WEST MAUI WATERSHED

Management Plan (*DRAFT*)

June 2021

US Army Corps of Engineers
Honolulu District

State of Hawaiʻi
Department of Land and Natural Resources
Division of Aquatic Resources

Cover Photo: USGS, 2009

DISCLAIMER: The information presented in this document is to provide a strategic framework of potential options to address problems within the West Maui watershed. Options identified will follow normal authorization and budgetary processes of the appropriate agencies. Any costs presented in this document are rough order magnitude estimates used for screening purposes only.

EXECUTIVE SUMMARY

Study Authority

The Honolulu District, U.S. Army Corps of Engineers (USACE) is partnered with the State of Hawai'i Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR) to jointly pursue watershed planning efforts for the West Maui watershed, Island of Maui, Hawai'i, in accordance with Section 729 of the Water Resources Development Act (WRDA) of 1986, Public Law 99-662, as amended (33 U.S.C. 2267a; hereinafter "Section 729"). Section 729 authorizes the development of watershed plans that are multi-purpose and multi-objective in scope and developed in cooperation with Federal, State and local government entities.

Non-Federal Sponsor

The Non-Federal Sponsor for the West Maui Watershed Management Plan is the State of Hawai'i, as represented by DLNR-DAR. DLNR-DAR manages the state's aquatic resources and ecosystems through programs in ecosystem management, place-based management, and fisheries management with a mission to work with the people of Hawai'i to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations. DLNR-DAR and USACE entered into a cost-share agreement on August 9, 2012 to assess the water resources needs of the West Maui watershed pursuant to Section 729.

Interagency Coordination and Collaboration

USACE collaborated the development of the West Maui Watershed Management Plan with the West Maui Ridge to Reef (R2R) Initiative to develop the watershed study objective used as the Shared Vision for this study. The West Maui R2R working group and FAST consist of members from the following agencies and organizations: Mauna Kahālāwai Watershed Partnership, Maui Cultural Lands, Ka'anapali Operators Association, Coral Reef Alliance, County of Maui (COM) Department of Public Works, University of Hawai'i (UH) Sea Grant College Program, Maui Land & Pineapple Co. Inc., 'Aha Moku Council, DLNR, State of Hawai'i Department of Health (DOH), U.S. Department of Commerce (DOC) – National Marine Fisheries Service (NMFS), U.S. Environmental Protection Agency (USEPA), National Fish and Wildlife Foundation (NFWF), U.S. Department of Agriculture (DOA) - Natural Resources Conservation Service (NRCS), U.S. Department of Interior (DOI) – U.S. Fish and Wildlife Service (USFWS), the U.S. Geological Service (USGS) and USACE. Regular and ongoing meetings by each of these bodies ensures collaboration of efforts to leverage technical capabilities and funding opportunities necessary to progress the West Maui R2R Initiative's mission and shared vision for this study.

Additionally, the USGS has partnered with USACE to provide technical assistance to furthering analysis of the management measures proposed by this study. The USGS has completed numerous water budget, groundwater, and stream discharge studies within the existing study area and brings regionally-specific scientific expertise to the USACE study.

Study Area

The West Maui watershed study area covers approximately 24,000 acres (9,712 hectares), includes five watersheds (Wahikuli, Honokōwai, Kahana, Honokahua, and Honolua), and the coral reef habitat north of Lahaina on the northwestern coast of the Island of Maui in the State of Hawai'i (Figure ES-1). The watersheds can be divided into three parts, as defined by their State of Hawai'i Land Use Districts. Progressing from mountain to sea these divisions are: Conservation, Agricultural, and Urban Districts. The Conservation District encompasses the upper most sections of the watersheds, featuring lush forested lands extending up to their divides at the crest of the mountains, the Agricultural District occupies the middle section of the watersheds, with lands historically used for agricultural activities, now mostly fallow and the Urban District encompasses the coastal lands known for beautiful beaches, abundant sunshine, and numerous resort hotels and condominiums. Rainfall is greatest in the Conservation District (365 inches annually) with a sharp decline into the Agricultural and Urban Districts (19 inches annually) (SRGI, 2012).

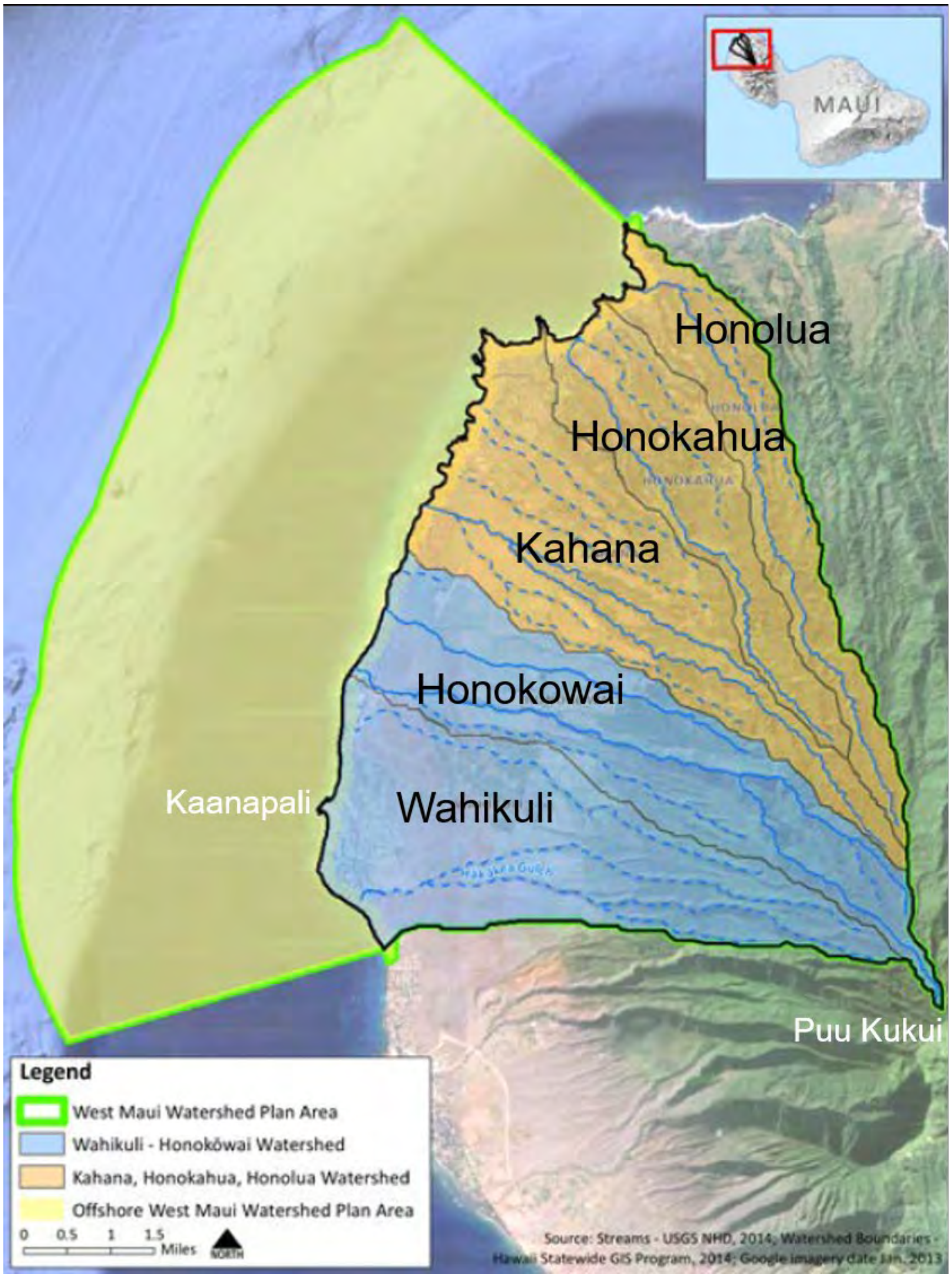

Figure ES- 1 West Maui Watershed Study Area

According to the Draft West Maui Community Plan, the population of the greater West Maui region increased from just over 22,000 in 2010 to nearly 25,000 in 2017 (approximately 11,000 in the study area). It is projected that the West Maui population will grow to 33,754 by 2040. Additionally, the area attracts visitors from around the world. In 2019, West Maui saw the largest average visitor population of around 36,000 per day (COM, 2021).

West Maui Coral Reefs

West Maui coral reefs provide several benefits to the local community, from attracting tourists that substantially support the local economy to sustaining recreational and commercial fisheries and protecting coastal property and infrastructure in addition to ecological and biodiversity benefits. Studies estimate the average annual benefit to the State from reef-related recreation and fisheries was $385 million and that the total economic benefit to the State was approximately $10 billion. Healthy coral reefs are wholly intertwined with life and culture in Hawai‘i and are simply irreplaceable. Climate change, land-based pollution and overfishing are the primary causes of global coral reef decline. Additionally, advances in our understanding of climate change points to ocean acidification and increased ocean temperatures as potentially more impactful contributors to marine ecosystem decline, making actions to address local stressors even more urgent. Like coral reefs across the world, West Maui reefs were not able to escape this tragedy—nearly 30% of coral reef cover in West Maui was lost in the last 30 years (USGS, Storlazzi, 2019).

In 2011, the U.S. Coral Reef Task Force (USCRTF) designated two watersheds, Wahikuli and Honokōwai, as priority watersheds, later extending to include Kahana, Honokahua and Honolua, a designation which encourages federal and jurisdictional agencies to work together to target restoration, pollution control, and monitoring to improve coral reef condition (USCRTF, 2019).

In 2012, initiated by local agency and community partners, the West Maui R2R Initiative was formalized and is comprised of the Funding and Agency Support Team (FAST) (leadership body),the R2R Working Group (community/local body), the R2R Hui, a more loosely affiliated group of organizations who work in support of the goals of the Initiative, and the West Maui Watershed and Coastal Management Coordinator. The primary objective of the West Maui R2R Initiative is to restore and enhance the health and resiliency of West Maui coral reefs and nearshore waters through the reduction of land-based pollution threats from the summit of Pu‘u Kukui to the outer reef, the efforts of which, will be guided by the values and traditions of West Maui. USACE worked with R2R partners to develop this objective which influenced the Shared Vision for this study.

The overarching recommendation from the R2R partners was to draft a comprehensive five-watershed management plan that compiles background data, identifies info gaps, to date and proposes and prioritizes strategic implementation measures across the entire study area over the next 50 years and including adaptive management of measures in response to projected natural and anthropogenic changes throughout West Maui (e.g. population growth, resource demand, climate change, etc.).

Cultural Considerations

The watershed concept or traditional *ahupua‘a* was historically integral to Native Hawaiian culture, lifestyle and identity. It remains integral to this day and should inform natural resource management and planning into the future.

The *ahupuaʻa* extends from mountain to ocean or *mauka* to *makai*. Hawaiʻi's streams and rivers form a lifeline joining the land and sea by an inseparable bond. The complex interconnectivity of *mauka* to *makai* as a single system, an *ahupuaʻa*, must form the context under which future watershed planning efforts are developed, to be successful. Since the arrival of humans to the Hawaiian Islands, Hawaiʻi's incredibly unique ecosystems have and continue to succumb to the external anthropogenic forces of deforestation, urbanization and other activities that introduce manmade threats to the natural environment (DLNR-DAR, 2020).

The Hawaiian cultural "renaissance" that began in the 1970s and continues today is the impetus for increasing interest in cultural, biocultural and ecological restoration throughout the islands. Globally, Hawaiian practices and values centered in sustainability are being praised and even considered for implementation to give insight to how large populations can survive harmoniously in their environment.

These practices are firmly rooted in the traditional Native Hawaiian concept of *mālama ʻāina*, literally, care for the land, which establishes a stewardship and wields a relationship between humans and the land where humans are the caretakers of the land, which sustains human life. This innate and inherent responsibility creates the foundation for ancient Hawaiian land management.

West Maui experienced many changes in land use and land management over time (Figure ES-2). From historic Native Hawaiian habitation to moderate expansion and colonization by religious missionaries, to the extensive and intrusive plantation era, to the overthrow and statehood resulting in rapid and expansive development across the State (COM, 2021). Each of these epochs contributes to the cultural and historic backdrop of the study area. As such, the implementation of any of these projects must consider potential impacts to both cultural and historic resources in accordance with State law and the National Historic Preservation Act of 1966, as amended (NHPA).

Figure ES- 2 West Maui land use over time

Shared Vision

Plan formulation for this watershed management plan adhered to the SMART (Specific, Measurable, Attainable, Risk Informed, and Timely) Watershed Planning Process, as described in USACE Planning Bulletin (PB) 2019-01. USACE worked with the members and agencies of the West Maui R2R to formulate the shared vision,

> *"[to] Develop a watershed management plan that addresses impacts from ridge to reef to improve West Maui coral reefs that provides coastal storm damage and shoreline protection and supports the West Maui economy".*

The shared vision is consistent with the R2R objective,

> "*to restore and enhance the health and resiliency of West Maui coral reefs and near-shore waters through the reduction of land-based pollution threats from the summit of Pu'u Kukui to the outer reef. These efforts will be guided by the values and traditions of West Maui.*"

Problems, Opportunities, Objectives, Constraints and Considerations

This comprehensive five-watershed management plan includes identification of and recommendations to address land-based pollutants that upon transport to the marine environment adversely affect nearshore coral reef ecosystems, thereby compromising the health of the West Maui watershed. From the shared vision, USACE, DLNR-DAR and the West Maui R2R identified the study problems, opportunities, objectives and constraints to begin formulating measures that would meet the study objective.

Problem Statement. Coral reef decline threatens the economy, ecosystem and community in West Maui.

Opportunities. The PDT compiled those measures that address this problem and also provide the following secondary benefits: protecting and restoring native ecosystems, incorporating cultural practices/restoration, promoting environmentally sensitive commercial agriculture, controlling invasive species, increasing and incorporating outdoor recreation and other low-impact activities and development such as greenspaces and community gardens, involving and educating the West Maui community and landowners, reducing coastal storm risk and also opportunities that give rise to ecotourism.

Objective. The objective of the study is to develop a list of recommendations for strategic implementation over the next 50 years that 1) reduces current and future pollutant sources, 2) reduces current and future conveyance of pollutants that threaten West Maui coral reefs, 3) the implementation of which would increase West Maui coral reef resistance and resiliency to the impacts of climate change.

Constraints and Considerations. The measures and recommendations were formulated given the following constraints and considerations: limited baseline data availability (e.g. LIDAR, rainfall, stream flow data, etc.) throughout West Maui, recommendations on private lands require support from landowner(s), minimize adverse effects to cultural resources/historic properties, minimize loss of floodplain, avoid proliferation of invasive species, waterways are regulated and affects streamflow/available water, impacts to tourism and the projected growth and housing demand in West Maui.

Plan Formulation

Recommendations were formulated in consideration of current Federal, State, and local planning and environmental guidance in conjunction with laws and policies concerning ecosystem restoration, flood risk management, water supply, water quality, stakeholder collaboration, and related purposes.

Management Measures

A measure is a specific structural or non-structural action that could contribute to the objectives of the watershed management plan by reducing or eliminating the identified problems. Management measures may address one or more study objectives and are the "building blocks" for conceptual alternatives. All management measures are considered to have an approximate 50-year period of analysis for individual projects, or in combination with other management measures.

This study carries forward relevant recommendations of the 2012 and 2016 Strategies and Implementation report by Sustainable Research Group International, Inc. and Group 70, respectively, and furthers those solutions that target in-stream erosion of historic fill terraces. Both structural and non-structural management measures were formulated under the following three categories: 1) Policy and Regulatory Measures (Non-structural), 2) Engineered Measures (Structural), and 3) Education & Outreach (Non-structural). Strategic measures identified across the three categories addressed the range of problems across the watershed.

