
IFIM	Instream Flow Incremental Methodology
KHPRC	Kauai Historic Preservation Review Commission
kW	kilowatt
LHDIS	Lower Hamakua Ditch Irrigation System
LID	low-impact development
LPC	Lihue Plantation Company
MDD	maximum daily demand
MG	million gallons
mgd	million gallons per day

NFPA	National Fire Protection Association
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
OEQC	Office of Environmental Quality
OHA	Office of Hawaiian Affairs
PHABSIM	Physical Habitat Simulation
PMIS	Pioneer Mill Irrigation System
PVC	polyvinyl chloride
R&D	Research and Development
Reclamation	Bureau of Reclamation
REF-ET	reference evapotranspiration
RO	reverse osmosis
RZWBM	Root Zone Water Balance Model
SHPD	State Historic Preservation Division
UIC	underground injection control
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WWRF	Wastewater Reclamation Facility

Executive Summary

Introduction

This report documents the U.S. Department of the Interior, Bureau of Reclamation (Reclamation) appraisal investigation of potential stormwater reclamation opportunities in the State of Hawaii. The study was performed to undertake a program to investigate and identify opportunities for water reclamation and reuse under Title XVI Program of Public Law 102-575, as expanded by Section 104(b) of the Hawaii Water Resources Act of 2000 (Public Law 106-566).

Agency Consultation and Opportunity Identification

Agency consultation meetings were conducted to collect stormwater reuse opportunity ideas for the appraisal study. As a result, 31 opportunities were identified for consideration.

Assessment of Potential Uses for Reclaimed Stormwater

Reclamation policy identifies uses that are appropriate for opportunities funded under Title XVI: environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Within those broad categories, more specific uses, particular to stormwater capture and local needs, were identified. For each opportunity, potential beneficial uses were listed. If no potential reuse was identified for an opportunity during the information-gathering phase, the opportunity was found not to contain sufficient information to proceed at this time.

Stormwater Reclamation Technologies

The types of stormwater reclamation technologies considered in the development of opportunities are summarized in Table ES-1.

TABLE ES-1
Stormwater Reclamation Technologies Considered

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

TABLE ES-1
Stormwater Reclamation Technologies Considered

Category	Description
Stormwater Distribution	Distribute stormwater via gravity ditch or pipe networks, operated/regulated ditch systems, pressure pipe networks, onsite wells.

Opportunities and Constraints

For purposes of this study, opportunities are those that have been identified as consistent with the goals of Title XVI and the desires of the participating stakeholders. The opportunities identified represent specific locations where there is significant potential for success in pairing supply and demand for reclaimed and reused stormwater. However, Title XVI also mandates that appraisal-level studies for these types of opportunities investigate some of the broader issues related to establishing the economic, social, and technical climate for expansion of water reuse as a mode of developing water supply. Demand and pricing and the need for research and demonstration studies were considered.

The types of constraints considered included the physical relationships between supply and demand of stormwater for reuse such as seasonality, volume, timing, spatial separation, changing conditions, sediment, temperature, and area of application. Similarly, regulatory and institutional constraints were evaluated for each opportunity.

Methodology for Selection

An integrated, watershed-based approach was followed, consisting of consultation with key agencies, assessment of reuse opportunities, analysis of long-term sustainability potential, evaluation of institutional factors, and preliminary cost estimates. Interviews with agency personnel, literature reviews, and field investigations were the methods used to acquire information throughout the selection process. A two-step screening process was followed to select candidate opportunities. The ranking and selection process identified top candidate opportunities without limitation on number.

Technical Appraisal

The initial set of 31 opportunities was reduced to 9 using a two-step screening process (preliminary and detailed). Preliminary screening criteria included factors such as implementability (institutional, regulatory, and land use), demand constraints, and generalized stakeholder acceptance. Detailed criteria, such as operational flexibility, long-term permit compliance, flow augmentation, groundwater recharge opportunities, and reuse potential were also considered.

During the screening process, the appraisal team worked with Reclamation staff and stakeholders to develop a prioritized list of stormwater runoff reclamation options for each island. The 9 projects that passed the screening process were evaluated on the basis of ease of delivery and operation, dependability of water supply, simplicity of storage and water treatment, institutional considerations, the degree to which prior investment has been maximized, and cost. Specific areas of investigation included basin land use, vegetation, soil, and slope characteristics; existing irrigation conveyance and natural stream networks; precipitation; expected demand area and size; and hydrology.

Institutional Factors

An institutional factors assessment was performed for candidate opportunities to identify potential direct and indirect effects on the institutional environment closest to the opportunity area. Existing knowledge and threshold-level information obtained informally during the study were used to establish the social and cultural context of the projects. Each candidate opportunity was assessed based on a series of institutional factors and rated accordingly. A primary objective of the assessment was to determine how the opportunity might be received and to predict which projects may encounter more support or engender more resistance.

Preliminary Cost Estimates

Following the guidelines of the Reclamation *Estimating Handbook* (1989), preliminary cost estimates for individual projects were prepared from rough general designs to compare with alternatives and other projects and to review opportunity benefits in light of the costs.

Candidate Opportunities

Nine stormwater reuse projects were selected for further conceptual development and evaluation. These projects were selected based on a number of screening criteria, including the greatest potential benefit and best chance of implementation with long-term, sustainable success. The candidate opportunities are summarized in Table ES-2. The opportunity number reflects the original numbering system for the larger group of 31 projects initially identified.

TABLE ES-2
Candidate Opportunities

Location and Number	Name	Description
Hawaii 1	Lower Hamakua Ditch/Waipio Valley	Construct a parallel ditch upslope of the existing Lower Hamakua Ditch to intercept stormwater and add a reservoir to store the water and provide settling. Water would be released from the new storage reservoir into the existing Lower Hamakua Ditch distribution system as needed.
Hawaii 3	Pahala Catch Basins	Install catch basins on several mountain gulches above Pahala to capture stormwater runoff from these ephemeral streams and divert the water into the conveyance pipeline of a separate agricultural water supply project proposed by the Natural Resources Conservation Service (NRCS) for the area.
Kauai 3	Lihue Garlinghouse Tunnel Potable Water Source	Using existing irrigation ditches, capture stormwater and convey it to a new infiltration basin located near County of Kauai Department of Water (DOW) potable wells. Infiltrating stormwater into the aquifer near the existing potable water wells would help speed the natural aquifer recharge process. Infiltration basins would also provide some peak stormwater flow storage.

TABLE ES-2
Candidate Opportunities

Location and Number	Name	Description
Kauai 4	Lihue Airport Landscape Irrigation Reuse	Construct a new, 5-acre surface reservoir near the lighthouse and the country club, and install gravity-flow pipelines from the airport drainage system and the DeMello Reservoir to the new reservoir. The new reservoir would store airport drainage. Install a pump station at the new reservoir to supply water for irrigation of airport landscaping.
Maui 2	Southwest Maui Watershed Stabilization and Central Maui Soil and Water Conservation	Construct stormwater infiltration basins or contour terrace ditches to capture, infiltrate, and store stormwater. The infiltrated water would subirrigate grass for cattle feed, recharge aquifers, and water left in the ponds would be used by livestock and wildlife. The terrace ditches would run perpendicular to the slope and capture overland flow runoff. This dry area of Maui is also prone to wildfires, which could be slowed by the moisture around these stormwater retention areas.
Maui 4	Lahaina Watershed	Modify the proposed Lahaina Watershed Flood Control facilities to create a groundwater infiltration basin and add two groundwater injection wells. Construct a 10-foot-deep infiltration basin on 0.5 acre in-line of the second outlet channel and two wells 100 feet deep and 12 inches in diameter. Water would flow by gravity into the basin and by gravity pipe to the wells.
Molokai 1	Molokai Irrigation System	Capture stormwater from Manawainui Gulch and Kaunakakai Gulch to augment the irrigation water supply in Kualapuu Reservoir, part of the Molokai Irrigation System. Diversions on the two gulches would channel stormwater into a pipeline that connects into the existing 30-inch steel pipeline of the Molokai Irrigation System downgradient of the tunnel.
Oahu 1	Waianae Agricultural Park	Add storage capacity to a stormwater flood control project currently being designed and add a reuse water distribution system for delivering the captured stormwater to farm plots at the existing agricultural park.
Oahu 4	Ewa Plains	Install a deep infiltration trench to capture stormwater from urban development and discharge it into the coarse coral soils and shallow groundwater. Introduction of fresh stormwater into the brackish aquifer would improve aquifer quality and quantity that could be extracted from existing irrigation wells at golf courses and agricultural areas.

Generalized Rating Scales

Each of the candidate opportunities was assessed on the basis of technical and institutional factors using a generalized rating scale of low, medium, or high. The scales are shown in Figures ES-1 and ES-2.

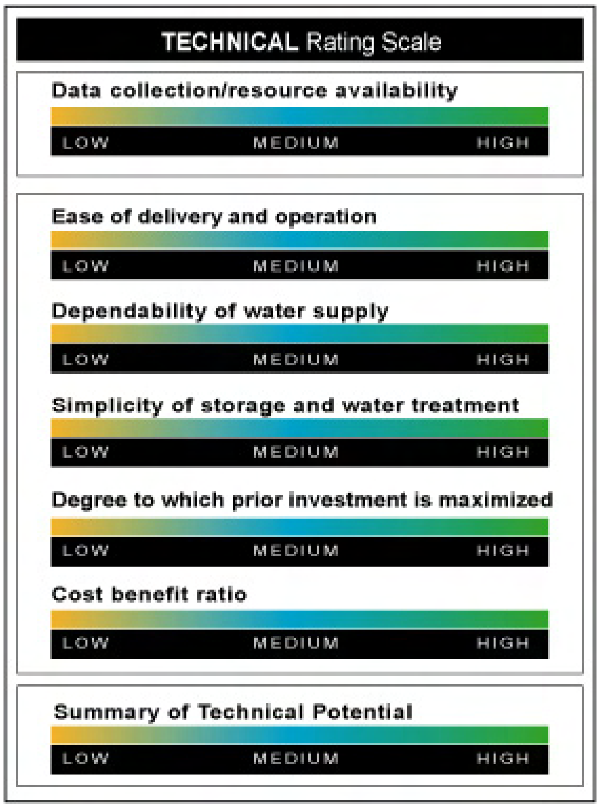

Figure ES-1. Technical Rating Scale

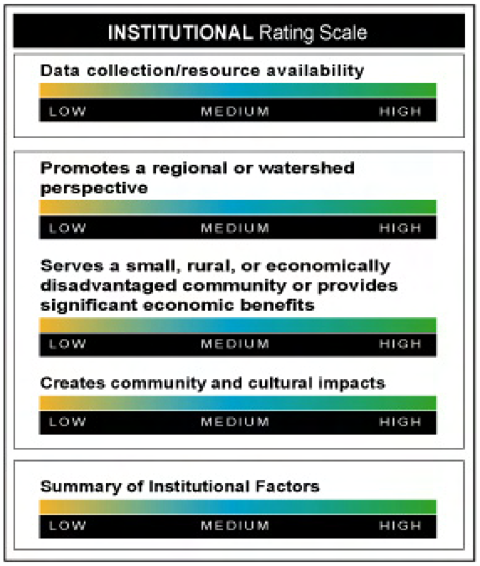

Figure ES-2. Institutional Rating Scale

Prioritized Numerical Ranking

The 9 candidate opportunities were numerically ranked according to the rating criteria identified in Figures ES-1 and ES-2. Opportunities were ranked on a scale of 1 to 10. A rank of "1" was assigned to opportunities with the greatest potential benefit, and a rank of "10" was assigned to opportunities with significant implementation challenges. Numerically ranked opportunities are shown in Table ES-3.

TABLE ES-3
Numerical Ranking of Candidate Opportunities

Numerical Rank	Location and Number	Name
1	Molokai 1	Molokai Irrigation System
2	Kauai 3	Lihue Garlinghouse Tunnel Potable Water Source
3	Oahu 4	Ewa Plains
4	Maui 2	Southwest Maui Watershed Stabilization (Site 1) and Central Maui Soil and Water Conservation (Site 2)
5	Hawaii 3	Pahala Catch Basins
6	Oahu 1	Waianae Agricultural Park
7	Maui 4	Lahaina Watershed
8	Kauai 4	Lihue Airport Landscape Irrigation Reuse
9	Hawaii 1	Lower Hamakua Ditch/Waipio Valley

SECTION 1

Introduction

This section provides an introduction to the Hawaii Stormwater Reclamation Appraisal. The appraisal purpose and objectives are identified, and a description of the overall appraisal investigation is presented.

Preparation of this report and the appraisal investigation it documents were completed under contract with the U.S. Department of the Interior, Bureau of Reclamation. The State of Hawaii, primarily through the Department of Land and Natural Resources (DLNR), was consulted on the scope and content of the appraisal investigation and provided input as the investigation progressed.

1.1 Purpose

The purpose of this study is to evaluate the potential for using stormwater as an alternative source of water on the islands of Hawaii.

1.2 Description of the Appraisal Investigation

The stormwater reclamation appraisal investigation identified potential stormwater opportunities for each island. An integrated, watershed-based approach to resource management was followed, consisting of consultation with key agencies, assessment of reuse opportunities, analysis of long-term sustainability potential, evaluation of institutional factors, and cost appraisals. The investigation objective was to identify the best potential uses for scarce water resources.

Previous experience with projects in Hawaii and in irrigation districts throughout the United States was useful. This prior experience contributed to an understanding of agricultural concerns and the institutional issues that may ultimately require public education and outreach. Reuse options were selected based on this bank of knowledge, and information gleaned from interviews with key agencies, including natural resource agencies and water supply organizations. Interviews were conducted with attention to potential technical, cultural, and institutional concerns, and field investigations were conducted with possible constraints as well as opportunities in mind.

The assessment of reclaimed stormwater runoff opportunities explored current watershed management techniques, whether sustainable development concepts have been considered, and how the environment is projected to change over time.

Interviews with agency personnel, literature reviews, and field investigations were the methods used to acquire information throughout the selection process. A set of ranking criteria were developed for final opportunity selection. Reclamation requested that the ranking and selection process identify top candidates without limitation on number.

The nine opportunities that passed the screening process were then evaluated on the basis of ease of delivery and operation, dependability of water supply, simplicity of storage and water treatment, institutional considerations, the degree to which prior investment has been maximized, and cost. Specific areas of investigation included basin land use, vegetation, soil, and slope characteristics; existing irrigation conveyance and natural stream networks; precipitation; expected demand area and size; and hydrology.

1.3 Organization of This Report

Reclamation guidelines established under Title XVI Program of Public Law 102-575, as expanded by Section 104(b) of the Hawaii Water Resources Act of 2000 (Public Law 106-566), formed the basis for organization of this report. The organization sequence is also aligned with the scope of work prepared in July 2004.

The report is organized as follows:

- Section 1 introduces the appraisal study and its purpose.
- Section 2 summarizes the agency consultation process and the approach followed to identify individual opportunities.
- Section 3 provides an assessment of potential beneficial uses for reclaimed stormwater, and the data research performed.
- Section 4 discusses applicable stormwater reclamation technologies and measures of success.
- Section 5 explores opportunities and constraints and the analytical tools available to evaluate them.
- Section 6 describes the methodology followed to conduct this appraisal study.
- Section 7 provides an in-depth description of each of the candidate opportunities selected for study. The description for each opportunity consists of the opportunity objective, background, scope, technical features, estimated cost, assessed rating relative to Reclamation guidelines, and contact information.
- Section 8 summarizes the ranking criteria and provides a numerical ranking of the candidate opportunities.
- Section 9 is a bibliography of references consulted.

Maps of each opportunity location are included in the Maps section.

Note: Mention of trade names or commercial products in this appraisal study does not constitute their endorsement by the U.S. Government.

SECTION 2

Agency Consultation and Opportunity Identification

Early in the study process, agency consultation meetings were conducted to collect stormwater reuse ideas for the appraisal investigation. Participants were encouraged to identify a broad spectrum of opportunities. The primary limitation in identifying opportunities was that water would not be diverted from a stream. The goal was to identify new sources of water supply through stormwater reuse.

2.1 Agency Consultation

Topics of discussion with agencies included the volume and frequency of flooding as well as the size and shape of the areas affected. Water supply needs, including volume, uses, and populations to be served, were addressed. The character of the surrounding watershed was noted. The team prioritized the criticality of each area identified based on both technical considerations but also on the agencies' judgment of the need for supply or for control in terms of public health, public access, environmental concerns and public understanding that would generate likely acceptance.

At these meetings, agencies were asked to identify those areas that have the greatest apparent opportunity for stormwater reclamation. These areas of opportunity were based on the agencies' existing studies of reclamation options, but also included discussion of reclamation techniques that have been used in other locations.

Discussions also were conducted with the agencies to understand institutional, environmental, and social constraints that they view as relevant to implementing stormwater reuse options. This discussion step helped to determine the relative readiness of involved anticipated stakeholders to implement stormwater reuse opportunities.

A list of agency contacts is provided in Appendix A. The agency consultation meetings schedule is summarized in Table 2-1.

TABLE 2-1
Agency Consultation Meetings

Date	Island	Organizations Represented
August 16, 2004	Oahu	Department of Land and Natural Resources
August 17, 2004	Oahu	Board of Water Supply Natural Resources Conservation Service Hawaii Department of Agriculture Maui County Farm Bureau Hawaii Department of Health, Safe Drinking Water Branch Commission on Water Resources Management
August 18, 2004	Hawaii	Department of Water Supply, County of Hawaii Department of Public Works, County of Hawaii
August 19, 2004	Kauai	Department of Water Department of Public Works

2.2 Opportunity Identification

After the agency meetings, a letter was sent to participants to solicit additional information regarding the opportunities. Subsequent to the initial meetings, a potential opportunity was identified on Molokai in discussions with local project staff. As a result of the agency consultations, 31 opportunities were identified for consideration:

- 5 on Oahu
- 12 on Kauai
- 8 on Hawaii
- 5 on Maui
- 1 on Molokai

Based on the information received, preliminary maps and summary tables for each opportunity were developed. This information formed the basis for the assessment of potential uses discussed in Section 3.

SECTION 3

Assessment of Potential Uses for Reclaimed Stormwater

This section provides an assessment of potential beneficial uses for reclaimed stormwater. Sources consulted in conducting the assessment are identified.

3.1 Potential Beneficial Uses

From the information obtained at the meetings discussed in Section 2, beneficial stormwater reuse opportunities were identified and assessed. Potential uses considered included environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Within those broad categories, more specific uses, particular to stormwater capture and local Hawaiian needs, were identified. For each opportunity, potential beneficial uses were listed. If no potential reuse was identified for an opportunity during the information-gathering phase, the opportunity was found not to contain sufficient information to proceed at this time. Potential uses are described as follows.

3.1.1 Crop Irrigation

This use encompasses application of collected water to either production agricultural crops or landscaped and grassed areas. Typically, this use is seasonal, with demand determined by area of irrigation, delivery efficiency, and crop type. The seasonal offset of stormwater availability and irrigation demand may require storage in surface impoundments or groundwater aquifers. Water quality is not considered a constraint for this type of use under most circumstances. However, sprinkler application to some food crops may be constrained when using runoff from urban areas. Sediment problems can typically be handled easily with filtration, as required for drip and some sprinkler systems. Conveyance of water to irrigation areas from onsite wells or offsite surface water may be by permanent or temporary/moveable pipelines, surface ditches, or a combination of operated ditch, pumping, and gravity flow. Irrigation application to crops may be by surface flooding, drip systems, or sprinklers.

3.1.2 Saltwater Intrusion Barrier

Along coastal zones, pumping of water from aquifers may increase the brackish zone of influence from saltwater intrusion, reducing available pumping yield or fouling wells. Recharging of these coastal aquifers with stormwater can help create a fresh water mound that prevents undue seawater intrusion and reduces the rate of discharge of the fresh water lens to the ocean. This water is not intended, necessarily, to be a direct source of supply for domestic or agricultural demands, but to act as an offset to those withdrawals, maintaining water balance within the aquifer. Demand for this type of use depends, to a certain extent, on withdrawal rates from the aquifer. However, because of the large demands on the local groundwater sources, it is assumed that demand for this type of use would exceed supply in most cases. Delivery for this type of use may be from bioswales, infiltration galleries, dry wells, or injection wells, depending on the permeability or percolation rate of the surface soil layers and depth to aquifer storage.

3.1.3 Potable Water

Drinking water may be stored in aquifers or surface impoundments. Stricter water quality determinations are required, particularly before injection of stormwater into an aquifer for potable use. Additional treatment and careful control of conveyance to prevent contamination are required. Demand is based on domestic and industrial use requirements, largely driven by population served and projected rates of growth.

3.1.4 Habitat Base Flow Augmentation

As a result of surface water withdrawals for irrigation or domestic use, and changing levels of impervious coverage in more urban watersheds, stormwater that previously infiltrated to shallow groundwater and released into streams may now run off the surface with higher peak flows and increased sediment loads conveyed into the natural channels. Restoring more natural hydrologic conditions can provide measurable benefits in streams that may have critical habitat or threatened or endangered species. Use of infiltration galleries and bioswales or detention systems can delay runoff sufficiently to allow percolation into the soil. This can result in larger dry-season base streamflows.

3.1.5 Ambient Water Quality

Ambient water quality can be improved in two fundamental ways: dilution of the contaminants already in the system or prevention of contaminants from entering the system. Both these approaches can include stormwater technologies, either to store and release at critical times to augment flow conditions, or to provide treatment by infiltration or sediment deposit prior to discharge to natural channels. Treatment can include a change in timing of delivery, but may also occur as end-of-pipe technology, with no additional storage expected.

3.1.6 Gray Water Reuse

Collection and distribution of untreated water for nonpotable use encompasses a broad range of possible applications. The most common application is domestic or commercial sprinkler/irrigation systems for grass and landscape features. In some cases, toilets and washing machines may be connected to gray water systems. Fire suppression has been included in this category, but may include either sprinkler systems with onsite storage tanks or larger surface ponds that are remote from the point of use.

3.1.7 Aquifer Recharge

Although ultimate use of water injected to aquifers may incorporate one or several uses already described, this category is identified separately as a result of the value of replenishing groundwater storage for long-term or undefined future need. Total yield, quality, and seasonal supply can all be positively affected by recharge of aquifers to offset uses from irrigation or domestic demand, or reduced inflows from land use changes.

3.1.8 Recreation

Recreation activities may include fishing, swimming, boating, rafting, or other water sports. In some cases, water quality is a major concern. In others, quantity and seasonal availability may be more critical. This category incorporates both flat water systems (bays, ponds, lakes, and reservoirs) and flowing systems (streams and rivers).

3.2 Data Availability

To investigate the application of reclaimed stormwater to meet the proposed uses within a watershed, geographic information system (GIS)-based mapping was developed based on publicly available layers created by others. This mapping was used to identify watershed boundaries, basin land uses, vegetation, soil, and slope characteristics. Natural and constructed conveyance systems, irrigation infrastructure, wells, groundwater aquifers, and other relevant data were collected within the opportunity areas.

3.2.1 Geographic Information Systems

Internet sites for the following organizations and resources were searched for GIS data:

- Natural Resources Conservation Service (NRCS)
- U.S. Geological Survey (USGS)
- U.S. Fish and Wildlife Service (USFWS)
- Pacific Islands Geographic Information System (GIS) Project
- Hawaii Statewide GIS Program
- Honolulu Land Information System (HOLIS)

Some data were obtained from the NRCS site, but most were obtained from the Hawaii Statewide GIS Program site. Statewide coverage is available for:

- Watershed/basin
- Perennial and ephemeral streams
- Land use and ground cover (vegetation)
- Inconsistent coverage of irrigation facilities, ditches, major pipelines, and storages
- Contours
- Soil characteristics
- Slope
- Precipitation contours and/or monitoring locations
- Lakes, reservoirs, and impoundments
- Airports, golf courses, and plantations
- Floodplains
- Municipal/county jurisdictional boundaries

- Roads and highways
- Agricultural Lands of Importance to the State of Hawaii (ALISH)
- 2000 Census Hawaiian Homelands
- Coastal Change Analysis Program (C-CAP) Land use/Land cover derived from Satellite Imagery (2000)
- Conservation District Subzones
- Critical Habitat Zones for Various Species

These coverages were used to evaluate potential stormwater capture volumes, determine suitable locations within a watershed, and develop spatial relationships horizontally and vertically within the watershed to estimate quantities and costs.

Electronic mapping originally created by the USGS was applied to maps incorporated in this report to ensure consistency and quality of data from site to site.

3.2.2 Previous Reports

Extensive documentation exists on many watersheds in the Hawaiian Islands and significant information regarding all the watersheds is available. During agency consultation meetings, copies of existing reports and study data that could be beneficial to the evaluation of potential stormwater reuse opportunities were requested. Copies of most of the documents that were identified in these meetings have been acquired and reviewed. The following reports were found to contain relevant information:

- Belt Collins Hawaii. January 2001. *Lualualei Flood Study Hydrologic Analysis, Waianae, Oahu, Hawaii*. Prepared for U.S. Army Corps of Engineers and U.S. Department of Agriculture, Natural Resource Conservation Service.
- Fukunaga and Associates, Inc. October 1976. *Flood Management Plans and Preliminary Engineering Studies for the Waimanalo Flood Control Project, Oahu, Hawaii*.
- Fukunaga & Associates, Inc. April 1994. *Statewide Capital Improvements Program Flood Control Projects, Report R98*.
- Gingerich, Stephen B., and D. S. Oki. 2000. *Ground Water in Hawaii*. U.S. Geological Survey Fact Sheet 126-00.
- Haraguchi, Paul. March 2001. *Post Flood Report, Storm of November 1-2, 2000, South Hilo, Puna and Kau Districts, Island of Hawaii, Circular C130*.
- R. M. Towill Corporation. October 1971. *Drainage Master Plan for the County of Maui, State of Hawaii.*
- R. M. Towill Corporation. February 1992. *Review Draft of Kauai Water Use and Development Plan, Island of Kauai, Hawaii*.
- State of Hawaii, Department of Land and Natural Resources, Land Division. December 1996. *State of Hawaii Flood Hazard Mitigation Plan*.

- State of Hawaii, Department of Land and Natural Resources, Division of Water and Land Development, in cooperation with Federal Emergency Management Agency, State Assistance Program. September 1983. *Flood Control and Flood Water Conservation in Hawaii, Volume II, Revised, General Flood Control Plan for Hawaii, Circular C93*.
- State of Hawaii, Department of Transportation, Highways Division. January 1996. *Hydrologic and Hydraulic Report for Inoaole Stream Bridge, Kalanianaole Highway, Inoaole Stream Bridge Replacement, Project No. 72A-01-90*.
- U.S. Army Corps of Engineers. October 1966. *Main Report and Technical Appendix, Flood Plain Information Study, Koloa-Poipu, Kauai, Hawaii*. Prepared for Board of Land and Natural Resources, State of Hawaii. Honolulu District, U.S. Army Corps of Engineer.
- U.S. Army Corps of Engineers. September 1970. *Flood Hazard Information, Island of Hawaii, Report R37*. U.S. Department of the Army. Honolulu District, U.S. Army Corps of Engineer.
- U.S. Army Corps of Engineers. August 1971. *Flood Hazard Information, Island of Maui, Report R39*. Pacific Ocean Division of U.S. Army Corps of Engineers.
- U.S. Army Corps of Engineers. July 1982. *Alenaio Stream, Island of Hawaii, Harbors and Rivers in Hawaii, Final Survey Report and Environmental Impact Statement*.
- U.S. Department of Agriculture, Natural Resource Conservation Service. December 1981. *Final Watershed Plan and Environmental Impact Statement, Waimanalo Watershed, City and County of Honolulu, Hawaii.*
- Yuen, George A. L. and Associates, Inc. June 1990. *Hawaii Water Plan – Water Resources Protection Plan Volumes l & ll*. Prepared for the Commission on Water Resource Management, Department of Land and Natural Resources, State of Hawaii.

Other documents (similar in number to those listed) were collected and reviewed, but were found to include minor references to the watersheds containing opportunities. These documents are not referenced because the information they contain is also contained in the documents listed previously.

SECTION 4

Stormwater Reclamation Technologies

The purpose of this section is to describe and categorize individual stormwater reclamation technologies that may be applicable to viable opportunities.

4.1 Stormwater Reclamation Categories

Stormwater runoff reclamation technologies can generally be classified in one of the following categories:

- Small Lot Reuse
- Source Reuse
- Stormwater Capture
- Stormwater Storage
- Stormwater Distribution

Descriptions of these categories are provided in Table 4-1.

TABLE 4-1
Stormwater Reclamation Technologies Considered

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

4.2 Applicable Technologies

Individual technologies are described as follows in accordance with the classifications identified in Table 4-1.

4.2.1 Small Lot Reuse

Small lot reuse methods are designed to manage precipitation or runoff as close to the source as is feasible on individual lots. Current techniques in low-impact development

(LID), or so-called "green" stormwater management solutions, are being integrated into new development and redevelopment sites to mimic local natural hydrologic conditions. Techniques based on LID mimic a site's hydrology with design approaches that infiltrate, filter, store, evaporate, and detain runoff close to its source. Techniques are based on the premise that stormwater management should not be seen as stormwater disposal. LID offers benefits over conventional stormwater management approaches in that it is an environmentally sound technology with a more economically sustainable approach to addressing adverse impacts. LID approaches to stormwater management include:

- Infiltration planter boxes
- Vegetated infiltration basins
- Eco-roofs (vegetated roofs)
- Porous pavements
- Disconnected downspouts
- Depressed parking lot planter strips for bio-filtration
- Narrowed street sections with parallel or pocket bioswales

Methods of source control are being used at the individual lot scale and at significantly larger development scales. The techniques described are being used individually and in combinations to intercept precipitation as close to the point of contact with the land, and to promote infiltration and long-term detention and retention. Site conditions will affect the applicability of various LID methods, and designers must consider safety and environmental factors in assessing the appropriate use of these technologies. One successful example of LID application occurs at the U.S. Environmental Protection (EPA) Federal Triangle headquarters in Washington, D.C. (Washington Business Journal, 2004). This technology was considered but did not fit any of the 10 candidate opportunities assessed.

4.2.2 Source Reuse

Use of rain barrels or cisterns to collect precipitation or stormwater runoff at the source can potentially provide water for a variety of nonpotable purposes or, with treatment, potable water. Gray water from domestic sources, including bathing facilities and washing machines, has been previously discussed as a source for irrigation and fire suppression water. Some commercial and industrial gray water sources have similar applications.

4.2.3 Stormwater Capture

Capture technologies include techniques to intercept surface water at points along the drainage path and route runoff to points or areas where treatment and/or reuse can occur.

Technologies included in stormwater capture include:

- Ditches: drainage, irrigation, roadside, other. Primarily for application in agricultural lands and locations that avoid removal of water from recognized streams or that negatively impact downstream instream flows.

- Storm drainage system interception. This technique would rely on an existing pipe network (primarily in urban areas) to deliver reclamation water to locations for infiltration or introduction to the subsurface.

- Dry-wells. Typically used to dispose stormwater in the subsurface by gravity drainage through perforated manhole sections. May require pretreatment of stormwater.
- Infiltration galleries. Trenches used to introduce stormwater into more pervious subsoils and accelerate recharge through the trench walls and bottom because of available head.
- Injection wells. Regulatory requirements for protection of groundwater or other rules may require pretreatment of surface water intended for subsurface injection.

4.2.4 Stormwater Storage

Storage technologies include techniques to detain surface water at points along its drainage path, either in surface or subsurface features, for subsequent extraction and reuse. Technologies in stormwater storage include the following:

- **Aquifer storage and recovery (ASR)**. Under certain hydrogeologic conditions water can be pumped into aquifers and stored for subsequent recovery. Aquifer tests must be conducted to determine storage and yield capacity and other aquifer properties and characteristics under groundwater mounding scenarios. Regulatory requirements for protection of groundwater or other rules may require pretreatment of surface water intended for subsurface injection.
- **Stream bank storage**. Similar to ASR, in certain cases surface waters can be infiltrated or injected into stream banks and detained. A primary benefit of this technique is to augment the dry-season base-flows of the surface channel associated with the stream bank. During normal conditions, the surface channel may lose flow to the surrounding subsurface. Such a stream is called a “losing stream.” Stream bank storage can reverse the hydraulic gradient so that water from the surrounding subsurface flows into the surface channel, thus creating a “gaining stream.”
- **Detention basins**. Typically associated with urban stormwater collection systems, detention basins are designed to store runoff for short periods of time, releasing at a lower rate than inflow during a large event. Generally, the purpose of detention basins is to reduce peak flows downstream, thereby relieving flooding. Often these basins are designed to match with a predetermined release rate, based on undeveloped conditions or thresholds developed to reduce or prevent flooding. Occasionally, water quality considerations are incorporated into a design to eliminate nutrients or sediments by requiring a minimum detention time within the basin. Use of these kinds of facilities for stormwater reclamation and reuse would either be related to improving water quality prior to use, or by delaying surface flows long enough to encourage additional infiltration through the bed and banks of the basin or into adjacent infiltration galleries.
- **Surface reservoirs**. Often constructed online with a natural conveyance, surface reservoirs are generally intended to store significant water supplies for multi-seasonal or multi-year time periods. Often new reservoirs are very expensive and have significant environmental and regulatory hurdles. Another common type of reservoir is often used for smaller-scale projects, particularly for pressure systems such as municipal, industrial, and agricultural supply. These covered tanks are offline, and may be elevated, ground-level, or buried. They may provide pressure to distribution systems, but usually require a pumping system and associated controls for filling the tank.

4.2.5 Stormwater Distribution

Methods to deliver reclaimed water to point-of-use are included in the distribution technologies category. Existing surface water collection infrastructure may suffice in many cases to route water to the necessary location; in other cases, new distribution infrastructure would be required to provide reclaimed water to the intended location and use. Infrastructure elements included in the suite of distribution technologies are common to most distribution systems, and may include:

- Gravity ditch or pipe networks, including existing stormwater drainage system or new infrastructure
- Operated/regulated ditch systems
- Pressure pipe networks and appurtenances
- Onsite wells

SECTION 5

Opportunities and Constraints

This section describes opportunities and constraints associated with development of the nine identified opportunities. Analytical tools for assessing opportunities and constraints are identified.

5.1 Opportunities

Specific opportunities that have been identified for consideration in the study are described in detail in Section 7. The opportunities identified in that section represent specific locations where there is significant potential for success in pairing supply and demand for reclaimed and reused stormwater. However, to provide a complete representation of each opportunity, the investigation included some of the broader issues related to establishing the economic, social, and technical climate for expansion of water reuse as a mode of developing water supply.

5.1.1 Demand and Pricing

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

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

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

5.1.2 Needed Research and Demonstration Studies

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

5.2 Constraints

The following constraints are exclusively related to the physical relationships between supply and demand of stormwater for reuse. Regulatory and institutional constraints are identified for each opportunity in Section 7.

5.2.1 Seasonality

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

5.2.2 Volume

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

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

5.2.3 Timing

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

5.2.4 Spatial Separation

Hawaii has a complex infrastructure of under-used historical drainage and irrigation conveyance elements that may alleviate the challenge of transfer of water from capture point to use. Nevertheless, for opportunities that intend to transfer collected water long distances, across basin boundaries, for example, it can be a significant challenge to construct the necessary infrastructure. Aquifer recharge can also alleviate this challenge by using subsurface connectivity to transmit water to the point of use.

5.2.5 Changing Conditions

Rapidly developing urban areas (or changes in agricultural use to a lesser extent) have the potential to change the stormwater runoff hydrology of a basin, as well as the expected demand for a beneficial reuse. Estimates of the potential impact are only as accurate as estimates of the expected changes.

5.2.6 Sediment

Most proposed beneficial reuses are not constrained by runoff with significant sediment. However, for ambient water quality, habitat development, or potable water use, the condition of source water quality can be a significant issue. In addition to soil particulates, urban runoff can contain a wide variety of contaminants, including heavy metals and hydrocarbons, that are associated with sediments.

5.2.7 Temperature

Ambient water quality and habitat development often have associated temperature criteria. This can become significant for releases from reservoirs, which may have stratified conditions, leading to release temperatures that do not match ambient and seasonal conditions. Alternatively, increasing base flow by infiltration and percolation through groundwater can restore more natural temperature management to stream systems.

5.2.8 Capture Location and Mechanism

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

5.2.9 Area of Application

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

5.2.10 Delivery Location and Mechanism

Some uses require subsurface delivery; others may require surface systems.

5.3 Analytical Tools

This section describes the analytical tools employed to assess the relationship between supply and demand of stormwater for reuse opportunities and to evaluate reuse constraints. These tools were used to further develop available data into information that allowed opportunities to be ranked. Certain tools were combined into a single procedure. For example, the water balance model used to evaluate several opportunities in Section 7 combines runoff volume, water balance, crop demand, and storage.

5.3.1 Flood Frequency

Many opportunities evaluated in this study have some element of flood control stated as one opportunity objective. To determine the type of event that might reasonably be mitigated by capture and reuse of stormwater, a flood frequency analysis is applicable. This procedure assigns a statistical likelihood of occurrence in a given year to a particular flow event. This allows a comparison to be made between the expected storage capability and the frequency with which that storage would be fully utilized. Use of streamflow gage data is preferred (USGS, 1981), but other methods, such as USGS regression equations may be used. Data needs include basin and local precipitation characteristics or gage data.