Leveraging USACE's technical expertise in hydraulic and hydrologic engineering and USGS' technical expertise in marine transport dynamics analytics, the PDT furthered structural measures to conceptual design for a specific subset of recommendations to address in-stream erosion of legacy agricultural deposits conveyed into the marine environment and affecting coral reefs. This focused work aligned with USGS' research in West Maui indicating that the largest source of sediment pollution are in-stream legacy deposits of terrigenous, fine-grain sediments that have the greatest impact on photosynthetic processes upon which coral reefs depend (USGS, Stock, 2016; USGS, Storlazzi, 2015).

The proposed structural measures were presented to the West Maui community to solicit feedback at a public meeting hosted by the West Maui R2R Working Group held in Lahaina on August 30, 2018. The PDT received input from the public, West Maui R2R working group and FAST group to evaluate the proposed in-stream legacy sediment reduction measures and eliminate those that did not meet the project objective or were not practical. These structural measures, individually, and combined into strategies, were quantitatively evaluated using The Water Resources Council's National Evaluation Criteria: completeness, effectiveness, efficiency and acceptability and utilizing the USGS marine transport dynamics analysis to understand the physical connection between the land-based management measure and nearshore coral reef ecosystem.

Recommended Conceptual Alternatives/Strategies

Recommended management measures were identified as either stand-alone actions or grouped into conceptual alternatives within three categories: 1) Policy and Regulatory Measures (Non-structural), 2) Engineered Measures (Structural), and 3) Education & Outreach (Non-structural).

The USACE in collaboration with the West Maui R2R Initiative recommends the following policy and regulatory strategies to address land-based pollution causing coral reef decline in the West Maui watershed:

- Support State Department of Health development of non-point source pollution management program
- Establish stormwater fees throughout West Maui
- Establish a low impact development (LID) requirement for development, redevelopment and improvement projects >1 acre for all landowner to incorporate LID measures into design and construction
- Establish a pool and vehicle wash water discharge policy

The following recommended structural alternatives (strategies) were preliminarily evaluated by the R2R Hui to determine alignment with the R2R mission and study objectives and prioritized accordingly using a range from High to Low. The initial list of recommendations as prioritized with input from the R2R Hui and indicating anticipated implementation is shown below:

Priority	Recommended Strategy	0-5 yrs	5-10 yrs	10-15 yrs	15+ yrs
High	Basin Modifications at Kaʻōpala, Kahana and Honokōwai	■			
High	Prevent agricultural soils from transport into streams and gulches by researching, piloting and implementation of stream/gulch bank management measures	■	■		
High	Address current in-stream sediment movement via* -Kahana desilting basin maintenance -Desilting basin monitoring and analysis -Desilting basin retrofits -Potential new desilting/sediment basins	■			
High	Measures to address in-stream sediment deposits and prevent transport downstream via:* -Microbasins in Kaʻōpala Wahikuli and Papua -Lo'i terraces in Honolua or Honokōwai	■	■		
High	Increase groundwater recharge and slow surface flows via -Conservation boundary fencing -Active ungulate & invasive weed management -Landscape restoration (e.g., restore native plant buffer below conservation boundary, restore native vegetation along degraded gulch edges)	■	■	■	■
Medium	Road and Trail Inventory Assessment and Pollution Source Minimization Practices	■			
Medium	Lahaina WWRF Injection Wells Alternate Disposal (Increase production of R-1 water for reuse)	■			
Medium	Burn Area Emergency Response Plan	■	■	■	■
Medium	Wildland Fire Management Measures e.g. Fire breaks		■		
Medium	Push pile assessment and stabilization		■	■	■
Medium	Urban Storm Water Management Retrofits		■	■	
Medium	Gulch Buffer Stacked Practices - optimal combinations of: Ripping, Terraforming, Micro-basins, Key lining/ripping on contour, Vetiver eyebrows in kickouts, Contour planting vetiver, Native plant establishment, Hydro-mulching and Check dams	■	■	■	■
Medium	Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch		■	■	
Low	Urban Pollution Control: Bioretention Cell e.g. Rain Garden	■			
Low	Assess roadside erosion at Honoapiilani Hwy and Lower Rd		■		
Low	Gulch buffers adjacent to Wahikuli and Hahakea Gulch	■	■	■	■

Table ES- 1 Recommended Engineered Conceptual Alternatives/Strategies

Additionally, the USACE, in collaboration with the West Maui R2R Initiative, recommends the following education and outreach strategies to address land-based pollution causing coral reef decline in the West Maui watershed:

- Continue to fund existing outreach initiatives and outreach coordinators
- Fund community outreach/education efforts
- Increase funding to and awareness of the Ocean-Friendly Landscaper Outreach Program
- Increase funding of Community Water Quality Monitoring Program

The PDT, in close coordination with DLNR-DAR and with feedback from the FAST, R2R Working Group and the R2R Hui, will continue to refine and prioritize the final list of recommendations for implementation in West Maui. This comprehensive five-watershed management plan serves to guide future decision-making for DLNR-DAR and the growing West Maui community for the next 50 years. It also includes parametric cost estimates and conceptual designs for the in-stream sediment reduction (structural) measures, included as Appendices to this plan. Recommendations for preservation and protection of cultural resources and for climate change resilience are also described.

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APPENDICES

Appendix A: Hydrology and Hydraulics

Appendix B: Proposed Structural Measures and Conceptual Alternatives

List of Acronyms

AEP	Annual Exceedance Probability
CRE	Committee on River Engineering
COM	County of Maui
CWRM	Commission on Water Resource Management
DAR	Division of Aquatic Resources
DEM	Digital Elevation Model
DLNR	State of Hawaii Department of Land and Natural Resources
DOA	U.S. Department of Agriculture
DOC	U.S. Department of Commerce
DOH	State of Hawaii Department of Health
DOI	U.S. Department of Interior
ESA	Endangered Species Act
FAST	Funding and Agency Support Team
H&H	hydrologic and hydraulic
HEC	Hydrologic Engineering Center
LiDAR	Light Detection and Ranging
MKWP	Mauna Kahālāwai Mountain Watershed Partnership
NED	National Elevation Dataset
NFWF	National Fish and Wildlife Foundation
NHPA	National Historic Preservation Act of 1966, as amended
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service
NNN	nitrate-nitrite-nitrogen
RAS	River Analysis System
ROM	Rough Order of Magnitude
R2R	West Maui Ridge 2 Reef Initiative
SMART	Specific, Measurable, Attainable, Risk Informed, and Timely
USACE	U.S. Army Corps of Engineers

USCRTF		U.S. Coral Reef Task Force
USEPA		U.S. Environmental Protection Agency
USFWS		U.S. Fish and Wildlife Service
USGS		U.S. Geological Service
UH		University of Hawaiʻi
WRDA		Water Resources Development Act
WWRF	-	wastewater treatment reclamation facility

1 - STUDY INFORMATION

The West Maui region has a rich, complex history, comprised of a range of different eras throughout time, reflective of the needs and visions of the humans within each era (Figure 1-1). Over that history, a dependent relationship with water and watershed formed. Humans depended upon and subsequently modified the natural waterways of West Maui, consistent with human settlement across all settled landscapes. Present day demand in this region is centered around community and economic development. However, that demand is complicated by the history of water resources development, manipulation, diversion and extraction and further challenged by climate change. Looking into the future, development of the water resources of the West Maui watershed will require careful, thoughtful, informed, collaborative and strategic planning to ensure a sustainable relationship between the West Maui community and the natural environment.

Figure 1- 1 West Maui land use over time (Top left: Polynesian voyagers, Top right: Missionaries, Bottom left: Plantation era, Bottom right: Urban and resort development)

The human footprint on the West Maui landscape is pervasive and concentrated. Such impacts include, but are not limited to centuries of human settlement, creeping urban and commercial development, conversion to impervious surfaces, deforestation, intense agricultural practices, heavy use of petroleum products, pesticides, fertilizers and other chemical pollutants, introduction of invasive flora and fauna species and diversion and channelization of natural drainageways. The watershed system is interconnected and interdependent, extending from ridge to reef, from the highest peaks of the West Maui Mountains to the nearshore marine environment, from *mauka* to *makai*. The human footprint in West Maui has not only affected the terrestrial landscape, it has undeniably, and perhaps irreversibly, degraded our ocean.

The innumerable physical and chemical pollutants across many sources are transported by a range of conduits directly into the nearshore waters. We can look to the health of our coral reefs as a reflection of the health of the adjacent landscape. The health of the West Maui reefs has consistently declined over the years. Scientists suggest that rate is accelerating as the population grows, exacerbated by the effects of climate change. Nearly 30% of coral reef cover in West Maui has been lost in the last 30 years. in addition to contributing to the ecological and biodiversity of the marine environment, West Maui coral reefs, provide several benefits to the local community, from attracting tourists that substantially support the local economy to sustaining recreational and commercial fisheries and protecting coastal property and infrastructure. Studies estimate the average annual benefit to the State from reef-related recreation and fisheries was $385 million and that the total economic benefit to the State was approximately $10 billion. Healthy coral reefs are necessary for the health of the West Maui Watershed and the West Maui community (USGS, Storlazzi, 2019).

In 2011, the U.S. Coral Reef Task Force designated two watersheds, Wahikuli and Honokōwai, as priority watersheds, later extending to include Kahana, Honokahua and Honolua, a designation which encourages federal and jurisdictional agencies to work together to target restoration, pollution control, and monitoring to improve coral reef condition (USCRTF, 2019). As a result of this designation, many agencies at the federal, state and local level have responded with funding, studies and initiatives to better understand and improve the state of this priority watershed.

In 2012, initiated by local agency and community partners, the West Maui Ridge to Reef (R2R) Initiative was formalized. The primary objective of the West Maui R2R Initiative is to restore and enhance the health and resiliency of West Maui coral reefs and nearshore waters through the reduction of land-based pollution threats from the summit of Pu'u Kukui to the outer reef, the efforts of which, will be guided by the values and traditions of West Maui. The R2R objective was adopted to form the primary goal of this study.

The following matrix shows shaded cells that depict which of the issues listed in the guidelines are of interest or considered an issue to one of the stakeholders or are clearly within the statutory authority of a partner agency (Table 1-1). A dollar $ indicates that an agency has provided support for the issue area such as technical expertise, direct funding or participation on one or more of the working groups associated with this project. This matrix highlights the large number of and shows the truly collaborative nature of the planning process.

	Agencies																	
	FUNDING AGENCY SUPPORT TEAM (FAST)										Other Partners							
Issues	USACE	USEPA	DOI-USFWS	DOC-NOAA	DOA-NRCS	USGS	DLNR / DAR	DLNR / CWRM	DLNR/DOFAW	HDOH	DHHL	WMMWP	County of Maui	UH	NFWF	ML&P	NGO Community	WMS&WCD
Land-Based sources of Pollutants (sediments and polluted runoff causing coraldecline)	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$	$
Fallow agricultural fields																		
Water supply						$		$					$					
Wildfire management				$			$		$			$	$			$		
Ecosystem restoration of upper watershed/ conservation area			$						$			$	$		$	$		
Ecosystem restoration of riparian habitat/gulches			$		$			$										
Ecosystem restoration of coral reefs		$		$	$	$	$						$	$		$	$	
Drought preparedness					$			$										
Climate change impacts	$	$	$	$		$												
Fishing pressure				$		$	$										$	

Table 1- 1: West Maui Watershed Study Agency Issues/Support

1.1 Study Area

The West Maui watershed study area covers approximately 24,000 acres (9,712 hectares) north of Lahaina on the northwestern coast of Ka‘anapali on the Island of Maui in the State of Hawai‘i. The study area The study area encompasses a collection of about twelve adjacent watersheds that are grouped by the State of Hawai‘i into five hydrologic units: Wahikuli to the south, Honokōwai, Kahana, Honokahua, and Honolua to the north (Figure 1-2).

The watersheds can be divided into three parts, as defined by their State of Hawai‘i Land Use Districts (Figure 1-3). Progressing from *mauka* to *makai*, these divisions are: Conservation, Agricultural, and Urban Districts. The Conservation District encompasses the upper most sections of the watersheds, featuring lush forested lands extending up to their divides at the crest of the mountains; the Agricultural District occupies the middle section of the watersheds, with lands historically used for agricultural activities, now mostly fallow; and the Urban District encompasses the coastal lands known for beautiful beaches, abundant sunshine, the bulk of the residential population and numerous resort hotels and condominiums. Rainfall is greatest in the Conservation District (365 inches annually) with a sharp decline into the Agricultural and Urban Districts (19 inches annually) (SRGI, 2012).

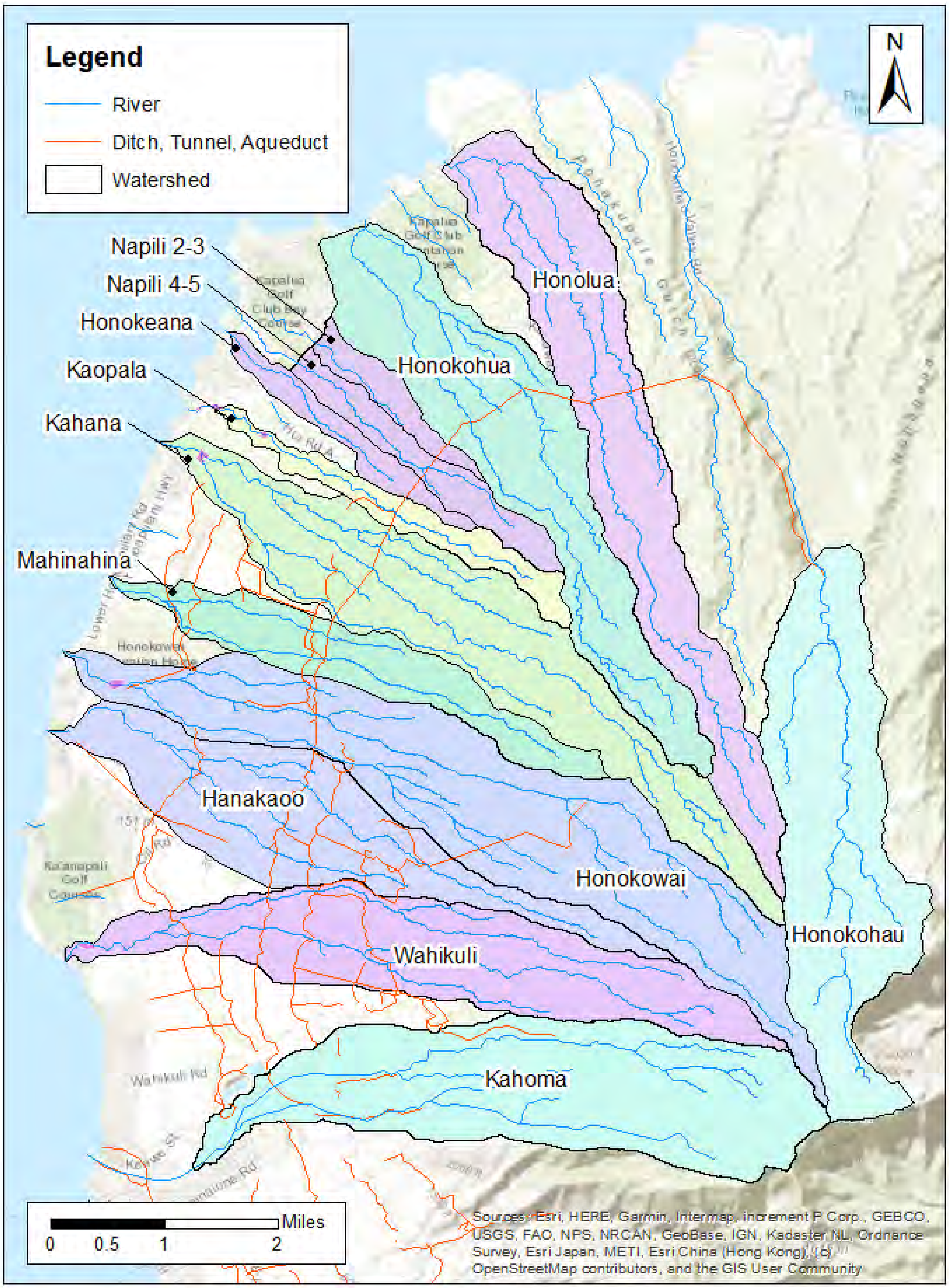


Figure 1- 2 West Maui Study Area Major and Sub-Watersheds (excluding Honokohau)