5.3.2 Runoff Volume

For projects with a specific designated use, it is important to understand the potential supply available. This requires development of some relationship of precipitation and available stormwater that may be captured for reuse. Usually, this relationship is centered around a statistical estimate, such as mean annual streamflow regression equations. More detailed analysis might consider the variability of supply and how that may relate to the designated use. For example, potable water demand is relatively consistent in volume and critical to maintain. Therefore, storage facilities must consider multiyear or seasonal fluctuations as well as alternative supply sources and the cost of losing supply when considering whether stormwater reuse provides a dependable alternative. In addition, only some fraction of expected streamflow can be captured prior to entry into the stream network. This value depends on the nature of the capture mechanism and the size of the upstream watershed area.

5.3.3 Water Balance

A water balance used to evaluate the array of water supply and demand sources and amounts is critical to the evaluation of reuse opportunities and conveyance and storage facility sizing. It is especially important for projects where water supply and demand has a strong seasonal variability, as with irrigation projects. Water balances may need to be evaluated from a field scale for individual irrigated area demands up to a basin scale for multiple reuse opportunity evaluations and can be considered over weekly, monthly, or annual time periods. Operational and institutional constraints can also be considered in the water balances to ensure opportunity components are appropriately sized.

The Root Zone Water Balance Model (RZWBM) version 1.04 (CH2M HILL, 2003), was used to estimate the expected demand area and size available for irrigating a particular crop or mixture of crops, using the long-term rainfall data, crop evapotranspiration (ET) data, and any additional sources of water available for the opportunity. Crop parameters used as model input are the rooting depth and the depletion fraction of the crop. Soil parameters used in the model are the field capacity, initial water content (for January), and permanent wilting point. Other models can be used to perform similar calculations but multiple models would be required to evaluate all of these inputs.

5.3.4 Changing Conditions/Land Use

This type of analysis has two elements. First, changing levels of urbanization or shifts from one kind of crop to another have the potential to change both supply and demand volumes and patterns. For those areas where this potential is high, an evaluation of the impacts of these expected changes on local hydrology and demand needs is important to understanding the long-term viability of stormwater reuse as an alternative. Second, for some beneficial uses, such as water quality and base flow augmentation, an evaluation of how source control technologies might impact downstream conditions is important to estimating their efficacy for meeting the needs expressed by stakeholders. Analysis can be done by the CH2M HILL proprietary Low Impact Feasibility Evaluation (LIFE™) model. This tool allows the user to identify specific technologies, such as infiltration galleries, eco-roofs, or porous pavement, that can be applied across a watershed to determine changes in downstream surface hydrology. Specific information regarding land use regulation can be found in Section 6.5.3 and in the Institutional Factors assessments in Section 7.

5.3.5 Crop Demand

Given a crop type and crop management information, area to be irrigated, irrigation system application efficiency, and local climate data, an estimate of crop irrigation water demand can be calculated at a weekly to monthly rate. The reference evapotranspiration (REF-ET) model (Allen, 2000) is one tool used to process basic climate data into REF-ET estimates. Crop irrigation water demand is important for determining the relationship in timing and volume between the desired irrigated demand and the expected stormwater supply. This is also a critical component of a site water balance and is required to estimate the sizes of conveyance and storage facilities.

For each candidate opportunity, general values for the soil and crop parameters were selected. For soil parameters, values for loamy sand (Rawls et. al, 1982) were used. The values are field capacity (0.13 inch/inch), permanent wilting point (0.06 inch/inch), and initial water content (0.13 inch/inch). No specific crop parameters were used. Instead, a general rooting depth of 3 feet and a depletion fraction for no stress of 0.5 inch/day were selected from the Food and Agriculture Organization (FAO) 56 publication because they represent the average for most of the common crops listed in the publication.

5.3.6 Domestic Demand

Domestic (nonagricultural) demand for water incorporates as many as nine distinct water uses in residential areas: toilets, showers, bathtubs, dishwashers, clothes washers, irrigation, faucets, leaks, and swimming pools. Of these uses, irrigation and toilets could be supplied with untreated stormwater, referred to as gray water for this study (sometimes gray water refers explicitly to water captured from showers, faucets, bathtubs, or other residential uses). To determine this demand, both a total demand and a subset of "gray" uses must be estimated. For this concept-level analysis, a simplified per capita approach is appropriate for estimating total demand. This average daily use also depends on local climate and practices.

A national study by the American Water Works Association Research Foundation (1999) found average per capita water use to be 172 gallons per day (gpd). Of this quantity, 101 gpd were for outdoor uses. This study included dry areas that typically require more landscaping water than would commonly be found in Hawaii. For a specific area, historic billing and plant data are used to determine demand, which is then extrapolated to projected growth. For example, Kauai County, in its Water Plan 2020, estimates the projected population served in 2020 to be 132,952 persons, with a per capita average daily use of 134 gpd, based on historic measurements (County of Kauai, 2001). This includes residential and industrial/commercial uses. County of Hawaii, in its Kau to South Kona Water Master Plan (County of Hawaii, 2004) reports that American Water Works Association (AWWA) guidance of 74 gpd residential usage is higher than observed, due to limited supply. Local residents of those areas are "adept at making the most of their water" and must have additional water hauled in to meet demand. In those areas, per capita residential usage averages 60 gpd, which might be considered a lower limit.

A recent Thames Water study (Birks et al., 2000) indicated that use of gray water systems for toilet flushing alone has potential to reduce potable water demand by 20 percent. Irrigation of landscaping, exterior washing, and other potential gray water uses are estimated to contribute another 10 to 15 percent of total residential demand.

For this concept-level analysis, potable water demand was estimated at 134 gallons per capita per day (gpcd), including all potential uses. Residential demand was assumed to be 74 gpcd, and gray water residential demand was assumed as 30 percent of 74 gpcd, or 22 gpcd. Candidate opportunities that provided water for uses other than crops did not require a water balance. Demand data for these opportunities was derived from current and projected demands on potable systems and wells identified in literature or in interviews.

5.3.7 Fire Flow

Quantity of water needed depends on delivery system (sprinklers, hydrants, and storage ponds) and on the area to be served. Pressure systems may require hydraulic modeling to determine that demands may be met without undue drops in system pressure. Often, local fire districts will have specific requirements that must be met for volume and/or pressure conditions over a period of time necessary to fight a fire. The *Uniform Fire Code* (International Fire Code Institute, 1997) requires 1,000 gallons per minute (gpm) be available for one- or two-family dwellings for a minimum of 2 hours. Modifications are allowed for isolated or rural areas. Locally, the minimum acceptable rate varies from 250 gpm for 1 hour to 1,000 gpm for 2 hours. At that volume, approximately 8,000 cubic feet of storage would be required per dwelling unit protected. Requirements for areas classified as rural would be determined from National Fire Protection Association (NFPA) 1142 (2001 edition, or as amended).

5.3.8 Water Quality

The EPA has developed a computer modeling tool called Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) that includes four components: Hydrological Simulation Program-Fortran (HSPF), Soil and Water Assessment Tool (SWAT), PLOAD, and QUAL2E (EPA, 2001). These models assess basin water quality with varying levels of complexity. HSPF is a comprehensive hydrologic model with the ability to simulate fate and transport of a variety of pollutants. SWAT is a large-scale rural hydrologic model with moderate data requirements including daily estimates of solar radiation, wind speed, and relative humidity. It is intended to evaluate the effects of land use change and agricultural production at the watershed scale. QUAL2E is a detailed water quality model with the capability to evaluate oxygen depletion and other spatial changes in pollutant effects. PLOAD is a simplified GIS-based model to estimate nonpoint loads of pollution at the basin level. It is designed to be a basic screening tool (CH2M HILL, 2000).

5.3.9 Aquifer Storage

The rate at which surface water percolates into aquifers or can otherwise be injected would determine how large surface storage facilities must be. For the basaltic and coastal sand aquifers expected near opportunity sites, the rate of percolation or injection would likely be the controlling variable for determining maximum practicable storage capacity for beneficial use. Further hydrogeological investigation, beyond the scope of this study, would be needed to more accurately quantify aquifer characteristics.

5.3.10 Aquifer Firm Yield

The rate at which an aquifer can be consistently pumped (which may include drawdown from numerous wells) is complex to determine. This is partly based on the rate and volume of injection, soil permeability, saltwater intrusion, and nature of the demand being exerted. It is beyond the scope of this assessment to determine how this allowable rate affects the candidate opportunities; however, in some instances it may be critical to determining the efficacy of stormwater for its intended beneficial reuse. For opportunities that include use of aquifers to store and use stormwater at a later time, this issue must be addressed in future phases.

5.3.11 Reservoir Firm Yield

For opportunities that include the use of surface reservoir facilities, it may be important to evaluate the reliability of the storage to serve beneficial uses across a variety of hydrologic conditions, and ultimately, a “design” drought event. This has traditionally been performed by development of a mass curve, or plot of cumulative inflow volumes as a function of time. From this, the required storage and estimated firm yield (defined as the draft or withdrawal that lowers the water content in a reservoir from a full condition to its minimum allowable level once during a selected critical drought) can be determined graphically. This approach requires some estimate of streamflows, most likely through historical data. Other, more probabilistic methods may also be used, including Monte Carlo simulation, which does not rely on historical streamflow records. An estimate of firm yield may be necessary to assess the likelihood of success for an opportunity; however, detailed calculations are beyond the scope of this study, and would be recommended for a future phase.

5.3.12 IFIM/PHABSIM

The Instream Flow Incremental Methodology (IFIM) is a method developed by the USFWS, with funding from the EPA, to quantify the biological effects of altered streamflows. The Physical Habitat Simulation (PHABSIM) model is a hydraulic modeling tool that is part of IFIM protocol, intended to determine instreamflow needs for specific habitat or species criteria (Waddle, 2001). For assessing these opportunities, the primary use of this tool would be to determine necessary instreamflows that might be augmented by reuse of stormwater discharge.

SECTION 6

Methodology for Selection

This section discusses the methodology used to select candidate opportunities for stormwater reuse. An integrated, watershed-based approach was followed, consisting of consultation with key agencies, assessment of reuse opportunities, analysis of long-term sustainability potential, evaluation of institutional factors, and cost appraisals. Interviews with agency personnel, literature reviews, and field investigations were methods used to acquire information throughout the selection process. A two-step screening process was followed to select candidate opportunities. A set of ranking criteria was developed to compare the selected opportunities.

6.1 Agency Consultation

The first step in the assessment was an initial consultation with key agencies, including natural resource agencies and water supply organizations. The Honolulu Board of Water Supply (BWS) provided a unique insight into the challenges and resources for potable water storage and recovery on the islands. Timing, location, and quality of reclaimed stormwater are key issues for watershed agencies. A number of agencies were consulted to assess their needs and operations. Various reclamation techniques were then evaluated based on goals. Both technical and nontechnical concerns were addressed. A list of agencies and organizations contacted is provided in Appendix A.

6.2 Opportunities Assessment

The second step in the opportunity selection process was the assessment of reclaimed stormwater runoff opportunities. For purposes of this study, opportunities are those that have been identified as consistent with the goals of Title XVI and the desires of the participating stakeholders. The opportunities identified represent specific locations where there is significant potential for success in pairing supply and demand for reclaimed and reused stormwater. However, Title XVI also mandates that appraisal-level studies for these types of projects investigate some of the broader issues related to establishing the economic, social, and technical climate for expansion of water reuse as a mode of developing water supply. Demand and pricing and the need for research and demonstration studies were considered.

The types of constraints considered included the physical relationships between supply and demand of stormwater for reuse such as seasonality, volume, timing, spatial separation, changing conditions, sediment, temperature, and area of application. Similarly, regulatory and institutional constraints were evaluated for each opportunity.

6.3 Sustainability Evaluation

Through literature reviews and interviews with key agencies, sustainable stormwater reuse practices, including combined technologies, were assessed. Finding the right mix of source control, storage, treatment, and conveyance involves seeking approaches to solve more than one problem at a time. For example, stormwater capture and infiltration can reduce peak flood flows, increase aquifer recharge, and improve habitat base flow volume and water quality.

6.4 Technical Appraisal

The technical appraisal consisted of a preliminary screening process and an analysis of the technical merits of each selected opportunity.

6.4.1 Screening Process

The initial set of 31 identified opportunities was reduced to 9 using a two-step screening process (preliminary and detailed). Preliminary screening criteria included factors such as implementability (institutional, regulatory, and land use), demand constraints, and generalized stakeholder acceptance. Detailed criteria consisted of water reuse potential, delivery and operations needs, constraints on timing, location, and quality of expected supply, and opportunity area characteristics (specifically, basin land use, vegetation, soil, and slope characteristics; existing conveyance and natural stream networks; precipitation; expected demand area and size; and hydrology).

During the screening process, the appraisal team worked with Reclamation staff and stakeholders to develop a prioritized list of stormwater runoff reclamation options for each island. The nine opportunities that passed the screening process were evaluated based on the following criteria:

- **Data and resource availability**. How available were data? Collection methods included interviews with agency personnel, literature reviews, and field investigations.
- **Ease of delivery and operation.** How efficient is the proposed mode of delivery (for example, subsurface vs. surface) and operation?
- **Dependability of water supply**. How consistent and reliable is the water supply generated?
- **Simplicity of storage and water treatment.** How much storage capacity is needed? Is water treatment necessary, and if so, how much?
- **Degree to which prior investment has been maximized**. Have previous projects been conducted or proposed in the area?
- **Cost/benefit ratio**. What are the anticipated component needs and estimated costs? Following the guidelines of the Reclamation *Estimating Handbook* (1989), preliminary cost estimates for individual opportunities were prepared from rough general designs to review opportunity benefits in light of the costs.

- **Institutional considerations**. What are the regulatory, land use, community, and cultural influences in the opportunity area?

6.4.2 Rating Criteria

Each of the 9 selected opportunities was rated according to the scale shown in Figure 6-1. The rating criteria in this scale mirror the bulleted list of criteria presented in Section 6.4.1. The scale assesses perceived opportunity potential on a simple high-medium-low range. The summary scale at the bottom of the figure is a threshold-level, uncalibrated assessment of overall opportunity potential based on the data collected. A technical rating scale is included in Section 7 for each opportunity. In Section 8, opportunities are numerically ranked according to the same criteria.

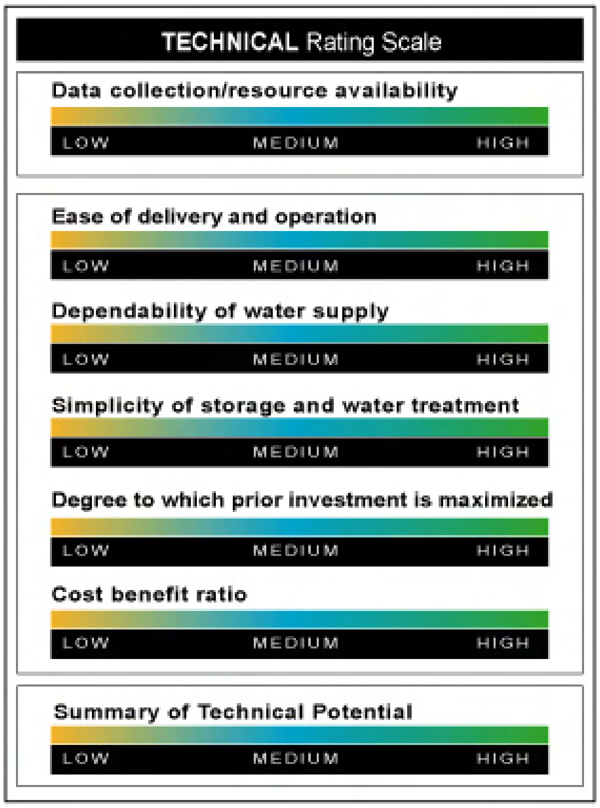

Figure 6-1. Technical Rating Scale

6.5 Institutional Factor Considerations

Institutional factors are issues and concerns regarding a project's potential impact on counties, communities, cultures, and watersheds. Impacts may be direct or indirect, intended or unintended, and positive or negative.

6.5.1 Function

A constraints and opportunities assessment was performed for each of the candidate opportunities (see Section 7). This assessment looked at the potential direct and indirect effects of the opportunity on the institutional environment closest to the opportunity area.

Constraints and opportunities were categorized and rated. These assessments were performed on the basis of existing knowledge and information obtained informally during the study. Threshold-level information is presented and only generally describes the institutional, social, and cultural context of the opportunity. A primary objective of the assessment performed is to determine, in a general sense, how the opportunity might be received before the initiation of an involvement program that would identify, in more detail, opportunities and constraints from a local or watershed perspective.

6.5.2 Data Collection Tools

The following data collection tools were used to characterize regulatory, demographic, and community and cultural factors:

- Qualitative interviews with State agencies and organizations. Information gained from interviews formed the basis for an assessment of opportunity impacts. An open-ended interview technique was employed. When additional references were provided, follow-up interviews with other stakeholders were conducted.

  The qualitative interviews requested information regarding the regulatory context of the opportunity, any cultural concerns (in terms of past experiences with similar or related projects in the area), and other issues that might be related to the success or repercussions that might be anticipated from the opportunity.

  Interviews were conducted recognizing that different perspectives might be held by other stakeholders and that all views concerning an opportunity are valuable. Because only a threshold-level assessment was sought, the evaluators relied principally on the views of State agencies, and did not perform an inclusive stakeholder review. To gain additional insight into the opportunity, a broader review of stakeholders may be useful. Such a review would recognize specific opportunities and constraints.

6.5.3 Land Use and Regulatory Factors Relevant to Each Opportunity

- State: Interviews were conducted with the Historic Preservation Division of the DLNR in Kailua Kona, Hawaii. The State of Hawaii has the preeminent role in managing natural resources. The State Historic Preservation Division administers the Hawaii Historic Preservation Act and staffs the burial councils. The DLNR has primary responsibility of the Public Land Trust.

- County: The Draft General Plans for each county were consulted. These Draft General Plans provided goals, policies, and direction for decisionmaking and for guiding government action to meet social, economic, environmental, and land use needs of each county. The Draft General Plans outline the county’s assumptions regarding socioeconomic development based on demographic information of the areas.

- Local: The National Historic Preservation Act requires native Hawaiian organization participation through the Office of Hawaiian Affairs (OHA) and Hui Malama.

6.5.4 Community and Cultural Factors Relevant to Each Opportunity

Cultural traditions and historic areas were considered in the opportunity appraisals. Native Hawaiians are entitled to special rights under the State Constitution and State Statutes. They have rights to water; to traditional and customary access and gathering rights; and to require land use permit applicants to conduct archaeological surveys and to protect archaeological sites and burial sites.

Water is a spiritual and essential life force in traditional Hawaiian cultural and subsistence practices. Ahupua'a is a traditional Hawaiian system of land management and may need to be considered along with values related to watershed management and restoration. To Native Hawaiians, the restoration of traditional and customary Hawaiian rights and practices has become as important to consider as economic feasibility or watershed restoration. Traditional Hawaiian culture and politics have been considered in political and judicial decisions regarding water, particularly when an opportunity might enhance or diminish the cultural practice of the cultivation of taro and the flow of water through the loi (taro ponds).

6.5.5 Institutional Factors Warranting Further Study

A number of cultural factors warrant further study at the next level of analysis for those opportunities that move forward. The factors are:

- Appurtenant water rights
- Riparian and other water rights
- Native Hawaiian water and gathering rights
- DLNR's Historic Preservation Division requirements (for example, archeological survey)
- State water licenses and revocable permits

6.5.6 Generalized Rating Scale

The degree of specificity in each opportunity description varies based on opportunity, location, and the knowledge of those who provided input during the review. The institutional factors assessment provides only a general indication of possible effects perceived by those interviewed. For example, what in this initial review might be predicted to have a major impact (positive or negative) may, once additional information is known or a public education and involvement program is undertaken, turn out to have only a minor impact. To this end, a rating scale is presented in Section 7 for each opportunity. The scale assesses perceived opportunity potential on a simple low-medium-high range, as shown in Figure 6-2. A "high" value is positive, with one exception: for "Creates community and cultural impacts," a high value is negative. The summary scale at the bottom of the figure is a threshold-level, uncalibrated assessment of overall opportunity potential based on the data collected.

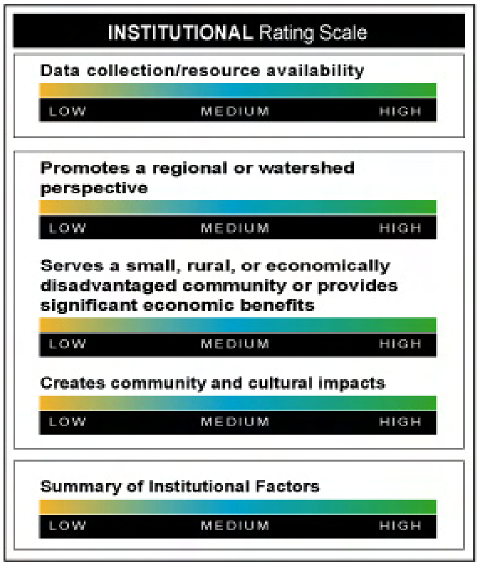

Figure 6-2. Institutional Rating Scale

6.6 Preliminary Cost Estimates

Preliminary cost estimates for individual opportunities were prepared from cost curves, simple sketches, or rough general designs. Estimates would be used as an aid in selecting the most economical plan by comparing alternative features such as dam types, dam sites, canal or pipeline routes, and pumping capacities.

According to the Reclamation *Estimating Handbook* (1989), appraisal estimates may be used in appraisal reports for the purpose of determining whether more detailed investigations of an opportunity are economically justified. This method of determining costs should be used only when it is desirable to obtain approximate costs in a short period of time with data that are inadequate for the preparation of feasibility estimates.

The allowance for unlisted items in appraisal estimates is 15 percent of the listed items. This line item in the appraisal estimate may be viewed as a contingency for design changes and as a way to eliminate itemizing the pay items in the estimate that would have little influence on the total cost. A contingency cost of 25 percent for construction unknowns is used. Engineering, construction management, and right-of-way acquisition costs of 35 percent of field cost are added.

SECTION 7

Candidate Opportunities

This section identifies and describes the 9 candidate opportunities for stormwater reuse. Opportunities are organized alphabetically by island.

7.1 List of Opportunities

After applying the screening process discussed in Section 6, nine opportunities were selected for further development from among the initial set of 31 and rated based on the technical and institutional ranking criteria shown in Figures 6-1 and 6-2, respectively. The 22 opportunities not selected are summarized in Appendix B. Table 7-1 identifies the candidate opportunities. Numbers in the first column reflect the original numbering system for the larger group of 31 opportunities initially identified.

TABLE 7-1
Candidate Opportunities

Number	Name
Hawaii 1	Lower Hamakua Ditch/Waipio Valley
Hawaii 3	Pahala Catch Basins
Kauai 3	Lihue Garlinghouse Tunnel Potable Water Source
Kauai 4	Lihue Airport Landscape Irrigation Reuse
Maui 2	Southwest Maui Watershed Stabilization (Site 1) and Central Maui Soil and Water Conservation (Site 2)
Maui 4	Lahaina Watershed
Molokai 1	Molokai Irrigation System
Oahu 1	Waianae Agricultural Park
Oahu 4	Ewa Plains

7.2 Hawaii 1—Lower Hamakua Ditch/Waipio Valley

7.2.1 Objective

Increase water availability for irrigated agriculture.

7.2.2 Background

Currently, stormwater runoff from the upslope areas is diverted from flowing into the existing Lower Hamakua Ditch by small flumes that convey stormwater over the ditch or by drainage culverts that convey stormwater under the ditch, which protects the existing ditch from sedimentation and damage. The relatively steep upslope area is drained by approximately 20 small ravines that flow intermittently during storm events. The stormwater from the upslope ravines and swales could be diverted to enter a new ditch upslope of the existing irrigation ditch. The new ditch would be designed specifically for stormwater capture. The captured stormwater could be stored in a new storage reservoir.

7.2.3 Opportunity Description

This opportunity would construct a parallel ditch upslope of the existing Lower Hamakua Ditch to intercept stormwater, and add a reservoir for water storage and to provide settling. Water would be released from the new storage reservoir into the existing Lower Hamakua Ditch distribution system as needed. The distribution system is an existing gravity ditch main canal system approximately 14 miles long with pipe and ditch distribution laterals. The system has five reservoirs, including one at the end of the main ditch. This irrigation system has been the subject of legal and institutional challenges and resolution of those challenges may impact the use of any additional water made available by pursuing this opportunity. For the purposes of this study, however, it was assumed that no new agricultural land would be irrigated.

With this opportunity, it would be possible to irrigate an additional 610 acres or reduce irrigation withdrawals from the headwaters of three streams in Waipio Valley at the 1,000-foot elevation by the amount of stormwater that is captured if the irrigated area is not expanded. The stream withdrawals during high-flow periods provide flood control for the Waipio Valley, but during lower flow times of the year, reduced withdrawals may produce multiple benefits such as more stable flows. This opportunity would irrigate new area or would reduce steam withdrawals.

This opportunity is illustrated in Map 1.

7.2.4 Assessment

Delivery and Operations Needs

The Hawaii Department of Agriculture (HDOA), which owns, maintains, and operates the system, is currently rehabilitating the delivery system. The parallel ditch system would have small diversion structures in the ravines and gulches that it crosses to divert flow. These diversion structures would need to be operated. The stormwater capture ditch would require seasonal cleaning to remove the silt and debris that it captures. The storage reservoir could have enough capacity to accumulate silt for up to 10 years before cleaning is required to restore its capacity. Additional operation of the gate on the reservoir would be required during the period when the distribution ditch system has enough capacity to receive additional flow from the stormwater reservoir.

Dependability of Expected Supply

The expected supply would be available primarily in the winter months when the farmers are not irrigating but the main ditch system is carrying flow to fill the reservoirs. Some flow would also be available during the irrigation season from the largest summer rainfall events. The flow could enter the system at any or all of the approximately nine gulches that the new stormwater capture ditch crosses. The water quality entering the ditch would be lower than the quality of water diverted from the streams, but should be appropriate for surface irrigation.

Stormwater that is captured in winter and stored in the stormwater reservoir for several weeks would have time to settle and be approximately the same quality as water diverted from streams. The new capture ditch would be approximately 3 miles long and generally 3 feet deep, with side slopes that are 2 feet horizontal to 1 foot vertical (2:1).

Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. The predominant land use is agriculture, with several patches of forest preserve across the upper slopes. Three small towns are located in the area: Kukuihaele at the west end of the ditch on the coast, Honokaa near the middle of the Lower Hamakua Ditch, and Paauilo near the east end. The new ditch would be upslope of Paauilo and would provide increased flood control in this area.

The soils above and below the ditch along the coast have high infiltration rates (Hydric Soil Group A). The slopes are generally less than 25 percent.

Existing Irrigation Conveyance and Natural Stream Networks. Precipitation is 50 inches annually along the main Lower Hamakua Ditch and the upslope area that could contribute stormwater into it. This is the area that is being considered for capture of stormwater by this stormwater reuse opportunity. More than 20 intermittent streams from this upslope area cross the ditch flowing to the ocean.

The headwater streams that supply the existing Lower Hamakua Ditch originate in highlands to the north, which have an annual rainfall of 100 to 150 inches per year.

The streams and layout of the existing Lower Hamakua Ditch are shown in the Lower Hamakua map (Map 1).

Expected Demand Areas and Sizes. The Lower Hamakua Ditch irrigation system once supplied more than 20,000 acres of irrigated land. The diversified agriculture that is replacing the previous sugar cane plantation is currently on approximately 5,000 acres. The HDOA expects that the agricultural use of the irrigation water could resume to nearly the same demand for which the system was originally built. The new reservoir would be approximately 10 feet deep and would store 370 acre-feet of water. Stored water would be released into the existing ditch system to augment water stored in the Nobriga and Paauilo Reservoirs.

The targeted area for stormwater collection is approximately 18 square miles within the Paauilo hydrologic unit. The estimate of total runoff in the unit averages 8 percent of the total precipitation (Yuen and Associates, 1990). Based on this runoff estimate and the 30-year period (1971 to 2000) rainfall data from Haina (214) Station (National Oceanic and Atmospheric Administration [NOAA], 2002), potential stormwater runoff from the two units for irrigation purposes was 1,916 million gallons (MG) (5,880 acre-feet) per year. Limited pipeline capacity and inefficient capture of peak flows would reduce the potential capture volume. The assumed capture would be less than 10 percent of the potential runoff or 192 MG (588 acre-feet). Table C-1 in Appendix C summarizes the salient water balance data for each opportunity.

The total area to be irrigated and the size of reservoir storage that would be required were estimated using the RZWBM v1.04 (CH2M HILL, 2003). Monthly rainfall averages for a 30-year period (1971 to 2000) from Haina (214) Station, and standard daily pan ET data from Honolulu Station 702.2 were used. The monthly pan ET values were converted to referenced grass ET by multiplying by 0.7. The additional source of water used in the model was the estimated stormwater captured from the Honokaa and the Paauilo hydrologic units distributed according to the monthly rainfall pattern.

Based on the assumptions stated above, the model estimated that the yearly gross irrigation requirement for the opportunity is approximately 13 inches, and for an irrigated land size of approximately 610 acres, a reservoir storage area volume of approximately 160 MG (490 acre-feet) would be required. Details of the model output are included in Appendix C. The remaining irrigated area would continue to receive water from the existing supply.

Estimated Cost. Table 7-2 provides estimated opportunity costs.

TABLE 7-2
Preliminary Cost Estimate for Lower Hamakua Ditch/Waipio Valley

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Grass-Lined Capture Ditch (3 feet deep, 2:1 side slopes)	15,840	LF	$10	$160,000
2	Reservoir ($15 per cubic yard excavation)	490	acre-feet	$24,300	$11,910,000
3	Diversion Structures	9	each	$20,000	$180,000
	SUBTOTAL				$12,250,000
	Allowance for Unlisted Items (15% of subtotal)				$1,840,000
	Contract Cost				$14,090,000
	Contingency (25% of Contract Cost)				$3,520,000
	Field Cost				$17,610,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$6,160,000
	Total Cost				**$23,770,000**

Groundwater Elements. The opportunity site lies in the Paauilo (80202) Aquifer system of the East Mauna Kea Aquifer sector.

7.2.5 Institutional Factors Assessment

The following data and resources have been used to assess institutional factors for each opportunity site.

Land Use and Regulatory Factors

- The HDOA operates the Lower Hamakua Ditch Irrigation System (LHDIS) and has a long-term lease with the landowners. The LHDIS is being converted to a small-scale diversified crop farming operation. The HDOA entered into a partnership with the U.S. Department of Agriculture (USDA), NRCS, and the Hamakua Soil & Water

Conservation District to plan and implement system improvements. As of 2003, an organized cooperative was not yet established to manage the system (Water Resource Associates, 2003b).

- The Department of Land and Natural Resources, Commission on Water Resource Management, has regulatory jurisdiction over streams and stream channels, such as the construction of new or expanded stream diversions, Stream Channel Alteration Permits, and Petitions to Amend Instream Flow Standards.
- The Commission on Water Resources Management has been involved in stream diversions.
- Legal disputes have occurred with regard to this opportunity and it is likely that no new water can be used in this area. Therefore, capture of stormwater would result in less water being diverted from streams.

Demographic Factors

- Socioeconomic: The Hamakua District of Hawaii County has shown a population growth of 10.2 percent since 1990, even with the closing of sugar operations in 1994. The 2000 population was 6,108 and the population continues to grow largely as a result of being a residential community for people who work in resort and tourist activities in the neighboring South Kohala district and to the settlement of the rural homestead areas.

  The economic mainstay is agriculture. There are numerous cattle ranches and diversified crops being grown. Of these, macadamia nuts are expected to play a large role in agricultural development. The County Draft General Plan promotes the assistance of further development in diversified agriculture and cooperation with the agricultural sector and other agencies to provide necessary services.

  The 2000 unemployment rate for Kukuihaele, north of the opportunity site, is 8.7 percent (U.S. Census Bureau, Census 2000).

Community and Cultural Factors

- Cultural property: The opportunity location is a culturally sensitive area. The ditch is designated a historical site. The County Draft General Plan requires developers of land to provide historical and archaeological surveys and cultural assessments prior to development when there are indications that the land under consideration has historical significance. The State Historic Preservation Division (SHPD) indicated they would require an archaeological investigation in this area (McGray, 2005).
- Stakeholder Interest: SHPD indicated that interested groups would be Hawaiian Civic Clubs (regional groups) and individual district members of the Hawaiian Burial Council.

7.2.6 Generalized Rating Scales

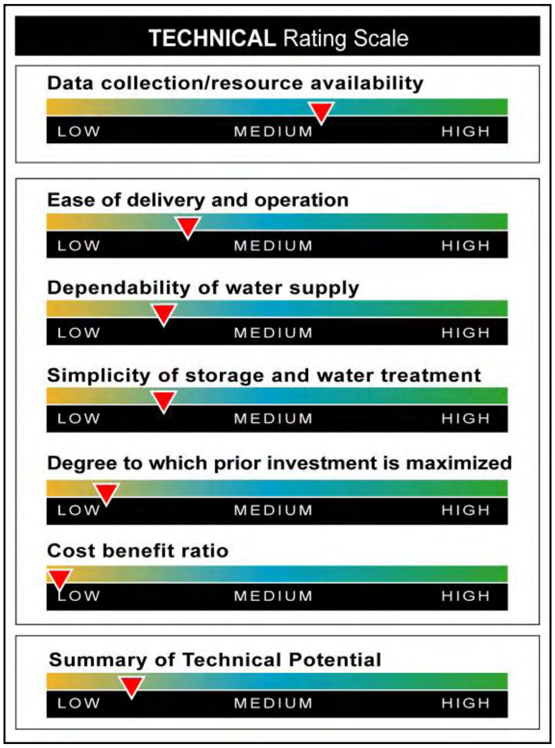

Figure 7-1. Technical Rating Scale for Lower Hamakua Ditch/Waipio Valley

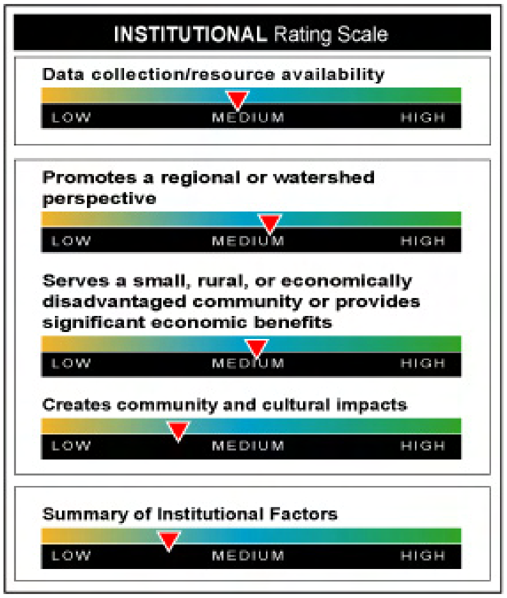

Figure 7-2. Institutional Rating Scale for Lower Hamakua Ditch/Waipio Valley

7.3 Hawaii 3—Pahala Catch Basins

7.3.1 Objective

Create a reliable water supply for irrigation and reduce stormwater flooding.

7.3.2 Background

The agricultural water supply in the Pahala area is inadequate to develop and sustain diversified farming, which is a County of Hawaii goal for the Kau District where it is located. Older water supply systems associated with the former sugar plantations in Pahala vary in reliability and level of maintenance because of changes in ownership and economic commitments since Kau Sugar Company ceased operations in 1996. Development of irrigation water is needed to effectively use the former sugar cane land for other crops.

Water supply issues are complicated by the high permeability of the soils and geology in the area, which prevent the creation of perennial streams, despite significant rainfall. The existing water supply systems obtain water from tunnels drilled into the side of Mauna Loa mountain. Additionally, flooding from winter storms is a problem, causing damage to agricultural facilities, such as flumes that traverse the slopes, and to roads and bridges. The right stormwater reuse opportunity could potentially improve the reliability of agricultural water supplies and at the same time help to control flooding in the area.

7.3.3 Opportunity Description

This opportunity would install catch basins on several mountain gulches (Pilkea, Keaiwa, Kauhuhuula, and Hionamoa) above Pahala to capture stormwater runoff from these ephemeral streams and divert the water into the conveyance pipeline of a separate agricultural water supply opportunity proposed by the NRCS for the area (USDA NRCS, 1994). Addition of this stormwater reuse component would increase the size of the associated capture conveyance pipelines. This Reclamation opportunity would increase the firm yield for the proposed NRCS opportunity.

The NRCS-proposed project would install concrete collection boxes at the Noguchi 2 tunnel (elevation 3,400 feet), Alili Spring (elevation 2,900 feet), and the Kaumaikeohu Tunnel (elevation 2,900 feet). Water from these sources would be transmitted to a storage reservoir west of Hionamoa Gulch at elevation 2,750 feet. The Pahala Catch Basins opportunity map (Map 2 in the Maps section) shows the NRCS-proposed agricultural supply project along with this stormwater reuse opportunity, which would build on the NRCS-proposed project.

The stormwater reuse opportunity catch basins would connect to the conveyance pipeline that descends from the Noguchi 2 Tunnel and crosses the Pilkea, Keaiwa, Kauhuhuula, and Hionamoa gulches on its way southwest to the new storage reservoir, which is referred to as the Pahala Reservoir. The conveyance pipeline would be sized to preclude pressurization.

The NRCS-proposed agricultural water supply project includes distribution pipelines from Pahala Reservoir to new agricultural areas (2,000 acres) at the Middle Mouala Camp Site and Keaiwa Camp along Kau Sugar Field Road (elevation 1,600 feet), and to the existing 5,500-acre Kau Agribusiness irrigation system (elevation 750 feet).

The NRCS-proposed project would have the capacity to provide a peak demand of 12 million gallons per day (mgd). The 2,400-foot-long transmission line from the Noguchi 2 Tunnel to the Pahala Reservoir would be 8-inch high-density polyethylene (HDPE) pipe. The stormwater reuse opportunity would increase the size of this pipeline to approximately 12-inch diameter after it crosses Pilkea until it crosses Kauhuhuula Gulch. Thereafter, the estimated increase in size would be up to 18 inches in diameter. The transmission lines from Kaumaikeohu Tunnel and Alili Spring for the planned water supply would remain the same as specified for the water supply project: 7,000-foot-long, 10-inch-diameter HDPE, and 6,000-foot-long, 12-inch-diameter HDPE, respectively. The Pahala Reservoir for the planned water supply opportunity would have a capacity of 800 MG.

Connecting this stormwater reuse opportunity would provide supplemental water supply, which would decrease withdrawals from the water sources so that they could be preserved for other uses. Because a sediment load would be added to the water, it would be necessary to add a 2-foot layer of soil over the HDPE-lined storage reservoir to protect the liner when sediment is removed to maintain the capacity of the reservoir. The distribution pipelines for the planned irrigation systems consist of 18,000 feet of 10-inch-diameter polyvinyl chloride (PVC), 8,000 feet of 24-inch-diameter PVC, and 1,000 feet of 30-inch-diameter PVC. These distribution pipelines are sized to provide a maximum capacity of 6,200 gpm.

A map of this opportunity is provided in the Maps section (Map 2).

7.3.4 Assessment

Delivery and Operations Needs

The stormwater collection structure would be designed to collect stormwater during moderate rain events and to overflow during intense rain events so as to avoid damage to the facility. The structures would moderate flooding, but are not expected to prevent damage from intense rain storms such as the one that occurred in November 2000 and damaged a bridge on the Mamalahoa Highway (State Highway 11).

At present, macadamia nuts are the predominant agricultural crop in the Pahala area, and future plans for the additional irrigation lands appear to target macadamia nuts, probably because of the high prices they are able to demand and the unfilled market for them. This could possibly change. For example, in the late 1990s, there were plans to establish papaya plantations in the Pahala area because of the 1995 ringspot virus infestation in the Puna region on the eastern coast of the Island of Hawaii. These plans were dropped when the crisis was averted through the conversion to virus-resistant varieties.

For macadamia nuts, irrigation is critical at the time of nut set, during nut filling, and during the vegetative growth period in midsummer. Macadamia nuts can withstand periods of drought, but the harvests are small and of low quality. Summertime is the dry season in the Pahala area. Therefore, storage is needed for stormwater collected during the wet season from October to March.

Dependability of Expected Supply

Stormwater flows in the gulches occur in the winter and need to be stored for the summer irrigation season. Runoff in the area produces high sedimentation loads. To protect the irrigation systems, the reservoir would need to serve as a sedimentation basin. Otherwise, water quality should be good because the runoff originates in the Kau Forest Reserve on the shoulder of Mauna Loa.

Stormwater needs to be collected in the gulches because the high permeability of the soils prevents overland flow from developing to a level that could be effectively captured by stormwater collection ditches at other locations.

Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. This opportunity is located in the Kau District. In this district, macadamia nuts are the major crop. Other crops, such as bananas, avocados, tomatoes, and carnations are cultivated on a limited scale. Other production includes vegetables, coffee, and hardwoods. Ranching operations are also found throughout the district. Eucalyptus trees are raised for biomass fuel to generate electricity. A private initiative has been undertaken to plant approximately 5,000 acres of eucalyptus trees.

The area is on the southeastern slope of Mauna Loa, southeast of the Kau Forest Reserve and south and southwest of the Hawaii Volcanoes National Park. Mauna Loa is an active volcano. Seismic activity is a factor in the area.

This opportunity is located in the Pahala subwatershed, which is located southwest of Wood Valley, below the Kau Forest Reserve to Nahuluhulu Point (along Enuhe Ridge and

Na Puu Kulua) including the Punaluu Gulch watershed. Land use in the Pahala subwatershed is summarized in Table 7-3.

TABLE 7-3
Land Use Summary
Pahala Subwatershed

Land Use	Acres	Percent
Range Land	11,500	24.3
Pastureland	200	0.4
Sugar Cane	7,600	16.1
Macadamia Nuts	4,800	10.2
Rural	350	0.7
Forest Reserve	17,500	37.1
Naturalized Vegetation	1,500	3.2
Other	3,800	8.0
Total	47,250	

Source: Kau River Basin Study, Hawaii County, Hawaii, Prepared by U.S. Department of Agriculture, Natural Resource Conservation Service, Honolulu, Hawaii, February 1994.

The major landowners in the Pahala subwatershed are the State of Hawaii, Bishop Estate, and C. Brewer Company. Ownership of C. Brewer lands is reported to have changed and to be changing because of land sales (Cross, 2004). As of 1994, the population in the Town of Pahala was 1,520.

The soils in the upper slopes of the opportunity area have high infiltration rates. In the lower slopes, they have moderate infiltration rates.

Existing Irrigation Conveyance and Natural Stream Networks. The former Kau Sugar Plantation irrigation system may be in disrepair. Water for the system was obtained from tunnels that accessed perched water in the mountains. Some of these may still be functional. Kau Agribusiness grows macadamia nuts on 3,500 acres of the former Kau Sugar Plantation. The current water supply sources for this irrigation are the Palima and Sisal wells.

Precipitation in the Pahala area ranges from 30 to 59 inches per year, but in the mountains above, the precipitation is 118 inches per year. Intense rain events occur in the area. For example, in November 2001, 40 inches of rain fell in 24 hours (Kubo, 2005). These storms produce tremendous runoff and flooding with high sediment loads. Flash flooding often occurs along the Mamalahoa Highway (State Highway 11) when streams in the area exceed culvert and bridge capacity.

Mean annual precipitation ranges from less than 20 inches per year at Ka Lae, near sea level, to 125 inches per year at the 3,000-foot elevation in the Kau Forest Reserve. Most of the annual rainfall occurs October through March. Humidity ranges from 60 to 70 percent. The annual mean temperature along the coast is approximately 72°F and decreases with elevation to approximately 55°F at 5,500 feet elevation. Temperatures vary approximately

15°F throughout the year with only 5°F variations for the average monthly or minimum temperatures.

Despite significant rainfall, all of the streams in the Pahala subwatershed are ephemeral. This is attributed to the extremely permeable volcanic series in the area. For the same reason, there are no fresh water lakes. The ephemeral streams in the area flow in gulches that descend the southeastern slope of Mauna Loa through the Kua Forest Reserve from approximately 7,000-foot elevation to 200 to 300 feet above sea level.

The water sources in the Pahala subwatershed do not have much storage capability and fluctuate with rainfall. Poor soil conditions, frequent seismic activity, and steep slopes have constrained the development of large storage facilities.

Most of the existing water storage facilities are owned and operated by Kau Agronomics Company. At one time, agricultural water storage consisted of 10 small dugout-type or aboveground structures with a capacity of 20.2 MG. As of 1994, only three of the reservoirs were still in use, storing 15.3 MG. The largest reservoir is the 13.9-MG Keaiwa, which collects water from the Noguchi 2 Tunnel, which has an average flow of 0.23 mgd. It is concrete lined, but due to age and seismic activity, it has major cracks that produce a leakage rate of approximately 27 percent of the water that enters the reservoir under average conditions. The Meyer Reservoir has a capacity of 1.1 MG, and the Pahala Factory Reservoir has a capacity of 0.3 MG.

During the dry season, the output of most of the springs and perched sources of water decreases. The addition of stormwater reuse would increase firm yield.

Expected Demand Areas and Sizes. This opportunity site lies in the Naalehu Aquifer System (80503) of the Southeast Mauna Loa Aquifer sector. The target area for stormwater capture is approximately 90 square miles. Estimated runoff from Naalehu Basin is 7 percent of the precipitation (Yuen and Associates, 1990).

Using the 7 percent estimated runoff from Naalehu hydrologic units, and the 30-year monthly averages (1971 to 2000) rainfall data from Pahala Mauka 21.3 Station (NOAA, 2002), potential stormwater runoff from the target area was 1,600 MG (4,900 acre-feet). Limited pipeline capacity and inefficient capture of peak flows would reduce the potential capture volume. The assumed capture is 2 percent of the potential runoff, or approximately 320 MG (980 acre-feet).

The total area to be irrigated and the size of reservoir storage that would be required were estimated using the RZWBM v1.04 (CH2M HILL, 2003). Monthly rainfall averages for a 30-year period (1971 to 2000) from Pahala Mauka 21.3 Station (NOAA, 2002), and standard daily pan ET data from Honolulu Station 702.2 were used. The monthly pan ET values were converted to referenced grass ET by multiplying by 0.7. The additional source of water used in the model was the estimated stormwater captured from the target area and was distributed according to the monthly rainfall pattern.

Based on these assumptions, the model estimated that the yearly gross irrigation requirement for this opportunity is approximately 21 inches, and for an irrigated land size of 540 acres, a reservoir storage volume of approximately 215 MG (660 acre-feet) would be required. Details of the model output are included in Appendix C. Additional storage would not be built because this opportunity is identified as an additional water source that would increase firm yield into the planned 800-MG reservoir.

Estimated Costs. Table 7-4 provides estimated opportunity costs.

TABLE 7-4
Preliminary Cost Estimate for Pahala Catch Basins

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Pipe 8 to 18 inches, increasing in size	5,800	LF	$75	$440,000
2	Pipe 8 to 12 inches, increasing in size	7,400	LF	$25	$190,000
3	Catch Basin	4	each	$20,000	$80,000
	SUBTOTAL				$710,000
	Allowance for Unlisted Items (15% of subtotal)				$110,000
	Contract Cost				$820,000
	Contingency (25% of Contract Cost)				$210,000
	Field Cost				$1,030,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$360,000
	Total Cost				**$1,390,000**

Groundwater Elements. The sources of water for the Pahala Water System (drinking water supply) are Alili Tunnel Spring (a groundwater source under the influence of surface water) and Pahala Well (a groundwater source).

The underground injection control (UIC) line is near the coastline. Subsurface flow is significant in the area. Several springs are known to exist in the area.

In the wet upland areas, the relatively impermeable Pahala Ash creates pockets of high-elevation groundwater. This perched water creates high-level springs and bodies of perched water, some of which have been tapped by tunnels.

Lateral movement of freshwater along the upper surface of the basal lens creates numerous fresh and brackish seeps and springs along the coastline. High drilling costs and thinness of the freshwater basal lens due to high permeability have prevented widespread use of basal water wells.

Key Environmental or Habitat Elements. According to a general location map of wetland areas (USDA NRCS, 1994), two intermittent riverine wetlands and two palustrine wetland areas appear to be located in the vicinity of this opportunity. Whether these wetlands depend on flow from the gulches on the upper slope of the mountainside is not clear. If they do, the catch basins should be designed so as to leave base flows in the gulches and capture stormwater flows in excess of base flows.

The stormwater catch basins in the gulches appear to be located in an area designated as containing a medium to high concentration of threatened and endangered plant species (USDA NRCS, 1994). The irrigation distribution elements of the water supply system are located in a low concentration area, which includes the Town of Pahala and the surrounding existing farmlands. Buffering flows by diverting peak stormwater runoff events may benefit wetlands and threatened and endangered species.

7.3.5 Institutional Factors Assessment

Background

In the early 1990s, the Hawaii State Legislature appropriated $500,000 to the County of Hawaii to be used toward the development of an agricultural water project in the Kau District. A portion of this funding was used by the County to develop rudimentary water supplies for displaced sugar plantation workers who were offered rent-free land for 5 years to farm. This program was offered by Kau Sugar when it ceased sugar plantation operations in 1996. Using the grant money, a new reservoir was built below the Keaiwa Reservoir. The balance of the grant money was targeted for another water supply project associated with a proposed Diamond Head Papaya Plantation in the Pahala area, but this project was canceled when the Puna region papaya plantations recovered from the ringspot virus infestation by using virus-resistant varieties.

The remaining grant money is being administered by the Research and Development (R&D) Department of the County of Hawaii. At present, the R&D Department is seeking opportunities to use the funds to promote agriculture in the area. In the meantime, Kau Sugar, which is owned by C. Brewer Company, is actively divesting itself of land ownership on the Island of Hawaii. The former Kau Agribusiness, which grew macadamia nuts in the Pahala area is now owned by M.L. Macadamia and Orchards L.P. This plantation is located along both sides of the Mamalahoa Highway south of the Town of Pahala.

The proposed agricultural water supply project that forms the basis for this stormwater reuse opportunity was formulated as part of a study conducted by the NRCS (USDA NRCS, 1994). The study develops infrastructure alternatives, but does not identify potential sponsors. Land ownership in the area is changing. As a result, it is difficult to establish the commitments needed to sponsor and fund an agricultural water supply system at the appropriate level of development.

Land Use and Regulatory Factors

The opportunity area is bounded by the forest reserve boundary. The Pahala area is dry and has been used for grazing. This opportunity could encourage more diversified farming in an economically depressed area.

This opportunity supports the following County of Hawaii Draft General Plan goals:

- Preserve the agricultural character of the island.
- Preserve and enhance opportunities for the expansion of Hawaii’s agricultural industry.

In addition, the following County of Hawaii Draft General Plan policy would be followed:

- Assist in the development of water for agricultural purposes.

The Draft General Plan states that "The lack of an adequate water supply is one of the major limitations to further agricultural development in the district." Specifically, for the Kau District, the County wishes to:

- Assist in the provision of water to agricultural areas.
- Encourage and support the expansion of diversified agriculture, including forestry and the macadamia nut industry in the Kau District.

The Department of Land and Natural Resources, Commission on Water Resource Management, has regulatory jurisdiction over streams and stream channels, such as the construction of new or expanded stream diversions, Stream Channel Alteration Permits, and Petitions to Amend Instream Flow Standards.

Demographic Factors

- Socioeconomic: Pahala Catch Basins serve an area that used to be in sugar cane cultivation but now serves smaller farmers. Flood control may be needed. Supporting NRCS on a storage plan for the agricultural water is well-advised (McGray, 2005). Some potential exists for stormwater protection with existing facilities. When a road washed out in 2000, the county assumed responsibility for it. Additional farming would provide a boost to the local economy, which is depressed. Wood Valley has a series of bridges that were overtopped as a result of floods.

  Population growth in the Kau District was 31.3 percent from 1990 to 2000. Unemployment rates in the Kau District are high. The Town of Pahala has 22.2 percent unemployment.

Community and Cultural Factors

- Cultural Property: The SHPD believes that the Pahala Catch Basin area would need an archaeological investigation and field inspections to determine conditions on the ground, previous reuse, and any existing structures (McGray, 2005).
- Stakeholders Interest: SHPD indicated that interested groups would be Hawaiian Civic Clubs (regional groups) and individual district members of the Hawaiian Burial Council (McGray, 2005).

7.3.6 Generalized Rating Scales

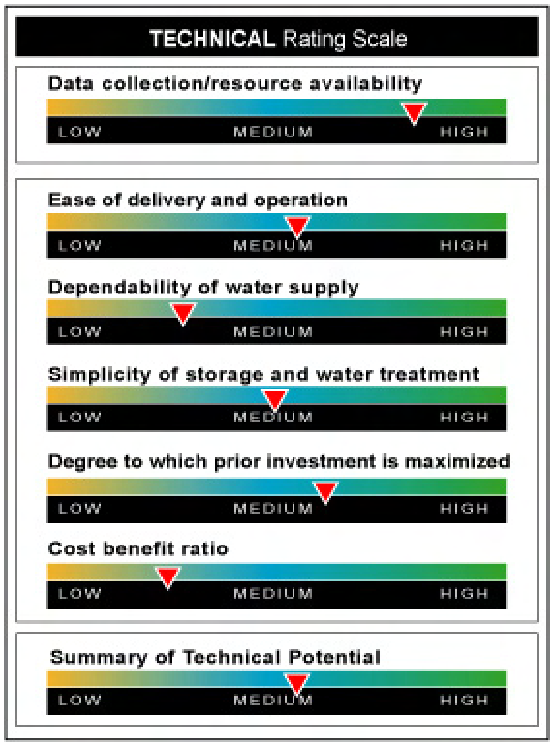

Figure 7-3. Technical Rating Scale for Pahala Catch Basins

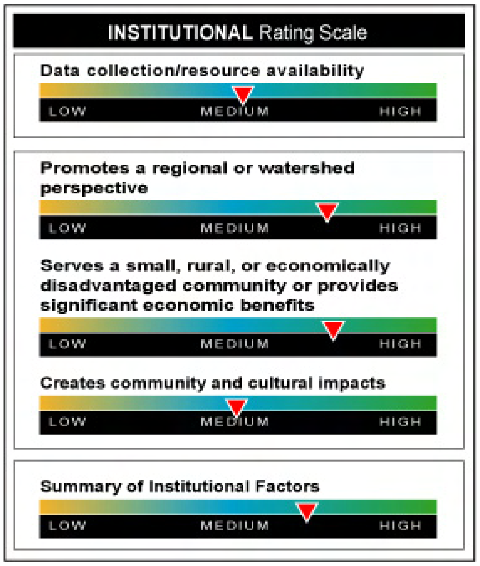

Figure 7-4. Institutional Rating Scale for Pahala Catch Basins

7.4 Kauai 3—Lihue Garlinghouse Tunnel Potable Water Source

7.4.1 Objective

Recharge potable aquifer with captured stormwater.

7.4.2 Background

A similar project was started in early 1990, but was abandoned when the island was hit by a hurricane in 1992. Virtually all of the public drinking water supplied by the County of Kauai DOW in the Lihue Basin comes from a volcanic-rock aquifer with low regional permeability. The DOW extracts water with either high-producing tunnels, or high-yielding wells. Areas of high soil permeability are localized, so high-yielding wells exist in only a few areas. A supply-demand analysis of the Puhi-Lihue-Hanamaulu water system in the *Kauai Water Plan 2020* compares supply from the existing 12 wells and tunnels with projected maximum daily demand (MDD). By 2020, a deficit of 1,096 gpm is projected. To meet these future demands, the DOW will develop six new water sources, meeting projected MDD through 2020. However, the area is expected to outgrow this enhanced supply by 2050, requiring the DOW to identify additional sources of water.

In recent years, the decreasing productivity and water levels in some of these tunnels and wells has raised concerns regarding the future of this water supply. The water level in some of the existing wells is projected to become low enough to make the wells unusable in the near future. Because the soils have such a low permeability, the aquifer surrounding the well is not able to recharge fast enough to keep up with demand over time. The DOW plans to develop new wells in order to spread the demand out over many wells. The goal is to decrease the localized drawdown on the existing wells, keep them in production, and prevent the necessity for deepening the existing wells.

Decreases in the potable water supply aquifer can be attributed to several factors. Local land use is transitioning from agriculture to commercial use, irrigation practices have changed significantly with local growers using new, more efficient methods, there is an increase in potable water demand as the local population increases, and possible rainfall variations (drought) may add to declining aquifer water levels. An example of changes in land use and irrigation practices can be seen with the Grove Farm Land Corporation, which owns more than 40,000 acres in the Lihue area that used to be a sugar plantation. Today, the land is used for diversified agriculture, shopping centers, and residential areas. The Grove Farm Land Corporation has adopted new irrigation practices, including converting from furrow irrigation to more efficient drip irrigation, which causes less water to infiltrate and replenish groundwater aquifers.

7.4.3 Opportunity Description

The DOW wants to develop a project to infiltrate captured stormwater into the Lihue area’s potable water aquifer. Stormwater would be captured and conveyed in existing irrigation ditches to new infiltration basins located near DOW potable wells. Infiltrating stormwater into the aquifer near the existing potable water wells would help speed the natural aquifer recharge process. Land in this area is nearly flat and approximately 1.5 miles inland from Kauai’s east coast. Infiltration basins could also provide some peak stormwater flow storage. The infiltration basins would be created by excavating to deepen existing small reservoirs and ditches supplying the reservoirs. Excavation would be to the depth of rock or down to 10 feet. The purpose of the excavation would be to increase dead storage and remove low-permeability silt and soil to increase leakage. Side slopes would be 2:1. Depths would vary. Three small reservoirs and 1 mile of ditch would be deepened.

A map of this opportunity is provided in the Maps section (Map 3).

7.4.4 Assessment

Potential Reuse

Stormwater reuse would occur in the form of aquifer recharge, replenishment of a public potable water source for the Lihue area, and the addition of fresh groundwater to act as a saltwater intrusion barrier.

Delivery and Operations Needs

Stormwater would be captured by the existing local irrigation system. Additional cleaning and maintenance would be required.

Dependability of Expected Supply

Stormwater capture and infiltration would fluctuate seasonally. The opportunity area receives most of its precipitation during the months of October through March.

The location must be above (*mauka*) the UIC line to ensure that the stormwater is infiltrating into an aquifer considered to be a drinking water source.

The quality of the expected supply is unknown. Sediment in the stormwater would clog the infiltration basins over time and require more maintenance. The potential supply greatly exceeds demand for this opportunity because only a small fraction of the supply of the previously irrigated area is still used for irrigation.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. Land use in the Hanamaulu watershed ranges from urban in the Cities of Lihue and Puhi to forest land in the higher altitudes. The drinking water wells are located on lowlands, near the urban and residential areas of Lihue. Agricultural land surrounds the urban and residential area and extends up into the foothills of Kilohana Crater. The land is open forest at higher elevations and slopes in the watershed.

The Lihue Basin is composed of Koloa Volcanics covering Waimea Canyon Basalt. The regional permeability of the Koloa Volcanics is low; however, there are localized areas of high permeability. Soils in the Hanamaulu watershed have moderate infiltration rates. Lihue-Puhi association soils at the coastal lowlands are deep, nearly level to steep, well-drained soils that have a fine or moderately fine-textured subsoil. Inland from these soils are Kapaa-Pooku-Halii-Makapili association soils. These soils are deep, nearly level to steep, well-drained to moderately well-drained soils that have a fine to moderately fine-textured subsoil. Farther upslope are rough mountainous land, rough broken land, rough outcrop association soils. These are well- to excessively well-drained soils on very steep, precipitous lands of mountains and gulches.

Existing Irrigation Conveyance and Natural Stream Networks. A privately owned irrigation system serves the irrigation needs of Hanamaulu watershed agriculture. This system is connected to the north with the East Kauai Irrigation System. The system collects water from the Hanamaulu stream via intakes, and captures overland flow. This private system could be used to convey water to the infiltration pond sites for the opportunity.

The Town of Lihue lies between two stream networks—the Hanamaulu Stream network and the Nawiliwili Stream network.

Precipitation. Throughout the watershed, annual average precipitation amounts range from more than 80 inches in the mountains to 41 inches at the Lihue Airport on the coast.

Hydrology. The hydrology within the watershed varies greatly, from steep, well-drained, forested slopes in the upper elevations, to flat, developed areas along the coast.

Estimate of Stormwater to Intercept for Recharge Purposes. Stormwater volumes entering the infiltration basins can exceed the amount that would infiltrate through the basins. The system is not source limited. The capacity of the existing wells can be sustained with an annual, average recharge of approximately 1,500 gpm, which meets the projected aquifer deficit in 2020. The recovery of recharged water is projected to be 75 percent of the total volume infiltrated.

Estimated Costs. Table 7-5 provides estimated opportunity costs.

TABLE 7-5
Preliminary Cost Estimate for Lihue Garlinghouse Tunnel Potable Water Source

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Excavation of existing facilities	50,000	yd^3	$15	$750,000
	SUBTOTAL				$750,000
	Allowance for Unlisted Items (15% of subtotal)				$110,000
	Contract Cost				$860,000
	Contingency (25% of Contract Cost)				$220,000
	Field Cost				$1,080,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$380,000
	Total Cost				**$1,460,000**

Groundwater Elements. Potable water for the Lihue area comes from the Hanamaulu Aquifer. This aquifer has a sustainable yield of 40 mgd (Izuka and Gingerich, 1998; Izuka and Oki, 2002).

7.4.5 Institutional Factors Assessment

Land Use and Regulatory Factors

- Land Use: The urban and residential area of Lihue and surrounding area consists of agricultural land.
- Regulatory: The Department of Land and Natural Resources, Commission on Water Resource Management, has regulatory jurisdiction over streams and stream channels, such as the construction of new or expanded stream diversions, Stream Channel Alteration Permits, and Petitions to Amend Instream Flow Standards.
- Historic Preservation Concerns: A small portion of Kauai land area has been surveyed for archaeological resources. The County Planning Department works with KHPRC and SHPD to require evaluation of project sites for archaeological resources and to provide a plan for preserving or salvaging any important site. Applicants typically hire a professional archaeologist to investigate and prepare a report. SHPD staff and Kauai Burials Council members report that archaeological resources or burials are often discovered during construction.

Demographic Factors

- Socioeconomic: Kauai’s population has increased from 29,800 in 1970 to approximately 56,600 in 1998. Because of the importance of tourism, the number of visitors to the island is taken into account when determining infrastructure and service needs. The visitor population increased to approximately 23 percent of Kaui's de facto population in 1998.

Community and Cultural Factors

- Cultural Property: The SHPD indicated that the tunnel was made a historic site last year (McMahan, 2005).

7.4.6 Generalized Rating Scales

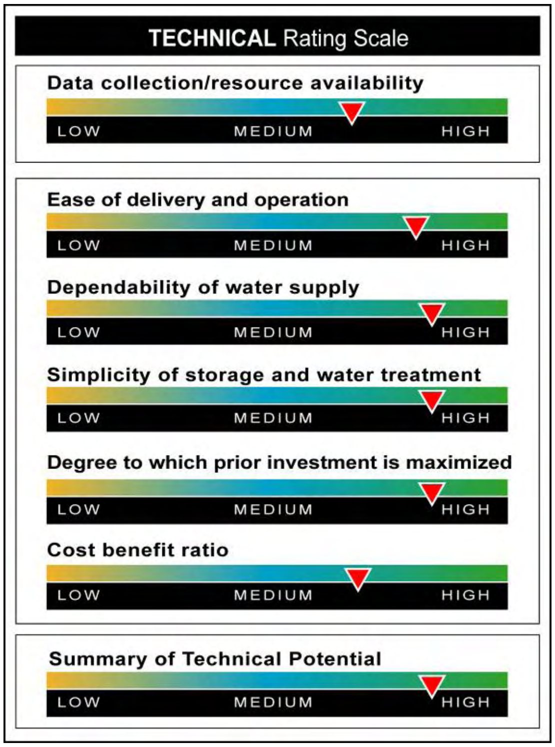

Figure 7-5. Technical Rating Scale for Lihue Garlinghouse Tunnel Potable Water Source

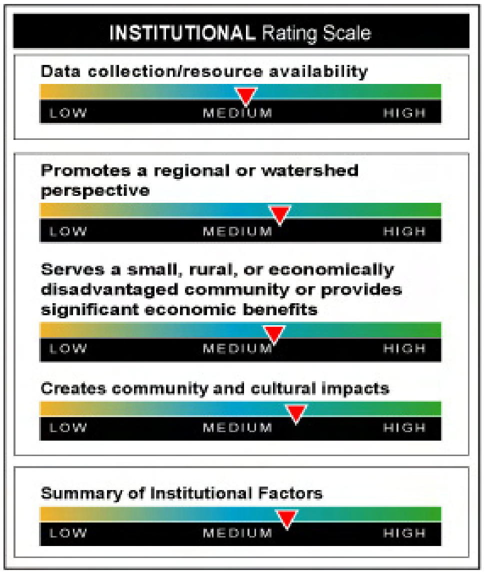

Figure 7-6. Institutional Rating Scale for Lihue Garlinghouse Tunnel Potable Water Source

7.5 Kauai 4—Lihue Airport Landscape Irrigation Reuse

7.5.1 Objective

Remove airport landscaping from potable water supply to extend supplies. Irrigate landscape with captured stormwater.

7.5.2 Background

The Lihue Airport occupies 872 acres approximately 1.5 miles east of Lihue, on the southeast coast of Kauai. Currently, the airport's landscape irrigation system is connected to the potable water supply. Because potable water is a limited resource on the island, it would be beneficial to disconnect the irrigation system from the potable water supply and, as an alternative, use stormwater to irrigate. Water would be captured and diverted into a storage reservoir at the airport. One stormwater source would be water from the airport's drainage system. Reserve supply could continue to be provided from the potable water system. While work done under this study identifies that adequate stormwater is available, it is important to note that contacts at the Lihue Airport, the Department of Transportation, and the County of Kauai Department of Public Works believe that identifying a stormwater source capable of meeting the demands of the airport may be difficult. They do not think that stormwater from the airport drainage system would fully meet the demand.

7.5.3 Opportunity Description

This opportunity proposes using airport drainage. The airport drainage would be stored in a new, 5-acre surface reservoir near the lighthouse and the country club. A pump station in the reservoir would supply irrigation. Airport drainage would be conveyed by gravity piping.

A map of this opportunity is provided in the Maps section (Map 4).

7.5.4 Assessment

Potential Reuse

This opportunity would reuse captured stormwater to irrigate landscaping at the Lihue Airport.

Delivery and Operations Needs

The Lihue Airport currently operates an irrigation system. The new components would include a connection to the stormwater collection system, conveyance to the storage basin at the airport, and pumping and conveyance from the storage basin to the irrigation system. Delivery of supplemental water from DeMello Reservoir or potable water would meet peak demands in drought years.

Dependability of Expected Supply

Stormwater capture will fluctuate seasonally, because this part of Kauai receives greater amounts of precipitation during the months from October through March. Precipitation data from the Western Regional Climate Center show that October through March are the wettest months in the Lihue area of Kauai, with monthly averages above 4 inches. November, December, and January all have monthly averages above 5 inches. The months from April through September receive less than 3 inches monthly. June is the driest month, with 1.7 inches on average.

The stormwater quality would depend on the water’s origination location. Water from the airport’s drainage system would contain traces of rubber, fuel oil, and sediments. Water from the Lihue Land Company’s reservoir would be of a higher quality. Storage in the reservoir would result in settling, and an oil-water separator and filter at the pump intake should result in irrigation water that is of good quality.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. The Lihue Airport is located on the east coast of Kauai, south of Hanamaulu Bay. The airport is in an urban area that is intermixed with residential land. Agricultural and open lands surround the urban areas of the Cities of Lihue and Puhi, and extend up into the foothills of Kilohana Crater. At higher elevations and slopes in the watershed, the land is open forest.

GIS maps indicate that soils in the Hanamaulu watershed have moderate infiltration rates. NRCS maps show that the Lihue Airport is located on Lihue-Puhi association soils, which are described as deep, nearly level to steep, well-drained soils that have a fine or moderately fine-textured subsoil. Inland from these soils are Kapaa-Pooku-Halii-Makapili association soils. These soils are deep, nearly level to steep, well-drained to moderately well-drained soils that have a fine to moderately fine-textured subsoil.

The airport property is on a gentle slope. The east boundary of the Lihue Airport is at sea level. The west boundary has an elevation of approximately 180 feet. Proceeding west from the airport, slopes gradually increase up to Kilohana Crater at 1,149 feet above sea level.

Existing Irrigation Conveyance and Natural Stream Networks. The Lihue Airport currently operates a potable water irrigation system for their landscaping, which is located around the entrance and throughout the parking area.

The airport is adjacent to the mouth of the Hanamaulu Stream at Hanamaulu Bay. There are also private irrigation systems that capture and convey stormwater in this area. Most overland flow in urban Lihue flows into the roadside swale system and empties into streams or wetlands.

Precipitation. The airport is adjacent to the mouth of the Hanamaulu Stream at Hanamaulu Bay. Private irrigation systems in the area capture and convey stormwater in this area. Most overland flow in urban Lihue travels into the roadside swale system and empties into streams or wetlands. The Lihue Airport has an average of 40 inches of rainfall annually. The Hanamaulu hydrologic unit has greater than 300 inches in the interior uppermost elevation of the watershed (Yuen and Associates, 1990).

The Lihue Airport has an average of 40 inches of rainfall annually. Average annual precipitation at the uppermost elevations of the Hanamaulu watershed is 80 inches.

Expected Demand Areas and Sizes. The Lihue Airport occupies 872 acres. Runoff from the airport area would be captured for storage and used as a source of irrigation water for landscape irrigation, in addition to normal precipitation, and supplemented with water from DeMello Reservoir.

It is unknown whether the airport irrigates year-round or seasonally. The highway landscaping adjacent to the airport is irrigated year-round. According to the Department of Transportation contact, the airport irrigates landscaping at the entry and throughout the parking area. Approximately 30 acres of landscape irrigation is possible.

The airport area lies within the Hanamaulu hydrologic unit, with estimated yearly runoff of 16 percent of the precipitation in the basin area (Yuen and Associates, 1990). For analysis purposes, the airport area was divided into two areas, impermeable and permeable. The impermeable areas were the runway, tarmac, parking, and building areas. The approximate total impermeable area is 21 acres and the assumption is that all rainfall can be captured from these areas and piped to the reservoir. Considering the land available for landscaping, only one-third of the remainder of the airport area was assessed for runoff-generating permeable areas using the 16 percent runoff from the Hanamalua Basin. The impermeable area runoff was estimated at 22 MG (67 acre-feet) per year, and the estimated runoff from one-third of the remaining permeable airport area was 49 MG (150 acre-feet), for a total volume of 71 MG (217 acre-feet) in additional water source.

The total area to be irrigated and the size of reservoir storage that would be required were estimated using the RZWBM v1.04 (CH2M HILL, 2003). Monthly rainfall averages for a 30-year period (1971 to 2000) from Lihue AP 1020.1 Station (NOAA, 2002), and standard daily pan ET data from the same station were used in the model. The monthly pan ET values were converted to referenced grass ET using a multiplier of 0.7. With gross irrigation requirements estimated at approximately 31 inches per year, the 30-acre landscape area only meets 87 acre-feet of the estimated 217 acre-feet of available new water sources, accounting for irrigation demands and reservoir evaporation.

Based on the previously stated assumptions, the model estimated that for the 30 acres available for landscaping, a reservoir size of 41 acre-feet would be required. This volume could irrigate the airport landscape year-round. Details of the model output are included in Appendix C. In normal rainfall years, no water would be needed from potable supply for irrigation.

One barrier to opportunity implementation as stated by airport staff was that the airport is in the airplane business, not water business. Airport staff are not enthusiastic about additional operation and maintenance that this opportunity would require. They would rather participate with the Department of Transportation to bring untreated water from Demello Reservoir (Dorn, 2005). This opportunity sited the reservoir near the existing coastal wetlands, assuming the existing bird attraction would not be expanded.

Airport staff also stated that a reservoir in the location described would not work, because of the bird hazard. An alternate location for the reservoir would be near the existing outlet.

Estimated Costs. Table 7-6 provides estimated opportunity costs.

TABLE 7-6
Preliminary Cost Estimate for Lihue Airport Landscape Irrigation Reuse

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	4-inch pressure pipe	13,200	LF	$25	$330,000
2	8-inch gravity pipe	26,400	LF	$50	$1,320,000
3	Reservoir (15$ per cubic yard excavation)	41	acre-feet	$24,300	$1,000,000
4	Pump Station	2	each	$100,000	$200,000
	SUBTOTAL				$2,850,000
	Allowance for Unlisted Items (15% of subtotal)				$430,000
	Contract Cost				$3,280,000
	Contingency (25% of Contract Cost)				$820,000
	Field Cost				$4,100,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$1,440,000
	Total Cost				**$5,540,000**

Groundwater Elements. This opportunity overlies the Hanamaulu Aquifer system in the Lihue sector. The Hanamaulu Aquifer system has an area of 55.22 square miles and a sustainable yield of 40 mgd (Yuen and Associates, 1990). The opportunity site is below (seaward [*makai*]) of the UIC line, which means the underlying aquifer is not considered a drinking water source.

7.5.5 Institutional Factors Assessment

Land Use and Regulatory Factors

- Land Use: SHPD did not anticipate issues with this opportunity site.
- Regulatory: The Department of Land and Natural Resources, Commission on Water Resource Management, has regulatory jurisdiction over streams and stream channels, such as the construction of new or expanded stream diversions, Stream Channel Alteration Permits, and Petitions to Amend Instream Flow Standards.
- Historic Preservation Concerns: A small portion of Kauai land area has been surveyed for archaeological resources. The County Planning Department works with KHPRC and SHPD to require evaluation of opportunity sites for archaeological resources and to provide a plan for preserving or salvaging any important site. Applicants typically hire a professional archaeologist to investigate and prepare a report. SHPD staff and Kauai Burials Council members report that archaeological resources or burials are often discovered during construction.

Demographic Factors

Socioeconomic: Kauai's population has increased from 29,800 in 1970 to approximately 56,600 in 1998. Because of the importance of tourism, the number of visitors to the island is taken into account when determining infrastructure and service needs. The visitor population increased to approximately 23 percent of Kauai's de facto population in 1998.

Community and Cultural Factors

Cultural Property: None noted by SHPD (McMahan, 2005).