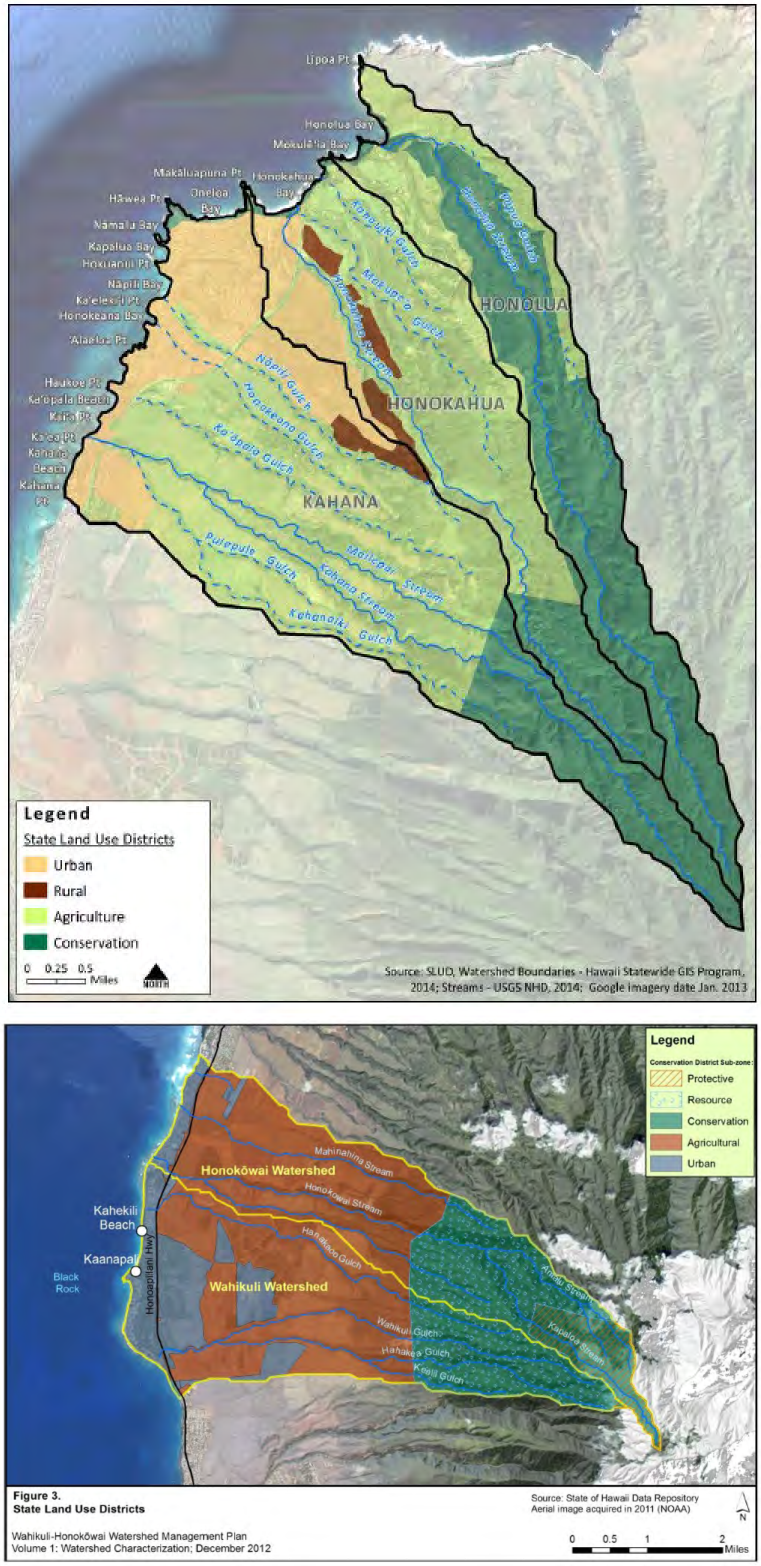


Figure 1- 3 West Maui Land Use Designations

1.2 Study Authority

Section 729 of the Water Resources Development Act of 1986, Public Law 99-662, as amended (33 U.S.C. 2267a), hereinafter "Section 729". Section 729 authorizes the development of watershed plans that are multi-purpose and multi-objective in scope and developed in cooperation with Federal, State and local government entities. The State of Hawaiʻi, represented by the Department of Land and Natural Resources (DLNR), Division of Aquatic Resources (DAR) is the Non-Federal Sponsor for the West Maui Watershed Management Plan.

DLNR-DAR manages the state's aquatic resources and ecosystems through programs in ecosystem management, place-based management, and fisheries management with a mission to work with the people of Hawaiʻi to manage, conserve and restore the state's unique aquatic resources and ecosystems for present and future generations. The State of Hawaiʻi, as represented by DLNR-DAR, and USACE signed a cost-share agreement on August 9, 2012 to assess the water resources needs of the West Maui watershed pursuant to Section 729.

In addition, under Engineering Circular 1105-2-411

> "*Watershed planning is an approach for managing water resources within specified drainage areas or watersheds and addresses problems in a holistic manner that reflects the interdependency of water uses, competing demands, and the desires of a wide range of stakeholders in addressing watershed problems and opportunities. Watershed planning facilitates the collaborative evaluation of a more complete range of potential solutions and is more likely to identify the most technically sound, environmentally sustainable, and economically efficient means to achieve multiple goals in the entire watershed over the long term, i.e., integrated water resources management.*"

The West Maui Watershed Management Plan meets both the stated water resource assessment guidelines stated in §729 of WRDA 1986 and EC 1105-2-411.

1.3 Planning for the Watershed

Watershed planning goes beyond project planning for specific USACE projects towards more comprehensive and strategic evaluations and analyses that include diverse political, geographic, physical, institutional, technical, and stakeholder considerations. Watershed planning addresses identified water resources needs from any source, regardless of agency responsibilities, and provides a shared vision of a desired end state that may include recommendations for potential involvement by USACE, other federal agencies, or non-federal interests. Watershed studies may identify potential USACE projects consistent with priority missions; however, this is not the primary consideration of watershed planning. In conducting watershed planning, USACE uses its planning capability in a broader sense to meet the changing water resources needs of the nation. Ultimately, watershed studies should inform multiple audiences and decision makers at all levels of government and provide a strategic roadmap to inform future investment decisions by multiple agencies.

Cultural Considerations

In consideration of the Native Hawaiian culture, USACE ensured incorporation of the traditional *ahupuaʻa* (watershed) concept into the study. *Ahupuaʻa* was historically integral to Native

Hawaiian culture, lifestyle and identity. It remains integral to this day and should inform natural resource management and planning into the future.

The *ahupuaʻa* extends from mountain to ocean or *mauka* to *makai*. Hawaiʻi's streams and rivers form a lifeline joining the land and sea by an inseparable bond. The complex interconnectivity of *mauka* to *makai* as a single system, an *ahupuaʻa*, must form the context under which future watershed planning efforts are developed, to be successful. Since the arrival of humans to the Hawaiian Islands, Hawaiʻi's incredibly unique ecosystems have and continue to succumb to the external anthropogenic forces of deforestation, urbanization and other activities that introduce manmade threats to the natural environment (DLNR-DAR, 2020).

The Hawaiian cultural "renaissance" that began in the 1970s and continues today is the impetus for increasing interest in cultural, biocultural and ecological restoration throughout the islands.

> *"The task is ongoing, and the idea arises now that in the next phase of the Hawaiian Renaissance, a goal should be to demonstrate that Hawaiians were, and can again be, masterful ecologists, naturalists, landscape engineers, and resource managers. Surviving an era of conscious suppression, during which both Hawaiian ecosystems and Hawaiian culture were gravely damaged, we enter a phase of rebuilding, recovery, and reestablishment of the relationships that originally resulted in a millennium of sustainable co-existence of people and nature" (Gon, et. al.,2019).*

Globally, Hawaiian practices and values centered in sustainability are being praised and even considered to give insight to how large populations can survive harmoniously in their environment. These practices are firmly rooted in the traditional Native Hawaiian concept of *malama ʻaina*, literally, care for the land, which establishes a stewardship and wields a relationship between humans and the land where humans are the caretakers of the land, which sustains human life. This innate and inherent responsibility creates the foundation for ancient Hawaiian land management. As stated in Senator Kenneth Brown's speech on the Senate Floor of the Hawaiʻi State Capitol,

> *"All of man's acts in Hawai`i must be dominated by the spirit of "Malama". The Pukui-Elbert Hawaiian Dictionary defines "Malama" thus: "To take care of, care for, preserve; to keep or observe, as a taboo; to conduct, as a service; to serve, honor, as God; care, preservation, support; fidelity, loyalty; custodian, caretaker." Because he knows so many ways to destroy his natural environment, Man must now become its custodian and caretaker for his own sake. He must exercise malama, because if he starts selling parts of his natural environment abroad for creature comforts, he will lose it all, and be unable to survive here. If he uses up his landscapes, mountains, valley and vistas, or if he degrades his air and waters, he will destroy the beauty and hence the spirit of Hawai`i, and in so doing, his own spirit. Malama is thus an imperative. It is applicable to our entire lives in Hawai`i." (Brown, 1973).*

West Maui experienced many changes in land use and land management over time (Figure ES-2). From historic Native Hawaiian habitation to moderate expansion and colonization by religious missionaries, to the extensive and intrusive plantation era, to the overthrow and statehood resulting in rapid and expansive development across the State (COM, 2021). Each of these epochs contributes to the cultural and historic backdrop of the study area. As such, the implementation of any of these projects must consider potential impacts to both cultural and historic resources. Any Federal action (e.g. expenditure of Federal funds, issuance of a Federal permit, and issuance of a Federal grant) would require compliance with Section 106 of the National Historic Preservation Act of 1966, as amended (NHPA).

Initial Watershed Assessment

In 2012, the National Oceanic and Atmospheric Administration (NOAA) Coral Program funded development of a watershed management plan for the two southern-most watersheds: Wahikuli and Honokōwai. That plan was comprised of two volumes. Volume I: Watershed Characterization, summarized the current and proposed future environmental conditions of Wahikuli and Honokōwai Watersheds, with an emphasis on identifying pollutant sources and types. Volume I concluded that sediment inputs are the key pollution source in the Agricultural District and pollutants contained in Lahaina Wastewater Reclamation Facility (WWRF) effluent discharged into the nearshore environment are the key issue in the Urban District. Volume II: Strategies and Implementation, discussed strategies for management of non-point source[1] pollutants that adversely impact water quality and the coral reef ecosystem, as identified in Volume I. Volume II recommended measures to reduce sediment erosion and transport from abandoned agricultural roads and fallow fields to the ocean, such as erosion controls, fertilizer management plans, and post fire rehabilitation plans in the Agricultural District. Management measures recommended in the Urban District revolve around reducing WWRF effluent discharges via injection wells by installing infrastructure necessary to increase number of end-users to beneficially reuse wastewater effluent and also reducing runoff carrying chemical pollutants to the ocean via stormwater retention/infiltration and storm sewer system retrofits.

USACE and DLNR-DAR co-funded development of a similarly constructed watershed management plan for the remaining three watersheds to the north, Kahana, Honokahua and Honolua in 2016. This plan also consisted of Volume I: Watershed Characterization and Volume II: Strategies and Implementation for these watersheds. Volume I concluded that past agricultural practices that deposited sediments in stream valleys that are transported to the ocean and current land uses that contribute fertilizers and animal waste pollutants to the marine environment are the primary contributor of land-based pollution of the marine environment. Volume II proposed both policy and management measures to remove policy blockages to reducing pollutant sources and transport and measures to reduce sediment sources, prevent sediment from entering or being transported downstream, address current in-stream sources and increase groundwater infiltration/recharge.

The data, analyses and conclusions drawn in the 2012 and 2016 plans were based on existing data at the time of publication. The overarching recommendation concluded by both 2012 and 2016 plans was to further these initial plans by drafting a comprehensive five-watershed management plan that would compile background data, identify info gaps to date and propose and prioritize strategic implementation of measures across the entire study area over the next 50 years and including adaptive management of measures in response to projected natural and

[1] Land-based pollutants generated across large areas and from diffuse sources are commonly referred to as non-point source pollutants

anthropogenic changes throughout West Maui (e.g. population growth, resource demand, climate change, etc.).

1.4 Local Support

DLNR-DAR. As the Non-Federal Sponsor, DLNR-DAR participated as part of the PDT throughout every facet of development of this watershed management plan to ensure that the team collected relevant data needed to develop recommendations that specifically addresses West Maui watershed concerns as expressed by the community. In addition, as work-in-kind contribution under the cost-share agreement with USACE, DLNR-DAR partially funded the West Maui Watershed Coordinator position and collaborated with various agencies and community organizations to further ancillary efforts throughout West Maui that align with the objectives of this study.

West Maui Ridge 2 Reef Initiative. In 2012, initiated by local agency and community partners, the West Maui Ridge to Reef (R2R) Initiative was formalized. The primary objective of the West Maui R2R Initiative is to restore and enhance the health and resiliency of West Maui coral reefs and nearshore waters through the reduction of land-based pollution threats from the summit of Pu‘u Kukui to the outer reef, the efforts of which, will be guided by the values and traditions of West Maui.

The West Maui R2R Initiative is comprised of the Funding and Agency Support Team (FAST) (leadership body), the R2R Working Group (community/local body), the R2R Hui, a more loosely affiliated group of organizations who work in support of the goals of the Initiative. The fast team is the leadership body of R2R and the following federal and state agencies that meet quarterly to advise on opportunities available within their agencies to further projects and initiatives throughout West Maui: USACE, DLNR (Division of Forestry and Wildlife, Commission on Water Resource Management and Division of Aquatic Resources), DOH, USEPA, DOA NRCS, DOI USFWS, DOC NMFS, and NFWF. The Working group is comprised of various local government agencies, local nonprofits and major stakeholders and landowners throughout West Maui and constitute the local or community body of the R2R Initiative. The R2R Hui is a group of organizations that work in support of the goals of the initiative.

Lastly, the West Maui R2R Initiative is guided by a single member, the R2R Watershed and Coastal Management Coordinator, that is funded by both DLNR-DAR and NOAA. The Watershed Coordinator monitors and manages all the R2R initiatives and remains in close contact with each of the R2R partners’ independent initiatives, as they relate to the health and welfare of the West Maui watershed. The Watershed coordinator illuminates overlap between initiatives to identify strategic opportunities for collaboration and furtherance of single objectives towards the bigger picture. In addition, and specific to this study, the R2R coordinator acts as a liaison between the R2R members, the West Maui community and the USACE and DLNR-DAR, guiding the study towards success by ensuring incorporation of independent and interrelated initiatives occurring beyond the purview of USACE and DLNR-DAR and providing insight into the community and its goals.

1.5 Watershed Problems, Opportunities, Planning Objectives, and Constraints

The first step in the USACE watershed planning process is to Identify Problems and Opportunities. This step requires USACE to determine problems, needs and opportunities in the watershed by involving study partners, water and related land resources interests (stakeholders), resource agencies and the public. Federal agency partnerships and expansive stakeholder involvement are necessary to collect a broad view of problems, needs and opportunities, including items that may not be seen in more conventional project planning, and reaffirm the purpose of the watershed study. Problems may include institutional barriers, where the associated opportunity is a full partnership by all relevant agencies to examine existing policies and procedures. Planning is an iterative process and the problems, opportunities, objectives, and constraints should be reassessed after key decision point milestones.

1.5.1 Watershed Problems

This watershed management plan includes an examination of watershed-wide problems affecting the West Maui watershed; in particular, West Maui coral reefs. The federal and state agency partners and community stakeholders collectively identified several concerns at early engagements and through the 2012 and 2016 characterization reports. Since then, several studies have furthered the work of the initial reports to fill and bridge information gaps in order to update the information base and subsequent recommendations.

This watershed management plan will serve as a long-term plan for sustainable management to address the problems and opportunities identified, that presently affect the watershed and that will continue to affect the watershed into the future. The concerns identified within study area are related to pollution sources located throughout the landside watershed and conveyance of pollutants from the landside to the nearshore marine environment within the West Maui study area. The collective understanding of the problems in the West Maui watershed are heavily influenced by recent and ongoing data collection throughout the study area that have informed identification of opportunities objectives and constraints for this study.

1.5.1.1 Land-Based Pollutants (Current USGS Data)

A watershed extends from mountain to sea, mauka to makai. What happens on land eventually affects what happens in the ocean. Pollutants originating on land are conveyed by natural means e.g. streams, groundwater, stormwater, as non-point source (NPS) discharges to downstream waters and eventually the marine environment. The rate at which NPS pollutants are generated and transported to water sources is greatly influenced by anthropogenic behaviors within a watershed. Various studies within the West Maui watershed by several agencies, organizations and local non-profits have occurred to better understand this dynamic, with the goal of identifying sources of pollutants and addressing those sources accordingly. While all pollutant sources could impact water quality, relative prioritization is needed to begin the process of identifying strategies for implementation that will achieve desired water quality goals for addressing coral reef ecosystem degradation from land-based pollutants.

Sediments ranging from large boulders to coarse grain sands down to silts and clays originate on land in areas of exposed Earth. These pollutant sources occur across all land use districts and are created both naturally and by humans. In the Conservation District, in denuded forests, recreational trails and stream channels prone to erosion; in the Agricultural District in fallow fields, unmaintained dirt roads and in stream channels and valleys that have accumulated legacy deposits; and in the Urban District in unvegetated areas, uncontrolled construction activity and both developed and undeveloped areas prone to erosion.

The U.S. Geological Survey (USGS) has completed numerous water budget, groundwater, and stream discharge studies within the existing study area. Two concurrent USGS studies, directed the focus of this study towards investigating measures that address transport of legacy deposits mobilized during the 2-year storm event and furthermore, addressing fine-grain terrigenous clays.

In a 2015 study, USGS related net impact to photo-dependent marine organisms such as coral to terrigenous (dark-hued), fine-grain clays in suspension in the nearshore marine environment. Due to their small mass, clays are easily suspended and resuspended and are the slowest to settle out of suspension i.e. longest residence time. Suspended sediments contribute to water column turbidity. Turbidity blocks light penetration into the water column preventing photosynthetically active radiation from reaching benthic, sessile photo-dependent marine organisms such as corals. Turbidity caused by fine grained, terrigenous clays results in longer duration impacts than coarser grain, lighter-hued, sands. The longer the duration and exposure of the impact, the greater the net impact to corals. This study recommends any engineering solutions addressing long-term coral reef ecosystem health focus on preferentially retaining on land fine-grained, terrigenous clay particles over coarse silt and sand particles (USGS, Storlazzi, et. al., 2015).

In a 2015 USGS Open File Report, USGS observed more frequent, lower intensity storm events contributing sediment conveyance through surface drainage to nearshore waters. USGS concluded that a plausible primary source of sediment as observed in nearshore sediment plumes after low intensity storm events may be a mix of coarse and fine-grain sediments deposited in the streams and valleys adjacent to plateau historically and intensely manipulated during the plantation era. These legacy agricultural deposits now comprise the stream banks and beds throughout the agricultural district of West Maui and are actively eroded during precipitation events that cause streamflow/conveyance out to the ocean (USGS, Stock, et. al., 2015).

This study was furthered by USGS and updated information was published in a Scientific Investigations Report in 2021. USGS used mapping, field experiments, monitoring, and data analysis to create a sediment budget that estimates the annual export of fine sediment (clays, silts, and sands) from the West Maui Watersheds. A sediment budget quantifies the sources, storage, and export of sediment from a watershed. USGS found that precipitation events measuring at least two hours of 10–20 millimeter (mm) per hour rainfall generates nearshore sediment plumes. West Maui communities can expect such rainfalls to cause coastal plumes at least 3–5 times annually. Investigations in this report further support past supposition that the primary source of fine-grain sediments are near-stream, legacy agricultural deposits that are mobilized when the fill terraces are eroded by streamflow. These fill terraces were likely deposited from side casting of excess agricultural soils into valleys. During 2015–2016, these deposits eroded at median rates of 5–24 mm per year, equivalent to a minimum of 920 tons of fine sand, silt, and clay to the ocean annually. The fill terraces are found downstream of historic agricultural fields and are extensive, occupying approximately 40% of streambank length. Any watershed management measure focused on coral reef health should concentrate efforts on reducing bank erosion (USGS, Stock, et. al., 2021).

1.5.1.2 Land-Based Pollutants (2012 and 2016 Watershed Characterization Reports)

In 2012 and 2016, the two southernmost watersheds followed by the northern three watersheds were characterized and recommendations made to address pollution originating on land and conveyed to the ocean. Since then, many associated studies, investigations and initiatives have built upon the knowledge bank. Some of the data contained in these reports has been overcome by events (see preceding section), while some remain relevant. A short summary of the problems identified in both reports is provided below.

2012, Wahikuli and Honokōwai. Investigations in 2012 focusing on Wahikuli and Honokōwai Watersheds to the South identified the following pollutant hot spots by land-use district:

Within the Conservation District, the highest priority NPS pollutant hotspots are the main dirt bike trail along the conservation area, locations with populations of feral ungulates (pigs), eroding sections of natural stream channels and bedding, and areas of wildfire potential.

Within the Agricultural District, the highest priority NPS pollutant hotspots are the steep upper segments of the dirt access roads within the pineapple and seed corn field regions, running perpendicular to the contours, the bare seed corn fields and the outlets of pineapple field terraces and access roads where they intersect stream channels. Since sugarcane and pineapple production has ceased, the amount of fertilizers and pesticides being applied in the Wahikuli and Honokōwai Watersheds on agriculture lands has decreased.

Within the Urban District, the highest priority NPS pollutant hotspots are unstabilized residential and commercial construction sites and unstabilized developed lands such as cemeteries and beach park erosion areas. Highest priority nutrient generation hotspots include the Lahaina Wastewater Reclamation Facility injection wells; and landscaping activities associated with the two Kaʻanapali Golf Courses as well as those associated with resort, commercial, and residential uses.

2016, Kahana, Honokahua and Honokohau. Sediment pollutant sources in agricultural and conservation districts are primarily agricultural sediment deposits in stream valleys, in addition to the following lesser priority sources: areas denuded by feral ungulates, impacts of invasive flora such as monocultures of shallow root systems, unauthorized human access causing erosion, access roads and highways contributing to pollutant conveyance, and fallow fields. The Urban District features chemical pollutant sources such as nutrients, hydrocarbons, metals and pesticides associated with public sewage, stormwater, drainage and transportation systems, recreational areas such as golf courses, current and planned impervious surfaces.

1.5.1.3 Pollution Conveyance

Land-based pollutants are carried to the ocean via surface water and groundwater. Surface water includes natural streams, artificial channels and stormwater drainages. Due to the volcanic geomorphology of the Hawaiian Islands, water that percolates into the ground may eventually end up in the groundwater/aquifer system. Surface waters can carry large pollutants such as trash, debris, sediment, chemicals and nutrients while groundwater typically carries that which is not filtered out by the porous basalt such as chemicals, metals, microbiota e.g., bacteria, etc., and organics. While all these pollutants impact the natural environment to varying degrees, the main pollutants of concern, both historically and currently, are sediments and to a lesser degree, nutrients e.g. Nitrogen and Phosphorous. In addition to addressing the pollutant sources, efforts to reduce land-based pollution of the marine environment should also address means of conveying pollutants to the ocean (Figure 1-4).

The first volume of both the 2012 and 2016 Watershed Characterization Reports describes the surface water and groundwater systems per watershed. Summary information is found in Section 2.6.

Figure 1. Photographs showing nearshore sediment pollution from terrestrial runoff in West Maui, September 14–15, 2016. Continued pollution risks the ecological, cultural, and economic value of these iconic West Maui sites. Images courtesy of Bill Rathfon, private citizen.

Figure 1- 4 Photographs of Ocean Sediment Plumes Generated by Terrestrial Runoff (USGS, 2020)

(a) *Stream Transport.*

The larger, more developed streams in the region have headwaters originating in the Conservation District where high rainfall amounts generate surface flow and recharge the aquifers that leak into the streams during dry periods. These large streams continue down slope through the Agricultural and Urban Districts before terminating at the coastline. Surface waters in West Maui are generally intermittent or perennial in the headwaters, flow in response to precipitation i.e. ephemeral from the Conservation District, through the Agricultural District to the Urban District and may be perennial (fresh or brackish) at the stream mouth. The flashy, steeply sloped watersheds give rise to large pulse-like events in response to rain causing large, relatively instantaneous releases of land-based pollutants into the marine environment followed by long periods of no rain or rain that is not of a frequency or intensity necessary to generate surface flow to the ocean (SRGI, 2012).

(b) *Groundwater Transport.*

Groundwater is water found in underground layers of rock or sediment, referred to as an aquifer. An aquifer is roughly defined as an area in which the spaces (voids) are filled with water. The volume of water discharging along the coast in seeps and springs and offshore as submarine groundwater has not been quantified. However, it is generally thought that volume of groundwater discharge is small when compared to volumes of surface water discharge (Soicher and Peterson 1996). Groundwater is generally associated with transporting ammonium and nitrate forms of nitrogen (Soicher and Peterson 1997).

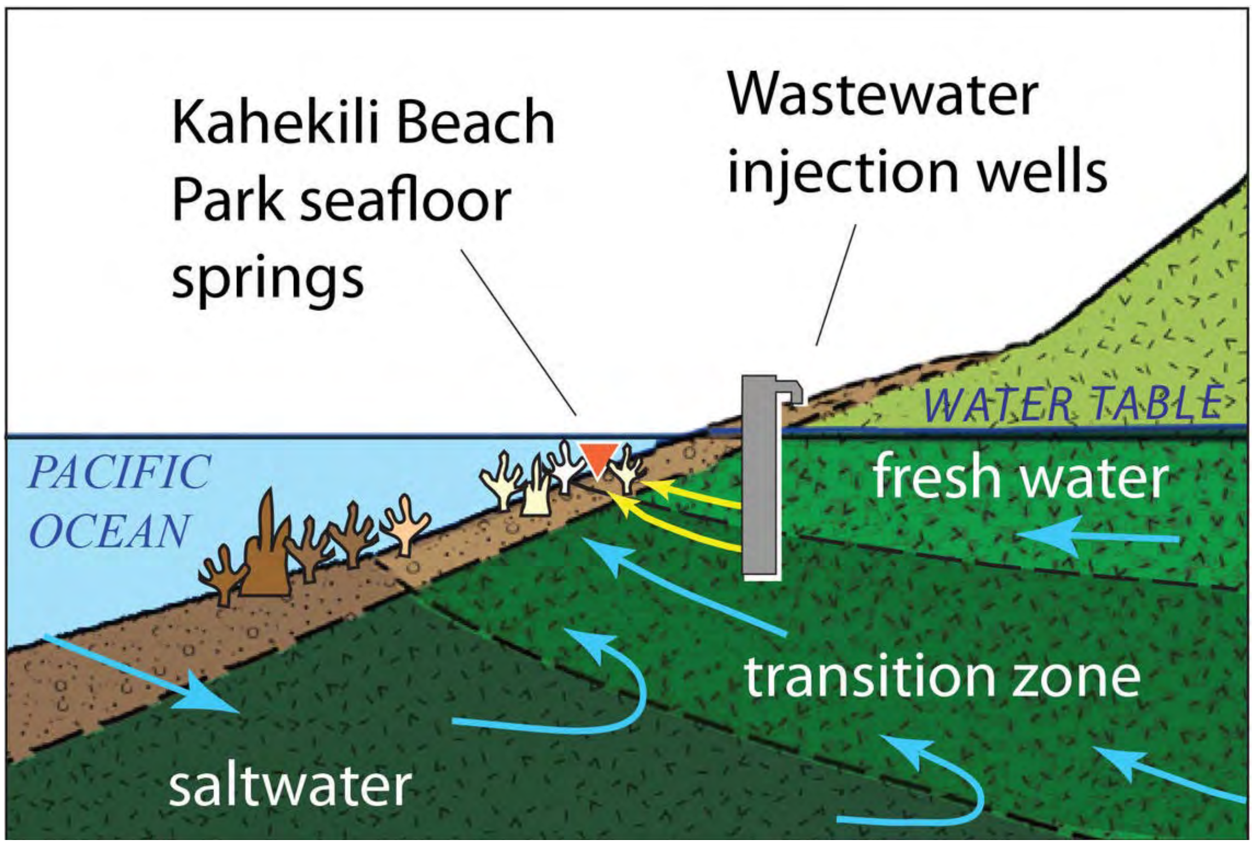


Figure 1- 5 Groundwater pollution conveyance pathway diagram at Kahekili, Hawai'i, USGS, 2018

(c) *Coastal Erosion.*

Coastal Erosion is a natural process where shorelines recede and accrete seasonally and over time. Sand is transported in the water column between beaches and from on-shore to off-shore and has negligible impacts on water quality. However, when erosion of the beach proceeds inland beyond the sandy beach towards terrigenous sediments, soil, silt, clay and organic material is released uncontrolled into the marine environment, causing much greater adverse impact to coastal water quality. Hardening of the coastline for infrastructure such as roads, beachfront property retention and shoreline stabilization has proven more of a problem than a solution. Hardened shorelines can accelerate velocities at the shoreline across the hardened surface and direct impact at neighboring natural shorelines. The problem of an eroding shoreline is then transferred from one hotspot to another location down current. The eroded shoreline is left susceptible to further erosion. Severe coastal erosion can cause property and infrastructure damage that could release additional pollutants such as construction materials and sewage into the ocean (COM, 2018).

1.5.2 Coral Reef Decline.

Coral reefs are valued globally and, are in decline, globally. Hawai‘i’s coral reefs have also declined dramatically over the past 100 years due to multiple anthropogenic stressors. In West Maui, Hawai`i, nearly one-fourth of all living corals have been lost in the thirteen (13) years period prior to 2008 (DAR & HCRI, 2008). Because of Hawai‘i's geographic isolation, over 25% of its coral reef species are found nowhere else in the world. The processes that degrade Hawaiian coral reefs are chronic, rather than episodic, thus the effect(s) of land-based pollution are difficult to discern on short time scales of months and even years. Measured over decades, overall reef health is on a downward spiral in many locations in Hawai‘i. As of 2019, less than 1 percent of Hawai‘i’s coastal habitats are effectively managed to protect corals from more loss (USGS, Field, et. al., 2019).

Degradation is not just about a loss of coral cover. Habitat quality and topographical complexity are also in decline. The biodiversity that supports ecosystem services, biological resources, and social benefits are diminished. The recreational and commercial value of reefs declines. Fish stocks migrate away or die. Related ocean resources decline. With the decline of coral reef resources also come social impacts on local communities such as changes to lifestyle, inability to rely on sustenance from ocean resources, and impacts to the Native Hawaiian culture which considers coral reefs a building block of their culture (USGS, Field, et. al., 2019).