7.5.6 Generalized Rating Scales

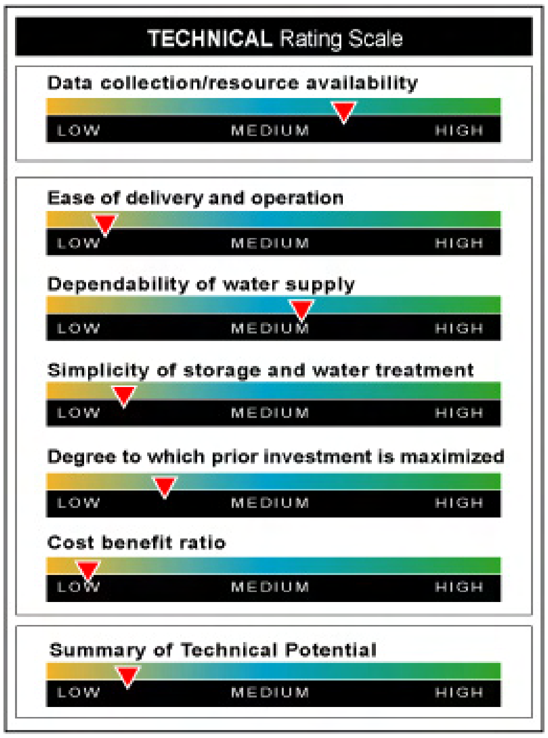

Figure 7-7. Technical Rating Scale for Lihue Airport Landscape Irrigation Reuse

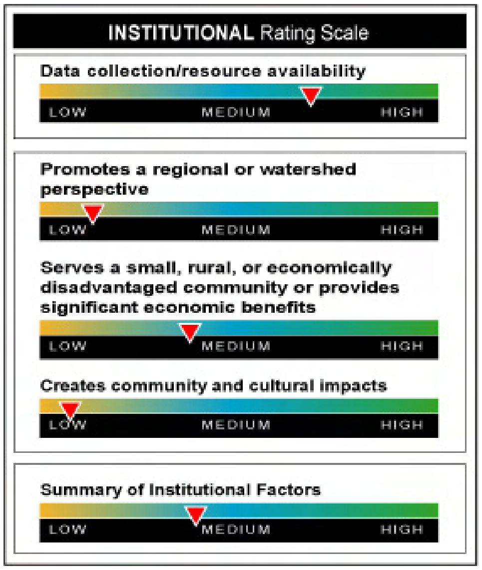

Figure 7-8. Institutional Rating Scale for Lihue Airport Landscape Irrigation Reuse

7.6 Maui 2—Site 1 (Southwest Maui Watershed Stabilization), and Site 2 (Central Maui Soil and Water Conservation)

7.6.1 Objectives

Capture and reuse stormwater for irrigation of pasture and livestock watering. Reduce erosion and sediment transport to coastal reefs. Provide flood control. Reduce fire hazard. This opportunity is a combination of previous Maui opportunities 2 and 3, which were merged because they have the same technological and institutional basis and share a common opportunity sponsor.

7.6.2 Background

Site 1: Range lands in the Wailea and Hapapa watersheds in southern Maui are being affected by drought, creating a higher demand for irrigation water.

Site 2: The opportunity area is located within two watersheds in southwest Maui, near Maalaea, which has range land to the west and agricultural land to the east. The range lands primarily grow grass for cattle grazing; however, southwest Maui is drought prone, which strains irrigation water availability.

7.6.3 Opportunity Description

This opportunity proposes to construct stormwater infiltration basins and contour terrace ditches to capture, store, and infiltrate stormwater. The infiltrated water would subirrigate grass for cattle feed, recharge aquifers, and provide water remaining in the basins for livestock and wildlife. The terrace ditches would run perpendicular to the slope and capture overland flow runoff. This dry area of Maui is also prone to wildfires, which could be slowed by the moisture around these stormwater retention areas.

These basins and ditches would also improve ocean water quality along the coast. Runoff from the range lands carries significant amounts of sediment and agricultural chemicals, which are transported to the ocean causing water quality issues and harming the near-shore biota. Stormwater collection basins would keep these pollutants out of the ocean and intercept vital topsoil. The basins would also provide some flood control.

The Central Maui Soil and Water Conservation District (CMSWCD) is seeking funding to implement this opportunity. CMSWCD has also submitted an EPA 319(h) grant proposal through the Hawaii Department of Health to develop a watershed-based plan for southwest Maui to identify other best management practices to improve water quality.

Map of this opportunity are provided in the Maps section (Maps 5 and 6)).

7.6.4 Assessment

Delivery and Operations Needs

No active irrigation management would be required. Periodic sediment recovery from basins and swales would be performed as needed.

Dependability of Expected Supply

The watersheds containing the opportunity location receive an annual average precipitation of between 39 inches on the eastern slope of Red Hill on Haleakala, and 16 inches along the southwest coast of Maui. Agricultural lands are located above the urban coastal area and up into the foothills, and receive between 16 and 30 inches annually. Stormwater capture rates are seasonal, generally peaking in the winter months between November and March, and during large summer storms.

The limited volume of supply does not justify a large, actively managed irrigation system, but is adequate to grow significant forage if it can be captured and infiltrated onsite.

The high sediment load that is carried with the runoff water could be captured in the contour terrace ditches to reduce soil loss from this steep agricultural area.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. Land use in this area of southern Maui consists primarily of range lands and agricultural land. Urban areas line the western coast. Some forest land is located in the upper elevations, along the eastern ridge of the watersheds. Along the coastline are the fast-growing residential, commercial, and resort areas of Makena to the south, Wailea, Keawakapu, Kamaole, and Kihei to the north.

The agricultural lands in southwest Maui are set between sparsely vegetated urban land to the west along the coast, and dry habitat species in the higher elevations along the ridge to the east.

Soil infiltration rates vary from slow in the northwest area of the watershed, to high through the central area where agricultural lands are located, to moderate in the higher slopes of the Red Hill ridge.

Existing Irrigation Conveyance and Natural Stream Networks. Seven gulches are located in this area, flowing nearly perpendicular to the coastline due west. Among the gulches are Li'ilioholo Gulch, Keokea Gulch, Waipuilani Gulch, and Kulanihakoi Gulch. No irrigation conveyance exists to irrigate this range land.

Expected Demand Areas and Sizes. The Hapapa, Wailea, and Mo'oloa watersheds cover 49,688 acres, of which 30,000 acres consist of range lands that could potentially use the basins and ditches proposed for this opportunity.

The opportunity would capture and reuse stormwater for irrigation of pasture and livestock watering. The target area for stormwater capture is the Kamaole and the Makawao hydrologic units. These basins cover 142 square miles and have an estimated annual runoff of 8 percent of the annual precipitation (Yuen and Associates, 1990). Using the 8 percent estimated runoff from the two basins, and the 30-year monthly average (1971 to 2000) rainfall data from Makena Golf CRS 249.1 Station (NOAA, 2002), potential stormwater runoff from the target areas was 2,685 MG (8,240 acre-feet). Limited infiltration and ditch capacity during peak flow events would reduce the potential captured volume. The assumed capture is 60 percent of the potential runoff, or 1,611 MG (4,950 acre-feet) on an average annual basis. The majority of this water would be infiltrated or used for livestock. The infiltration ditches and basins will fill and empty many times per year.

Estimated Costs. Table 7-7 provides estimated opportunity costs.

TABLE 7-7
Preliminary Cost Estimate for Southwest Maui Watershed Stabilization and Central Maui Soil and Water Conservation (Sites 1 and 2)

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Contour ditches (1 foot deep, 3:1 side slope)	58,080	LF	$3	$170,000
2	Detention (infiltration) Basin (5 feet deep, 0.25-acre area) ($15 per cubic yard)	19	BASINS	$24,300	$460,000
	SUBTOTAL				$630,000
	Allowance for Unlisted Items (15% of subtotal)				$90,000
	Contract Cost				$720,000
	Contingency (25% of Contract Cost)				$180,000
	Field Cost				$900,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$320,000
	Total Cost				**$1,220,000**

The Central Maui Soil and Water Conservation District is seeking funding to implement this opportunity. Site 1 includes 10 miles of contour ditches 1 foot deep, with 3:1 slopes and 10 5-foot-deep detention basins of 0.25-acre each, near Kihei. Site 2 includes 1 mile of ditch and five basins of similar size.

Groundwater Elements. The Kamaole Aquifer is located in this area and has a sustainable yield of 11 mgd (Yuen and Associates, 1990). The basins would be located above (*mauka*) the UIC line, and may be subject to more stringent permit limitations because they are infiltrating into a potable aquifer.

Key Environmental or Habitat Elements. Southwest Maui is drought prone.

- A reef just off the coast is being negatively impacted by polluted runoff.

7.6.5 Institutional Factors Assessment

Land Use and Regulatory Factors

- Regulatory: USFWS, Endangered Species Act—In 2002, there was a proposal to designate approximately 126,531 acres on Maui as critical habitat for 61 native plant species. Earthjustice has an interest in protecting natural and cultural resources throughout Hawaii and was involved in this project.

- Land Use: The Community Plan states objectives to preserve existing geographic, cultural, and traditional community lifestyles by limiting and managing growth, to use land for the social and economic benefit of all residents, and to preserve lands that are suited for agricultural pursuits.

Demographic Factors

- Socioeconomic: Wailea is a master-planned resort community. Makena contains resort facilities but retains many village characteristics and Hawaiian cultural landscapes. This area has seen significant growth and projected population for 2010 in Kihei-Makena region is between 22,800 and 24,500.

Community and Cultural Factors

- Cultural Property: The SHPD would need to determine the precise location to establish whether that particular location has been surveyed. Many areas are not surveyed; and of those that have been, some were surveyed more than 10 years ago. The archaeological survey would determine if any mitigation is required.

- Stakeholder Interest: There would be interest from both the community and SHPD, from both cultural and archaeological perspectives. As noted earlier, Earthjustice works with environmental, Native Hawaiian, and community groups in cases to protect island ecosystems and restore water and cultural rights of Native Hawaiian communities.

7.6.6 Generalized Rating Scales

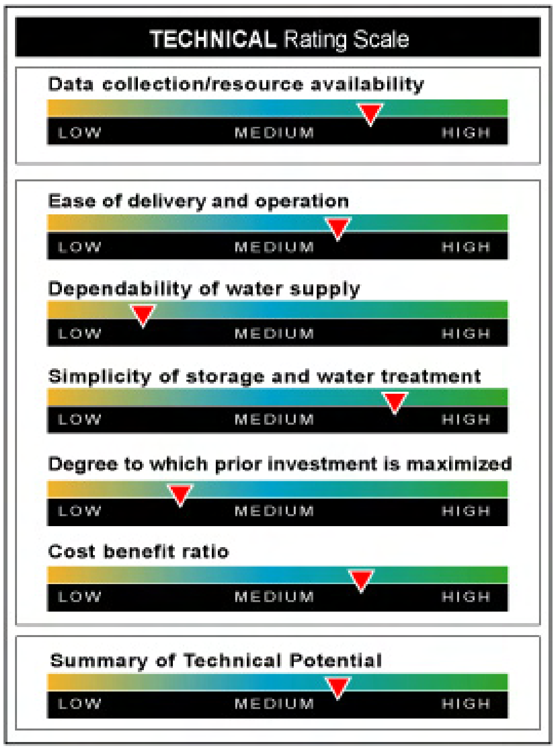

Figure 7-9. Technical Rating Scale for Southwest Maui Watershed Stabilization

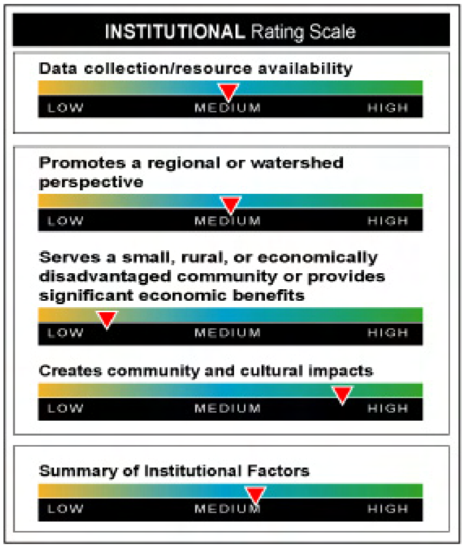

Figure 7-10. Institutional Rating Scale for Southwest Maui Watershed Stabilization

7.7 Maui 4—Lahaina Watershed

7.7.1 Objective

Add freshwater to the groundwater aquifer to improve ambient water quality, increase water resources in the vicinity for agricultural and urban use, and create a saltwater intrusion barrier.

7.7.2 Background

This opportunity would modify the proposed Lahaina Watershed Flood Control Project facilities to create groundwater infiltration basins and add groundwater injection wells. The selected plan for the Lahaina Watershed Flood Control Project is to construct a floodwater diversion system that starts south of Lahainaluna Road at approximately 153 feet above mean sea level and extends approximately 7,000 feet across the watershed to a debris basin at Kauaula Stream. This diversion channel would intercept runoff from the Lahaina subwatershed before it reaches the flood-prone areas of the Town of Lahaina. The diversion channel is proposed to be grass-lined except for reinforced-concrete channel reaches near Lahainaluna Road and adjacent to Wainee Reservoir. The proposed diversion channel also includes an inlet basin and three sediment basins. The debris basin at Kauaula Stream provides an outlet spillway to a 3,600-foot-long grass-lined channel to the south, called the Second Outlet. The Second Outlet would include a sediment basin, a culvert under

Honoapiilani Highway, and a shoreline outlet. Another spillway from the debris basin would release flows to the existing concrete-lined Puamana channel. All bare earth areas, including all diversion surfaces, would be vegetated.

The proposed Lahaina Watershed Flood Control Project would provide a 100-year level of flood protection that would benefit an area that includes single- and multi-family residential land uses, business and commercial land uses, public land uses, and agricultural and former agricultural land uses. The floodwater diversion system would require approximately 42 acres of land for installation of the floodwater diversion channel and related structures.

The original suggestion for the Lahaina stormwater reuse opportunity, which was obtained during a meeting with interested agencies in Hawaii on August 17, 2004, identified the Lahaina Watershed Flood Control Project and the Lahaina By-Pass Highway Project as two projects that might both be amended in a coordinated way to create a stormwater reuse opportunity. The Lahaina By-Pass Highway Project, however, does not include a significant stormwater drainage component and the potential reuse opportunity associated with the landscaping is minor.

7.7.3 Opportunity Description

This opportunity would modify the proposed Lahaina Watershed Flood Control Project facilities to create a groundwater infiltration basin and add two groundwater injection wells. A 10-foot-deep infiltration basin on 0.5 acre inline of the second outlet channel would be constructed along with two wells 100 feet deep and 12 inches in diameter. Water would gravity flow into the basin and flow by gravity pipe to the wells. The wells would be located 200 feet on either side of the basin. All facilities are just outside the UIC boundary, northwest of Kauaula Stream and southwest of Lower Lahaina pump ditch.

A map of this opportunity is provided in the Maps section (Map 7).

7.7.4 Assessment

Delivery and Operations Needs

Stormwater would be captured by the diversion channel. The proposed basin would allow infiltration to shallow groundwater, and groundwater injection wells would be used to inject into deeper groundwater. The facilities must protect the area from flooding. Secondarily, the facilities can be operated to recharge groundwater as stormwater flows allow.

Many reviewers of the draft environmental impact statement for the Lahaina Watershed Flood Control Project suggested more consideration be given to installing or improving measures on the uphill agricultural fields and in the forested areas to increase infiltration and aquifer recharge and store stormwater for agricultural use. The project was not altered to incorporate these measures because NRCS determined that intensification of the land treatment program or installation of practices with greater capacities would not achieve the goal of flood protection from the 100-year storm for the Town of Lahaina area. Improved land treatment of the upper watershed areas, however, would continue to be implemented under the NRCS' conservation technical assistance program. This interest in groundwater infiltration for agriculture supports the idea that agricultural demand for additional water supplies in the area exists. Increasing groundwater availability may also provide a source for nonpotable urban or golf course irrigation or industrial uses.

Dependability of Expected Supply

Potential constraints are seasonal supply, limited volume of supply, and timing of supply; changing volumes and peaks; high sediment load; temperature; and capture prior to stream entry.

Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. The area surrounding the Town of Lahaina is primarily agricultural, with most of the land categorized as agricultural lands of importance to the State of Hawaii (ALISH).

The opportunity site is on an alluvial fan of the Pulehu-Ewa-Jaucas soil association, which is described as deep, nearly level to moderately sloping, well-drained and excessively drained soils that have a moderately fine-textured to coarse-textured subsoil or underlying material. The soils at the opportunity site have moderate infiltration rates.

The agricultural areas upslope of the opportunity site that extend north and south on the lower slopes of Puu Kukui have soils of the Waiakoa-Keahua-Molokai association, which are described as moderately deep and deep, nearly level to moderately steep, well drained soils that have a moderately fine-textured subsoil. South of Kahoma Stream, most of these lands have slow infiltration rates; North of Kahoma Stream they have moderate infiltration rates.

Existing Irrigation Conveyance and Natural Stream Networks. Formerly, the Pioneer Mill Irrigation System (PMIS) extended north and south of Lahaina. It originally consisted of three ditch systems: (1) the Honolua-Honokohau, 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 compose the existing PMIS.

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 used both Honolua-Honokokua Ditch water and surface water sources south of Lahaina (Kanaha, Kauaula, Launiupoko, Olowalu, and Ukumehame Streams). The Honolua-Honokohau Ditches were complex irrigation systems composed of stream intakes, transmission and development tunnels, ditches, flumes, inverted siphons across gulches, hydropower plants, and large-capacity sources of groundwater from coastal infiltration galleries, called Maui-type shafts.

Since the collapse of sugar cane agriculture in Hawaii in the 1990s, the PMIS has broken up into different ownerships, some of the irrigation system facilities have fallen into disuse and disrepair, and water use patterns have become variable and uncertain. Water supply demand is expected to revive as diversified agriculture is established in the area. Agricultural irrigation is being promoted not only for the direct economic benefits of producing agricultural products, but because the irrigated orchards and fields serve as an aesthetic background to the area for tourism. Without irrigated agriculture, some of the upslope areas are turning brown, which degrades the quality of the scenery and increases fire hazard.

Expected Demand Areas and Sizes. The target area for stormwater capture is the Launipoko hydrologic unit. The basin covers 18 square miles and has an estimated annual runoff of 23 percent of the annual precipitation (Yuen and Associates, 1990). Using the 23 percent estimated runoff from the two basins, and the 30-year monthly average (1971 to 2000) rainfall data from Lahaina (361) Station (NOAA, 2002), potential stormwater runoff from the target areas was estimated to be 975 MG (3,000 acre-feet). Infiltration trench capacity and peak flow volumes would reduce potential captured volume. The assumed capture is 20 percent of the potential runoff, or 195 MG (600 acre-feet) on an average annual basis.

It is estimated that groundwater pumping could recapture approximately 75 percent of the infiltrated recharge. With a gross irrigation requirement of approximately 52 inches per year in this area, 450 acre-feet of recaptured recharge could supply full irrigation to approximately 100 acres of irrigated land.

Estimated Costs. Table 7-8 provides estimated opportunity costs.

TABLE 7-8
Preliminary Cost Estimate for Lahaina Watershed

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Pipe	1,000	LF	$75	$80,000
2	Infiltration Basin ($15 per cubic yard excavation)	5	acre-feet	$24,300	$120,000
3	Groundwater Injection Wells (two at 100 feet each)	200	ft	$200	$40,000
	SUBTOTAL				$240,000
	Allowance for Unlisted Items (15% of subtotal)				$40,000
	Contract Cost				$280,000
	Contingency (25% of Contract Cost)				$70,000
	Field Cost				$350,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$120,000
	Total Cost				**$470,000**

Groundwater Elements. This opportunity overlies the Launipoko Aquifer system in the Lahaina sector. The Launipoko area is 18.29 square miles. Weighted average annual rainfall for the area is 75 inches. ET is 40 inches per year. Infiltration to groundwater is estimated to be 18 inches per year (16 mgd). The aquifer system sustainable yield is 8 mgd (Yuen and Associates, 1990).

The opportunity site is below (seaward [*makai*]) of the UIC area line, which means the underlying aquifer is not considered a drinking water source.

In the area of the opportunity site, other projects have encountered an impervious layer below shallow groundwater (Krueger, 2005). This layer causes the shallow groundwater to rise during rainstorms and flood below-ground-surface rooms in local buildings. A nearby State highway project determined it was necessary to drill an 85-foot-deep infiltration well from an elevation of 15 or 16 feet to reach the groundwater aquifer below the impervious layer and discharge stormwater from the project. The sewage treatment plant approximately 3 miles north of the site drilled injection wells 100 to 150 feet deep.

The infiltration basin would recharge the shallow groundwater above the impervious layer and the two, 100-foot-deep wells would penetrate the layer and recharge the deeper aquifer. This layered recharge should create an effective seawater intrusion barrier.

7.7.5 Institutional Factors Assessment

Land Use and Regulatory Factors

- Federal: USFWS, Endangered Species Act. Proposal in 2002 to designate approximately 126,531 acres on Maui as critical habitat for 61 native plant species
- County: County of Maui, Community Plans. West Maui Community Plan 1996 covers the entire Lahaina Judicial District and western slopes and coastal plan of West Maui. The plans are strategic planning documents to guide government actions and decisionmaking.
- Land Use: The area surrounding the Town of Lahaina is primarily agricultural, with most of the land categorized as agricultural lands.

Demographic Factors

- Socioeconomic: Prime industries are tourism and agriculture with the production of sugar and pineapples. West Maui has seen significant growth in population since 1970. Resident population was 14,574 in 1990. The projected resident population for 2010 is 22,633 with unconstrained growth and 21,149 if growth is constrained. The forecast for visitors is for 37,734 by 2010 if growth is not constrained and 31,775 if growth is constrained. The constrained forecasts are used as the guidelines in determining future land uses and community development needs.

Community and Cultural Factors

- Cultural Property: During the time Lahaina served as the capital of the Hawaiian Kingdom and Hawaiian royalty, a number of important sites were established. South of Lahaina are lands containing evidence of Hawaiian agricultural terraces, Heiau sites, complexes of temporary habitation, petroglyphs, and small shrines.
- Streams that were used for irrigated taro cultivation are located north of Lahaina.
- An archaeological survey is recommended for this area by Dr. Kirkendall of the SHPD.
- Stakeholder Interest: There would be interest from community groups and the SHPD.

7.7.6 Generalized Rating Scales

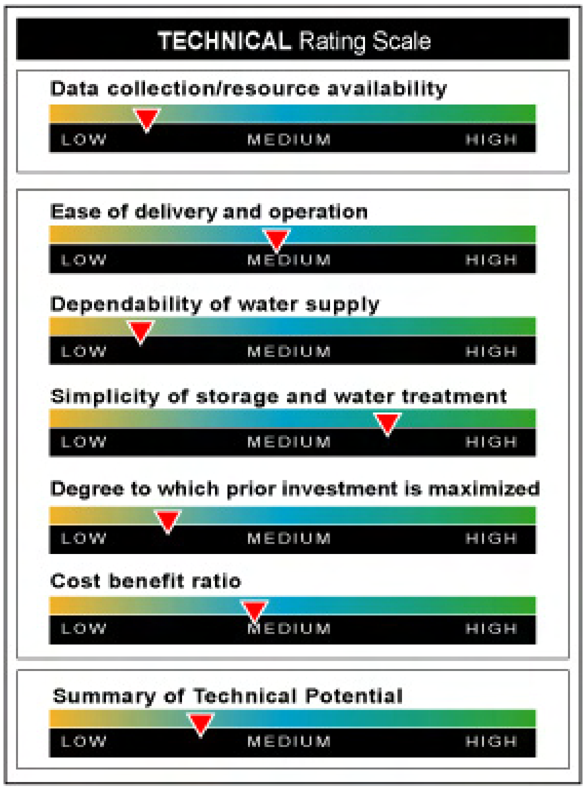

Figure 7-11. Technical Rating Scale for Lahaina Watershed

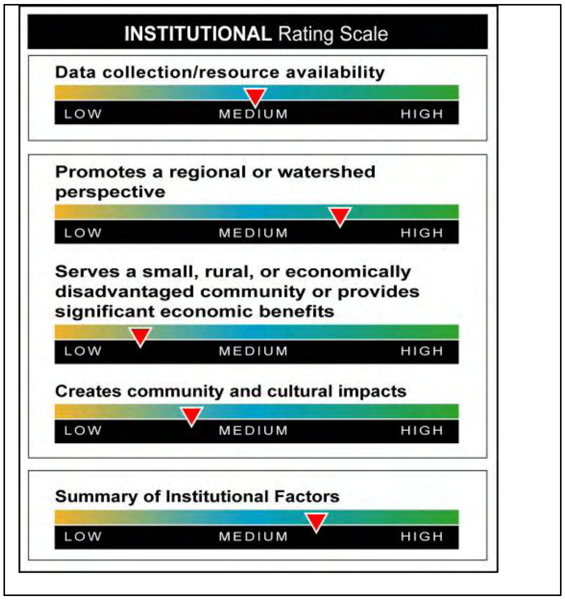

Figure 7-12. Institutional Rating Scale for Lahaina Watershed

7.8 Molokai—Molokai Irrigation System

7.8.1 Objective

Reuse stormwater to augment the central Molokai irrigation water supply and increase firm yield in Kualapuu Reservoir. Provide possible flood control benefits.

7.8.2 Background

Currently, the Waikolu Valley Watershed is the Molokai Irrigation System's sole source of water. There are four stream intakes to capture seasonal stormwater, and five wells to supplement the supply during droughts and low-flow periods. Water flows by gravity down the 5-mile-long Molokai Tunnel, through a short concrete flume, to a 30-inch steel pipeline that starts near the North Fork of the Kaunakakai Gulch. The steel pipeline is approximately 4 miles long and terminates at the Kualapuu Reservoir, just west of the Town of Kualapuu.

Severe droughts in the Waikolu Valley over the past few years have prompted the Molokai Irrigation System Water Users Advisory Board to seek out additional water sources. Possible sources include brackish water wells and recycled sewage effluent. An estimated cost for the development of these sources is $4,009,000 (Water Resource Associates, 2003b).

7.8.3 Opportunity Description

This opportunity would capture stormwater from Manawainui Gulch and Kaunakakai Gulch in order to augment the irrigation water supply in Kualapuu Reservoir, part of the Molokai Irrigation System. Most farming is in the central Molokai plain between Kawela to the east and Mahana to the west. Nearly all of the irrigation water for this area comes from the Kualapuu Reservoir. This 1.4-billion-gallon reservoir has never been filled to capacity due to the lack of source development. During dry periods, water levels in the reservoir become low enough to require restrictions to ensure that all farmers receive some water for irrigation. This opportunity would utilize stormwater to maximize the storage capacity of the Kualapuu Reservoir.

Very small concrete diversion structures on the two gulches would channel stormwater into a pipeline that connects into the existing 30-inch steel pipeline of the Molokai Irrigation System downgradient of the tunnel. For gravity flow to occur in the pipeline, the diversion must be located at a higher elevation than the tie-in to the 30-inch-diameter pipeline. The existing 30 inch-diameter pipe would not be enlarged.

This opportunity could also have flood control benefits. The Manawainui Gulch empties into the ocean near the Palaau Homesteads in southcentral Molokai. The Town of Kaunakakai is located at the mouth of the Kaunakakai Gulch. These areas would be less impacted by the gulch flows if the stormwater was intercepted and diverted upstream.

A map of this opportunity is provided in the Maps section (Map 8).

7.8.4 Assessment

Potential Reuse

This opportunity would reuse stormwater for irrigation and could also have some flood control benefits.

Delivery and Operations Needs

Diverted stormwater would be gravity fed by a pipeline to the Molokai Irrigation System. Because the system is gravity fed, when the pipelines reach capacity during a storm event, excess stormwater would be forced to bypass the diversion and continue down the gulches.

Dependability of Expected Supply

Stormwater supply is seasonal on Molokai, with higher precipitation between November and March. June through September make up the dry season, with monthly rainfall averages of less than 1 inch. January is the wettest month, with a monthly rainfall average of 4.6 inches.

The irrigation system source in the Waikolu Valley receives an annual rainfall average of approximately 75 inches. Average annual rainfall values decrease, moving west to a minimum annual average of 15 inches in the central Molokai plain, where most of the farmland is located.

Stormwater captured from the gulches would contain a sediment load likely to settle out in the reservoir.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. Up until the 1970s, agricultural lands in the central Molokai plain were dominated by Del Monte's pineapple operations. Since their closure, land has been converted to diversified agriculture, with crops including seed corn, coffee, sweet potato, papaya, herbs, bell peppers, tomatoes, and cattle ranching. Land along the conveyance pipeline to the east is range land, with some forest land in higher elevations along the Molokai Tunnel and the intakes.

The Town of Kualapuu is just east of the Kualapuu Reservoir, and the Molokai Airport is 3 miles west of the reservoir. No other towns lie in the opportunity area. The towns of Kaunakakai and the Palaau Homesteads are located at the mouths of the affected gulches.

Soils in this area of Molokai have moderate infiltration rates. The farmlands in the central Molokai plain and the reservoir site have Molokai-Lahaina association soils. These soils are deep, nearly level, well-drained soils. Both gulch diversions are located in areas with rough broken land-Oli association soils, which are shallow to deep, very steep, well-drained soils in gulches. The irrigation system intakes in the Waikolu Valley are located on rough mountainous land Amalu-Olokui association soils that are shallow, poorly drained, on very steep lands of mountains and gulches, and are located over soft, weathered rock.

Existing Irrigation Conveyance and Natural Stream Networks. The existing Molokai Irrigation System was funded by Reclamation's Small Reclamation Projects Act Loan Program. The irrigation system is operated and maintained with funds from water use revenues and supplemented by HDOA funds. The system consists of four stream intakes, five groundwater wells, two booster pumps, a 0.25-MG concrete tank, and a 1,400-MG open reservoir. Water is conveyed from the intakes to the reservoir through 5 miles of tunnel, a short concrete flume, and 4 miles of 30-inch steel pipe. Downstream of the reservoir, a network of irrigation pipes serves 3,100 acres of agricultural land.

There are more gulches in central Molokai than natural stream networks. The irrigation system's current source is in the Waikolu stream valley just east of the Kalaupapa Peninsula. This opportunity seeks to capture stormwater from the Kaunakakai and Manawainui Gulches, which both flow south to the ocean.

Precipitation. The Molokai Irrigation System intakes are located in the Waikolu Valley, which receives an annual rainfall average of approximately 75 inches. Moving west along the irrigation system, annual rainfall averages drop to approximately 20 inches at the Kualapuu Reservoir. The gulches where the proposed diversions would be placed drain watersheds with annual average rainfall values between 20 and 60 inches.

Expected Demand Areas and Sizes. The Molokai Irrigation System serves approximately 235 customers on 3,100 acres, with an annual water demand of 1.224 billion gallons (3.35 mgd). The opportunity would capture stormwater from the Kamiloloa hydrologic unit at a higher elevation and pipe it by gravity into the existing 30-inch-diameter steel pipe. Another diversion near the 30-inch-diameter pipe would receive stormwater from the Kualapuu hydrologic unit. The average runoff estimated for these two units is approximately 5.4 percent of the annual precipitation (Yuen and Associates, 1990). The target area for the stormwater capture is approximately 36 square miles.

Using the 5.4 percent estimated runoff from the two basins, and the 30-year monthly averages (1971 to 2000) rainfall data from Molokai Kuankakai AP52 (NOAA, 2002), potential stormwater runoff from the target areas was estimated to be 832 MG (2,555 acre-feet). Limited pipeline capacity and inefficient capture of peak flows would reduce the potential captured volume. The assumed capture is 40 percent of potential runoff, or approximately 1,020 acre-feet.

The total area to be irrigated and the size/volume of storage that would be required were estimated using the RZWBM v1.04 (CH2M HILL, 2003). Monthly rainfall averages for a 30-year period (1971 to 2000) from Molokai Kuankakai AP52 Station (NOAA, 2002), and standard daily pan ET data from Honolulu Station 702.2 were used. The monthly pan ET values were converted to referenced grass ET by a factor of 0.7. The additional source of water used in the model was the estimated stormwater captured from the target area, distributed according to the monthly rainfall pattern.

Based on the assumptions stated previously, the model estimated that the yearly gross irrigation requirement for the opportunity is 41 inches. Using surface storage of the captured runoff, approximately 240 acres of irrigated land could be served with approximately 580 acre-feet of new reservoir storage. Details of the model output are included in Appendix C. The existing 3,100-acre project currently has a partial water supply. This new opportunity adds enough new water to fully irrigate approximately 240 additional acres, or it could be used to supplement irrigation over all 3,100 acres.

Estimated Costs. Table 7-9 provides estimated opportunity costs.

TABLE 7-9
Preliminary Cost Estimate for Molokai Irrigation System

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Pipe	9,500	LF	$50	$480,000
2	Diversion Structures	2	each	$100,000	$200,000
	SUBTOTAL				$680,000
	Allowance for Unlisted Items (15% of subtotal)				$100,000
	Contract Cost				$780,000
	Contingency (25% of Contract Cost)				$200,000
	Field Cost				$980,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$340,000
	Total Cost				**$1,320,000**

Groundwater Elements. The irrigation system delivers water to farmland over the Manawainui and Hoolehua Aquifers, each having sustainable yields of 2 mgd. The irrigation system source in the Waikolu Valley is located in the Waikolu Aquifer, which has a sustainable yield of 5 mgd. Aquifers under the length of the irrigation system have sustainable yields of between 3 and 5 mgd. The Kualapuu Reservoir is located below (*makai*) the UIC line, while the remainder of the irrigation system is above (*mauka*) the UIC line (EGIS, 1999).

7.8.5 Institutional Factors Assessment

Land Use and Regulatory Factors

The opportunity sites for stormwater collection are located north of Kaunakakai, the island's major population and commercial center, and east of the Molokai Airport and Kualapuu Reservoir. There are small plantation communities such as Kualapuu in the central plain, and the less-compact rural Hawaiian homestead settlements of Ho'olehua and Kalamaula.

The land use goal of the Community Plan is to enhance the unique qualities of the island so that future generations have the opportunity to experience rural and traditional lifestyles. Traditional land use is strongly supported in the Community Plan. The need to protect Molokai as one of the last Hawaiian places is emphasized and a working definition of "traditional" land use is provided in the plan with the intent that this concept be explored.

The Department of Land and Natural Resources, Commission on Water Resource Management, has regulatory jurisdiction over streams and stream channels, such as the construction of new or expanded stream diversions, Stream Channel Alteration Permits, and Petitions to Amend Instream Flow Standards.

Demographic Factors

- Socioeconomic: The island has a rural agricultural base and depends on its abundant agriculture and potential for alternative energy for future economic development. Limited economic opportunity is the most significant problem facing the community. Other factors limit development opportunities, such as the high cost of housing caused by lack of available affordable land near established infrastructure, lack of sufficient water resources, lack of social recreation facilities and public services, and limited post-secondary educational opportunities on the island.

  The current population is relatively stable at 6,717 and forecasts indicate a projected population of approximately 9,019 residents over the next 20 years. It is estimated that more than 2,500 of the island's inhabitants have more than 50 percent Hawaiian ancestry.

Community and Cultural Factors

- Cultural Property: Molakai has a traditional, culturally significant history represented by many ancient sites.
- Stakeholder Interest: There would be interest from both the community and SHPD, from both cultural and archaeological perspectives.

7.8.6 Generalized Rating Scales

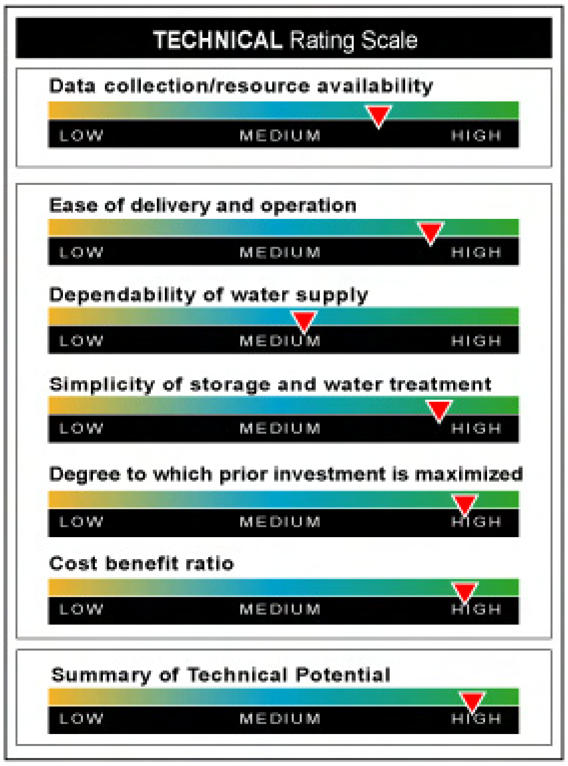

Figure 7-13. Technical Rating Scale for Molokai Irrigation System

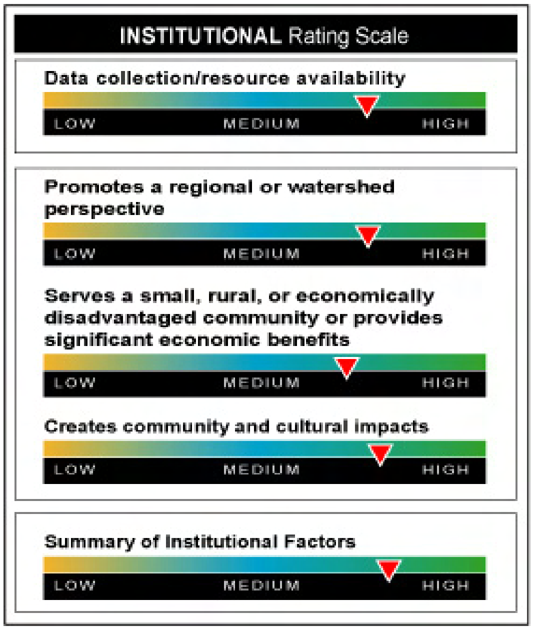

Figure 7-14. Institutional Rating Scale for Molokai Irrigation System

7.9 Oahu 1—Waianae Agricultural Park

7.9.1 Objective

This opportunity stores water for irrigation at the Waianae Agricultural Park. It would offset current use of potable water for irrigation and provide flood control.

7.9.2 Background

The agricultural park is located 2 to 3 miles north of Farrington Highway along the Waianae Valley Road on the west side. Piliuka Place dead ends on the park. The agricultural park sits at the base of the Kamaileunu Ridge in Waianae Valley. Because of stormwater runoff, the farm plots are affected by erosion.

In 1996 and 1997, stormwater erosion caused the park to close for 1 year. Federal Emergency Management Agency (FEMA) funds were used to rebuild the entering roadway, which was damaged by flooding, and put in a sediment basin on the upstream side of the roadway to prevent the culverts from filling and flooding.

in the first quarter of 2005, the Hawaiian Department of Agriculture (HDOA) designed a large diversion ditch to redirect stormwater flow to the sediment basin and through the culverts to prevent erosion and damage to the road. The diversion ditch is approximately 1 mile long, 12 feet deep, and 15 feet wide. This project would capture the 50- to 100-year storm. The ditch would be grass lined with riprap along the embankment. Design and construction of the ditch is being funded by HDOA. The preliminary cost estimate is $2.2 million. The project was scheduled for construction bid in the summer of 2005.

Currently, tenants at the park irrigate with potable water from the City and County of Honolulu Board of Water Supply (BWS). This reuse opportunity would enable the tenant farmers to irrigate with less expensive water and help the BWS conserve potable water supplies for other uses.

The opportunity area is on the inland side (*mauka*) of the UIC line, so the underlying aquifer is considered a drinking water source.

Storage capacity could be increased by siting a detention pond at the agriculture park. A detention pond would decrease the acreage of the park used for farming, but could potentially be located on currently unfarmed land or perhaps in the area upslope of the eastern end of the park.

7.9.3 Opportunity Description

This opportunity would add storage capacity to a stormwater flood control project currently being designed and provide a reuse water distribution system for delivering the captured stormwater to farm plots at the existing agricultural park.

A map of this opportunity is provided in the Maps section (Map 9).

7.9.4 Assessment

Delivery and Operations Needs

A distribution system would be developed to deliver stormwater for irrigation at the 17 farm plots. Currently, irrigation water is obtained from the BWS potable water system. The nurseries and orchid farms use overhead spray irrigation. The farms with landscaping shrubs and trees use drip irrigation.

A stormwater supply system would require an agricultural-type filter station to remove particles that could plug the drip irrigation emitters. The storage pond would have a pump station with a variable speed pump to deliver flow on demand. The pipeline from the pump station would connect to each of the existing 17 irrigation systems, which would have a backflow preventer to protect the drinking water system. Alternatively, if the storage pond could be sited upslope of the eastern end of the agricultural park, the stored water could be conveyed to the Makaha Booster Pump (owned by BWS) and distributed by way of the existing pipelines to the agricultural plots. This arrangement would also require a filter station and backflow preventer.

The reservoir water would meet the early season demand at a reduced cost per 1,000 gallons, with the more expensive potable water used to meet late-season or high peak demands.

An irrigation district would need to be created to operate and maintain the distribution system. The system would need to be solely supported by water delivery charges in order to fit into the irrigation program. A break-even cost would be approximately the current County rate, if not higher, and the irrigation water would be nonpotable. The reservoir would be located at the downstream end of the proposed ditch. Insufficient rainfall would likely make this system unreliable.

Dependability of Expected Supply

Located on the leeward side of the island, the opportunity site is very dry in the summer. Rainfall is greatest in the winter months of December and January.

The stormwater would be captured before it enters the nearest stream, which is the Kawiwi.

The only food crops are fruit trees. The water quality requirements for this type of crop would need to be met. Most of the crops grown at the park are not food crops and could use stormwater reuse water for irrigation. Data were not available to perform a firm yield analysis.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. The opportunity site is located in Waianae Valley north of Kawiwi Stream and south of Kamaileunu Ridge. The Kamaileunu Ridge is steep and dry with few trees, low brush, and cacti.

The soil in the agricultural park is rocky. The soil has very slow infiltration rates.

Existing Irrigation Conveyance and Natural Stream Networks. Kaupuni Watershed: 3.58 square miles (Yuen and Associates, 1990). Kawiwi Stream is downslope on the southern border of the agricultural park. It is approximately 50 feet wide and usually dry, except during heavy rain storms.

The 30-year precipitation normal from the Waianae 798 station is 21 inches per year (NOAA, 2002).

Expected Demand Area and Sizes. The Waianae Agricultural Park covers approximately 150 acres. Only 100 acres are suitable for agriculture. The park is subdivided into 17 plots, which are planted with orchids, nursery stock, and landscaping plants. Three of the plots are growing fruit trees, however, there is no fruit processing at the park at this time. The Waianae Agricultural Park is located in the Waianae hydrologic unit with a total area of 7.66 square miles. This basin has an estimated runoff of 5 percent of the annual precipitation (Yuen and Associates, 1990). Using a 30-year monthly average precipitation from the Waianae 798 Station (NOAA, 2002), this basin is expected to yield 148 MG (453 acre-feet) per year that could be used as an additional water source for irrigation. However, the stormwater ditch along the edge of the Agricultural Park only captures runoff from approximately 10 percent of the basin, yielding approximately 45 acre-feet per year.

The total area that could be irrigated with the captured stormwater and the size of reservoir storage that would be required were estimated using the RZWBM v1.04 (CH2M HILL, 2003). Monthly rainfall averages for a 30-year period (1971 to 2000) from Waianae 798 Station (NOAA, 2002), and standard daily pan ET data from Honolulu Station 702.2 were used. The monthly pan ET values were converted to referenced grass ET by multiplying by 0.7.

Based on the assumptions stated above, the gross irrigation requirement was estimated at 45 inches per year. The stormwater captured over 10 percent of this basin would be sufficient to irrigate approximately 10 acres of the Agricultural Park if a 25-acre-foot reservoir was provided to store water. Details of the model output are included in Appendix C.

Estimated Costs. Table 7-10 provides estimated opportunity costs.

TABLE 7-10
Preliminary Cost Estimate for Waianae Agricultural Park

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Pipe	1,500	LF	$75	$110,000
2	Reservoir ($15 per cubic yard excavation)	25	acre-feet	$24,300	$610,000
3	Pump Stations	1	each	$50,000	$50,000
4	Ag.-type Filter Station	1	each	$20,000	$20,000
	SUBTOTAL				$790,000
	Allowance for Unlisted Items (15% of subtotal)				$120,000
	Contract Cost				$910,000
	Contingency (25% of Contract Cost)				$230,000
	Field Cost				$1,140,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$400,000
	Total Cost				**$1,540,000**

Groundwater Elements. Waianae Aquifer System area is 7.66 square miles (Yuen and Associates, 1990). Runoff is 2 inches per year. ET is 28 inches per year. Infiltration to groundwater totals 8 inches per year (3 mgd). Sustainable yield equals 2 mgd. Precipitation over the Waianae Aquifer System is 38 inches per year (Yuen and Associates, 1990).

7.9.5 Institutional Factors Assessment

Land Use and Regulatory Factors

Land Use: The State Department of Hawaiian Homeland (HH) Waianae Homestead is located southeast of the agricultural park. The homestead residents do not farm in the agricultural park. The agricultural park is owned by the State of Hawaii and leased by the HDOA to resident Hawaiian tenant farmers.

Farmers at the park irrigate with potable water from the BWS at agricultural rates. The agricultural rates have been $1.77 per 1,000 gallons for the first 13,000 gallons and $0.75 per 1,000 gallons for all gallons thereafter. This rate is projected to increase to $2.00 per 1,000 gallons for the first 13,000 gallons, and $0.77 per 1,000 gallons for all gallons thereafter. In July 2006, the rates are projected to increase again to $2.17 per 1,000 gallons for the first 13,000 gallons, and then $0.79 per 1,000 gallons for all additional gallons. To obtain agricultural rates, the service holder must submit a written application each FY to the BWS and furnish satisfactory proof that they are engaged in crop production, stock raising, or dairy farming on a commercial basis. The agricultural rates are lower than residential rates, but still almost double the HDOA agricultural water rates.

For comparison, HDOA charges for water in two ways: annual acreage assessment and water delivery. The annual acreage assessments are $24 per acre per year. The water delivery fee is $0.32 per 1,000 gallons. New rates are being proposed to address HDOA budget shortfalls: $0.40 per 1,000 gallons, to be raised yearly as follows: $0.46, 0.52, 0.58, 0.60, and 0.62 in 2011. From Hawaii Administrative Rules, Adoption of Chapter 4-157, August 4, 2004, it appears that rates were changed to $0.62/1,000 gallons to take effect FY 2006.

Oahu potable water supplies are primarily obtained from groundwater. Groundwater resources need to be conserved. This opportunity would benefit long-term planning for development of Oahu by making more potable water available for future growth. Farming of the agricultural park would continue unchanged (Board of Water Supply, 2005).

Demographic Factors

- Socioeconomic: The population of the region has grown significantly in the past 50 years. In 1998, there were approximately 40,000 people living in the Wai'anae District. If the growth trend continues, the district could add 10,000 to 20,000 people by 2020. Population growth and land development in the Waianae District has been trending toward urban and suburban development. This development has consumed agricultural lands and put stress on Waianae's infrastructure and rural values.

Community and Cultural Factors

- Cultural Property: Visual landmarks, significant views, and historic, cultural, and archaeological features may exist.
- Stakeholder Interest: Interested parties would include tenants of the agricultural park.

7.9.6 Generalized Rating Scales

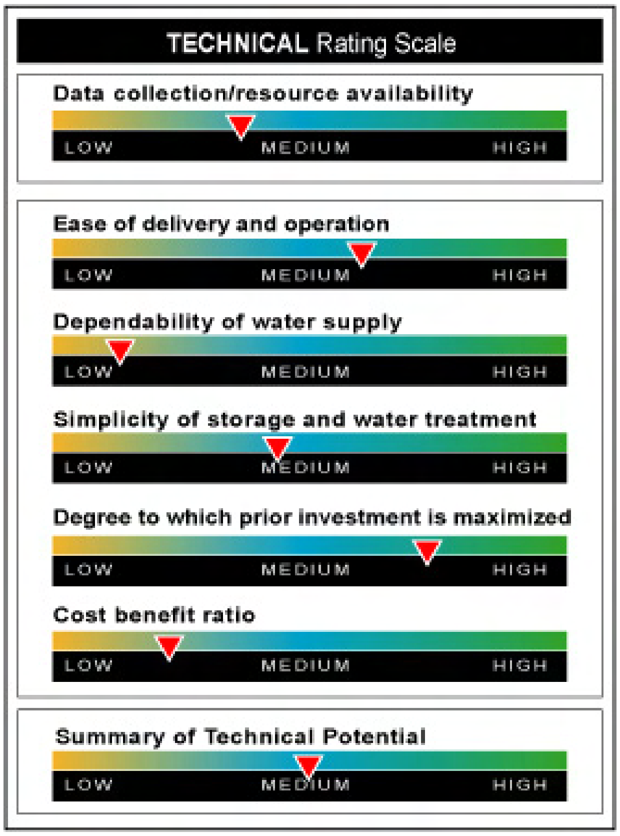

Figure 7-15. Technical Rating Scale for Waianae Agricultural Park

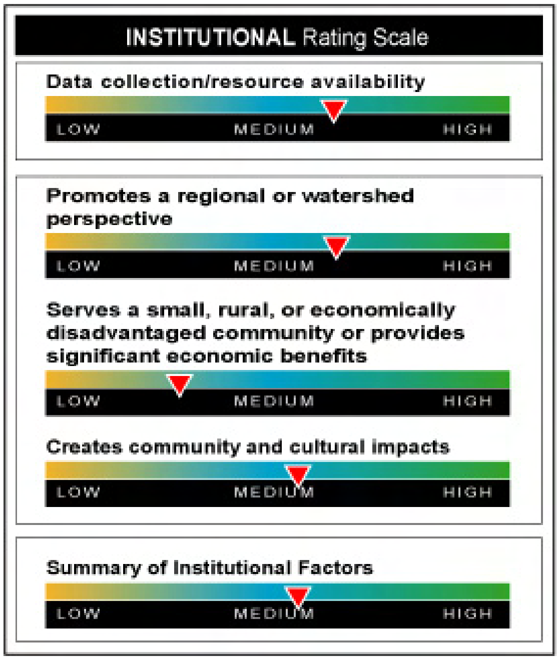

Figure 7-16. Institutional Rating Scale for Waianae Agricultural Park

7.10 Oahu 4—Ewa Plains

7.10.1 Objective

Reuse stormwater for groundwater recharge in the over-drafted, brackish Ewa Plains Aquifer to improve groundwater supply quality and quantity used for golf course and agricultural irrigation.

7.10.2 Background

The opportunity site is located in southwest Oahu, east of Ewa Gentry, just outside the urban growth boundary on agricultural land. The infiltration ditch would be sited seaward (*makai*) of the Island of Oahu UIC area line (Hawaii Department of Health, 1999) so that stormwater would infiltrate into an underlying aquifer that is not considered a drinking water source.

The identified site is east of Fort Weaver Road and north or south of Iroquois Point Road. It may be possible to expand an existing drainage swale just outside the urban growth boundary and south of Iroquois Point Road.

7.10.3 Opportunity Description

This opportunity consists of a deep infiltration trench to capture stormwater from urban development and discharge it into the coarse coral soils and shallow groundwater. The introduction of fresh stormwater into the brackish aquifer would improve aquifer quality and quantity that could be extracted from existing irrigation wells at golf courses and agricultural areas.

A map of this opportunity is provided in the Maps section (Map 10).

7.10.4 Assessment

Potential Reuse

Reuse would occur with stormwater that is recharged into the aquifer during storm events and extracted any time of the year from wells. The aquifer in this relatively flat area has significant storage capacity for seasonal storage to meet irrigation and nonpotable demands.

Delivery and Operations Needs

Stormwater collected in storm drain pipes in the residential and low-density apartment areas west of the site would be diverted to an infiltration trench to be constructed on the bordering agricultural land. It may be possible to expand the existing drainage swale on the south side of Iroquois Point Road instead. The infiltration trench would be located and constructed in such a way that if it fills, the excess water would flow into a nearby drainage way. A diversion structure in the existing stormwater collection system would be needed to divert stormwater into the infiltration trench.

Dependability of Expected Supply

Infiltration trenches in coarse coral soils are very tolerant of variable water quality. Excessive amounts of organic matter or soil would eventually cause partial plugging, but open trenches can be cleaned if necessary. Water quality sufficient for surface irrigation systems should be acceptable for recharge because this aquifer is brackish and not used for potable services. No water treatment is required.

Opportunity Area Characteristics

Basin Land Use, Vegetation, Soil, and Slope Characteristics. The site is located just outside the urban growth boundary on agricultural land. The land use east of the site is agricultural and military. The agricultural land, which is owned by the U.S. Navy, lies within the blast zone of the U.S. Naval Reserve farther east on the shore of the West Loch of Pearl Harbor. The land uses west of the site are predominantly residential and low-density apartments. The next major land use is golf courses. These areas are interspersed with commercial, park, and light industrial land uses.

Soils at the site are an anomaly of coral uplift (very high infiltration rates). The land near the site has very flat slopes. The site and reuse areas are at an elevation between 200 feet and sea level.

The soil association for the area is Lualualei-Fill land-Ewa, which is deep, nearly level to moderately sloping, well-drained soils that have a fine-textured or moderately fine-textured subsoil or underlying material, and areas of fill land; on coastal plains.

The Hawaii Prince Hotel Golf Course is located in the vicinity southwest of the site, also adjacent to the agricultural area.

Existing Irrigation Conveyance and Natural Stream Networks. There appears to be a drainage swale on the agricultural land just outside the urban growth boundary south of Iroquois Point Road. No irrigation distribution systems or network of streams appear to be present in the area. The area to the east is primarily residential and low-density apartments. This area has an extensive network of storm drain pipes. A gravity flow sewer main is aligned with Iroquois Point Road and flows northeast where it connects with a force main that crosses West Loch.

Expected Demand Areas and Sizes. The stormwater for this opportunity would be collected from an urban, residential development. Assuming that any stormwater that contacts a permeable surface and infiltrates would go into the same aquifer that this opportunity is recharging, the existing water losses from the basin are primarily through stormwater runoff, ET, depression storage, and other abstractions.

The stormwater collection area covers approximately 1,500 acres. This area would grow as development continues, increasing the amount of stormwater available for this aquifer recharge opportunity. Assuming 75 percent of rainfall across this highly developed area can be captured as stormwater runoff, a total of approximately 1,760 acre-feet per year is expected to be available for capture and aquifer recharge. Of that volume recharged, it is assumed that only 50 percent or 880 acre-feet can be recaptured from groundwater pumping for irrigation use.

The expected demand exceeds the expected supply in this area because many nonpotable wells currently exist in this brackish aquifer to irrigate golf courses, parks, and agricultural areas. The demand for nonpotable water is great enough to make it possible for the Honouliuli Wastewater Reclamation Facility (WWRF) to sell recycled water to golf courses and parks for irrigation and to local industries for industrial uses. The area is planned to be developed extensively, which would probably increase water demands.

The gross irrigation requirement in this area is estimated at 47 inches per year. Assuming 880 acre-feet of new groundwater supply were available, approximately 225 acres could be supplied with full irrigation.

Estimated Costs. Table 7-11 provides estimated opportunity costs.

TABLE 7-11
Preliminary Cost Estimate for Ewa Plains

Pay Item	Description	Quantity	Unit	Unit Price	Amount
1	Pipe (LF)	250	LF	$75	$20,000
2	Diversion Structures	1	each	$20,000	$20,000
3	Infiltration trench	10,000	cy	$15	$150,000

TABLE 7-11
Preliminary Cost Estimate for Ewa Plains

Pay Item	Description	Quantity	Unit	Unit Price	Amount
	SUBTOTAL				$190,000
	Allowance for Unlisted Items (15% of subtotal)				$30,000
	Contract Cost				$220,000
	Contingency (25% of Contract Cost)				$60,000
	Field Cost				$280,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)				$100,000
	Total Cost				**$380,000**

Groundwater Elements. The groundwater in the aquifer to be recharged is brackish and at approximately sea level. The groundwater system has historically been fresher, however over-pumping has caused drawdown and seawater intrusion. The high porosity of the aquifer allows rapid movement of freshwater to the sea and only a small groundwater mound is expected to occur at the infiltration area.

The opportunity site is located above the Puuloa aquifer system, which is part of the Ewa Caprock (Fukunaga & Associates, 2003).

Key Environmental or Habitat Elements. The addition of freshwater to the groundwater aquifer may benefit the springs associated with the Pearl Harbor National Wildlife Refuge by improving the water quality in the aquifer and by buffering the springs from the impacts of groundwater pumping in the area.

7.10.5 Institutional Factors Assessment

Land Use and Regulatory Factors

- Federal: The Ewa Plains Akoko was first listed under the USFWS Endangered Species Act in August 24, 1982. It is currently designated as endangered in the entire range.
- County: The Ewa Development Plan has a key role in implementing the directed growth policies of the Draft General Plan of the City and County of Honolulu. Ewa is designated as a Secondary Urban Center for Oahu, centered at Kapolei. Its policy is also to support agricultural diversification in agricultural areas.
- Land Use: Southeast of the site, the Honolulu WWRF distributes water to the following facilities in the area: Ewa Village Golf Course, Fort Weaver Road Medials, Coral Creek Golf Course, Hawaii Prince Golf Course, Kapolei Golf Course, West Loch Golf Course, West Loch Shoreline Park, and Asing Park. R-1 water is the highest category of recycled water, which means it has been filtered and disinfected. The WWRF also delivers reverse osmosis (RO) treated water to AES Hawaii Inc., Kaiaeloa Cogeneration, Tesoro Hawaii Corporation, the Gas Company, and Chevron Refinery. These recycled water uses may be addressing immediate, short-term nonpotable water demands, but long-

term demands would likely exceed production capacity. The agricultural land is owned by the U.S. Navy and leased to Puuloa Farms, Inc.

Gentry Homes, Ltd., is the developer for the master planned community adjacent to the opportunity site. A final environmental impact statement for the last increment of the master plan was submitted in September 2003. This development, which is referred to as Gentry Ewa Makai, is located in an area farther south of the opportunity site, but also abutting the agricultural land. Depending on the current status of this development opportunity, it may be possible to coordinate with the development to divert stormwater to the opportunity site or to another site farther south.

Demographic Factors

- Socioeconomic: In 1990, the population of Ewa was 43,000. It is projected to grow to 125,000 in 2020. Nearly 28,000 new housing units will have been added in master planned communities. Job growth will likewise grow, from 17,000 jobs to more than 64,000 in 2020.

Community and Cultural Factors

- Cultural Property: The Ewa Development Plan supports preserving visual landmarks, significant views, and historic, cultural, and archaeological features.
- Stakeholder Interest: Interested groups could be local community clubs such as the Ewa Beach Community.

7.10.6 Generalized Rating Scales

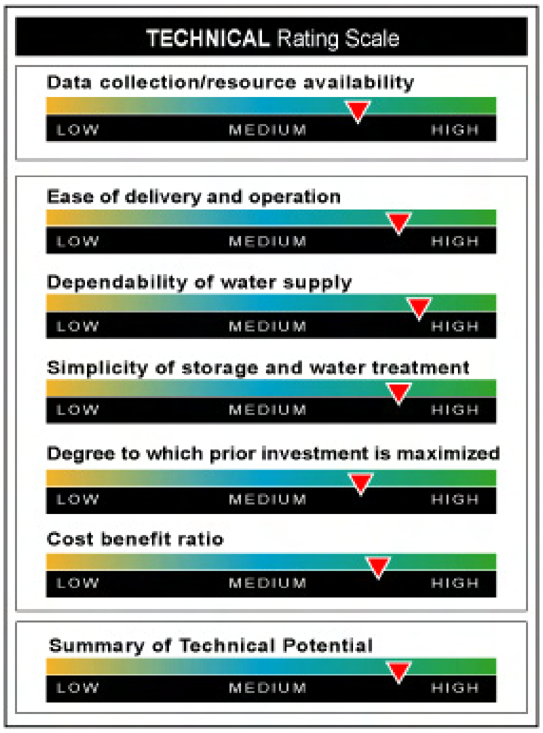

Figure 7-17. **Technical Rating Scale for Ewa Plains**

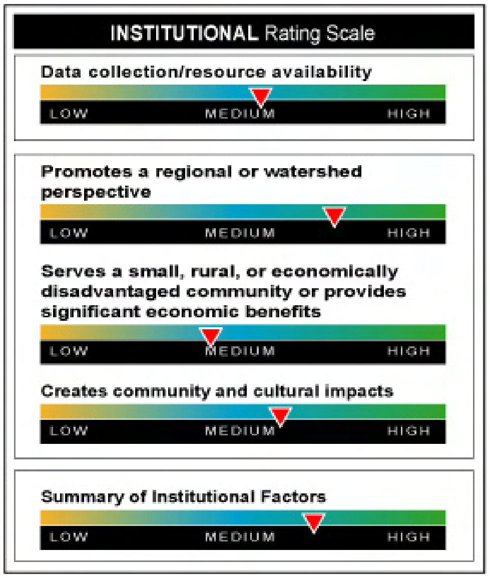

Figure 7-18. **Institutional Rating Scale for Ewa Plains**

SECTION 8

Prioritized Opportunity Ranking

This section numerically ranks the nine candidate opportunities according to the criteria identified earlier in this appraisal report. Opportunities are ranked on a scale of 1 to 10. A rank of "1" is assigned to opportunities with the greatest potential benefit, and a rank of "10" is assigned to opportunities with significant implementation challenges. Ranking criteria are summarized in this section. Table 8-1 provides a simple numerical ranking of each opportunity. Table 8-2 provides a more detailing ranking of opportunities against the criteria specified in the rating scales shown in Section 7.

8.1 Technical Appraisal

The nine opportunities that passed the screening process were evaluated on the basis of a series of rating criteria, as follows:

- **Data and resource availability**. How available were data? Collection methods included interviews with agency personnel, literature reviews, and field investigations.
- **Ease of delivery and operation.** How efficient is the proposed mode of delivery (for example, subsurface vs. surface) and operation?
- **Dependability of water supply**. How consistent and reliable is the water supply generated?
- **Simplicity of storage and water treatment.** How much storage capacity is needed? Is water treatment necessary, and if so, how much?
- **Degree to which prior investment has been maximized**. Have previous projects been conducted or proposed in the area?
- **Cost/benefit ratio**. What are the anticipated component needs and estimated costs? Following the guidelines of the Reclamation *Estimating Handbook* (1989), preliminary cost estimates for individual opportunities were prepared from rough general designs to review opportunity benefits in light of the costs.

Section 7 provides an evaluation of each opportunity according to these criteria.

8.2 Institutional Considerations

Institutional ranking criteria for the nine candidate opportunities are as follows:

- **Data collection and resource availability**. How available were data? Collection methods included interviews with agency personnel, literature reviews, and field investigations.

- **Promotes a regional or watershed perspective.** To what extent does the opportunity address regional considerations and focus on the local watershed level, in addition to the individual waterbody.
- **Serves a small, rural, or economically disadvantaged community or provides significant economic benefits**. Of what potential value might this opportunity be to these groups?
- **Creates community and cultural impacts**. To what extent would this opportunity impact the surrounding community and cultural considerations within that community? A “low” rating is positive for this criterion.

Section 7 provides an evaluation of each opportunity according to these criteria.

8.3 Findings

Reclamation has performed this study to investigate and identify opportunities for reclamation and reuse of stormwater.

Clearly, for all the prospective opportunities described in this study, feasibility (as defined in this process) has not been established. To move the opportunities toward funding for construction, several key elements must be addressed:

- Congressional authorization needs to be obtained for Reclamation involvement in conducting feasibility studies.
- A project sponsor must be identified. In some cases, there is already an organization or entity that has taken responsibility for success of the project. In others, discussion with local stakeholders has focused to date on whether the project represents a “good idea” and is valuable and viable. It is vital to this process to investigate interest in ownership and market the opportunities to local groups capable of completing the funding and construction process.
- Owing to the significant nonfederal funding contribution required, additional education and outreach to local stakeholders is needed. In many cases, matching contributions for a project will be allocated by nonfederal elected representatives. To maximize the chances of success, key constituent groups would have to be identified and approached regarding the potential benefits of the project. Such groups must be given ample opportunity to explain concerns and needs for making the project successful for all involved.

Table 8-1 provides a comparative ranking of the nine opportunities. Table 8-2 provides an unweighted, numerical ranking of each opportunity against the technical and institutional rating criteria summarized above and in Section 6, Methodology for Selection. The rankings are subjective. Opportunities are ranked relative to each other and based on the professional judgment of the evaluator.

TABLE 8-1
Numerical Ranking of Candidate Opportunities

Numerical Rank	Location and Number	Name
1	Molokai 1	Molokai Irrigation System
2	Kauai 3	Lihue Garlinghouse Tunnel Potable Water Source
3	Oahu 4	Ewa Plains
4	Hawaii 3	Pahala Catch Basins
5	Maui 2	Southwest Maui Watershed Stabilization (Site 1) and Central Maui Soil and Water Conservation (Site 2)
6	Oahu 1	Waianae Agricultural Park
7	Maui 4	Lahaina Watershed
8	Hawaii 1	Lower Hamakua Ditch/Waipio Valley
9	Kauai 4	Lihue Airport Landscape Irrigation Reuse

TABLE 8-2
Comparative Opportunity Ranking

	Hawaii 1—Lower Hamakua Ditch/ Waipio Valley	Hawaii 3—Pahala Catch Basins	Kauai 3—Lihue Garlinghouse Tunnel Potable Water Source	Kauai 4—Lihue Airport Landscape Irrigation Reuse	Maui 2—Site 1 (Southwest Maui Watershed Stabilization), and Site 2 (Central Maui Soil and Water Conservation)	Maui 4—Lahaina Watershed	Molokai—Molokai Irrigation System	Oahu 1—Waianae Agricultural Park	Oahu 4—Ewa Plains
Ranking Criteria	**Rank**	**Rank**	**Rank**	**Rank**	**Rank**	**Rank**	**Rank**	**Rank**	**Rank**
Technical									
Data collection and resource availability	4	3	4	5	3	8	4	7	4
Ease of delivery and operation	6	5	3	9	4	5	2	4	2
Dependability of water supply	8	7	2	5	8	9	5	9	2
Simplicity of storage and water treatment	7	5	2	9	3	4	2	5	3
Degree to which prior investment is maximized	9	4	2	8	7	8	1	3	4
Benefit/Cost	10	6	4	10	3	6	1	9	2
Summary of Technical Potential	9	5	2	8	4	7	1	6	3
Institutional									
Data collection and resource availability	5	5	5	4	5	5	3	4	5
Promotes a regional or watershed perspective	4	3	4	9	5	3	3	4	3
Serves a small, rural, or economically disadvantaged community or provides significant economic benefits	5	3	4	6	8	8	3	7	6
Creates community and cultural impacts	6	5	3	10	3	7	3	5	4
Summary of Institutional Factors	6	3	3	6	5	6	3	5	4

NOTE: 1 = Best and 10 = Worst.

SECTION 9

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Maps

Hawaii - Site 1

Lower Hamakua Ditch/Waipi'o Valley

Map 1

Island of Hawaii

U.S. Department of the Interior
Bureau of Reclamation
Hawaii Stormwater Reclamation Appraisal

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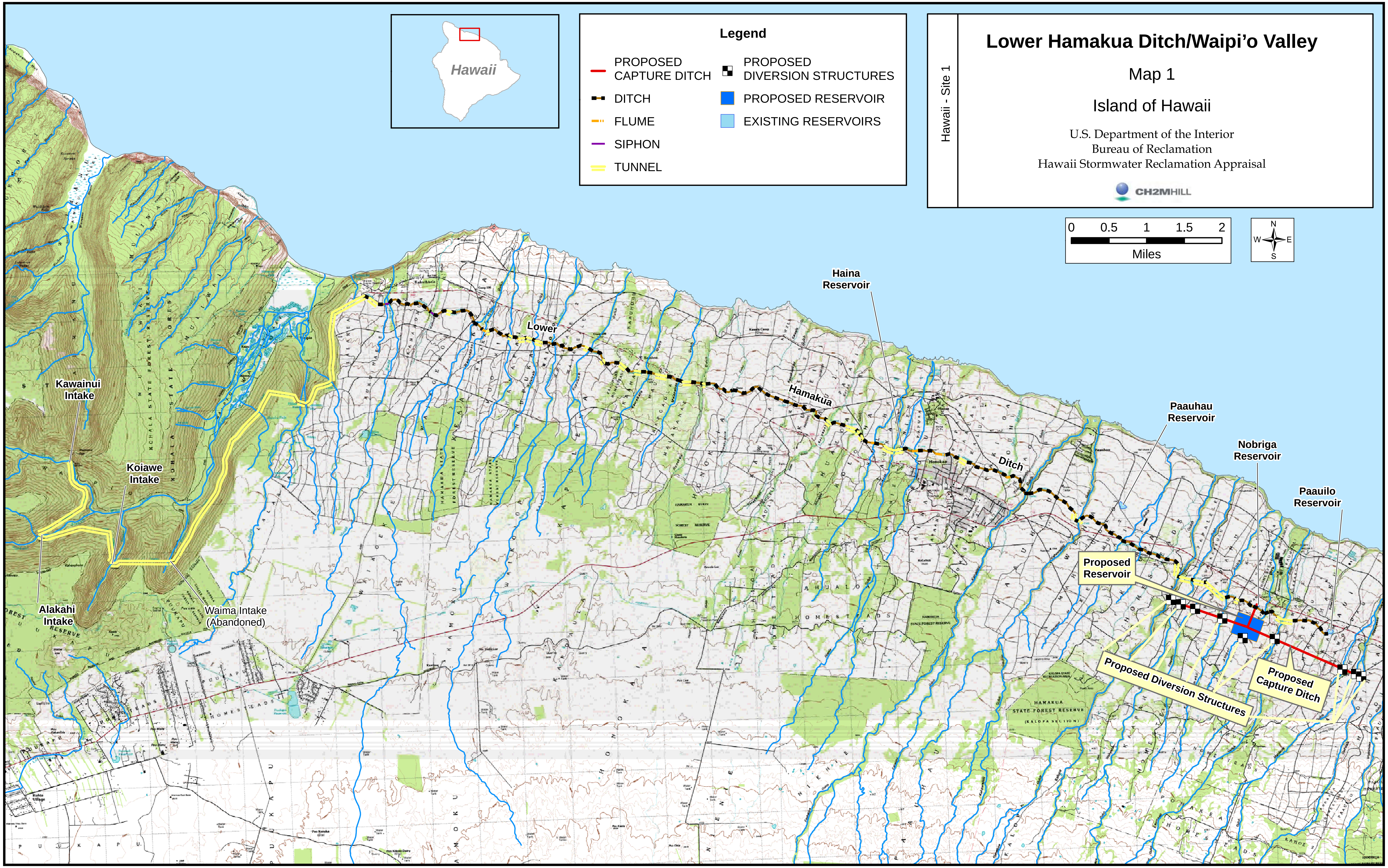

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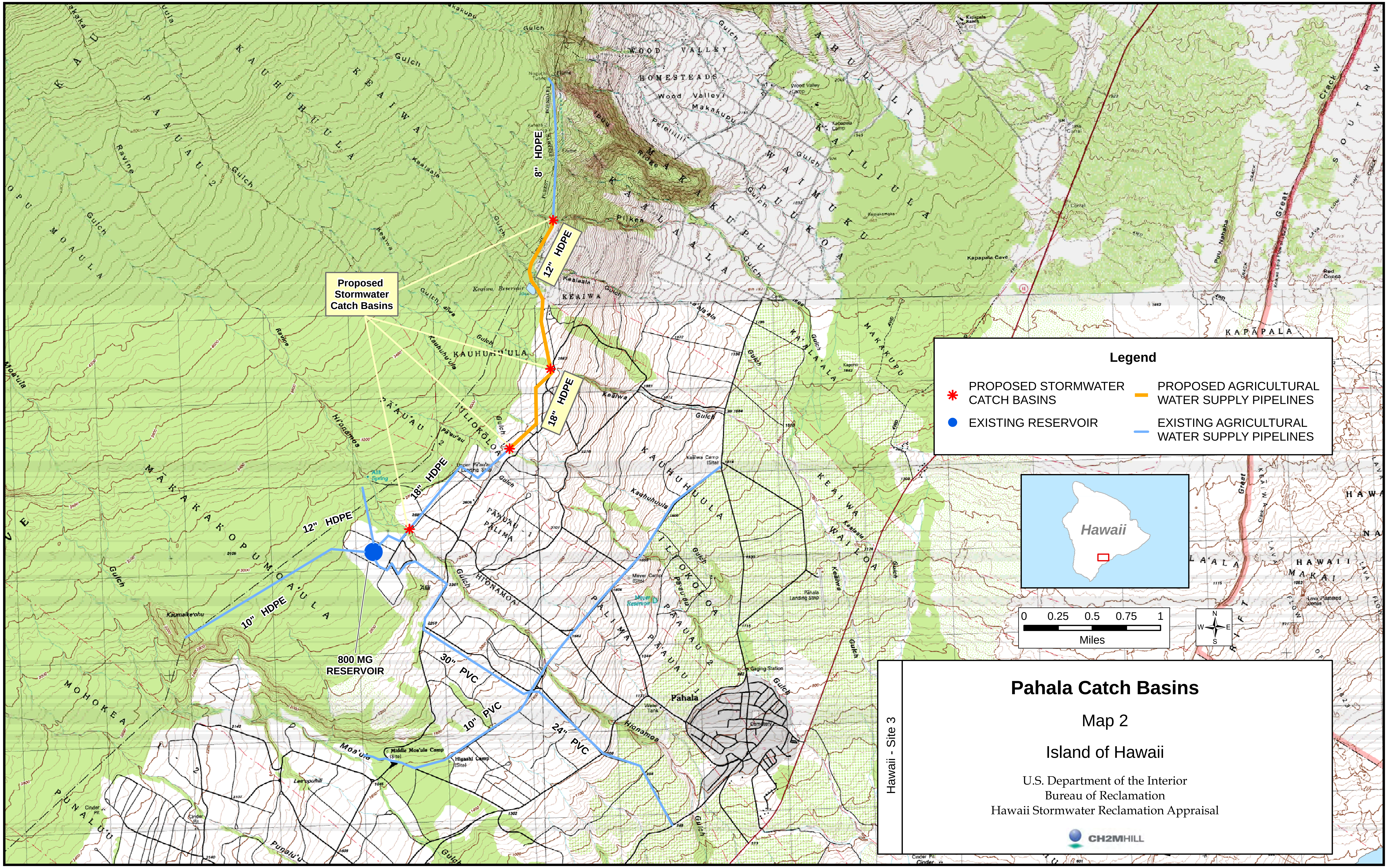