The causes of coral reef decline are complex and not yet fully understood. However, land-based pollution (increased sediment, nutrients, and other pollutants) is a clear and serious threat to coral reef ecosystems. Surface water run-off from storm events and ground water discharge both transfer pollutants into the near shore marine environment. Elevated nutrient levels from surface water run-off and groundwater discharge into nearshore waters has been linked to an increase in alien invasive algal species in the nearshore. Increased sedimentation associated with loss of forestland, historical plantation agriculture practices, legacy sediments in riparian corridors, stream channelization, and rapid development have clearly impacted coral reef health (USGS, Field, et. al., 2019).

The potential adverse effects of climate change on land use, land cover and hydrology/hydraulics of the watershed could cause further watershed-wide ecosystem degradation and in particular, coral reef ecosystem degradation. Low-intensity rainfall events that generate sediment plumes are occurring at a slightly progressive rate, while less precipitation in general is causing reduced vegetative cover and heightening erodibility of sediments throughout the study area. Additionally, globally, coral reef ecosystems are threatened by climate change effects such as ocean acidification and rising ocean temperatures. Corals stressed by land-based pollutants are more susceptible to and less resilient in recovering from the impacts of climate change. The most effective response to climate change is to develop measures that improve coral reef health by minimizing land-based pollutant-induced stresses to corals (USGS, Field, et. al., 2019).

Coral reefs are widely recognized as critical to Hawai'i's economy, recreational and commercial fisheries, ecological biodiversity and as the State's first defense against coastal storm damage. A 2002 analysis estimated the annual net benefits derived from Hawai'i coral reefs is $360 million a year for Hawai'i's economy. The overall asset value of the state's 410,000 acres of coral reefs is estimated at nearly $10 billion. Note, this is a conservative estimate based on actual economic value and does not consider the intrinsic value of these reefs beyond their utility (Cesar, et.al., 2002).

1.6 Problem Statement

"*Coral reef decline threatens the economy, ecosystem and community in West Maui*."

The problem statement aligns with Section 729 authorizing USACE to partner with local sponsors to investigate water resources needs related to ecosystem and watershed protection and restoration.

1.7 Opportunities.

In proposing management measures and developing strategic recommendations, the study team looked for solutions that incorporated the following opportunities for secondary benefit(s):

- Protect and restore native ecosystems
- Incorporate cultural practices/restoration
- Environmentally sensitive commercial agriculture
- Invasive species control
- Increase/Incorporate outdoor recreation and low-impact activities (greenspaces, community garden, low impact development, etc.)
- Involve and educate West Maui community and landowners
- Reduce coastal storm risk
- Create and promote ecotourism
- Close data gaps

1.8 Watershed Planning Objectives

The watershed planning objectives for this study have been identified in collaboration with the West Maui R2R Initiative:

- Address pollutant source(s). Develop list of recommendations that reduce current and future (+50 years) land-based sources of pollution throughout West Maui watershed
- Address pollutant conveyance(s). Develop list of recommendations that reduce current and future (+50 years) conveyance of pollutants to West Maui coral reefs
- Reducing land-based pollution of the marine environment will increase resistance and resiliency of West Maui coral reefs for the next 50 years.

1.9 Watershed Planning Assumptions and Constraints

Unlike planning objectives that represent desired positive changes, planning constraints represent restrictions on the planning process. Conceptual plans should be formulated to meet the study objectives and to avoid violating constraints. Constraints identified and considered by the study team in developing recommendations for improving coral reef health are as follows:

- Limited data availability (e.g. LIDAR, rainfall, stream flow data, etc.);
- Recommendations on private lands require support from landowner;
- Minimize adverse effects to cultural resources/historic properties;
- Minimize loss of floodplain;
- Avoid proliferation of invasive species;
- In-stream flow standards are regulated by the State government, affecting watershed hydrology;
- Impact to tourism; and,
- Projected growth, housing demand.

1.10 Interagency Coordination

Federal agency partnerships and expansive stakeholder involvement are necessary to collect a broad view of problems, needs and opportunities, including items that may not be seen in more conventional project planning, and reaffirm the purpose of the watershed study. Additionally, interagency collaboration should result in an overall cost-savings to the public as agencies work together more effectively towards watershed planning efforts.

USACE has engaged federal, state and local resource agencies and organizations to ensure alignment on the development and direction of this study since its inception and beginning with the Shared Vision (November 2015). Additionally, as one of many originating agency members of the West Maui R2R, USACE has ensured consistency with the objectives of the West Maui R2R, representative of the collective agency group. USACE participates in quarterly FAST meetings to update and obtain feedback from agency partners.

This draft watershed management plan will be formally circulated to the federal and state agency partners for comment. USACE will continue to involve the resource agency partners in the impending development of the draft final watershed management plan.

The following is a list of those entities that comprise the West Maui R2R FAST :

- USACE,
- DLNR (DOFAW, CWRM, DAR),
- DOH,
- USEPA,
- DOC-NOAA,
- USGS,
- DOA-NRCS,
- DOI-USFWS, and
- NFWF

In addition to the members of the FAST described above, the collaborative nature of this planning process is multi-tiered and includes both Federal and state agencies represented by the FAST as well as on-the-ground representation on Maui. The on-the ground representation is comprised of two additional groups, the West Maui Watershed Working Group (WMWG), and the Hui. Members of the WMWG include representatives from the large landowners, tourism sector, agricultural sector, Native Hawaiian community, Non-Governmental Organizations (NGOs), COM, and DLNR-DAR. The group is chaired by DAR and provides input on community concerns and priorities to the FAST. The Hui is a loosely affiliated group of mainly community and NGO representatives that also have provided support to the West Maui Watershed planning initiative. Collectively this entire interactive and collaborative process is called the West Maui Ridge to Reef Initiative. Figure 1-6 depicts the inter-relationship among the various stakeholders in the process.

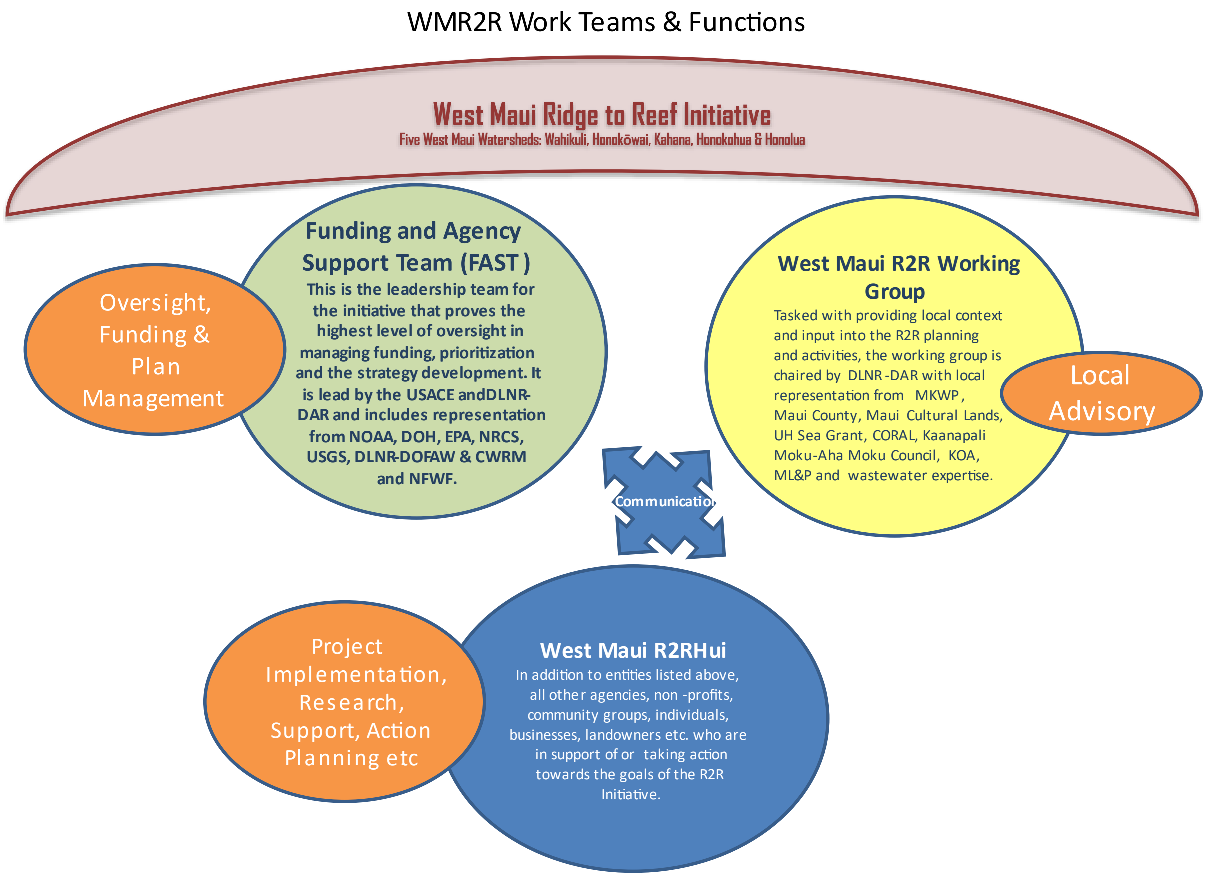


Figure 1- 6 West Maui Watershed Study collaborative stakeholder engagement

2 - EXISTING CONDITIONS WITHIN THE WATERSHED

Volume 1 of the 2012 and 2016 Watershed Characterization Reports provides, in great detail, discussion of the following watershed characteristics: current and future population and land use characteristics including local land use designations, major landowners and managers, as well as physical and natural features of each watershed, including geology, topography, soils, land cover, climate—including precipitation, temperature and natural hazards, climate change, hydrology—both surface and groundwater, natural waterways and manmade diversions for agriculture, flora, fauna, water quality, and a discussion of the coral reef ecosystem. Updated inventory and forecast of relevant characteristics that contribute to the furthering of this study, in particular, pollutant sources and conveyance, and that address the problems and objectives identified in Section 1.5, are discussed below and are intended to supplement the data presented in Volume 1 of the 2012 and 2016 Watershed Characterization Reports.

2.1 Inventory and Forecast.

2.1.1 Population

The West Maui area encompasses 96 square miles, covering over 13% of the island of Maui. Although the West Maui region is somewhat isolated from the rest of the island, due to steep topography and limited highway access, the region had nearly 25,000 residents in 2017 (ESRI, 2017). The Ka'anapali *moku* or district (comprised of Census Tracts 315.01 – 315.03, nearly identical to the study area) has 8,875 persons living in 3,587 households (ACS, 2019). Population demographics of the study area are 51% white, 19% Hispanic, 14% Asian, 5% Native Hawaiian or Pacific Islander, 0% black, and 10% two or more races (compared with all of Hawai'i: 22% white, 10% Hispanic, 37% Asian, 9% Native Hawaiian or Pacific Islander, 2% black, and 19% two or more races) (ACS, 2019).

Population growth rates between 2010 and 2017 were a combined 13.6% in West Maui—a faster rate in West Maui than the rest of Maui County and the state of Hawai'i (ESRI, 2017). Between 2004 to 2016, 59% of Maui County's population growth came from natural increase (local births minus deaths), 35% from international migration, and 6% from domestic migration (DBEDT, 2018).

West Maui is also a popular tourist destination and the second largest employment center in Maui, with an estimated average daytime population of 63,706 persons. This includes about 10,287 residents who remain in West Maui during the day, 19,868 workers both from West Maui and commuters to West Maui, and 33,551 visitors (ESRI, 2017) (DBEDT, 2018). West Maui also has the highest number of estimated visitor units on the island, at roughly 16,000 units (Hawai'i Tourism Authority, 2018), with over 4,000 visitor units in the study area specifically (ACS, 2019).

The study area, specifically, contains 5,143 employed individuals, over 5,000 of whom commute to work an average of 16 mins (roughly the travel time from Kapalua to Lahaina under light traffic conditions) (ACS, 2019). The major industries in the study area are entertainment & food service (42% of workers), professional services (12% of workers), retail (10%), insurance & real estate (9%), education & health care (8%), and construction (6%) (ACS 2019). 10.7% of households in the study area are below the federal poverty standards (compared to 10.5% nationally) while 70% of households have an income above the national median (ACS, 2019).

Housing Type	Total Units Needed by 2040	Units Available (2012)	Additional Units Needed by 2040
Resident	13,358	8,070	5,288
Non-Resident	3,359	1,724	1,635
Total	16,717	9,794	6,923

Table 2- 1 West Maui Housing Inventory and Forecast (Source: DBEDT 2018; County of Maui Socio-Economic Forecast, 2014)

The increased number of people living, working, and spending time in West Maui is putting a strain on housing, roads, transit, infrastructure, and other public resources, in addition to the natural environment. With the population of West Maui projected to grow to 33,750 by 2040 (an increase of 35%, or an annual growth rate of over 1.5%), the demand for housing, water, and other infrastructure will continue to grow. It is estimated that West Maui will need a total of 13,358 housing units to accommodate this resident growth (County of Maui, Land Use Forecast, 2014), which means that an additional 5,288 new homes will need to be built, as well as an additional 1,635 visitor units (Table 2-1). This is about 330 housing units per year (including non-resident demand) to keep pace with growth. Between 2008 to 2017, development of new homes in West Maui did not keep pace with demand, so meeting this goal may be a challenge for local government.

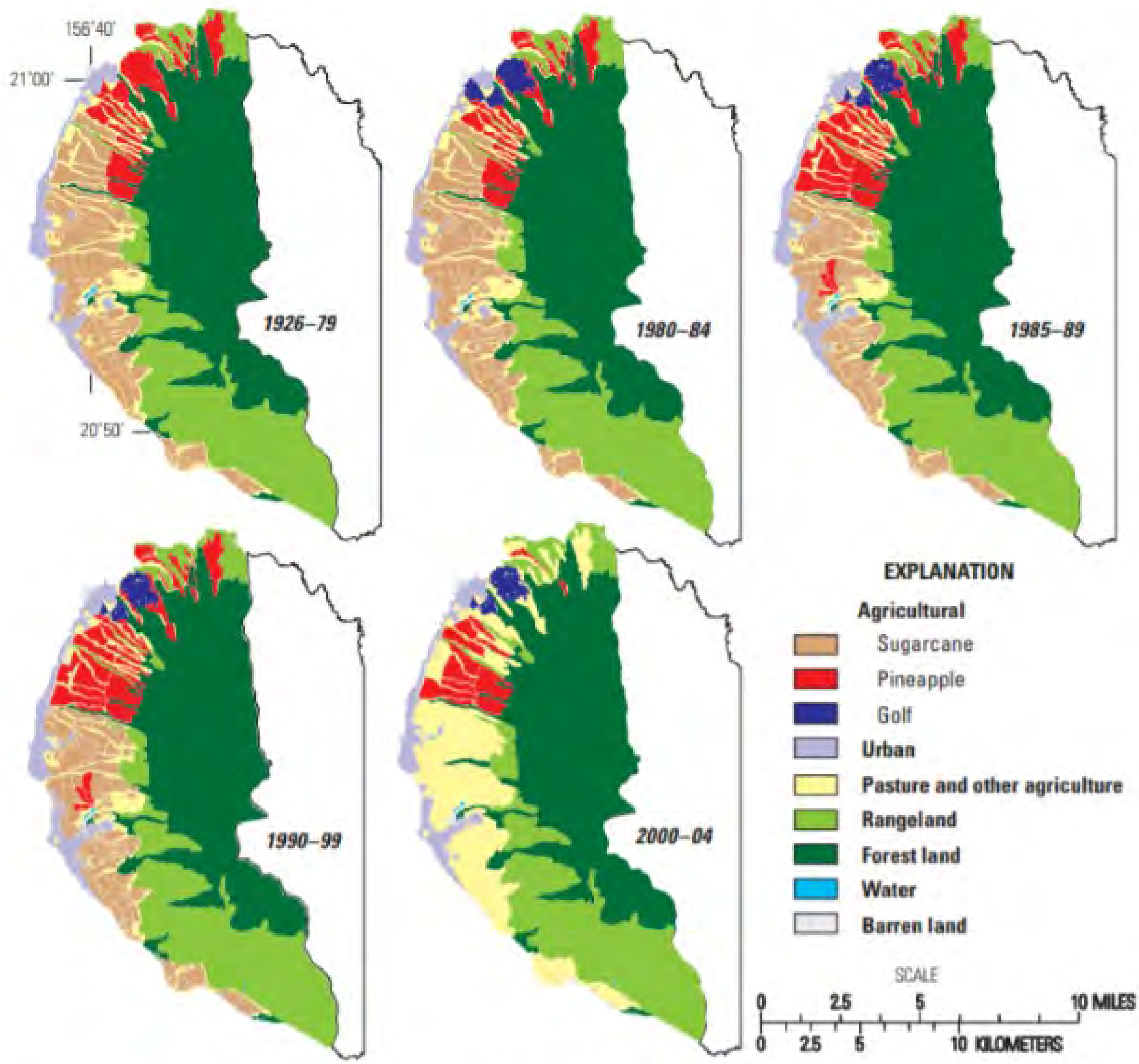
Because of Hawai'i's high-priced housing market, lower-priced housing is especially scarce, despite the high demand. Low supply and limited housing options make it difficult for many individuals and families to find needed housing that they can afford. West Maui is one of the county's primary employment centers, but many jobs are low-paying service industry and tourism jobs that are vulnerable to downturns in the local and national economy. The shortage of affordable housing in West Maui makes it challenging for employers to find and retain qualified workers because many workers are not willing to make the long commute to West Maui.

Those who are willing to commute face increasing traffic congestion, which has a negative impact on the local economy. The long delays that are a daily occurrence on West Maui roadways restrict the free flow of freight, workers, and visitors, in addition to diminishing the quality of life of residents. The imbalance of jobs-to-housing in West Maui is a major contributing factor to this traffic congestion. West Maui had more than two jobs for every occupied housing unit. In 2017, more than 6,800 workers commuted into West Maui from elsewhere on the island (U.S. Census Bureau 2017). Blockage or damage to Honoapi'ilani Highway, the primary roadway connecting West Maui with the rest of the island, can leave the region cut off from critical services and resources, as well as cause major disruptions for businesses that rely on commuters to function. Because West Maui is likely to continue to grow faster than the rest of the county, this problem will only get worse in the future.

2.1.2 Land Use Districts and Habitat Areas

Volume 1 of the 2012 and 2016 Watershed Characterization Reports discusses at length an inventory and forecast of land use designations throughout West Maui watersheds, from the mauka Conservation District, through the middle Agricultural District and makai to the Urban

District (Figure 2-1). Below is an updated discussion of land divisions based on manmade factors such as property ownership and local zoning designations and based on natural resource distribution in West Maui watersheds.



Base modified from U.S. Geological Survey National Hydrography Dataset, 1:24,000, Universal Transverse Mercator projection, zone 4, NAD83 datum.

Figure 2- 1 West Maui Land Use Over Time 1926-2004, USGS, 2012

West Maui watersheds include multiple resources and uses, and for discussion purposes is divided into the following land use districts and habitat areas: upper watershed, middle watershed, stream and wetland habitat, lower watershed and nearshore waters. Framing this under the USACE planning process, this report includes the inventory and forecast of the five watersheds. While the exact impact of climate change on West Maui is unpredictable and ever-evolving, a brief discussion of current predictions is provided for each land use district and habitat area below.

The information presented is taken from various sources, including the Applying Risk Informed Decision-Making Framework for Climate Change to Integrated Water Resource Management Planning – West Maui Watershed Plan (USACE, April 2013) and technical papers supporting the West Maui Community Plan presently undergoing final review by the Maui County Council.

Upper Watershed. The upper watershed of West Maui (Figure X) is managed by the Mauna Kahālāwai Mountain Watershed Partnership (MKWP), as a conservation area. The upper watershed is designated by the State of Hawaiʻi, a Conservation District, focused on preserving and restoring native forests. Through management efforts by the MKWP, pristine native forests and tropical montane bogs are protected. The MKWP successfully works to conserve these areas and to restore adjacent, buffering habitat. Invasive species, both aggressive plant species and introduced ungulate species, such as pigs, goats and increasingly deer, pose a primary threat to the native forests and bogs.

Figure 2- 2 West Maui mountains (Source: maunakahalawai.org)

The upper watershed supports a variety of rare indigenous flora and fauna. Many of these species are listed as threatened or endangered under the Endangered Species Act (ESA). The habitats of upper watershed protected species have very specific ranges and are particularly sensitive to relatively small changes in temperature and precipitation. With the potential for significant increases in temperature, especially in higher elevations, and reduced mean annual precipitation, it is likely that the range that native species can inhabit will be reduced and the potential for increases in ranges of invasive species, especially plant species will increase. This is a concern for the overall stability of the ecosystem, as well as rare and endangered species which may become further stressed.

Impacts to the stability of the forested ecosystem are also a concern for water resources. As quality forest cover declines, the quality and quantity of water may also decline. The hydrology in Hawai‘i forests that are dominated by invasive species, such as strawberry guava, significantly differs from that of native forests. Non-native dominant forests are typically associated with increased sedimentation and erosion as the invasive trees canopy, water uptake rates, and chemistry prevent the establishment of understory vegetation and soil retention. Climate change is likely to result in an increase spread in invasive species in the upper watershed and thereby an increase in sediment and erosion inputs into the lower watershed and nearshore. The increased dry periods may also render the forest more directly susceptible to fire, another source for sediment erosion. Once a fire moves through this area, the native forest is permanently degraded and can no longer provide the same ecosystem services (Brosius, 2012).

Figure 2- 3 West Maui Agricultural District. The Coral Reef Alliance (CORAL) installs and evaluates the effectiveness of planting vetiver “eyebrows” at removing water from agricultural roads and trapping sediment during rain events. (Source: CORAL)

Middle Watershed. During the plantation era, from the mid-1800s to the mid 1900s, the middle watershed was historically dominated by agricultural uses, with sugarcane stopping approximately 20 years ago and pineapple production terminated in 2009 (COM, 2021). The middle watershed is currently dominated by invasive grass and tree species due to inactivity in most of the agriculture fields (the exception being coffee in Wahikuli watershed). Wildland fires are not part of the natural disturbance regime of Hawai'i and the island of Maui. With the increase of human presence and invasive vegetation, wildland fires have increased, with several in the project area in the past decade. As increase in temperatures and decreases in mean annual rainfall are likely to occur with climate change, the invasive grasses are likely to increase in the upper watershed, increasing the fuel source for wildland fires. The drier conditions are likely to trigger wildland fires at increased frequencies and enhance the ability of the fire to spread once started.

The middle watershed was once dominated by agricultural activities and required large amounts of water to support growth. Past agricultural practices altered the surface water supply, diverting surface flow from streams to irrigate lands. Plantation farming in the watersheds stopped due to the cost of growing commercial crops in Hawai'i compared to other areas around the world. The area is now dominated by fallow fields filled with grasses and scrub trees, limited diversified agriculture and one coffee farm. With the closure of the agricultural plantations, sediment and erosion management practices such as properly maintaining service roads, irrigation systems, smaller sediment basins and riparian buffers were also abandoned (Figure 2-3).

Several planned developments are already planned and permitted in this agricultural area. While these plans are subject to change and development will be based on future economic demand, there are currently nearly 3,500 single family homes and over 2,200 multi-family dwellings planned in four of the five watersheds. According to the West Maui Community Plan, availability of affordable housing is an ongoing concern. Depending on the type of development, urbanized areas may increase the introduction of sediment, erosion and contaminants with an increase in impervious surface and storm-water run-off.

As climate change continues, it is likely that groundwater and surface water supplies may decrease due to a decrease in mean annual rainfall, a shift to more intense rainfall events even if annual rainfall means remain similar, and hydrologic shifts associated with increase in invasive species in the upper watershed. If groundwater and surface water supplies decline, the cost of maintaining agricultural activities may continue to increase and the feasibility of continued agricultural practices declines further.

As seen presently, an increase in abandoned fields and/or shift to land uses with greater amounts of impervious surface will result in an increase in sediment, erosion and contaminants into the nearshore waters. The agricultural areas (when maintained) provide a greenbelt that helps protect the upper watershed from wildland fire, as well as maintains access for firefighting crews. An increase in abandoned fields could also result in an increase in wildland fires and associated erosion. In addition, monotypic fields provide a managed landscape which once insulated the native forest from the incursion of invasive species, such as weeds, which now dominate formerly farmed areas.

Stream and Wetland Habitat. Similar to native forests, riparian habitats are threatened by invasive species. With the presence of non-native species and alterations to stream channels from land use activities, an estimated 40% of stream reaches along the agricultural district are currently storing unnaturally high levels of fine sediment originating from the fields above resulting in increased erosion and sediment transport to the nearshore areas. Instream flow has already been impacted by historic and existing irrigation systems. All of the streams in the lower four watersheds are dry and only flow on an intermittent basis due to stream diversions or the natural flow conditions.

Anticipated changes in climate for Hawai'i may include a decrease in mean annual precipitation that will likely reduce normal low flow conditions and increase opportunities for invasive species expansion. The large storm events are likely to become more frequent and with a greater intensity. As the stream and riparian habitat changes, unstable banks and areas of exposed soils are likely to increase. With more large and intense storm events, erosion of these unstable areas is likely to increase. The shifts in the upper and middle watersheds will also contribute more sediment to the system and to the nearshore reefs.

In addition, coral reef habitats have a constrained range of tolerance for freshwater inputs. Constant, diffuse, low flows of freshwater into the nearshore are typically tolerated by coral reefs. Where streams have been altered – low flow conditions are reduced and high flow conditions increase. This change in water flow has resulted in damage to coral reefs as the freshwater input results from episodic events above the tolerance levels of coral reefs. Expected changes to hydrology from climate change are likely to cause similar conditions – reduced low flow and increased episodic high flows. The coral reef habitat may experience greater decline near stream mouths.

Figure 2- 4 Historic lo'i in Honokohau Valley (Source: Bishop Museum)

Historically, wetlands occurred throughout the watersheds, primarily in areas adjacent to the streams and in the lower flatlands of the watershed. Native Hawaiians converted many of the wetlands to taro ponds or fishponds (Figure 2-4). While altered, these ponds continued to provide wetland functions for floodwater retention and sediment catchment. All of the wetlands in the middle and lower watershed have been drained and converted to different land uses. There is an effort within the watersheds to reestablish wetlands, mainly taro ponds, for both their cultural and natural habitat functions. Changes in precipitation are likely to alter the surface hydrology and physical shift and reduce the ranges where wetlands may be able to establish.

Shifts in precipitation and temperature patterns are likely to reduce groundwater availability. Associated increases in invasive species are likely to exacerbate these shifts.

Lower Watershed. The lower watershed is dominated by coastal development (Figure 2-5); resorts and residential areas dominate the lower watershed and are continuing to expand into the middle watershed. Since European introduction, alterations, and fill to the coastal areas of Hawaiʻi resulted in significant loss of coastal wetlands and dune systems. The extensive resort and urban development along the shoreline has further altered this environment, increasing impervious surfaces and decreasing natural processes that used to trap sediments behind the dunes prior to entering the ocean. The current practice is to instead use stormwater discharge outlets to allow the flow of water and related pollutants directly from the developed areas and roadways to the nearshore waters (Figure . Additionally, dune systems provided a buffer to natural and seasonal shoreline shifts and prevented erosion of terrigenous sediments into the ocean.

Figure 2- 5 Urban District, Kahana Coastline, COM, 2020

As sea level rises, the pressure for shoreline hardening or other means to protect existing development will increase. If the shoreline is hardened, isolated processes, including littoral sediment transport, are altered. Typically, this results in reduced sediment availability and increased erosion to either side of the hardened shoreline. Engineered solutions to adapt urban development to sea level rise could potentially increase impervious surfaces and storm-water discharge to nearshore areas. Many of the current utilities, including wastewater, occur in the coastal fringe.

Presently, the coral reefs in the watersheds are stressed from the introduction of contaminants from wastewater and stormwater discharge, landscaping and agricultural activities that introduce pollutants into the groundwater and enter the nearshore at natural freshwater submerged discharge areas. As sea level rises and the saltwater influence in the groundwater moves landward, there is a potential for more of these sources to intercept submerged groundwater discharge routes. Other interim and long-term solutions to sea level rise such as beach renourishments currently being pursued in three stretches of coast, and managed retreat will also have novel impacts not yet fully understood.

In recent years, sea level rise and high waves are already driving an increase in coastal erosion. In areas where the sub surface is volcanic alluvium, land-based soil is accessed as waves run up higher and higher, creating highly turbid nearshore waters in areas where there are no stream inputs. Early data from Hui O Ka Wai Ola suggests that high turbidity is trending upwards for sites with eroding coastlines. As wave run up and sea level rise increase, this source of sediment stress to nearshore reefs will also increase.

Figure 2- 6 Honolua Coral Reef (Source: The Nature Conservancy)

Nearshore Habitat. The nearshore waters include sensitive coral reef ecosystems and are designated as part of the Hawaiian Humpback Whale National Marine Sanctuary (Figure 2-6). In addition to the Federally designated Marine Sanctuary, there are two State designated reef conservation areas including the Kahekili Herbivore Fisheries Management Area in the Honokōwai watershed and the Honolua/Mokuleia Marine Life Conservation District in the Honolua watershed. Much of the land area in the Honolua watershed is also zoned as conservation. Research has shown that healthy well-established coral reefs have a greater resiliency to withstand physical changes to the environment. Coral reefs in the study area are already impaired by a variety of threats, including land-based pollution.

Because of its cooler and deeper waters, Hawai'i is only recently beginning to experience coral bleaching associated with increased sea temperatures. The first widespread, mass bleaching event across Hawai'i occurred in 2014 and 2015. Predicted changes in sea temperatures are likely to increase coral bleaching. Increasing ocean acidification associated with climate change will also impair the corals growth and health. Added impacts from fishing pressure also exacerbate this decline. As the corals continue to decline from a variety of stressors including increased land-based pollution this decline will likely be exacerbated by climate change and their ability to recover may significantly decrease. Coral reefs are also impacted by the re-suspension of fine sediments by certain wave patterns and energies (DLNR-DAR, 2017).

In summary, climate change is likely to increase sources of land-based pollution beyond existing conditions throughout the watershed if no action is taken to reduce these threats. Land-based pollution is one of the key threats impacting coral reefs in Hawaiʻi along with fishing pressure, increased sea surface temperatures, ocean acidification, overuse from recreational activities, spread of coral disease and aquatic invasive species. Both locally and globally and consistent with scientific literature, establishing a network of permanent no-take Marine Protected Areas and establishing a network of Herbivore Fishery Management Areas were the top ranked actions critical to post-bleaching coral recovery in Hawaiʻi. (DLNR-DAR, 2017).

2.2 Water Quality

All State waters are required to meet Hawaiʻi Administrative Rules, Chapter 11-54, Water Quality Standards. However, funding and manpower limitations at DOH prevent routine sampling and monitoring of all waters across the State of Hawaiʻi, including across the entire shoreline of the West Maui study area to ensure this standard is met. Volume II of the 2016 Strategies and Implementation plan recommended comprehensive water quality monitoring to better understand the pollutant sources, conveyance pathways and efficacy of existing management measures throughout West Maui (G70, 2016).