Hawaii - Site 3

Pahala Catch Basins

Map 2

Island of Hawaii

U.S. Department of the Interior
Bureau of Reclamation
Hawaii Stormwater Reclamation Appraisal

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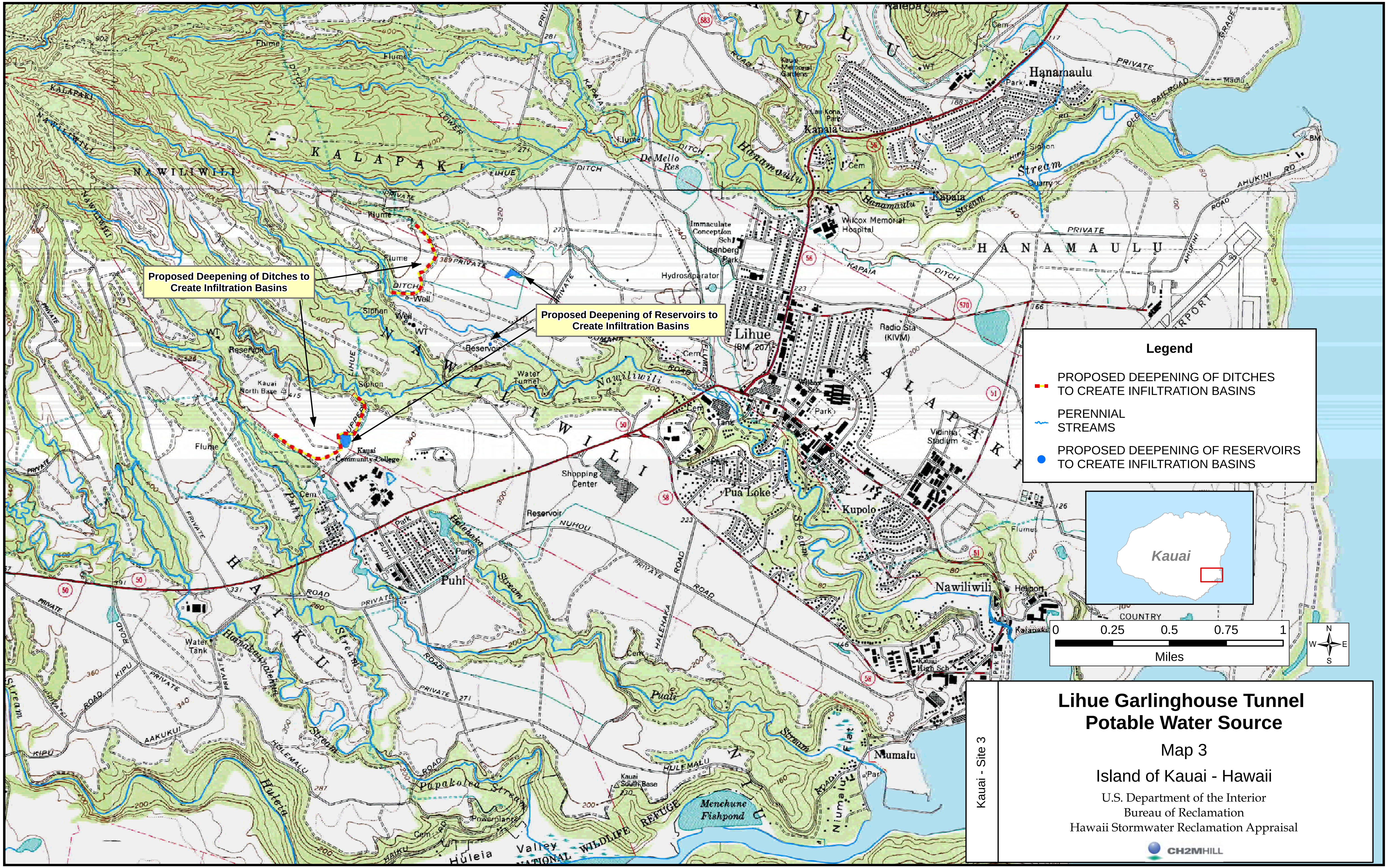

Proposed Deepening of Ditches to Create Infiltration Basins

Proposed Deepening of Reservoirs to Create Infiltration Basins

Legend

🟥	PROPOSED DEEPENING OF DITCHES TO CREATE INFILTRATION BASINS
~	PERENNIAL STREAMS
●	PROPOSED DEEPENING OF RESERVOIRS TO CREATE INFILTRATION BASINS

Kauai - Site 3

Lihue Garlinghouse Tunnel Potable Water Source

Map 3

Island of Kauai - Hawaii

U.S. Department of the Interior
Bureau of Reclamation
Hawaii Stormwater Reclamation Appraisal

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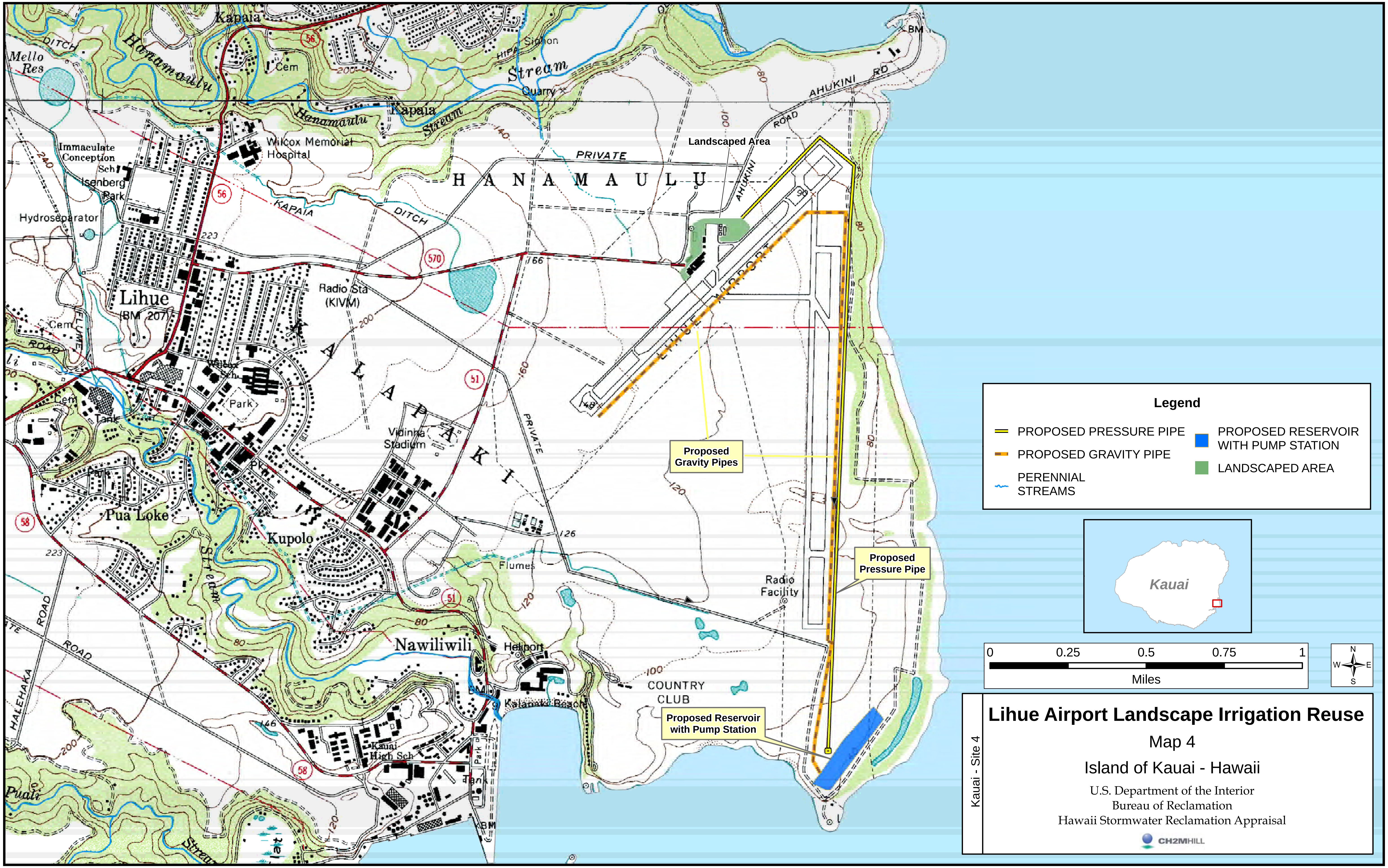

Legend

- ▬ PROPOSED PRESSURE PIPE
- ▬ PROPOSED GRAVITY PIPE
- 〰 PERENNIAL STREAMS
- 🟦 PROPOSED RESERVOIR WITH PUMP STATION
- 🟩 LANDSCAPED AREA

Kauai - Site 4

Lihue Airport Landscape Irrigation Reuse

Map 4

Island of Kauai - Hawaii

U.S. Department of the Interior
Bureau of Reclamation
Hawaii Stormwater Reclamation Appraisal

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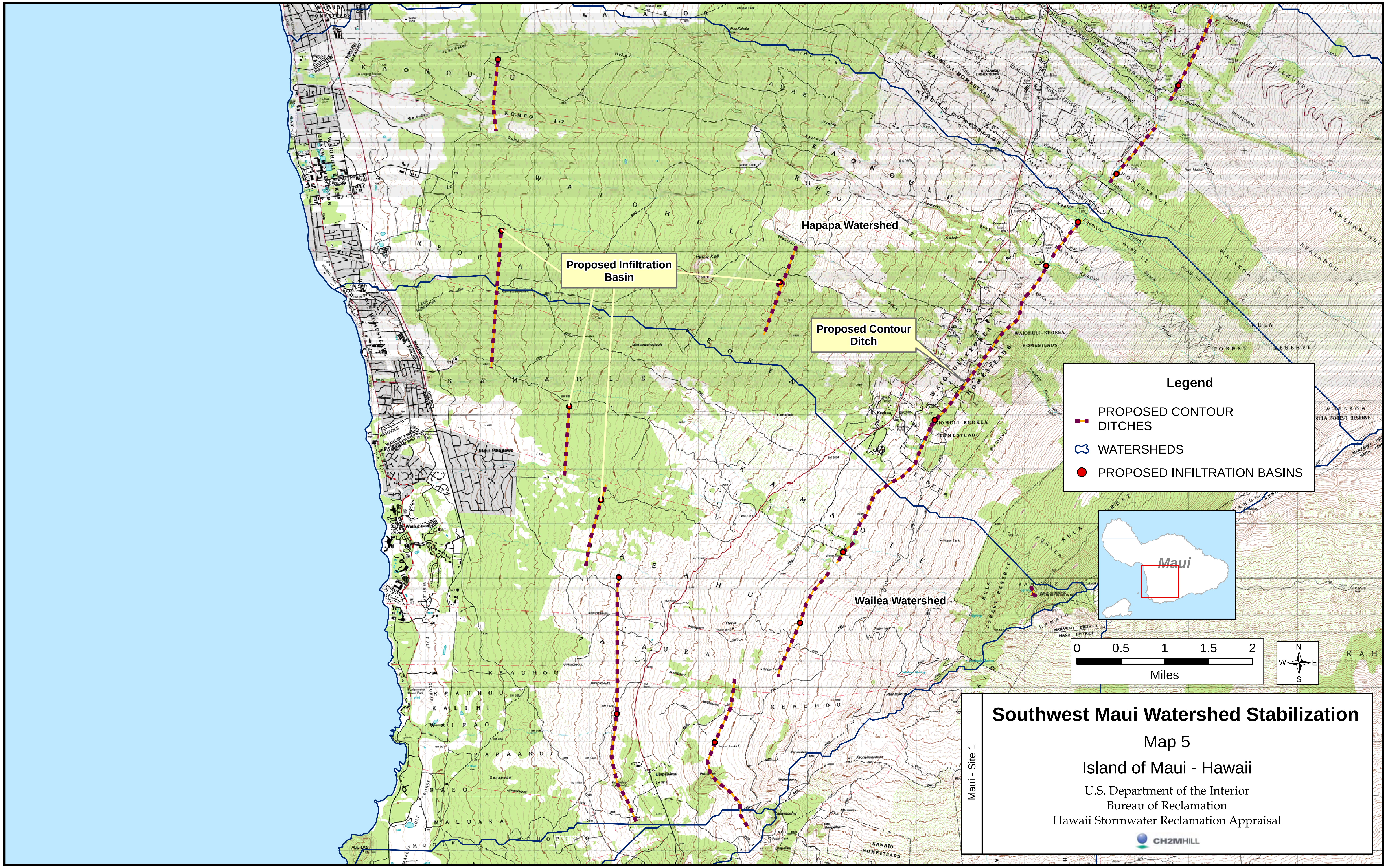

Southwest Maui Watershed Stabilization

Map 5

Island of Maui - Hawaii

U.S. Department of the Interior
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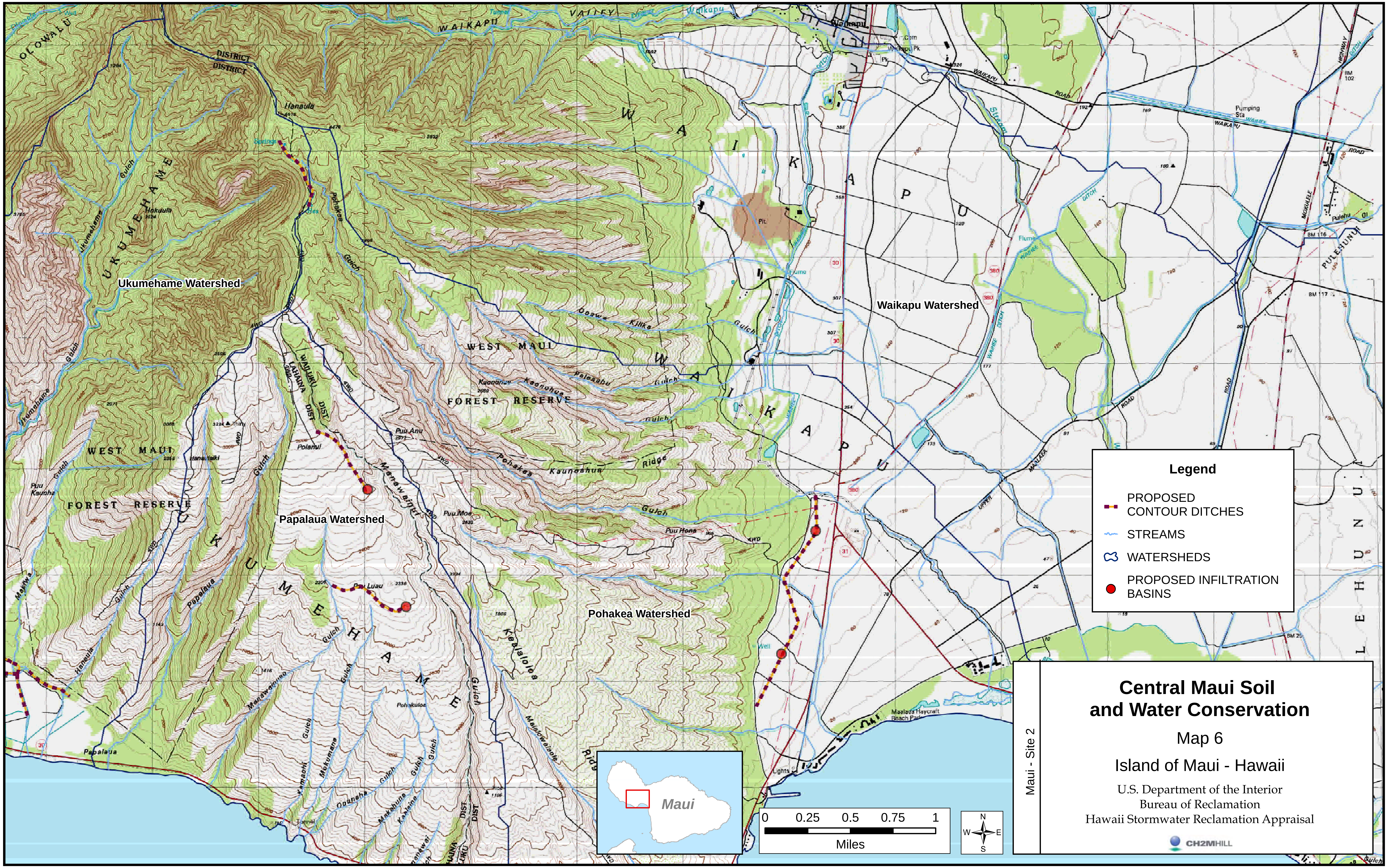

Maui - Site 2

Central Maui Soil and Water Conservation

Map 6

Island of Maui - Hawaii

U.S. Department of the Interior
Bureau of Reclamation
Hawaii Stormwater Reclamation Appraisal

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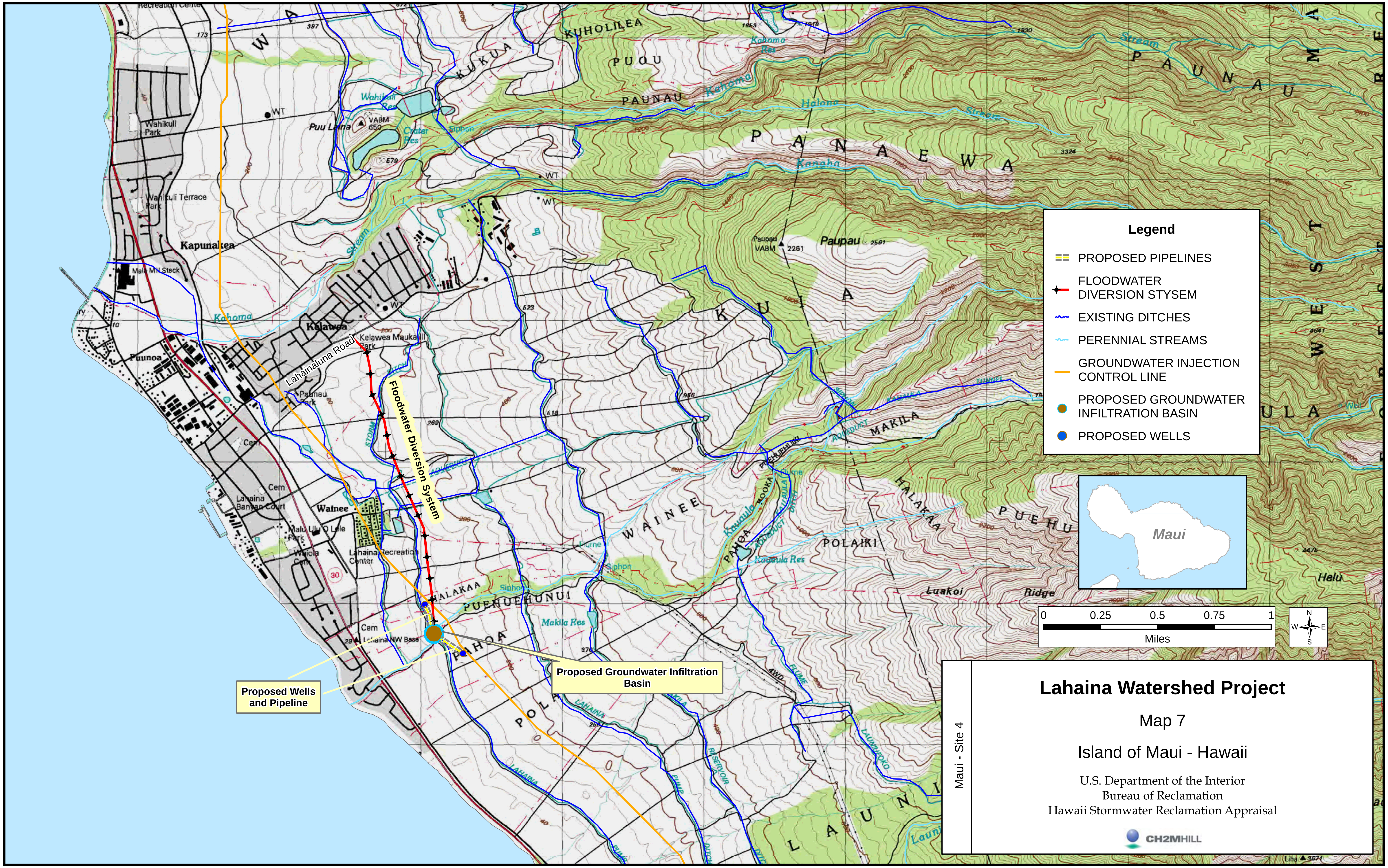

Maui - Site 4

Lahaina Watershed Project

Map 7

Island of Maui - Hawaii

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Molokai - Site 1

Molokai Irrigation System

Map 8

Island of Molokai - Hawaii

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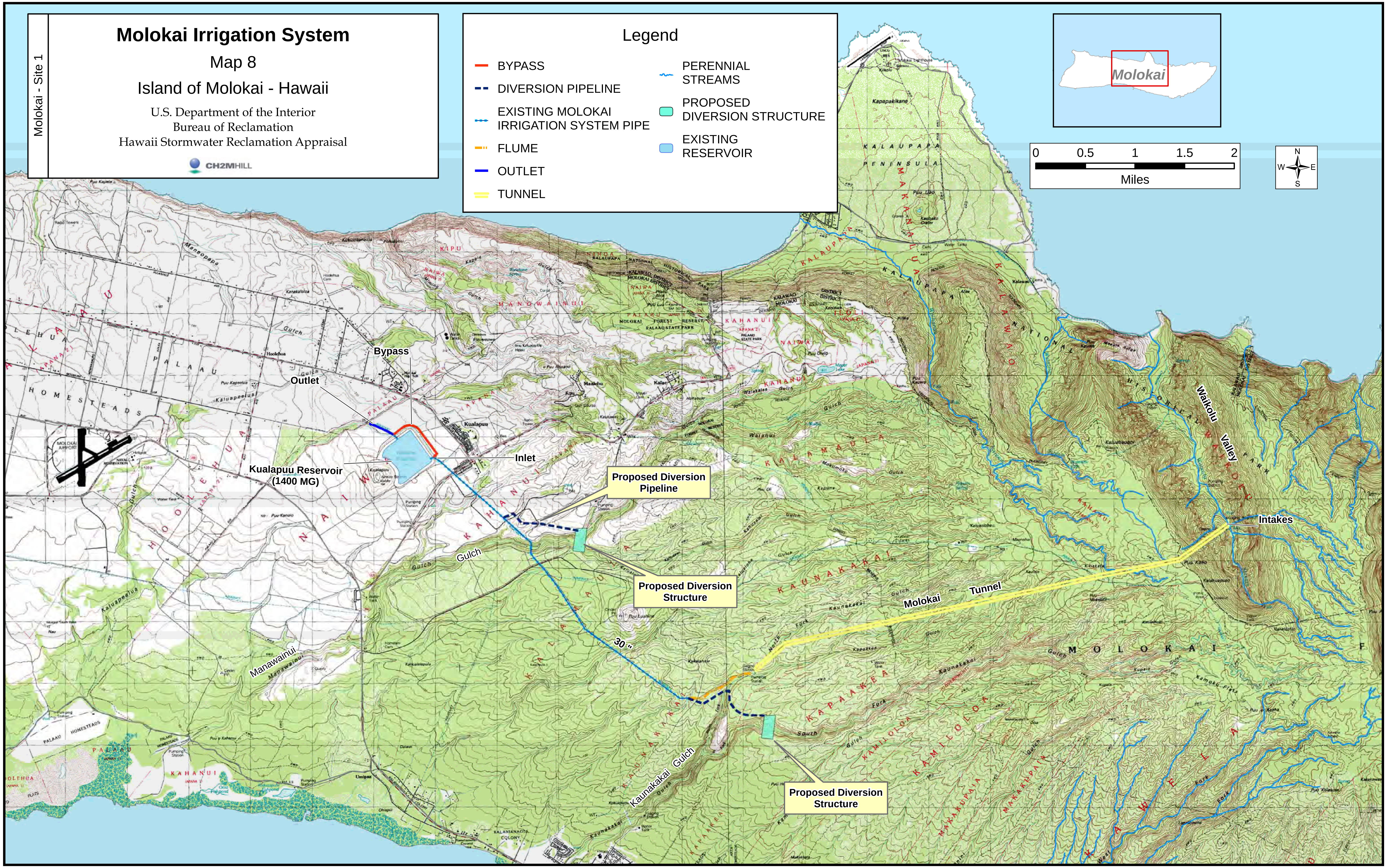

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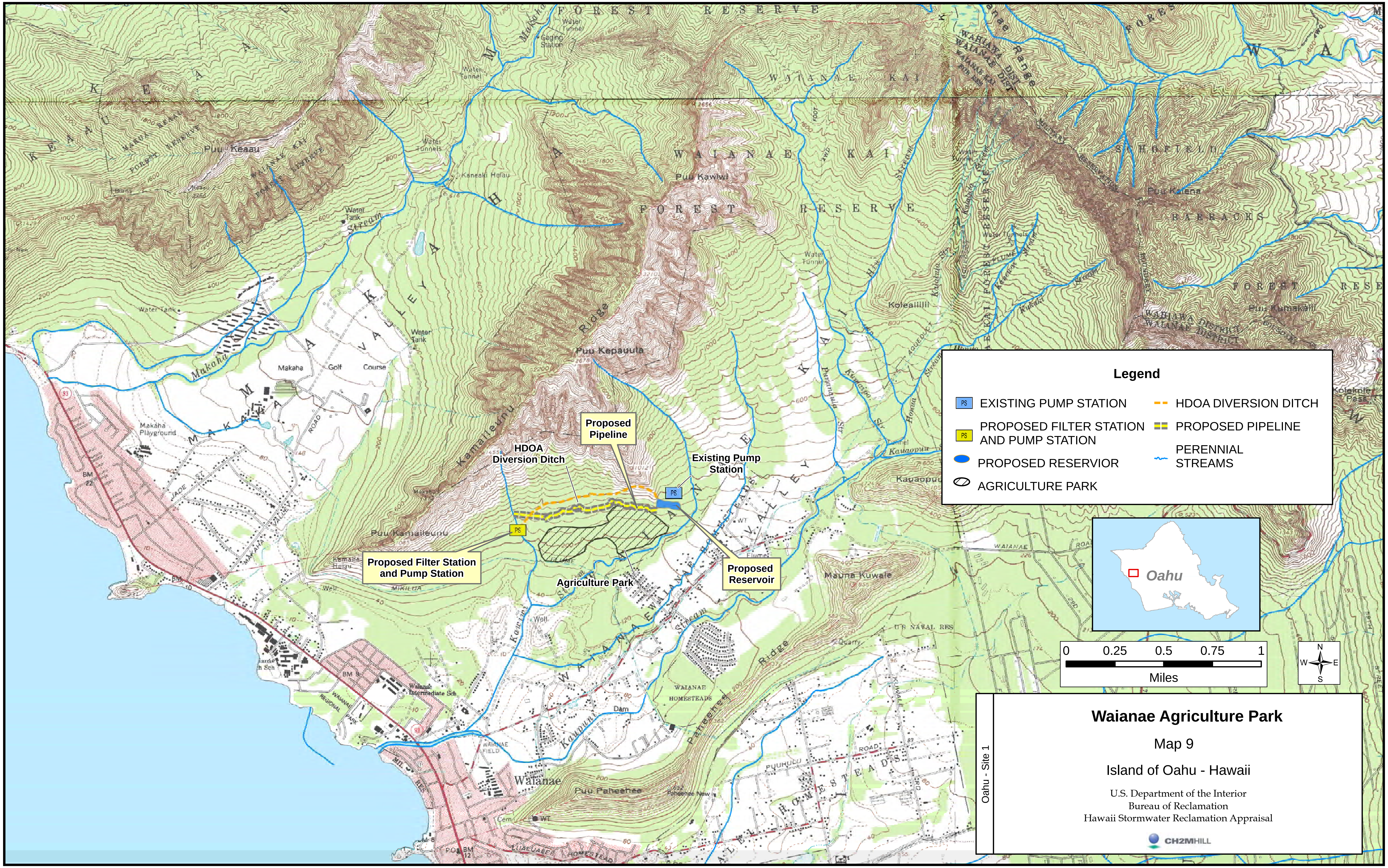

Oahu - Site 1

Waianae Agriculture Park

Map 9

Island of Oahu - Hawaii

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Hawaii Stormwater Reclamation Appraisal

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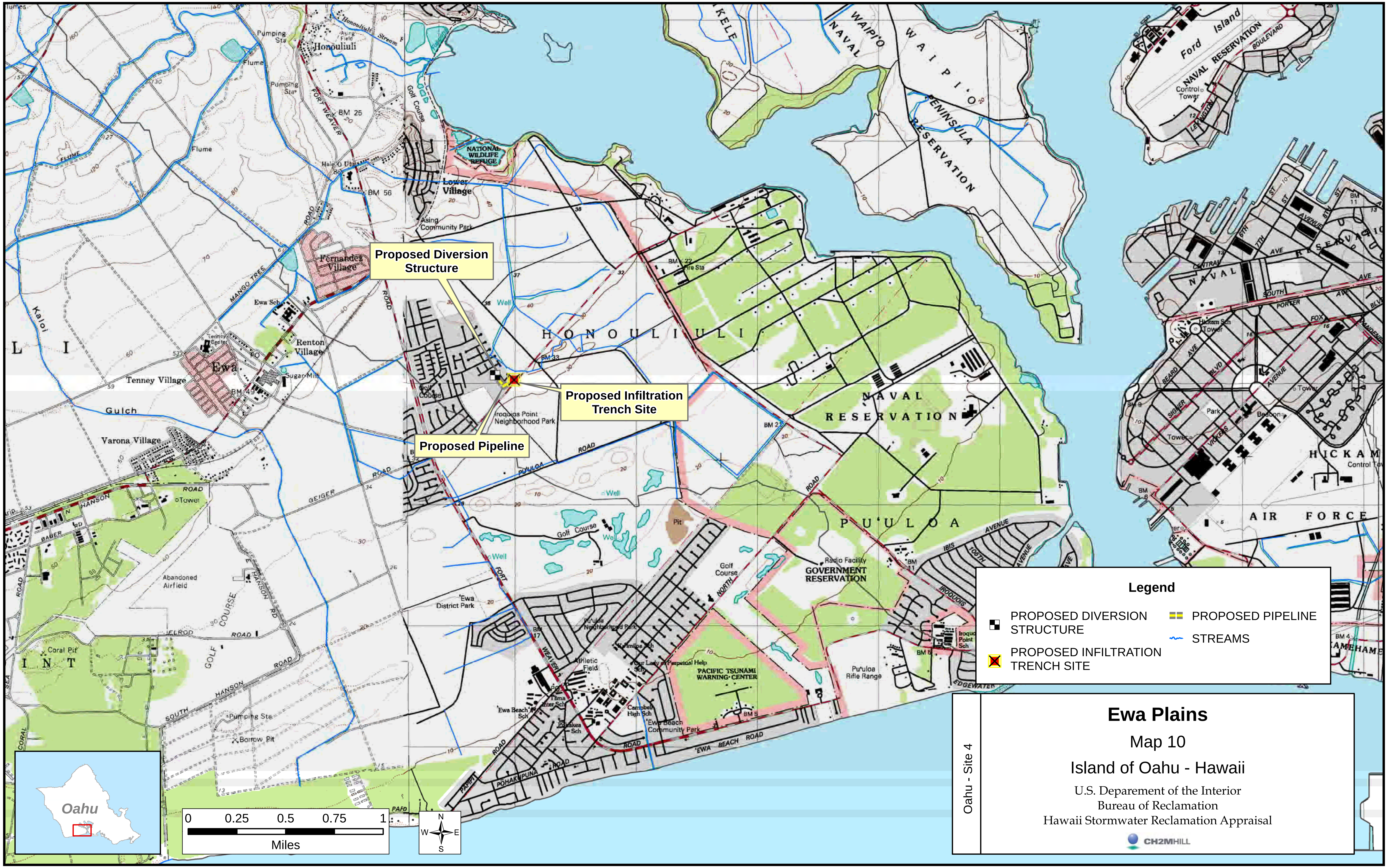

Legend

- ▚ PROPOSED DIVERSION STRUCTURE
- ☒ PROPOSED INFILTRATION TRENCH SITE
- 🟨 PROPOSED PIPELINE
- ～ STREAMS

Oahu - Site 4

Ewa Plains

Map 10

Island of Oahu - Hawaii

U.S. Deparement of the Interior
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APPENDIX A

Agencies and Organizations Contacted

APPENDIX A

Agencies and Organizations Contacted

Hawaii Stormwater Reclamation Appraisal Report

Project No.	Name	Contacts
Oahu 1	Waianae Agricultural Park	Dudley Kubo U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118 Honolulu, HI 96850 (808) 541-2600 x124 (808) 541-1335 fax dudley.kubo@hi.usda.gov Randy Teruya Hawaii Department of Agriculture (808) 973-9478
Oahu 4	Ewa Plains	Richard Ching Right of Way Appraiser Hawaii Department of Transportation (808) 692-7342 [Regarding Kapolei retention basin]
Kauai 1	East Kauai Irrigation System Ditch Maintenance Project	East Kauai Water Users Cooperative 4334 Rice Street, Suite 202 Lihue, Kauai, Hawaii 96766 Jerry Ornellas, President of the East Kauai Water Users Cooperative (808) 821-2948
Kauai 3	Lihue Garlinghouse Tunnel Potable Water Source	Nancy McMann, State Historic Preservation Division on Kauai Gregg Fujikawa, County of Kauai Department of Water (808) 245-5416

Project No.	Name	Contacts
Kauai 4	Lihue Airport Landscape Irrigation Reuse	Steve Kyono, District Engineer, Department of Transportation Kauai District (808) 241-3006 Steve.Kyono@hawaii.gov Jeff Dorn, Lihue Airport Engineer (808) 246-1412

Project No.	Name	Contacts
Hawaii 1	Lower Hamakua Ditch/Waipi'o Valley	Brian Kau Hawaii Department of Agriculture Honolulu, Oahu (808) 973-9473 Katina Henderson U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118 Honolulu, HI 96850 (808) 541-2600 x131 (808) 541-1335 fax Katina.henderson@hi.usda.gov Hudson Minshew U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118 Honolulu, HI 96850 (808) 541-2600 x134 (808) 541-1335 fax hudson.minshew@hi.usda.gov Doug Toews U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) Dudley Kubo U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118

Project No.	Name	Contacts
		Honolulu, HI 96850 (808) 541-2600 x124 (808) 541-1335 fax dudley.kubo@hi.usda.gov
Hawaii 3	Pahala Irrigation Ditch	Dudley Kubo U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118 Honolulu, HI 96850 (808) 541-2600 x124 (808) 541-1335 fax dudley.kubo@hi.usda.gov
		John Cross Kau Agribusiness Hilo: (808) 964-8412 Pahala: (808) 928-9012
		Margarita (Dai Dai) Hopkins Research and Development County of Hawaii (808) 961-8366
		Randy Cabral Vice President of Farming Operations ML Macadamia and Orchards LP (808) 928-3041

Project No.	Name	Contacts
Maui 2	Southwest Maui Watershed Stabilization	Richard Sylva, Associate Director CMSWCD 15660 Haleakala Hwy. Kula, HI 96790 (808) 878-1706 Dr. Melissa Kirkendall State Historic Preservation Division 808-243-5169
Maui 3	Central Maui Soil and Water Conservation	Richard Sylva, Associate Director CMSWCD 15660 Haleakala Hwy. Kula, HI 96790 (808) 878-1706
Maui 4	Lahaina Watershed Project	Joe Krueger Lahaina Watershed Flood Control Project Engineering Department County of Maui (808) 270-7745 Dudley Kubo U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) 300 Ala Moana Blvd., Rm. 4-118 Honolulu, HI 96850 (808) 541-2600 x124 (808) 541-1335 fax dudley.kubo@hi.usda.gov Wayne Kawahara Lahaina Traffic Master Plan Hawaii Department of Transportation

Project No.	Name	Contacts
		(808) 587-6357 Wayne.Kawahara@Hawaii.gov
Hawaii 5	Parker Ranch/Waimea	Chris Kanazawa CEO, Parker Ranch (808) 885-2324
		Mauna Kea Soil and Water Conservation District P.O. Box 2975 Kamuela, HI 96743 (808) 885-6602 dpahio@hikamuela.fsc.usda.gov
Molokai 1	Molokai Irrigation System	Elson Gushiken Vice President, ITC Water Management P.O. Box 458 Haleiwa, HI 96712 Phone: (808) 637-5078 Fax: (808) 637-4779 Ecgushiken@aol.com
Molokai 2		N/A
Oahu 2	No name	N/A
Oahu 3	Wilson Dam	Board of Water Supply 630 South Beretania Street Honolulu, HI 96843 (808) 550-9151 fax
Oahu 5	Waimanalo Area	N/A
Kauai 2	Waimea Irrigation System Ditch Maintenance Projects	Rhoda Libre Kaua'I West Side Watershed Council (808) 645-1210 rhoda@hawaiilink.net

Project No.	Name	Contacts
		Pioneer Seed Corporation
Kauai 5	Waimea Department of Water Tank Site Diversion Project	N/A
Kauai 6	Nawiliwili Bay Watershed Council Runoff Pollution Prevention	Cheryl Loveli-Obatake Nawiliwili Bay Watershed Council (808) 245-8783
		David Martin, Nawiliwili Bay Watershed Council (808) 823-8977
Kauai 7	Private Developer Reuse Opportunities	Grove Farm
		Alexander & Baldwin
		Princeville
		Kauai Watershed Alliance
Kauai 8	Waimea River Flood Control Project	COE
		Russell Sugano Kauai County
Kauai 9	Kamehameha Schools Bishop Estates	N/A
Kauai 10	Waipa Foundation Fish Farm Restoration	Linda Sproat
Kauai 11	Alexander Reservoir Drought Mitigation	N/A
Kauai 12	Hanalei River	The Nature Conservancy
Hawaii 2	Waiakea Project in Hilo	N/A
Hawaii 4	Improve Water Quality in Hilo Bay	Mary James, Watershed Advisory Group (WAG)
		University of Hawaii at Hilo
Hawaii 6	Lalakea Ditch System (in vicinity of Hamakua Ditch)	NRCS
		Earth Justice
Hawaii 7	Wailuku River Diversion	N/A

Project No.	Name	Contacts
Hawaii 8	Wailuku/Akolea Diversion/Hilo	NRCS, Waiakea Soil and Water Conservation District Mauna Kea SWCD Hamakua SWCD
Maui 1	Stormwater as a source of supply for agriculture (many locations)	Mae Nakahata (808) 877-6967
Maui 5	East and West Maui Watershed Roadmap to Conservation Project	Maggie Kramp Maui SWCD (808) 244-3100, ext. 101 maggie.kramp@hi.nacdnet.net Randall Moore Central Maui SWCD (808) 877-6968 rmoore@hcsugar.com Potential collaborators: Maui Land and Pineapple Co., East Maui Irrigation Co., Sierra Club, SWCDs, NRCS. Comprehensive outreach and education possible through: University of Hawaii, Maui Community College, Maui Farm Bureau, and County planning officials.