Hui O Ka Wai Ola[2] (Hui) is a West Maui community-based water quality monitoring initiative. Hui's network of volunteers works to routinely obtain ocean water samples at 11 sites throughout West Maui and input the data collected into a database (Figure 2-7). The water quality information presented here was collected and quality assured by Hui and is inclusive of data collected from 2016 through 2020 (although sampling in the northern three watersheds did not start until 2017). The Hui collects the following coastal water quality data: salinity, pH, temperature, total nitrogen, nitrate-nitrite-nitrogen (NNN), ammonium, total phosphorus, phosphate, silicates, dissolved oxygen (DO) and turbidity at the following sites: Honolua, Oneloa, Kapalua Bay, Napili, Kaʻōpala, Kahana Village, Pohaku, Kaʻanapali Shores, Kahekili Two, Canoe Beach and Wahikuli. Some water samples are immediately tested at mobile labs, while others are processed for testing at the UH School of Ocean and Earth Science and Technology Laboratory.

[2] For more information about Hui, go to www.huiokawaiola.com.

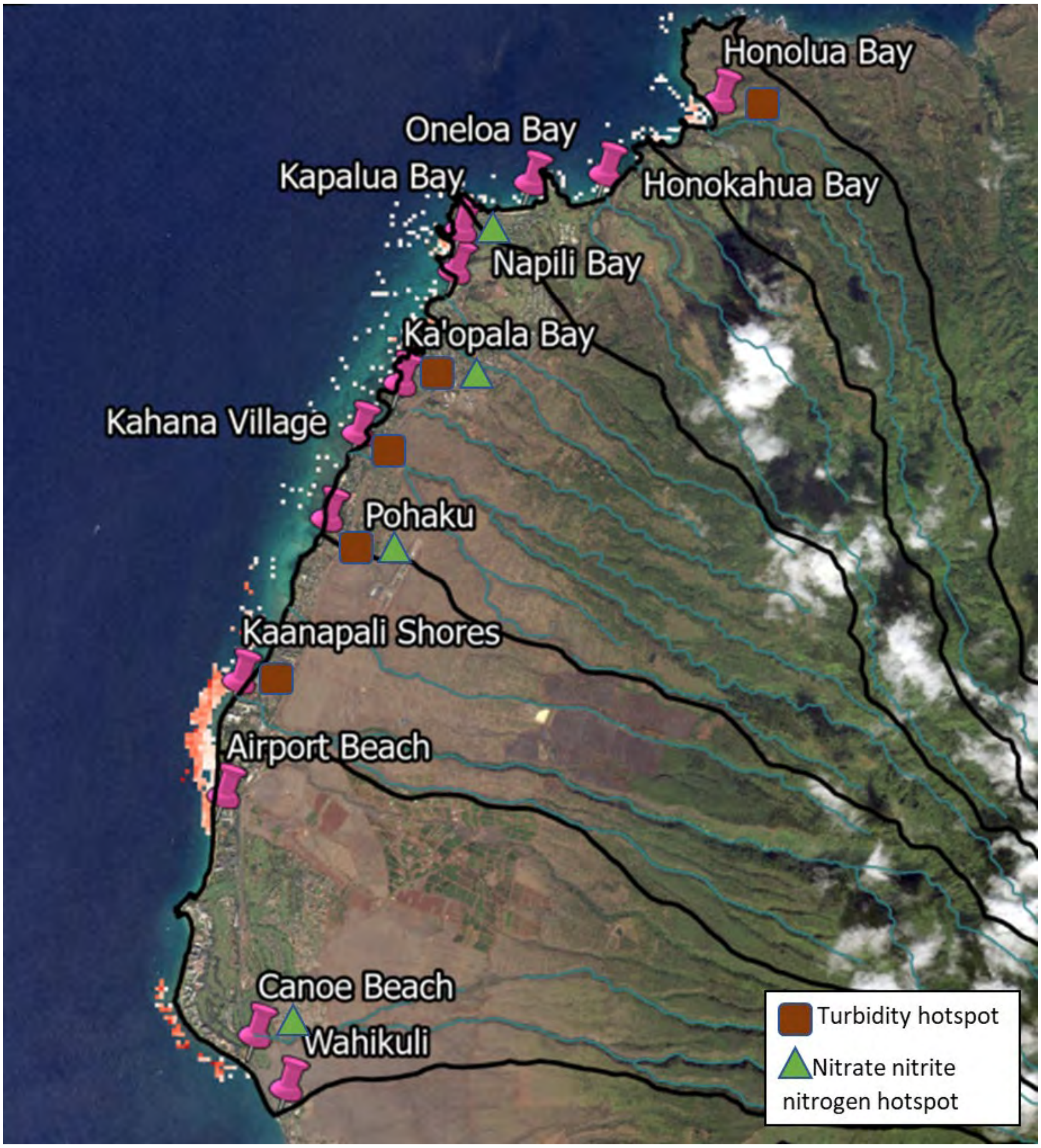


Figure 2- 7 Locations of Hui O Ka Wai Ola coastal water quality sampling sites in the study area. Hotspots for turbidity (brown square) and NNN (green triangle) are depicted. Superimposed are coral reef health shown in shades of red.

High turbidity, a measure of water quality and presence of sediment, and elevated nutrients, in particular, Nitrate, Nitrite and Nitrogen, are the most problematic of the water quality parameters tested in West Maui. Turbidity levels exceed the State standard of 0.2 NTU for all coastal testing sites in Maui. Throughout West Maui, geomeans exceed 4 to 44 times the State standard, with Kahana, Kapalua, Honolua and Pohaku reporting the highest values. For nitrate-nitrites, 8 of 11 sites exceed the State standard of 3.5 ug/L. The highest site geomean in West Maui is Pohaku Beach Park at 33 times the State standard, with Kapalua, Canoe Beach and Kaʻōpala also showing elevated levels. This data supports the study objectives at Section 1.5

above, that mitigation measures are needed on the landscape to address land-based pollutant sources that impair coastal water quality. See Figures 2-8 and Table 2-2.

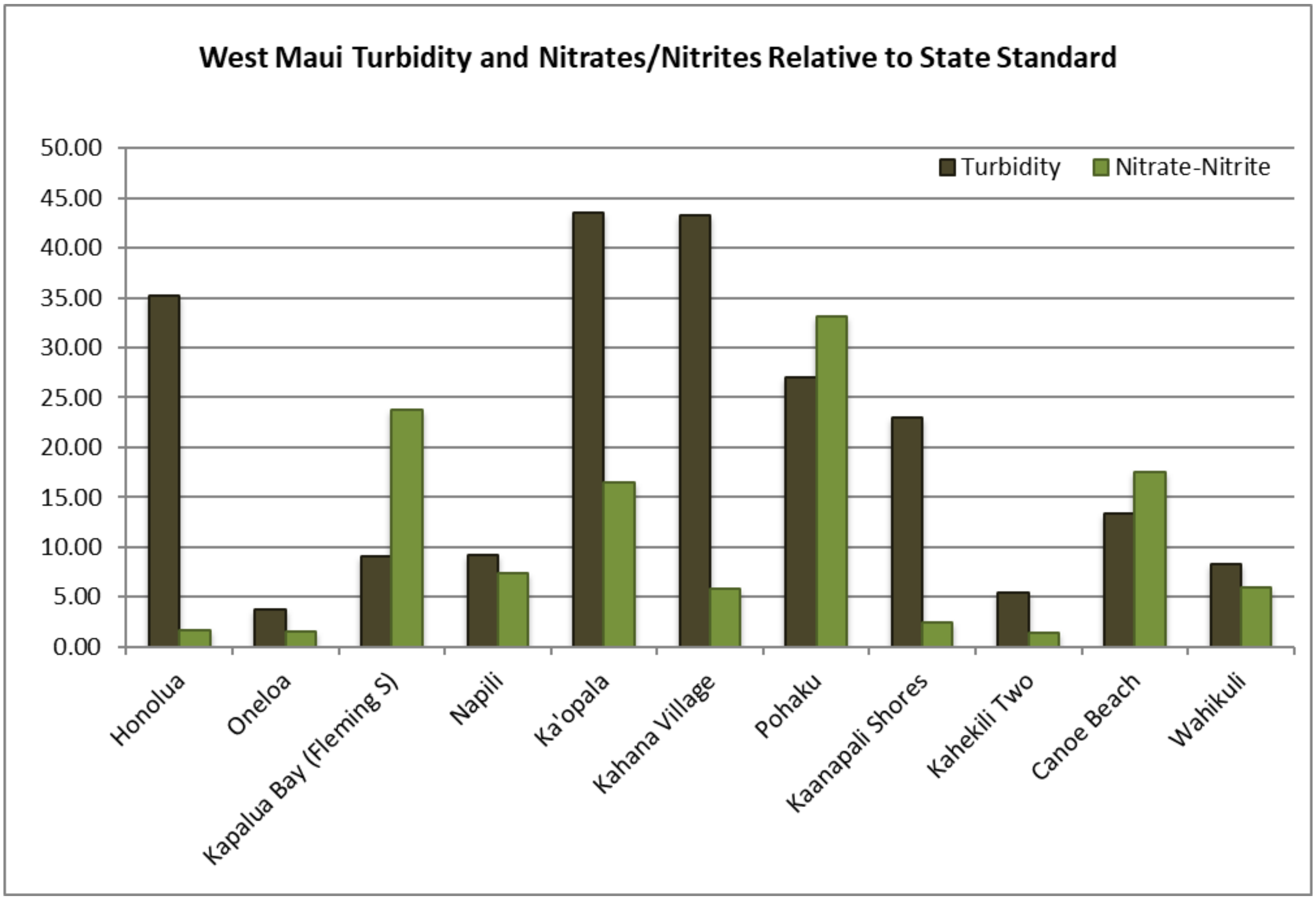


Figure 2- 8 Geomeans for turbidity and nitrate nitrite nitrogen normalized relative to Hawai'i Department of Health standards.

Figure 2-8 depicts turbidity and nutrient data collected in West Maui in comparison to the State standard. Values greater than one represent the number of times over the State standard. For example, samples taken at Honolua indicate turbidity is 35 times the state standard.

Site	Turbidity (NTU)	TN (ug/L)	TP (ug/L)	PO4 (ug/L)	NNN (ug/L)	NH4 (ug/L)	Silicate (ug/L)
Honolua	7.03	98.86	11.91	7.90	5.85	5.42	405.19
Oneloa	0.74	81.65	9.42	4.17	5.22	1.54	101.87
Kapalua Bay	1.81	174.06	17.76	14.30	83.24	3.71	861.02
Napili	1.84	118.28	12.80	8.57	25.80	3.94	415.84
Ka'ōpala	8.71	131.02	13.30	10.35	57.50	2.83	537.27
Kahana Village	8.66	100.81	10.54	7.19	20.22	2.57	407.93
Pohaku	5.41	204.32	17.02	13.51	116.13	3.97	900.78
Ka'anapali Shores	4.59	92.16	11.10	6.47	8.45	3.32	284.86
Kahekili Two	1.07	95.38	7.69	4.31	4.65	1.94	138.60
Canoe Beach	2.66	143.00	13.42	8.50	61.38	3.81	584.10
Wahikuli	1.65	96.17	14.97	9.90	20.72	1.63	648.40

Table 2- 2 Geomeans for all West Maui sites for Hui O Ka Wai Ola Data from 2016 (Wahikuli and Honokōwai watersheds) or 2017 (Kahana, Honokahua and Honolua watersheds) through 2020. The two most problematic parameters use colors to indicate range of exceedance of s state standards ranging from slightly in exceedance at yellow to progressively in exceedance through oranges and red.

2.2.1 Sediment Impacts on Coastal Turbidity

The largest source of sediment is in-stream accumulations in the bed and banks of streams in the Agricultural District that are conveyed by streams and gulches when it rains and that drives high turbidity in coastal waters (USGS, Stock, 2020) At higher rainfall intensities, the fallow agricultural landscape also becomes hydrologically connected, increasing the sediment loads coming from the streams. The second main cause of turbidity is driven by coastal erosion as the sea level rises and wave run up events become more frequent.

Figures 2-9 and 2-10 depict turbidity readings from 2017-2020 at Kahana, Honokahua and Honolua and from 2016-2020 at Wahikuli and Honokōwai, respectively. The data collected by Hui during this time period indicates a slight downward trend in turbidity in Honolua, Ka'ōpala, Kahana and Honokōwai Streams and a slight upward trend at Wahikuli Stream only. While informative, a longer time series is needed to confirm the reason for these trends. For example, the downward trend could indicate either declining number and/or size of land-based sediment sources or variability in storm size intensity, or some other plausible cause. Comparisons of coastal turbidity across sites illustrates that variability in rainfall, drainage size and elevation of headwaters in sub watersheds impact hydrologic connectivity, or in other words, brown water in one drainage during a rainstorm does not guarantee a turbidity spike at neighboring stream mouth sites.

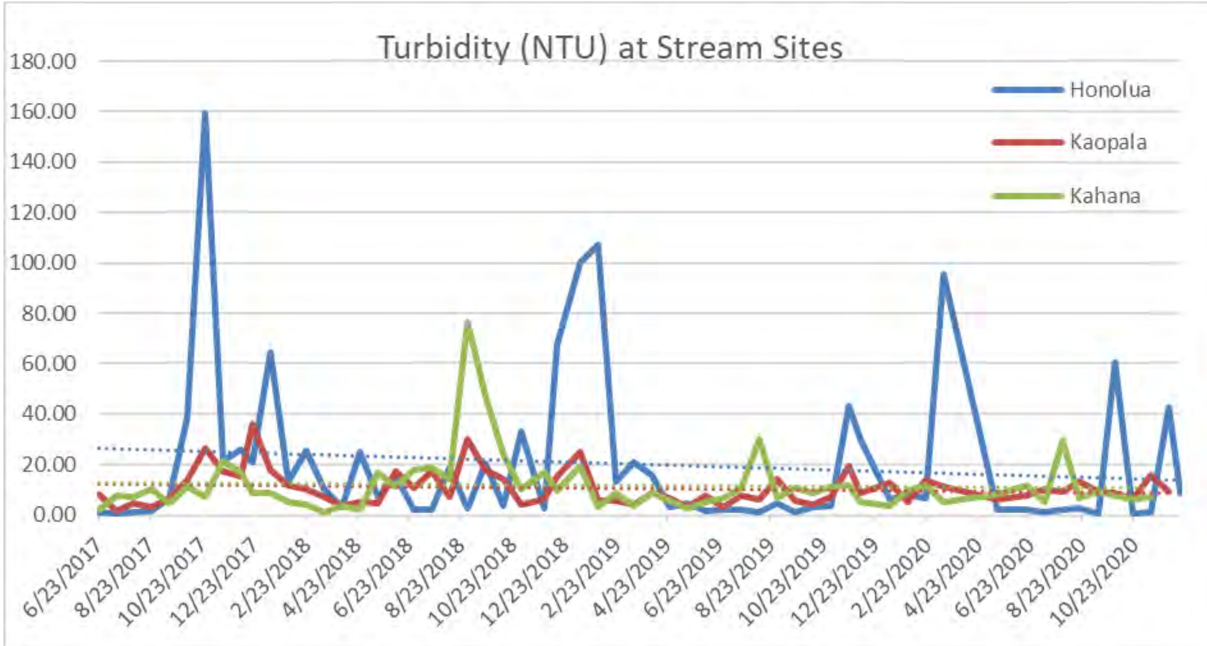


Figure 2- 9 Turbidity trends over the past four years for northern three watersheds

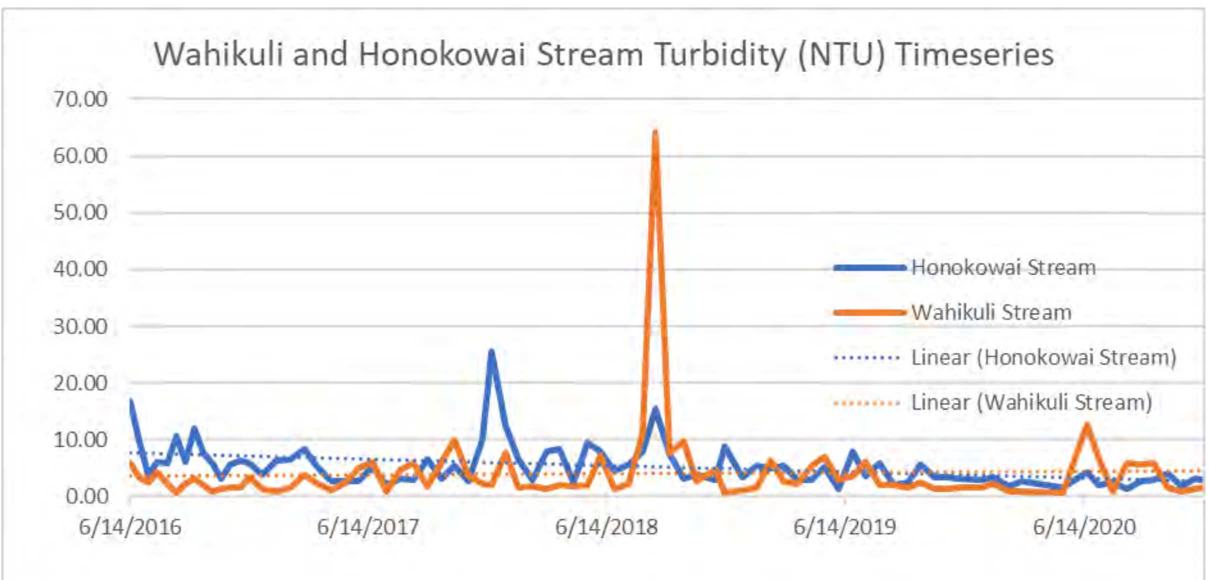


Figure 2- 10 Turbidity trends over the past five years in southern two watersheds.