APPENDIX B

Opportunities Not Selected

APPENDIX B

Opportunities Not Selected

This appendix documents the initial set of 31 proposed stormwater reclamation opportunities. A summary assessment of each of the 31 opportunities was performed to identify possible benefits and uses. Ultimately, nine opportunities were selected for further study and possible development.

Identification of Initial Set of Opportunities

Early in the study process, agency consultation meetings were conducted to collect stormwater reuse project ideas for the appraisal study (Table 1). Participants were encouraged to identify a broad spectrum of opportunities. The primary limitation in identifying opportunities was that water would not be diverted from a stream. The goal was to identify new sources of water supply through stormwater reuse.

TABLE 1
Agency Consultation Meetings

Date	Island	Organizations Represented
August 16, 2004	Oahu	Department of Land and Natural Resources
August 17, 2004	Oahu	Board of Water Supply Natural Resources Conservation Service Hawaii Department of Agriculture Maui County Farm Bureau Hawaii Department of Health, Safe Drinking Water Branch Commission on Water Resources Management
August 18, 2004	Hawaii	Department of Water Supply, County of Hawaii Department of Public Works, County of Hawaii
August 19, 2004	Kauai	Department of Water Department of Public Works

A follow-up letter was sent to participants to solicit additional information about the potential opportunities. The participant contact list is provided in Appendix A to the Appraisal Report. As a result of the agency consultations, 31 potential projects were identified for consideration:

- 5 on Oahu
- 12 on Kauai
- 8 on Hawaii
- 5 on Maui

A Molokai opportunity was added subsequent to this process.

Based on the information received, maps of the potential projects were developed using geographic information system (GIS) data. These maps are provided in the attachment to this document. Each potential project site is shown in a series of four maps that depict infrastructure/land use, natural features, land use/land cover, and soils.

This information formed the basis for an assessment of potential uses.

Assessment of Potential Uses and Viability

Reclamation policy identifies uses that are appropriate for projects funded under Title XVI: environmental restoration, fish and wildlife, groundwater recharge, municipal, domestic, industrial, agricultural, power generation, and recreation. Within those broad categories, more specific uses, particular to stormwater capture and local needs, were identified. For each potential project, possible beneficial uses were listed. If no potential reuse was identified during the information-gathering phase, the potential project was found not to contain sufficient information to proceed at this time.

From the initial compilation of data and matching of objectives, constraints, analysis tools, and technologies, it was determined that some opportunities would not be pursued. In particular, those opportunities for which no owner or sponsor was identified, site locations were unclear, or, as stated in the paragraph above, no potential stormwater reuse was identified, were recommended to be omitted from the pool.

A summary of the 22 opportunities not selected follows.

Summary of Opportunities Not Selected

Oahu 2—Stormwater Detention Basins in Honolulu

This opportunity would reduce peak flow during storm events, and provide water storage basins for fire protection. Stormwater would be captured in bioswales and stored in detention basins and reservoirs until needed. The potential reuse would be to provide grey water for use in urban sprinklers, toilets, and fire protection. Key data still needed would be site locations and owners or sponsors. The potential project would be located in urban areas. It would likely be located in areas of slopes less than 25 percent, on soils with moderate to high infiltration rates. The opportunity was not selected because of limited value of use.

Oahu 3—Wilson Dam

This opportunity would provide a sizable detention basin for treated wastewater before it enters the reservoir so that the reservoir can be considered a cleaner source of stormwater for reuse. Potential reuse options include crop irrigation, habitat baseflow augmentation, and ambient water. The site would be located just above the reservoir. It is located in an urban setting, in an unvegetated area, but with agricultural land nearby. There are rain gauges within a mile of the site. The soils at the site have very slow infiltration rates (Hydric Soil Group D). The opportunity was dropped because it is being developed by the Board of Water Supply.

Oahu 5—Waimanalo Area

This opportunity would be for flood control in a coastal plain area. More data would need to be collected on the potential reuse options. The site is located near the top of the watershed and within a few miles of the coast. The predominant land use around the site is forest land and agricultural land, with urban land and wetlands down slope of the site. The site is located near the beginning of the Waimanalo River. There are rain gauges and stream gauges within a mile of the site. The Waimanalo area site is in slopes of less than 25 percent. The soils at the site have moderate infiltration rates (Hydric Soil Group B). The opportunity was dropped because a reuse opportunity could not be defined.

Kauai 2—Waimea Irrigation System Ditch Maintenance

The objective would be to continue providing peak flow capture and diversion in areas where downslope development has occurred and potentially increase irrigation water availability. The site is located in agricultural lands, less than 2 miles from the ocean. The site is in the lower part of the watershed and is within the 100-year floodplain. The slopes are less than 25 percent slope, and the soils have moderate infiltration rates (Hydric Soil Group B). The opportunity was not selected because it is primarily a maintenance project.

Kauai 5—Waimea Department of Water Tank Site Diversion

The objective would be for flood control. This would improve the downstream drainage flow by discharging into a different watershed. This site is located within 2 miles of the ocean, but is at the top of two adjoining watersheds. The site is adjacent to urban areas, downslope of agricultural lands. There are a number of streamgauges just inland of the site, and rain gauges are in the area. The site is located on slopes greater than 25 percent, and the soils have slow infiltration rates (Hydric Soil Group C). The opportunity was not selected because it is flood control without reuse.

Kauai 6—Nawiliwili Bay Watershed Council Runoff Pollution Prevention

The objective would be to improve filtration at every homeowner's lot to reduce surface runoff for pollution control. The site is located in an urban area, 1 mile from the ocean. It is located near wetlands in the 100-year flood zone. The site slopes are less than 25 percent. The soils have moderate infiltration rates (Hydric Soil Group B). The opportunity was not selected because coordination with many individuals was required to achieve benefits, and the opportunity was perceived as lower value than three other opportunities on Kauai.

Kauai 7—Private Developer Reuse Opportunities

The objective of the potential project is to incorporate blending stormwater with wastewater in nonpotable reuse systems, when putting in new developments in urban and nonurban settings. There are two site areas for the project, one at the north end of Kauai, and the other at the south. The site at the north end of the island, 7N, is in urban or built up lands. The site at the south end of the island, 7S, is in agricultural lands. Both are adjacent to lakes and wetlands. Rain gauges are located within a half-mile of the site. The north site is in slopes of less than 25 percent, with soils of moderate infiltration rates (Hydric Soil Group B). The south site is in slopes of greater than 25 percent, also with soils of moderate infiltration rates (Hydric Soil Group B). The opportunity was not selected because the private owners/ developers would likely proceed independently.

Kauai 8—Waimea River Flood Control

The objective is to provide flood control by dredging the river channel to increase peak flow capacity. The site is on the border between urban and agricultural lands, within one mile of the ocean. Stream gauges and rain gauges are located close to the site. The slope in the project area is less than 25 percent. The soils in the immediate vicinity of the project have slow or moderate infiltration rates (Hydric Soil Group C or B). The opportunity was not selected because it is flood control without reuse.

Kauai 9—Kamehameha Schools Bishop Estates

The objective would be to capture stormwater for reuse water for irrigation. The opportunity was not selected because inadequate information was available to formulate the opportunity.

Kauai 10—Waipa Foundation Fish Farm Restoration

The objective would be to capture stormwater for reuse water to supply the fish farm. The opportunity was not selected because inadequate information was available to formulate the opportunity.

Kauai 11—Alexander Reservoir Drought Mitigation

The objective is to upgrade facilities at the Reservoir site to mitigate for effects of drought. The lead agencies for this opportunity would be Kauai Coffee Company, DOFAW, and the Kauai Fire Department. The project is located in a high-elevation, forested area. The opportunity was not selected because other agencies were developing a drought mitigation plan and it did not appear that an additional reuse opportunity existed.

Kauai 12—Hanalei River

The objective would be to provide a public demonstration site for various methods of stormwater management and reuse. The opportunity was not selected because inadequate information was available to formulate the opportunity.

Hawaii 2—Waiakea Project in Hilo

The objective is to provide flood control through the use of detention basins to reduce peak flows. The site is located on the Wailoa River in an urban area, approximately 2 miles from the ocean. There are rain gauges on the river within a mile from the site. The slope in the project area is less than 25 percent. The soils in the immediate vicinity of the opportunity have slow or moderate infiltration rates (Hydric Soil Group C or B). The opportunity was not selected because it is flood control without reuse.

Hawaii 4—Improve Water Quality in Hilo Bay

The objective is to control flooding in the Wailoa River and reduce sediment in the bay. The site is located on the Wailoa River, adjacent to Hilo Bay. It is in an unvegetated area, in the 100-year flood zone. The slope in the project area is less than 25 percent. The soils in the immediate vicinity of the potential project have very slow infiltration rates (Hydric Soil Group D). The opportunity was not selected because it is primarily a flood control project for water quality improvements without reuse.

Hawaii 5—Parker Ranch/Waimea

The objective is to develop stormwater detention basins to reduce flooding and provide water for firefighting. The site is located in agricultural lands, about a mile from rangeland, and about 10 miles from the ocean. There are several rain gauges proximate to the project area. The site is located on slopes less than 25 percent. The soils in the immediate vicinity of the project have moderate infiltration rates (Hydric Soil Group B). The opportunity was not selected because the private owners/developers would likely proceed independently.

Hawaii 6—Lalakea Ditch System near Hamakua Ditch

The objective is to provide flood control. The site is located in a forested area, with greater than 25 percent slopes. There is a rain gauge about a mile from the project, and a stream gauge a few miles up on the Lalakea River. The soils in the immediate vicinity of the potential project have high infiltration rates (Hydric Soil Group A). The opportunity was not selected because it is flood control without reuse.

Hawaii 7—Wailuku River Diversion

The objective is to create an extension to capture Waipahoehoe Stream and to reduce flooding in developing urban area of Hilo. The site is located on the border between urban and agricultural lands. There are several rain gauges and stream gauges a mile or two upstream of the project site, and a stream gauge half a mile downstream of the site. The project site is located on slopes greater than 25 percent. The soils in the immediate vicinity of the project have high infiltration rates (Hydric Soil Group A). The opportunity was not selected because it is flood control without reuse.

Hawaii 8—Wailuku/Akolea River Diversion in Hilo

The objective is to provide flood control from Waipahoehoe-Kaluilki tributaries. The site is close to the Hawaii 7 site, and is located on the border between urban and agricultural lands. There are several rain gauges and stream gauges 2 miles upstream of the project site, and a stream gauge just upstream of the site. The project site is located on slopes greater than 25 percent. The soils in the immediate vicinity of the project have high infiltration rates (Hydric Soil Group A). The opportunity was not selected because it is flood control without reuse.

Maui 1—Stormwater as a Source of Supply to Agriculture

The objective is to capture stormwater to control flooding, while providing water for irrigation. The potential project could be sited in many locations around the island. The island has a combination of urban or built-up areas and agricultural areas. During rain events, stormwater could be captured in irrigation ditches, and delivered to storage reservoirs for later irrigation. There are rain gauges and stream gauges throughout Maui, so project sites could have access to this information. Generally, urban and agricultural areas would be located on slope of less than 25 percent. The opportunity was not selected because the concept was similar to the concept in the Maui 2 opportunity, which did move forward, and a specific additional site was not located.

Maui 3—Central Maui Soil and Water Conservation

The objective is to capture and reuse stormwater for irrigation of pastures and livestock watering and to reduce erosion and sediment transport to coast reefs. The opportunity was not selected because the concept was similar to the concept in the Maui 2 opportunity, which did not move forward.

Maui 5—East and West Maui Watershed Road Map to Conservation

The objective is to use irrigation infrastructure that has historically transported water between watersheds on Maui as a means to capture storm water for reuse, flood control, and aquifer recharge. Also, urban runoff could be captured for agricultural reuse. The potential project would be located primarily in agricultural lands, although some infrastructure for capturing runoff and storm water does exist in the urban areas. Slopes for project areas could be both less than and greater than 25 percent. Soils in these areas would typically have slow to moderate infiltration rates. There are rain gauges and stream gauges throughout Maui, so project sites could have access to this information. The opportunity was not selected because the private owners/developers would likely proceed independently.

Kauai 1—East Kauai Irrigation System Ditch Maintenance Opportunity

This opportunity was initially selected as one of the proposed stormwater reclamation opportunities. After further assessment, it was determined that this opportunity really consists of maintenance or rehabilitation of an existing water system, rather than a reuse concept. Because it does not meet the basic criteria for consideration under this study, it was moved to the group of opportunities not selected for further study. The complete analysis performed for the initial investigation follows.

Objective

Continue to provide peak flow capture and diversion in areas where downslope development has occurred, and flood control with infiltration to recharge groundwater for potential potable and irrigation reuse.

Background

The East Kauai Irrigation System (EKIS) was built in the 1920s by the Lihue Plantation Company (LPC) and the East Kauai Water Company to irrigate approximately 12,500 acres of sugar cane. The EKIS consisted of 51 miles of ditches and tunnels, 18 stream intakes, three major reservoirs, and two hydropower plants. The average capacity of the EKIS was 100 to 150mgd. The LPC closed in 2000, but the EKIS continues operation under the East Kauai Water Users' Cooperative and the Lihue Land Company. The East Kauai Water Users' Cooperative is a private users group with a revocable permit to use the State's infrastructure (in this case the old irrigation water canals) through the auspices of the DLNR. Recently, in House Bill 165 and Senate Bill 1218, the Hawaii State legislature declared that "a potential crisis is developing at the East Kauai Irrigation System" and that the EKWUC "faces a serious funding shortfall."

The EKIS consists of the Kapaa, Kalepa, and Hanamaulu-Lihue sections, described as follows:

- The Kapaa Section has 22.5 miles of ditches and tunnels. Water is diverted from the North Fork of the Wailua River (Wailua Ditch Intake) and Kapaa Stream (Kapaa Stream Intake). Three reservoirs are located in this section—the Wailua Reservoir (240 MG), the Upper Kapahi Reservoir (30 MG), and the Lower Kapahi Reservoir (25 MG), for a total storage capacity of approximately 295 MG.
- The Kalepa Section has three intakes, two on the North Fork of the Wailua River (Blue Hole Intake and Stable Storm Intake) and one on the Wailua River's south fork (Hanamaulu Ditch Intake). Two hydroelectric power plants (the Upper and Lower Waiahi Hydropower Plants) are located in this section, diverting water from the South Fork of the Wailua River to generate approximately 1,300 kilowatts (kW) of power.
- The Hanamaulu-Lihue Section consists of the Upper and Lower Lihue ditches, which divert water at the Lower Waiahi Hydropower Plant and from the Hanamaulu Ditch. This section of the EKIS is located on privately owned land.

The EKIS is still operable, but is old and in need of repairs and improvements. Of the original 12,500 acres irrigated, only 4,000 can now be irrigated. Currently, only several hundred acres of the 4,000 are used by customers.

Opportunity Description

To rehabilitate the EKIS, the *Hawaii Water Resources Study* (Water Resource Associates, 2003a) lists six needed improvement opportunities:

- Lateral 8 Transmission Ditch—Replace corrugated pipe and ditch sections.
- Hanamaulu Wooden Flume—Replace with concrete flume.
- Twin Reservoir—Replace one wooden catwalk and one control gate.
- Upper Kapahi Reservoir—Replace two wooden catwalks and five control gates.
- Wailua Reservoir—Replace one control gate.
- Reservoir 21—Replace one control gate.

A detailed description of the EKIS, along with the irrigation system's history, current condition, and needed maintenance, can be found in the *Hawaii Water Resources Study* (Water Resources Associates, 2003a). This opportunity would implement the six needed improvements to preserve EKIS and encourage irrigated agriculture.

The map attached to this appendix illustrates the features of this opportunity.

Assessment

Potential Reuse. The EKIS offers several potential reuse opportunities. Directly, the irrigation system provides stormwater for crop irrigation. Indirectly, the irrigation system allows stormwater to infiltrate into the ground, recharging aquifers, contributing to the saltwater intrusion barrier, and supplementing the potable groundwater supply. By capturing and diverting stormwater, the EKIS also provides flood control. Upgrades and maintenance of abandoned EKIS facilities could prolong and enhance their value for revitalizing and expanding irrigation, recharging groundwater, and providing flood control. These reuse values would occur if the system continues to operate.

Delivery and Operations Needs. The EKIS captures water through stream intakes or intercepting overland flow of stormwater, and distributes the water via gravity ditch or pipe, operated ditch, and pressure pipe. This distribution system delivers the water directly to irrigated fields, point-of-use pressure distribution systems, storage reservoirs, recharge basins, and to aquifers through infiltration. The level of operations required would be similar to historical levels.

Dependability of Expected Supply. Stormwater capture and infiltration would fluctuate seasonally. The greatest amount of precipitation in the opportunity area occurs from October through March. Precipitation data from the Western Regional Climate Center show that October through March are the wettest months in the Lihue area of Kauai, with monthly averages above 4 inches. November, December, and January all have monthly averages above 5 inches. The months of April through September receive monthly averages less than 3 inches. June is the driest month, with 1.7 inches on average.

Location and water quality do not appear to be constraining issues.

Opportunity Area Characteristics. The EKIS crosses the Hanamaulu, Wailua, and Kapaa watersheds. Urban and residential areas are located along the coast and are surrounded by agricultural and open lands, which extend up into the foothills of Kilohana Crater. At higher elevations and slopes in the watershed, the land is open forest.

Soils in the Hanamaulu watershed have moderate infiltration rates. Lihue-Puhi association soils occur at the coastal lowlands, and are deep, nearly level to steep, well-drained soils that have a fine or moderately fine-textured subsoil. Inland from these soils are Kapaa-Pooku-Halii-Makapili association soils. These soils are deep, nearly level to steep, well-drained to moderately well-drained soils that have a fine to moderately fine-textured subsoil. Farther upslope are rough mountainous land, rough broken land, -rough outcrop association soils. These are well- to excessively well-drained soils on very steep, precipitous lands of mountains and gulches.

The EKIS serves lands of diversified agriculture, including taro crops, fruit trees, and cattle ranching. The sugar industry departed in 2000, and it has been a slow process transitioning the land to these new crops. Necessary maintenance activities were not performed prior to the sugar industry's departure. The East Kauai Water Users' Cooperative is actively trying to bring papaya growers to the area, and would need to provide an adequately maintained irrigation system.

Existing Irrigation Conveyance and Natural Stream Networks. Existing irrigation conveyance systems are composed of gravity ditches or pipes, operated ditches, and pressure pipes.

Three stream networks provide water sources for the EKIS—the Hanamaulu Stream, the Wailua River, and the Kapaa Stream.

Expected Demand Areas and Sizes. The EKIS land area available for diversified agriculture covers approximately 12,500 acres and three hydrologic units. The hydrologic units are Anahola (20104), 50 square miles; Wailua (20103), 52 square miles; and Hanamaulu (20102), 55 square miles. These basins have annual precipitation ranging from 50 inches in the coastal lowlands to 146 inches in the higher-elevation areas of the basins. The estimated average runoff from the three basins is 27 percent of the annual precipitation (Yuen, 1990). Stormwater that could be captured for storage in reservoirs and direct groundwater recharging for agricultural purposes across this 157-square-mile area is estimated at approximately 111,000 acre-feet. The volume exceeds what would be required across the area available for diversified agriculture.

The RZWBM (CH2M HILL, 2003) was used to estimate required reservoir storage size to serve the 12,500-acre area. Monthly rainfall averages for a 30-year period (1971 to 2000) from Wailua Kai 1065 Station (NOAA, 2002), and standard daily pan ET data from Lihue WSO AP 1020.1 Station, were used. The monthly pan ET values were converted to referenced grass ET using a multiplier of 0.7.

Based on the above-stated assumptions, the gross irrigation requirement was estimated at 25 inches. The model estimated that for an irrigated land size of 12,500 acres in the EKIS area served completely from surface storage of captured runoff, approximately 14,000 acre-feet of reservoir storage capacity is needed. The EKIS opportunity has a reservoir capacity of 905 acre-feet in place already (Waikua has 767 acre-feet, Upper Kapali has 92 acre-feet, and Lower Kapali has 77 acre-feet). There are five other reservoirs (Twin, Aahoaka, Kapaia, Ali, and Reservoir 21) of uncertain capacity. Assuming these reservoir capacities add up to at least half the capacity of the three for which capacities are known, the existing storage volume is approximately 1,400 acre-feet. Because no new reservoirs would be constructed for this opportunity, the existing reservoirs would need to be maintained so they remain available as the full 12,500 acres gradually returns to agricultural production. The reservoir capacity is less than required to meet full irrigation demand because run-of-the-river flows are available most of the year.

Estimated Costs

Table 2 provides estimated opportunity costs.

TABLE 2
Preliminary Cost Estimate for East Kauai Irrigation System Ditch Maintenance

Pay Item	Description	Amount
1	Lateral 8	$20,000
2	Hanamaulu Flume	$60,000
3	Twin Reservoir	$220,000
4	Upper Kapahi Reservoir	$220,000
5	Wailua Reservoir	$190,000
6	Reservoir 21	$10,000
	SUBTOTAL	$720,000
	Allowance for Unlisted Items (15% of subtotal)	$110,000
	Contract Cost	$830,000
	Contingency (25% of Contract Cost)	$210,000
	Field Cost	$1,040,000
	Engineering, Construction Management, and Right-of-Way Acquisition (35% of Field Cost)	$360,000
	Total Cost	**$1,400,000**

The Water Resource Associates Study (2003a) estimates that EKIS rehabilitation costs will total approximately $1,400,000. The Hawaii State Senate has appropriated $100,000 for fiscal year (FY) 2005-2006 and $100,000 for FY 2006-2007 for the East Kauai Water Users' Cooperative to operate and maintain the EKIS. The Hawaii State House of Representatives has appropriated $50,000 for FY 2005-2006 to operate and maintain the EKIS and to facilitate the development of diversified agriculture on Kauai. Rehabilitation will occur, but it is lower priority.

Institutional Factors Assessment

Land Use and Regulatory Factors. County: The Kauai Draft General Plan is the primary policy directing long-range development, conservation, and the use and allocation of land and water resources. The County created the Kauai Historic Preservation Review Commission (KHPRC) to coordinate reviews with SHPD. The Kauai Draft General Plan envisions that some old agricultural ditches and reservoirs would be maintained as part of the existing drainage/flood prevention system.

- Historic Preservation Concerns: Only a small portion of Kauai land area has been surveyed for archaeological resources. The County Planning Department works with KHPRC and SHPD to require evaluation of project sites for archaeological resources and provide a plan for preserving or salvaging any important site. Applicants typically hire a professional archaeologist to investigate and prepare a report. SHPD staff and Kauai Burials Council members report that archaeological resources or burials are often discovered during construction.

- Land Use: Approximately 60 percent of Hawaii's taro comes from the Hanalei Valley on Kauai.

Demographic Factors

- Socioeconomic: Tourism is the State's largest industry and the source of approximately 40 percent of Kauai's jobs. Recreation and tourism opportunities are plentiful (for example, kayaking, horse back riding, golf, and vacation communities in the area). Continued health of the Wailua Reservoir, which is part of the system, would assist the State's plans for a public fishing area, campground, and educational center for children in the area.

  Some recreational activities in the area (kayaking, hiking, some horseback groups) have negatively affected the burial and archaeological sites. Use permits on the Wailua River and restrictions on use in the area have been implemented (McMahan, 2005).

  Those involved in tourism favor expanded development. People who live in the watershed or those who have moved away but have family ties to the area have not been supportive of development. However, few families are left in the area. When the plantations managed the watershed area, access was more open. Now the access is controlled at the headwaters by Grove Farm Land Corp (McMahan, 2005).

  Kauai's population has increased from 29,800 in 1970 to approximately 56,600 in 1998. Because of the importance of tourism, the number of visitors to the island is taken into account when determining infrastructure and service needs.

Community and Cultural Factors

- Cultural Property: The EKIS watershed area has archaeological sites. Hawaiian Royals lived on Kauai, and there are several key archaeological sites.

  A monastery on the Wailua River uses the irrigation system for their landscaping.

  The Fern Grotto is located near the Wailua River and is a popular tourist attraction. Ferns at the Grotto dried up after a 10-year drought, but have been replanted in the last few years and are connected to an irrigation system from the Wailua Reservoir. The Fern Grotto is now maintained by the East Kauai Water Users Cooperative.

Generalized Rating Scales

Figures 1 and 2 provide a high-medium-low rating of technical and institutional potential for this opportunity.

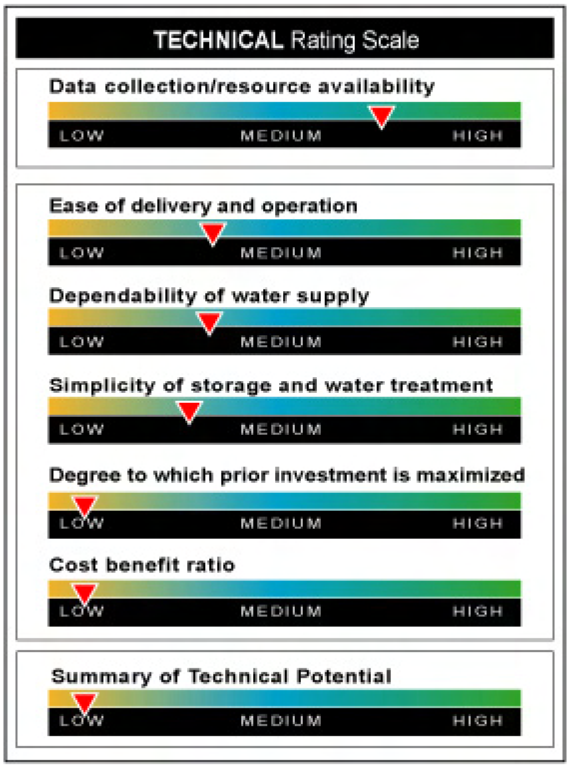


FIGURE 1. **Technical Rating Scale for East Kauai Irrigation System Ditch Maintenance**

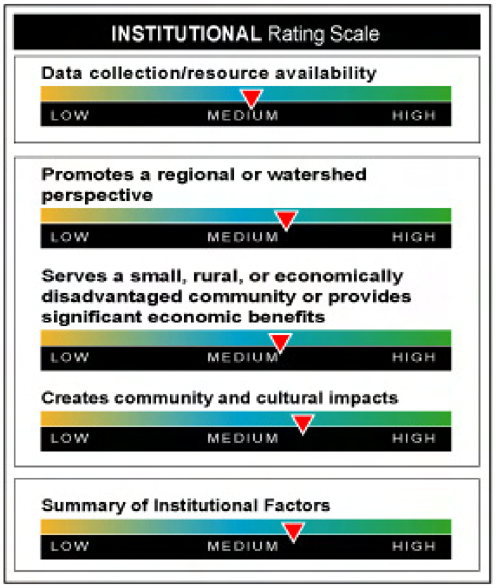


FIGURE 2. **Institutional Rating Scale for East Kauai Irrigation System Ditch Maintenance**

APPENDIX C

Water Balance Data

TABLE C-1
Water Balance Data

Total Annual	**Hawaii 1— Lower Hamakua Ditch/Waipio Valley***	**Hawaii 3— Pahala Catch Basins***	**Kauai 1—East Kauai Irrigation System Ditch Maintenance Project***	**Kauai 3—Lihue Garlinghouse Tunnel Potable Water Source**	**Kauai 4—Lihue Airport Landscape Irrigation Reuse***	**Maui 2— Site 1 (Southwest Maui Watershed Stabilization), and Site 2 (Central Maui Soil and Water Conservation)**	**Maui 4— Lahaina Watershed Project**	**Molokai— Molokai Irrigation System***	**Oahu 1—Waianae Agricultural Park***	**Oahu 4—Ewa Plains**
Precipitation (inches)	77	53	49	61	40	14	14	25	21	19
Evapotranspiration/Water Demand (inches)	64	64	68	NA	68	64	64	64	64	64
Reservoir Storage (acre-feet)	490	660	14,000	NA	41	20	5	580	25	NA
Irrigated Area (acres)	610	540	12,500	NA	30	100	100	240	10	225
New Water Supply (acre-feet)	590	980	27,800	1,800	87	4,950	600	1,020	45	880

Notes:
* Detailed water balances are provided in this appendix for projects with storage reservoirs and irrigation.
NA = Not applicable.

Root Zone Water Balance Working Model

Project Name: LHD (Hawaii Site 1)
Project Number: 320074.HR.04.ML

Designer: S. Asare/Emond
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	9.79	5.49	10.44	9.07	4.43	3.58	5.44	4.48	3.34	4.87	9.02	6.62	76.57
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	1.96	0.55	0.52	0.45	0.00	0.00	0.00	0.00	0.00	0.24	0.90	0.99	5.62
Effective Rainfall	[in]	7.83	4.94	9.92	8.62	4.43	3.58	5.44	4.48	3.34	4.63	8.12	5.63	70.95
Other Sources Available	[in]	1.49	0.83	1.58	1.38	0.67	0.54	0.83	0.68	0.51	0.74	1.37	1.00	11.62
	[MG]	24.50	13.74	26.12	22.70	11.09	8.96	13.61	11.21	8.36	12.19	22.57	16.57	191.61
	[mgd]	0.79	0.49	0.84	0.76	0.36	0.30	0.44	0.36	0.28	0.39	0.75	0.53	
	[ac-ft]	75.18	42.16	80.17	69.65	34.02	27.49	41.78	34.40	25.65	37.40	69.27	50.84	588.02
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Actual Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Net Irrigation Requirement	[in]	0.00	0.00	0.00	0.00	1.79	3.02	1.63	2.60	2.84	0.76	0.00	0.00	12.65
Gross Irrigation Requirement	[in]	0.00	0.00	0.00	0.00	1.79	3.02	1.63	2.60	2.84	0.76	0.00	0.00	12.65
	[MG]	0.00	0.00	0.00	0.00	29.58	49.84	26.89	42.96	46.87	12.60	0.00	0.00	208.75
	[ac-ft]	0.00	0.00	0.00	0.00	90.79	152.96	82.53	131.85	143.85	38.66	0.00	0.00	640.64
Total Irrigation Applied	[in]	0.00	0.00	0.00	0.00	1.79	3.02	1.63	2.60	2.84	0.76	0.00	0.00	12.65
	[MG]	0.00	0.00	0.00	0.00	29.59	49.85	26.90	42.97	46.88	12.60	0.00	0.00	208.78
	[ac-ft]	0.00	0.00	0.00	0.00	90.80	152.99	82.54	131.87	143.87	38.66	0.00	0.00	640.74
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	9.79	5.49	10.44	9.07	4.43	3.58	5.44	4.48	3.34	4.87	9.02	6.62	76.57
Reservoir Evaporation	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Peak Precipitation - Reservoir Evaporation	[in]	6.49	1.81	5.52	3.57	-1.79	-3.02	-1.63	-2.60	-2.84	-0.52	4.86	3.06	12.89
	[MG]	8.64	2.41	7.35	4.75	-2.39	-4.03	-2.17	-3.47	-3.79	-0.69	6.47	4.08	17.18
Transfer of Other Sources to Reservoir	[MG]	24.50	13.74	26.12	22.70	11.09	8.96	13.61	11.21	8.36	12.19	22.57	16.57	191.61
Change in Reservoir Storage	[MG]	33.14	16.15	33.48	27.45	-20.89	-44.92	-15.46	-35.23	-42.31	-1.11	29.04	20.65	0.00
Cumulative Active Storage	[MG]	82.83	98.98	132.46	159.91	139.02	94.10	78.64	43.41	1.11	0.00	29.04	49.69	
	[ac-ft]	254.20	303.75	406.50	490.74	426.63	288.78	241.35	133.23	3.39	0.00	89.12	152.49	

Reservoir Area = 49.07 acres

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	4.5	1.3	5.0	3.1	0.0	0.0	0.0	0.0	0.0	0.0	4.0	2.1	19.9
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 608 acres

Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches
Available Water Holding Capacity = 2.52 inches
Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

General Design Parameters

Notes:

Crop Parameters

Depletion Fraction	[-]	0.50
Rooting Depth	[ft]	3.0

Depletion Fraction - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.

Soil Parameters

Field Capacity	[in/in]	0.13
Permanent Wilting Point	[in/in]	0.06
Initial Water Content (January)	[in/in]	0.13

Field Capacity - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity.*All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*

Irrigation System Parameters

Combined Irrigation Application Efficiency	[-]	1.00

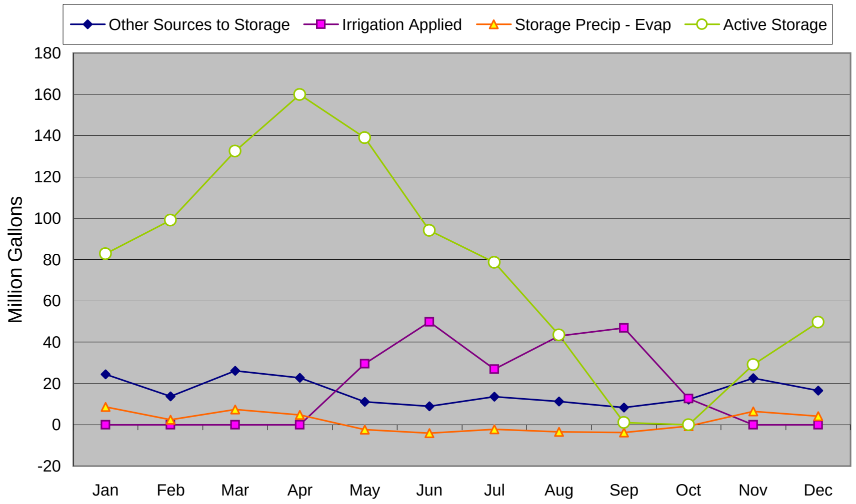
Combined Irrigation Application Efficiency - (average depth of water infiltrated and retained in the root zone following irrigation) / (average depth of water applied). *See "Calc-Irrig Applic Efficiency" for guidelines on estimating. ***must be greater than zero and less than or equal to 1.0*

Storage Constraints

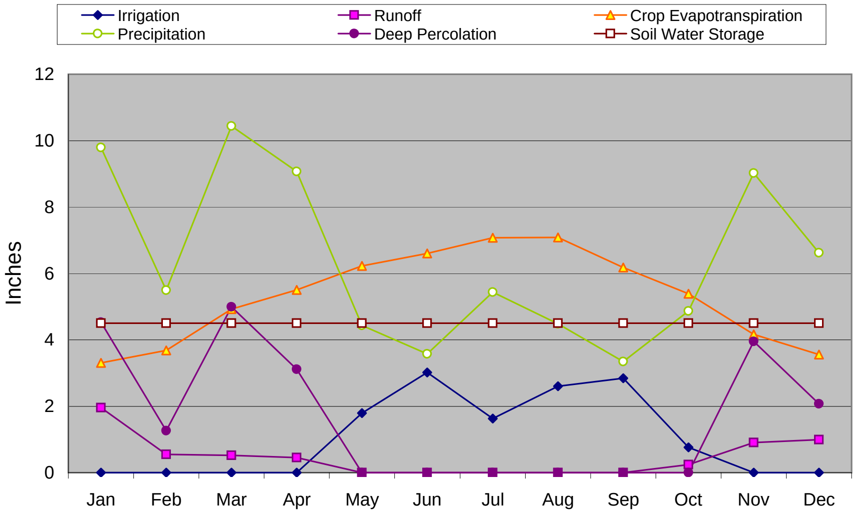
Limiting Reservoir Depth	[ft]	10.00

Limiting Reservoir Depth - Maximum allowable depth for reservoir facilties. ***must be greater than zero

RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART



Root Zone Water Balance Working Model

Project Name: Pahala I.D. (Hawaii Site 3)
Project Number: 320074.HR.04.ML

Designer: S. Asare/Smesrud
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	5.74	4.46	5.50	3.71	1.80	1.37	3.87	3.48	4.95	4.77	7.95	4.86	52.46
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	1.15	0.45	0.28	0.19	0.00	0.00	0.00	0.00	0.00	0.24	0.80	0.73	3.82
Effective Rainfall	[in]	4.59	4.01	5.23	3.52	1.80	1.37	3.87	3.48	4.95	4.53	7.16	4.13	48.64
Other Sources Available	[in]	2.40	1.86	2.30	1.55	0.75	0.57	1.62	1.45	2.07	1.99	3.32	2.03	21.91
	[MG]	34.91	27.13	33.45	22.56	10.95	8.33	23.54	21.17	30.11	29.01	48.35	29.56	319.07
	[mgd]	1.13	0.97	1.08	0.75	0.35	0.28	0.76	0.68	1.00	0.94	1.61	0.95	
	[ac-ft]	107.14	83.25	102.66	69.25	33.60	25.57	72.24	64.96	92.39	89.03	148.39	90.71	979.19
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Actual Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Net Irrigation Requirement	[in]	0.00	0.00	0.00	1.98	4.42	5.23	3.20	3.60	1.23	0.86	0.00	0.00	20.53
Gross Irrigation Requirement	[in]	0.00	0.00	0.00	1.98	4.42	5.23	3.20	3.60	1.23	0.86	0.00	0.00	20.53
	[MG]	0.00	0.00	0.00	28.80	64.42	76.19	46.61	52.49	17.93	12.50	0.00	0.00	298.96
	[ac-ft]	0.00	0.00	0.00	88.39	197.71	233.82	143.04	161.10	55.03	38.37	0.00	0.00	917.46
Total Irrigation Applied	[in]	0.00	0.00	0.00	1.98	4.42	5.23	3.20	3.60	1.23	0.86	0.00	0.00	20.53
	[MG]	0.00	0.00	0.00	28.81	64.43	76.20	46.62	52.50	17.93	12.51	0.00	0.00	299.00
	[ac-ft]	0.00	0.00	0.00	88.41	197.74	233.86	143.06	161.12	55.03	38.38	0.00	0.00	917.60
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	5.74	4.46	5.50	3.71	1.80	1.37	3.87	3.48	4.95	4.77	7.95	4.86	52.46
Reservoir Evaporation	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Peak Precipitation - Reservoir Evaporation	[in]	2.44	0.78	0.58	-1.79	-4.42	-5.23	-3.20	-3.60	-1.23	-0.62	3.79	1.30	-11.22
	[MG]	4.36	1.39	1.04	-3.21	-7.91	-9.36	-5.72	-6.45	-2.20	-1.11	6.77	2.33	-20.07
Transfer of Other Sources to Reservoir	[MG]	34.91	27.13	33.45	22.56	10.95	8.33	23.54	21.17	30.11	29.01	48.35	29.56	319.07
Change in Reservoir Storage	[MG]	39.27	28.52	34.49	-9.45	-61.40	-77.23	-28.80	-37.78	9.97	15.40	55.12	31.89	0.00
Cumulative Active Storage	[MG]	151.65	180.17	214.66	205.21	143.81	66.59	37.78	0.00	9.97	25.37	80.49	112.38	
	[ac-ft]	465.41	552.92	658.76	629.77	441.35	204.34	115.95	0.00	30.60	77.85	247.02	344.89	

Reservoir Area = 65.88 acres

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	1.3	0.3	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.6	5.5
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 536 acres

Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches

Available Water Holding Capacity = 2.52 inches

Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

General Design Parameters

Crop Parameters		
Depletion Fraction	[-]	0.50
Rooting Depth	[ft]	3.0
Soil Parameters		
Field Capacity	[in/in]	0.13
Permanent Wilting Point	[in/in]	0.06
Initial Water Content (January)	[in/in]	0.13
Irrigation System Parameters		
Combined Irrigation Application Efficiency	[-]	1.00
Storage Constraints		
Limiting Reservoir Depth	[ft]	10.00

Notes:

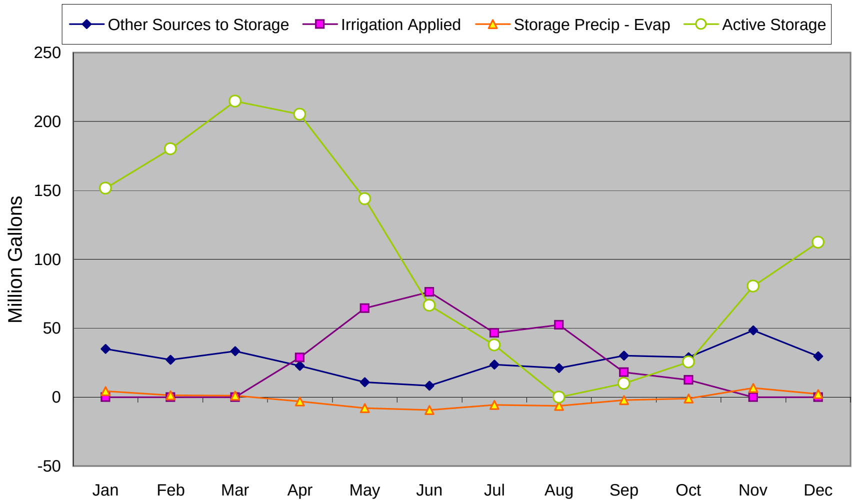
Depletion Fraction - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.

Field Capacity - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity.*All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*

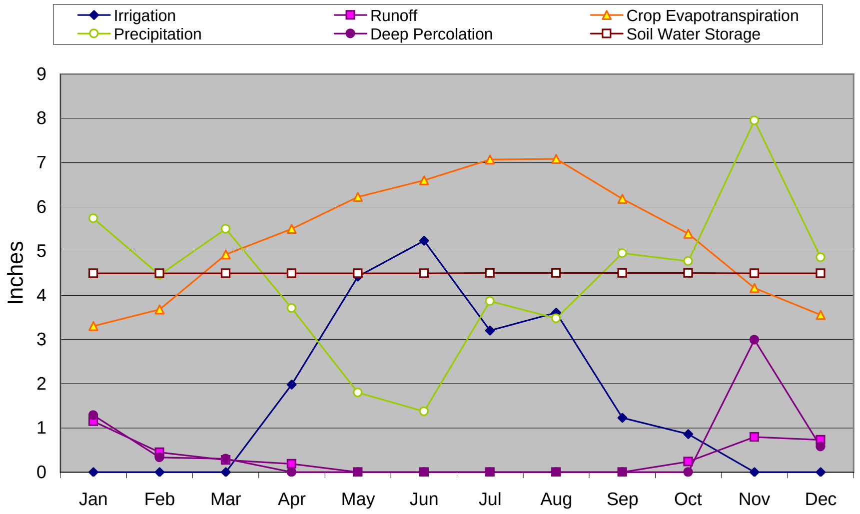
Combined Irrigation Application Efficiency - (average depth of water infiltrated and retained in the root zone following irrigation) / (average depth of water applied). *See "Calc-Irrig Applic Efficiency" for guidelines on estimating. ***must be greater than zero and less than or equal to 1.0*

Limiting Reservoir Depth - Maximum allowable depth for reservoir facilties. ***must be greater than zero

RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART



Root Zone Water Balance Working Model

Project Name: EKIS Ditch Maint. (Kauai Site 1)
Project Number: 320074.HR.04.ML

Designer: S. Asare/Smesrud
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	5.34	3.97	4.04	4.28	3.65	2.54	2.92	2.91	2.84	4.50	6.71	5.37	49.07
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	1.07	0.40	0.20	0.21	0.00	0.00	0.00	0.00	0.00	0.23	0.67	0.81	3.58
Effective Rainfall	[in]	4.27	3.57	3.84	4.07	3.65	2.54	2.92	2.91	2.84	4.28	6.04	4.56	45.49
Other Sources Available	[in]	2.90	2.16	2.19	2.32	1.98	1.38	1.59	1.58	1.54	2.44	3.64	2.92	26.64
	[MG]	983.57	731.23	744.12	788.33	672.29	467.84	537.83	535.99	523.10	828.85	1235.91	989.10	9038.16
	[mgd]	31.73	26.12	24.00	26.28	21.69	15.59	17.35	17.29	17.44	26.74	41.20	31.91	
	[ac-ft]	3018.47	2244.07	2283.64	2419.30	2063.19	1435.75	1650.55	1644.90	1605.33	2543.65	3792.87	3035.43	27737.13
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Actual Crop Evapotranspiration	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Net Irrigation Requirement	[in]	0.00	0.76	1.50	1.67	2.78	4.37	4.34	4.22	3.58	1.35	0.00	0.00	24.58
Gross Irrigation Requirement	[in]	0.00	0.76	1.50	1.67	2.78	4.37	4.34	4.22	3.58	1.35	0.00	0.00	24.58
	[MG]	0.00	257.96	510.14	568.19	942.22	1482.92	1472.73	1433.36	1214.78	459.23	0.00	0.00	8341.53
	[ac-ft]	0.00	791.64	1565.58	1743.70	2891.58	4550.91	4519.66	4398.83	3728.01	1409.33	0.00	0.00	25599.23
Total Irrigation Applied	[in]	0.00	0.76	1.50	1.67	2.78	4.37	4.34	4.22	3.58	1.35	0.00	0.00	24.58
	[MG]	0.00	258.00	510.22	568.27	942.37	1483.14	1472.95	1433.58	1214.96	459.30	0.00	0.00	8342.78
	[ac-ft]	0.00	791.76	1565.81	1743.96	2892.01	4551.59	4520.34	4399.49	3728.57	1409.54	0.00	0.00	25603.08
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	5.34	3.97	4.04	4.28	3.65	2.54	2.92	2.91	2.84	4.50	6.71	5.37	49.07
Reservoir Evaporation	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Peak Precipitation - Reservoir Evaporation	[in]	1.42	-0.36	-1.30	-1.46	-2.78	-4.37	-4.34	-4.22	-3.58	-1.13	2.32	1.42	-18.38
	[MG]	53.72	-13.73	-49.22	-55.23	-105.01	-165.28	-164.14	-159.75	-135.39	-42.67	87.80	53.53	-695.38
Transfer of Other Sources to Reservoir	[MG]	983.57	731.23	744.12	788.33	672.29	467.84	537.83	535.99	523.10	828.85	1235.91	989.10	9038.16
Change in Reservoir Storage	[MG]	1037.29	459.50	184.69	164.83	-375.09	-1180.57	-1099.26	-1057.34	-827.25	326.88	1323.71	1042.62	0.00
Cumulative Active Storage	[MG]	3730.50	4190.00	4374.69	4539.52	4164.43	2983.86	1884.59	827.25	0.00	326.88	1650.59	2693.21	
	[ac-ft]	11448.50	12858.66	13425.45	13931.29	12780.18	9157.13	5783.61	2538.75	0.00	1003.15	5065.48	8265.18	

Reservoir Area = 1393.13 acres

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.6	2.6
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 12500 acres

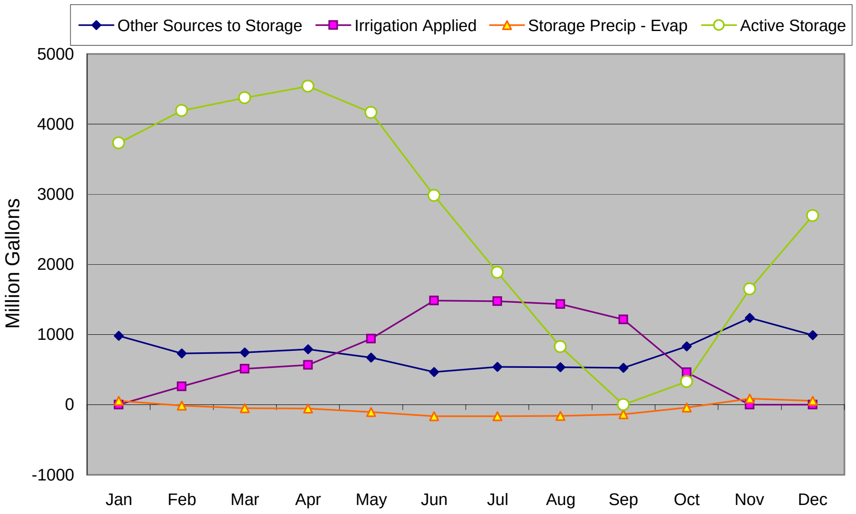
Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches
Available Water Holding Capacity = 2.52 inches
Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

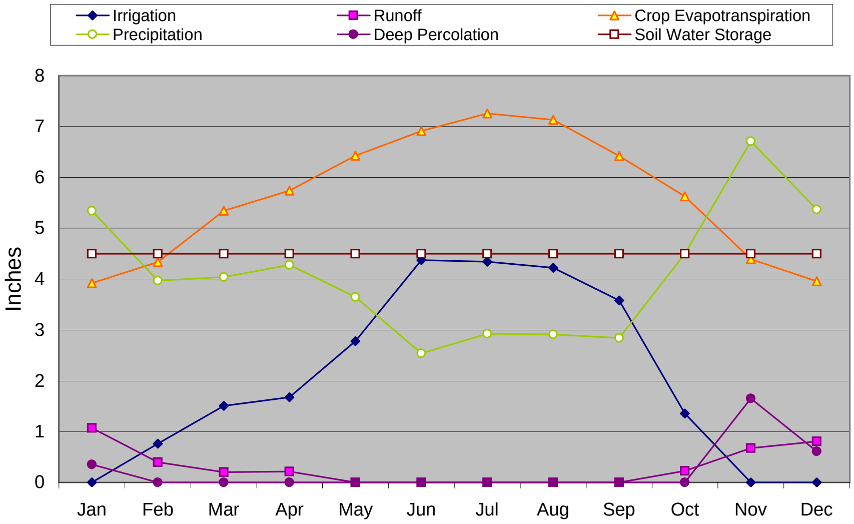
General Design Parameters

Crop Parameters			**Notes:**
Depletion Fraction	[-]	0.50	*Depletion Fraction* - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.
Rooting Depth	[ft]	3.0	
Soil Parameters			
Field Capacity	[in/in]	0.13	*Field Capacity* - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity. *All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*
Permanent Wilting Point	[in/in]	0.06	
Initial Water Content (January)	[in/in]	0.13	
Irrigation System Parameters			
Combined Irrigation Application Efficiency	[-]	1.00	*Combined Irrigation Application Efficiency* - (average depth of water infiltrated and retained in the root zone following irrigation) / (average depth of water applied). *See "Calc-Irrig Applic Efficiency" for guidelines on estimating. ***must be greater than zero and less than or equal to 1.0*
Storage Constraints			
Limiting Reservoir Depth	[ft]	10.00	*Limiting Reservoir Depth* - Maximum allowable depth for reservoir facilties. ***must be greater than zero

RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART



Root Zone Water Balance Working Model

Project Name: Lihue AirportLIR (Kauai Site 4)
Project Number: 320074.HR.04.ML

Designer: S. Asare/Smesrud
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	4.59	3.26	3.58	3.00	2.87	1.82	2.12	1.91	2.69	4.25	4.70	4.78	39.57
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	0.92	0.33	0.18	0.15	0.00	0.00	0.00	0.00	0.00	0.21	0.47	0.72	2.97
Effective Rainfall	[in]	3.67	2.93	3.40	2.85	2.87	1.82	2.12	1.91	2.69	4.04	4.23	4.06	36.60
Other Sources Available	[in]	4.04	2.87	3.15	2.64	2.52	1.60	1.86	1.68	2.37	3.74	4.13	4.20	34.80
	[MG]	3.28	2.33	2.56	2.14	2.05	1.30	1.51	1.36	1.92	3.04	3.36	3.42	28.28
	[mgd]	0.11	0.08	0.08	0.07	0.07	0.04	0.05	0.04	0.06	0.10	0.11	0.11	
	[ac-ft]	10.07	7.15	7.85	6.58	6.29	3.99	4.65	4.19	5.90	9.32	10.31	10.48	86.78
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Actual Crop Evapotranspiration	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Net Irrigation Requirement	[in]	0.25	1.40	1.94	2.89	3.56	5.09	5.14	5.22	3.73	1.59	0.16	0.00	30.96
Gross Irrigation Requirement	[in]	0.25	1.40	1.94	2.89	3.56	5.09	5.14	5.22	3.73	1.59	0.16	0.00	30.96
	[MG]	0.20	1.14	1.58	2.35	2.89	4.14	4.18	4.25	3.03	1.29	0.13	0.00	25.17
	[ac-ft]	0.62	3.49	4.84	7.21	8.87	12.69	12.82	13.03	9.30	3.97	0.40	0.00	77.23
Total Irrigation Applied	[in]	0.25	1.40	1.94	2.89	3.56	5.09	5.14	5.22	3.73	1.59	0.16	0.00	30.96
	[MG]	0.20	1.14	1.58	2.35	2.89	4.14	4.18	4.25	3.03	1.29	0.13	0.00	25.17
	[ac-ft]	0.62	3.49	4.84	7.21	8.87	12.70	12.82	13.03	9.30	3.97	0.40	0.00	77.24
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	4.59	3.26	3.58	3.00	2.87	1.82	2.12	1.91	2.69	4.25	4.70	4.78	39.57
Reservoir Evaporation	[in]	3.92	4.33	5.34	5.74	6.43	6.91	7.26	7.13	6.42	5.63	4.39	3.96	67.45
Peak Precipitation - Reservoir Evaporation	[in]	0.67	-1.07	-1.76	-2.74	-3.56	-5.09	-5.14	-5.22	-3.73	-1.38	0.31	0.83	-27.88
	[MG]	0.07	-0.12	-0.20	-0.31	-0.40	-0.57	-0.57	-0.58	-0.42	-0.15	0.03	0.09	-3.11
Transfer of Other Sources to Reservoir	[MG]	3.28	2.33	2.56	2.14	2.05	1.30	1.51	1.36	1.92	3.04	3.36	3.42	28.28
Change in Reservoir Storage	[MG]	3.15	1.07	0.79	-0.51	-1.24	-3.40	-3.24	-3.46	-1.52	1.59	3.26	3.51	0.00
Cumulative Active Storage	[MG]	11.52	12.59	13.37	12.86	11.63	8.22	4.99	1.52	0.00	1.59	4.85	8.36	
	[ac-ft]	35.34	38.63	41.04	39.47	35.68	25.24	15.31	4.68	0.00	4.88	14.90	25.66	

Reservoir Area = 4.10 acres

Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 30 acres

Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches
Available Water Holding Capacity = 2.52 inches
Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

General Design Parameters

Crop Parameters
Depletion Fraction [-] 0.50
Rooting Depth [ft] 3.0

Soil Parameters
Field Capacity [in/in] 0.13
Permanent Wilting Point [in/in] 0.06
Initial Water Content (January) [in/in] 0.13

Irrigation System Parameters
Combined Irrigation Application Efficiency [-] 1.00

Storage Constraints
Limiting Reservoir Depth [ft] 10.00

Notes:

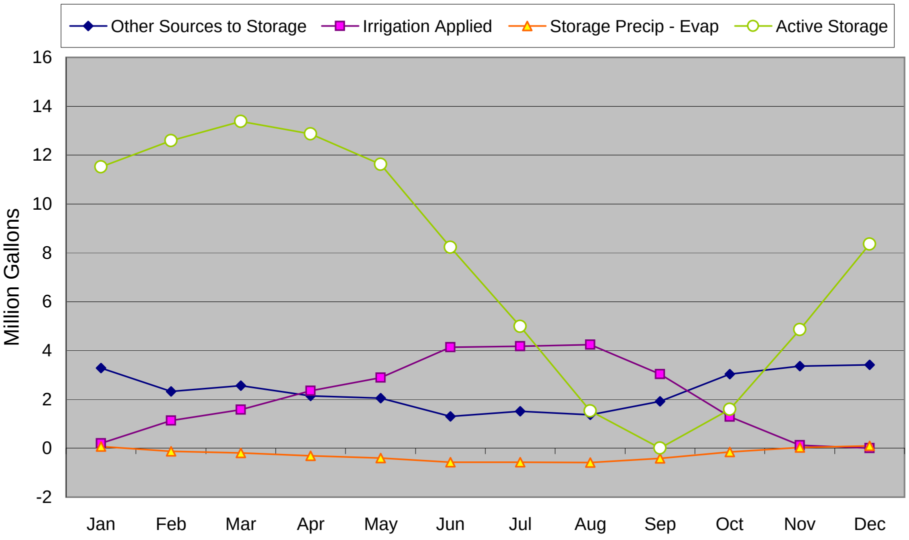
Depletion Fraction - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.

Field Capacity - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity. *All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*

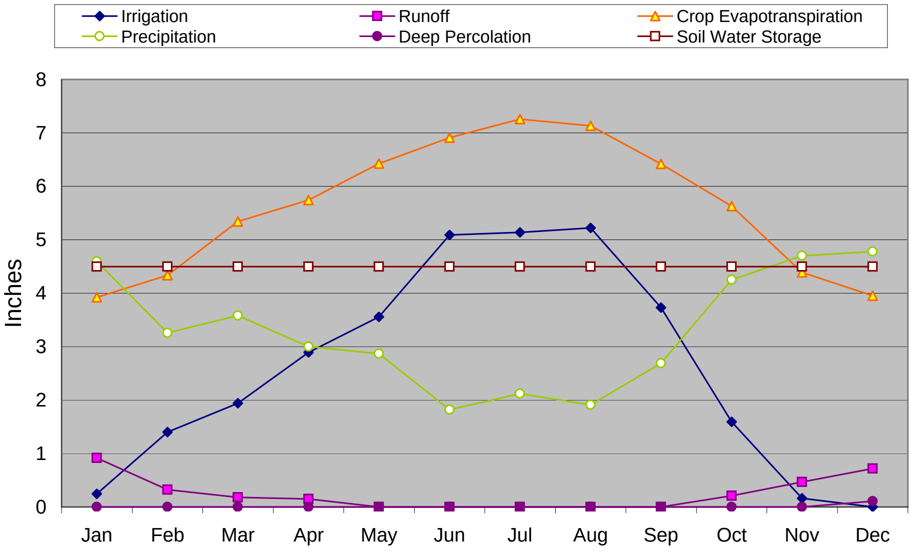
Combined Irrigation Application Efficiency - (average depth of water infiltrated and retained in the root zone following irrigation) / (average depth of water applied). *See "Calc-Irrig Applic Efficiency" for guidelines on estimating. ***must be greater than zero and less than or equal to 1.0*

Limiting Reservoir Depth - Maximum allowable depth for reservoir facilties. ***must be greater than zero

RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART



Root Zone Water Balance Working Model

Project Name: Molokai Irrigation System (Molokai 1
Project Number: 320074.HR.04.ML

Designer: S. Asare/Smesrud
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	3.74	3.65	2.51	2.10	1.41	0.66	0.59	0.61	0.76	1.78	2.83	4.00	24.64
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	0.75	0.37	0.13	0.11	0.00	0.00	0.00	0.00	0.00	0.09	0.28	0.60	2.32
Effective Rainfall	[in]	2.99	3.29	2.38	2.00	1.41	0.66	0.59	0.61	0.76	1.69	2.55	3.40	22.32
Other Sources Available	[in]	7.70	7.51	5.17	4.32	2.90	1.36	1.21	1.26	1.56	3.66	5.83	8.23	50.72
	[MG]	50.54	49.32	33.92	28.38	19.05	8.92	7.97	8.24	10.27	24.05	38.24	54.05	332.95
	[mgd]	1.63	1.76	1.09	0.95	0.61	0.30	0.26	0.27	0.34	0.78	1.27	1.74	
	[ac-ft]	155.09	151.36	104.09	87.09	58.47	27.37	24.47	25.30	31.52	73.82	117.36	165.88	1021.80
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Actual Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Net Irrigation Requirement	[in]	0.31	0.40	2.54	3.51	4.81	5.94	6.48	6.47	5.42	3.70	1.62	0.16	41.35
Gross Irrigation Requirement	[in]	0.31	0.40	2.54	3.51	4.81	5.94	6.48	6.47	5.42	3.70	1.62	0.16	41.35
	[MG]	2.05	2.61	16.66	23.03	31.61	39.01	42.55	42.51	35.60	24.29	10.63	1.02	271.57
	[ac-ft]	6.29	8.00	51.12	70.68	97.00	119.73	130.59	130.47	109.25	74.55	32.61	3.14	833.43
Total Irrigation Applied	[in]	0.31	0.40	2.54	3.51	4.81	5.94	6.48	6.47	5.42	3.70	1.62	0.16	41.35
	[MG]	2.05	2.61	16.66	23.03	31.61	39.02	42.56	42.52	35.61	24.29	10.63	1.02	271.62
	[ac-ft]	6.29	8.00	51.13	70.69	97.01	119.75	130.61	130.49	109.27	74.56	32.61	3.14	833.56
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	3.74	3.65	2.51	2.10	1.41	0.66	0.59	0.61	0.76	1.78	2.83	4.00	24.64
Reservoir Evaporation	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Peak Precipitation - Reservoir Evaporation	[in]	0.44	-0.03	-2.41	-3.40	-4.81	-5.94	-6.48	-6.47	-5.42	-3.61	-1.34	0.44	-39.04
	[MG]	0.69	-0.05	-3.79	-5.35	-7.56	-9.33	-10.18	-10.17	-8.52	-5.67	-2.10	0.70	-61.34
Transfer of Other Sources to Reservoir	[MG]	50.54	49.32	33.92	28.38	19.05	8.92	7.97	8.24	10.27	24.05	38.24	54.05	332.95
Change in Reservoir Storage	[MG]	49.17	46.66	13.47	0.00	-20.12	-39.44	-44.77	-44.45	-33.85	-5.91	25.52	53.72	0.00
Cumulative Active Storage	[MG]	128.41	175.08	188.55	188.54	168.42	128.99	84.22	39.77	5.91	0.00	25.52	79.24	
	[ac-ft]	394.09	537.30	578.63	578.62	516.87	395.85	258.45	122.04	18.15	0.00	78.31	243.18	

Reservoir Area = 57.86 acres

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 242 acres

Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches
Available Water Holding Capacity = 2.52 inches
Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

General Design Parameters

Notes:

Crop Parameters

Depletion Fraction	[-]	0.50
Rooting Depth	[ft]	3.0

Depletion Fraction - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.

Soil Parameters

Field Capacity	[in/in]	0.13
Permanent Wilting Point	[in/in]	0.06
Initial Water Content (January)	[in/in]	0.13

Field Capacity - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity. *All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*

Irrigation System Parameters

Combined Irrigation Application Efficiency	[-]	1.00

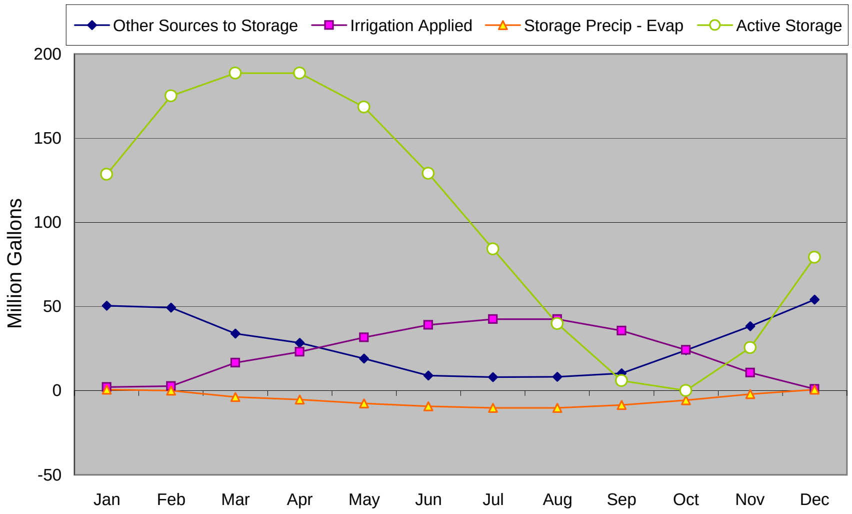
Combined Irrigation Application Efficiency - (average depth of water infiltrated and retained in the root zone following irrigation) / (average depth of water applied). *See "Calc-Irrig Applic Efficiency" for guidelines on estimating. ***must be greater than zero and less than or equal to 1.0*

Storage Constraints

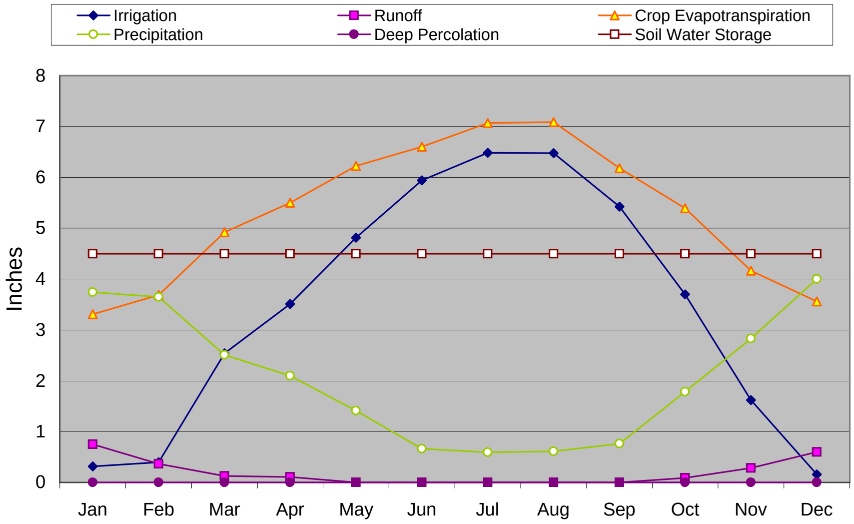
Limiting Reservoir Depth	[ft]	10.00

Limiting Reservoir Depth - Maximum allowable depth for reservoir facilties. ***must be greater than zero

RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART



Root Zone Water Balance Working Model

Project Name: Waianae Agric Park (Oahu Site 1)
Project Number: 320074.HR.04.ML

Designer: S. Asare/Smesrud
Crop: Unspecified

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Days/Month	31	28	31	30	31	30	31	31	30	31	30	31	365
Water Supply														
Average Precipitation	[in]	3.54	2.66	1.59	0.85	0.81	0.63	0.63	0.56	0.94	2.96	2.57	3.19	20.93
% Effective Precipitation	[%]	80%	90%	95%	95%	100%	100%	100%	100%	100%	95%	90%	85%	
Surface Runoff	[in]	0.71	0.27	0.08	0.04	0.00	0.00	0.00	0.00	0.00	0.15	0.26	0.48	1.98
Effective Rainfall	[in]	2.83	2.39	1.51	0.81	0.81	0.63	0.63	0.56	0.94	2.81	2.31	2.71	18.95
Other Sources Available	[in]	9.47	7.11	4.25	2.27	2.17	1.68	1.68	1.50	2.51	7.92	6.87	8.53	55.97
	[MG]	2.50	1.88	1.12	0.60	0.57	0.44	0.44	0.40	0.66	2.09	1.81	2.25	14.77
	[mgd]	0.08	0.07	0.04	0.02	0.02	0.01	0.01	0.01	0.02	0.07	0.06	0.07	
	[ac-ft]	7.66	5.76	3.44	1.84	1.75	1.36	1.36	1.21	2.04	6.41	5.56	6.91	45.32
Other Sources Flow to Irrigation/Storage?	(Y/N)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Irrigation Requirements and Management														
Potential Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Actual Crop Evapotranspiration	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Net Irrigation Requirement	[in]	0.47	1.29	3.41	4.69	5.41	5.97	6.44	6.52	5.24	2.58	1.85	0.84	44.73
Gross Irrigation Requirement	[in]	0.47	1.29	3.41	4.69	5.41	5.97	6.44	6.52	5.24	2.58	1.85	0.84	44.73
	[MG]	0.12	0.34	0.90	1.24	1.43	1.58	1.70	1.72	1.38	0.68	0.49	0.22	11.80
	[ac-ft]	0.38	1.04	2.76	3.80	4.38	4.84	5.22	5.28	4.24	2.09	1.50	0.68	36.22
Total Irrigation Applied	[in]	0.47	1.29	3.41	4.69	5.41	5.97	6.44	6.52	5.24	2.58	1.85	0.84	44.73
	[MG]	0.12	0.34	0.90	1.24	1.43	1.58	1.70	1.72	1.38	0.68	0.49	0.22	11.81
	[ac-ft]	0.38	1.04	2.76	3.80	4.38	4.84	5.22	5.28	4.25	2.09	1.50	0.68	36.23
Irrigation Losses	[in]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Reservoir Storage Water Balance														
Peak Precipitation	[in]	3.54	2.66	1.59	0.85	0.81	0.63	0.63	0.56	0.94	2.96	2.57	3.19	20.93
Reservoir Evaporation	[in]	3.30	3.68	4.92	5.50	6.22	6.60	7.07	7.08	6.18	5.39	4.17	3.56	63.68
Peak Precipitation - Reservoir Evaporation	[in]	0.24	-1.02	-3.33	-4.65	-5.41	-5.97	-6.44	-6.52	-5.24	-2.43	-1.60	-0.37	-42.75
	[MG]	0.02	-0.07	-0.23	-0.32	-0.37	-0.41	-0.45	-0.45	-0.36	-0.17	-0.11	-0.03	-2.96
Transfer of Other Sources to Reservoir	[MG]	2.50	1.88	1.12	0.60	0.57	0.44	0.44	0.40	0.66	2.09	1.81	2.25	14.77
Change in Reservoir Storage	[MG]	2.39	1.47	-0.01	-0.96	-1.23	-1.55	-1.70	-1.78	-1.08	1.24	1.21	2.00	0.00
Cumulative Active Storage	[MG]	6.85	8.31	8.30	7.34	6.11	4.56	2.86	1.08	0.00	1.24	2.45	4.46	
	[ac-ft]	21.01	25.51	25.48	22.53	18.75	14.00	8.78	3.32	0.00	3.80	7.53	13.67	

Reservoir Area = 2.55 acres

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Soil Profile Water Balance														
Beginning Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Ending Soil Moisture	[in]	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	
Deep Percolation	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Crop Needs Not Met - Monthly	[in]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
- percent of gross irrig req	[%]	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	

Irrigated Land = 10 acres

Soil Water Storage at Field Capacity = 4.50 inches

Soil Water Storage at Permanent Wilting Point = 1.98 inches
Available Water Holding Capacity = 2.52 inches
Soil Water Storage at Minimum Management Allowed Soil Moisture = 3.24 inches

General Design Parameters

Crop Parameters		
Depletion Fraction	[-]	0.50
Rooting Depth	[ft]	3.0
Soil Parameters		
Field Capacity	[in/in]	0.13
Permanent Wilting Point	[in/in]	0.06
Initial Water Content (January)	[in/in]	0.13
Irrigation System Parameters		
Combined Irrigation Application Efficiency	[-]	1.00
Storage Constraints		
Limiting Reservoir Depth	[ft]	10.00

Notes:

Depletion Fraction - Average fraction of total available soil water that can be depleted from the root zone before moisture stress resulting in ET reduction occurs.

Field Capacity - Defined as the water held at a tension of 0.33 Bar. *Permanent Wilting Point* - Defined as the water held at a tension of 15 Bar. *Initial Water Content* - Water content in the root zone for January used to initialize the model. In most Northern Hemisphere irrigated systems, this should be set equal to the field capacity. *All water content measurements expressed in inches of water per inch of rooting depth. See " Ref-Soil Properties" for typical values of field capacity and permanent wilting point for USDA soil textures.*

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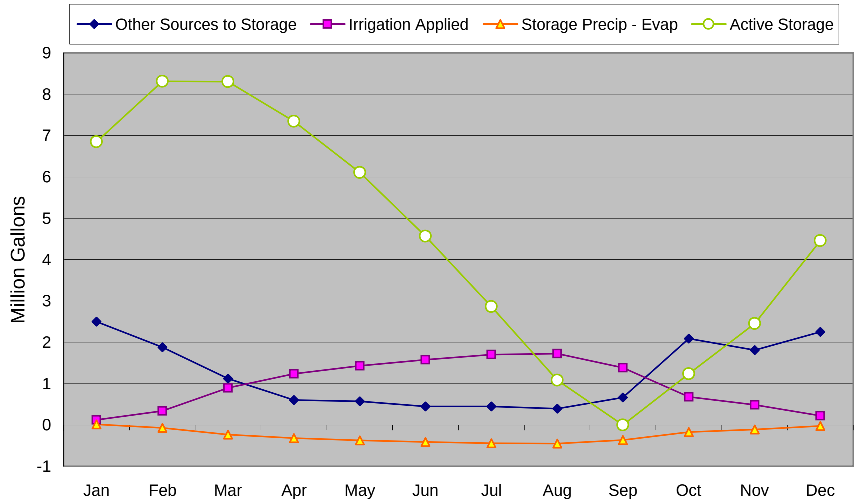
RESERVOIR WATER BALANCE CHART



ROOT ZONE WATER BALANCE CHART