Figure 2-11 depicts turbidity trends at the following locations selected due to presence of coastal erosion: Pohaku, Kapalua and Napili over a four-year period. Median turbidity readings at these select locations appear to be lower in comparison to stream sites. Turbidity readings depict a stable trend, with no upward or downward trend during the monitoring period. Stream conveyance of sediments in West Maui in response to certain rainfall events appears to contribute pulse-like, episodic, high turbidity, while coastal erosion appears to contribute chronic, comparatively lower turbidity. Both delivery methods of turbidity negatively affect coral reef health, in similar, yet different ways.

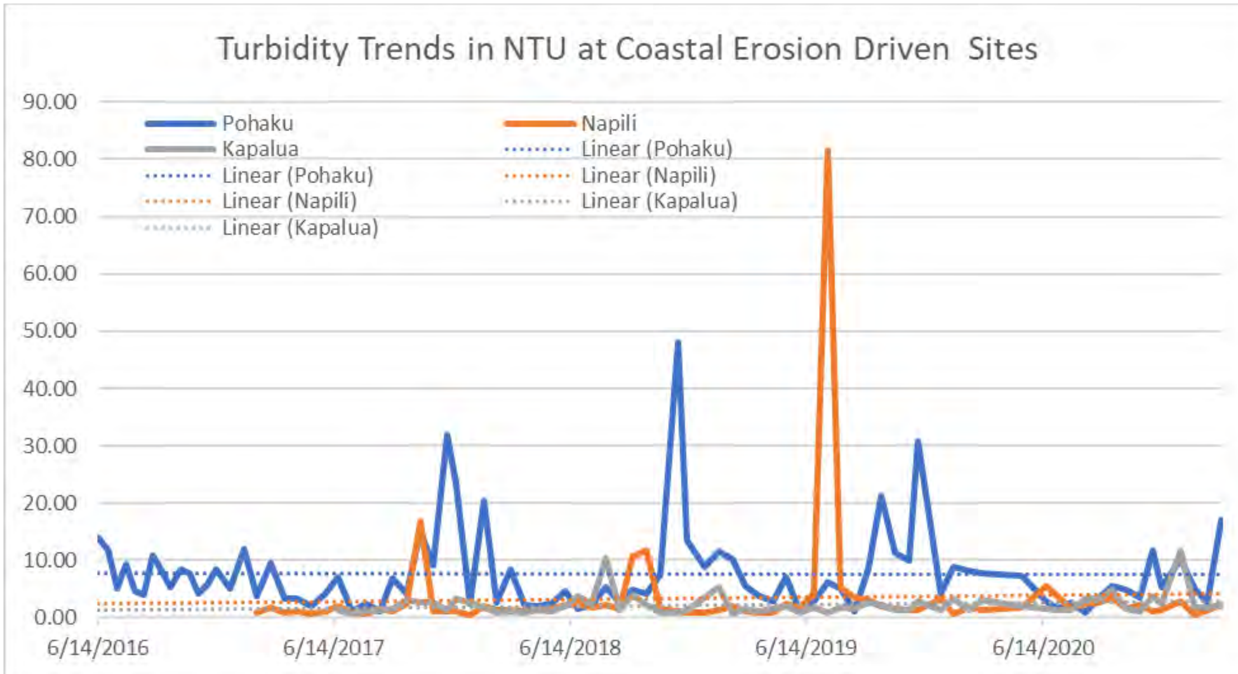


Figure 2- 11 Turbidity trends for locations dominated by coastal erosion. The spike at Napili in 2019 is a storm; the basin above overtopped and introduced sediment from the stream, so this value is not based on coastal erosion alone.

To understand the totality of the problem of turbid coastal waters, it is important to not only look at individual high data points, but also frequency of high data points. For example, Honolua, Ka‘ōpala and Kahana streams yield high turbidity readings of $\geq$10 NTU more than 40% of sample days (Figure 2-12). Surveys of coral reefs in close proximity to these streams indicate these reefs are highly degraded.

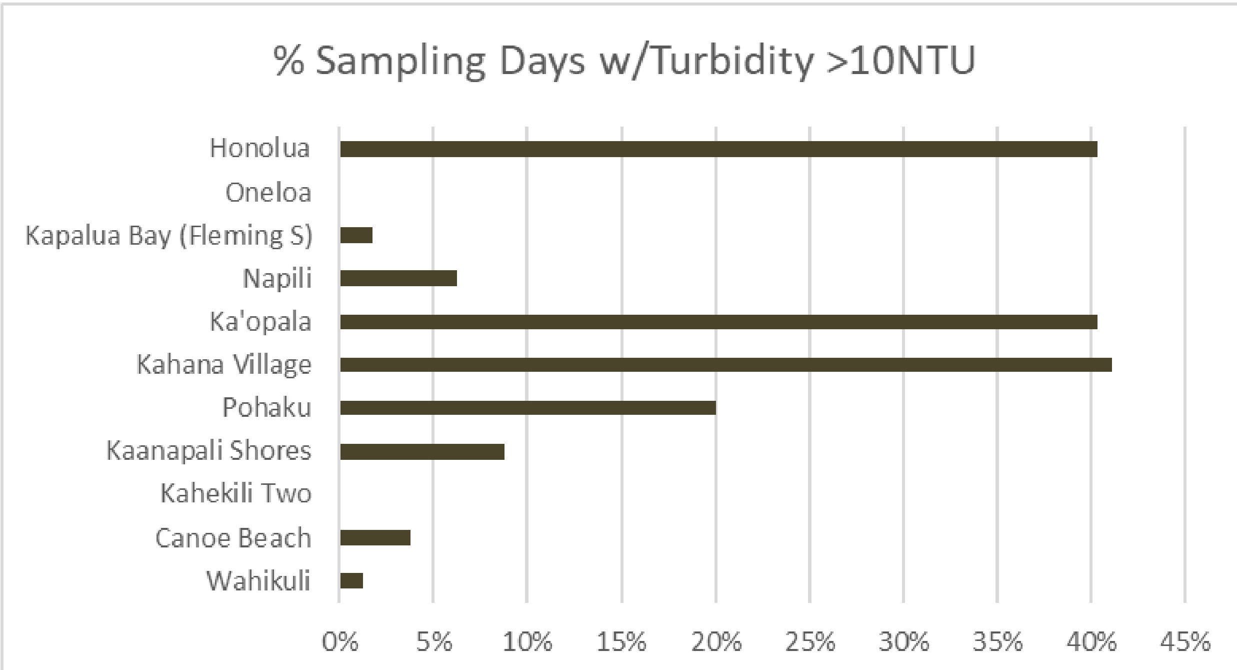


Figure 2- 12 Percentage of days with high turbidity over 10NTU (very low water clarity) at West Maui coastal sampling locations.

2.2.2 Impact of Nutrients on Coral Reef Health

Of the nutrient parameters measured, NNN is the most in exceedance of state standards, and most concerning for nearshore ecosystem health. Silica in groundwater is exclusively derived from water–rock interaction. The circulating groundwater dissolves the silica derived from the chemical weathering of silicate minerals in rocks and sediments (Hem 1959). High NNN values correlate tightly with silicate values as seen in the figure below, suggesting that these high concentrations are conveyed through submarine groundwater discharge, not stream inputs. Additional research is needed to confirm whether the elevated concentrations of NNN measured are driven by fertilizer or sewage sources. Based on past studies, the northern portion of Honokōwai watershed where Pohaku Beach Park is located was determined to be the most nutrient intense site because of the concentration of former agricultural production, both sugar cane and pineapple, mauka of this sampling location (Soicher and Peterson, 1997).

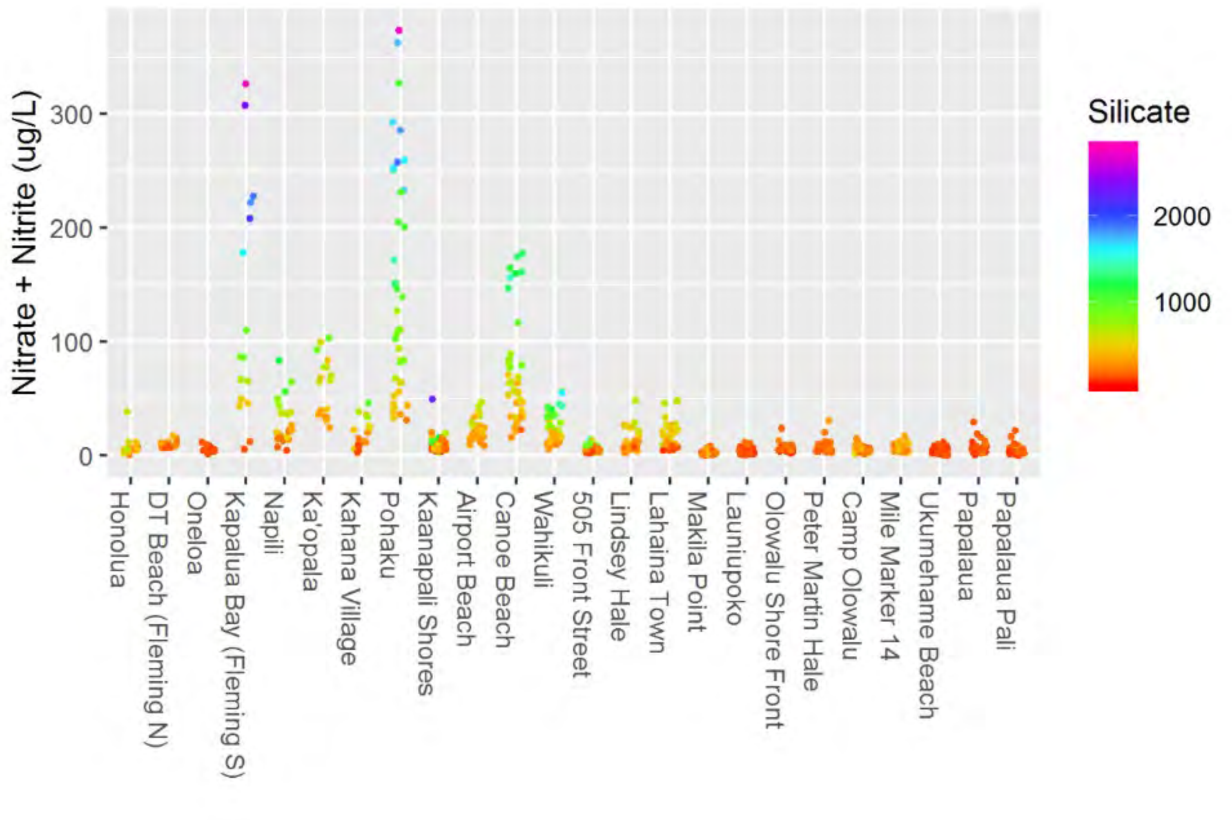


Figure 2- 13 Correlation between elevated nitrate-nitrites and silicates suggest nutrients are conveyed through submarine groundwater discharge

Given the conveyance pathway for nutrients is via submarine groundwater discharge, values are highly variable depending on the height of the tide during the sample collection. Since sample times are relatively consistent and the sampling interval is every three weeks, all tidal conditions are sampled over time. Low tide conditions result in the highest groundwater concentration, and therefore nutrient load.

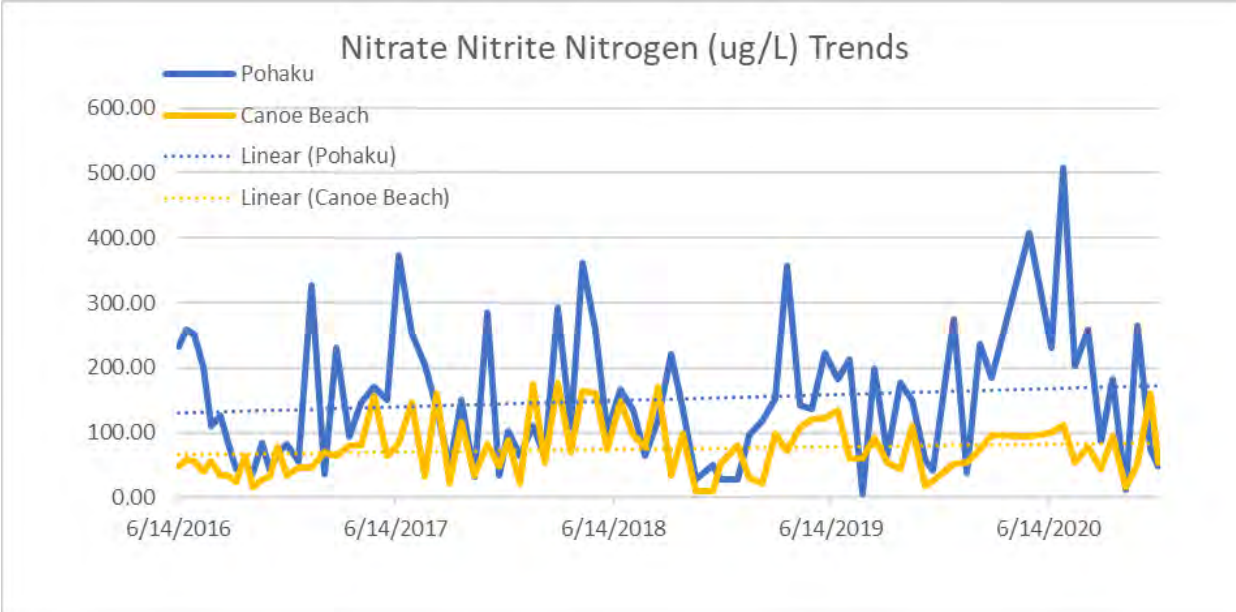


Figure 2- 14 NNN trends over time at hotspot locations (Pohaku Beach Park and Canoe Beach) in southern watersheds

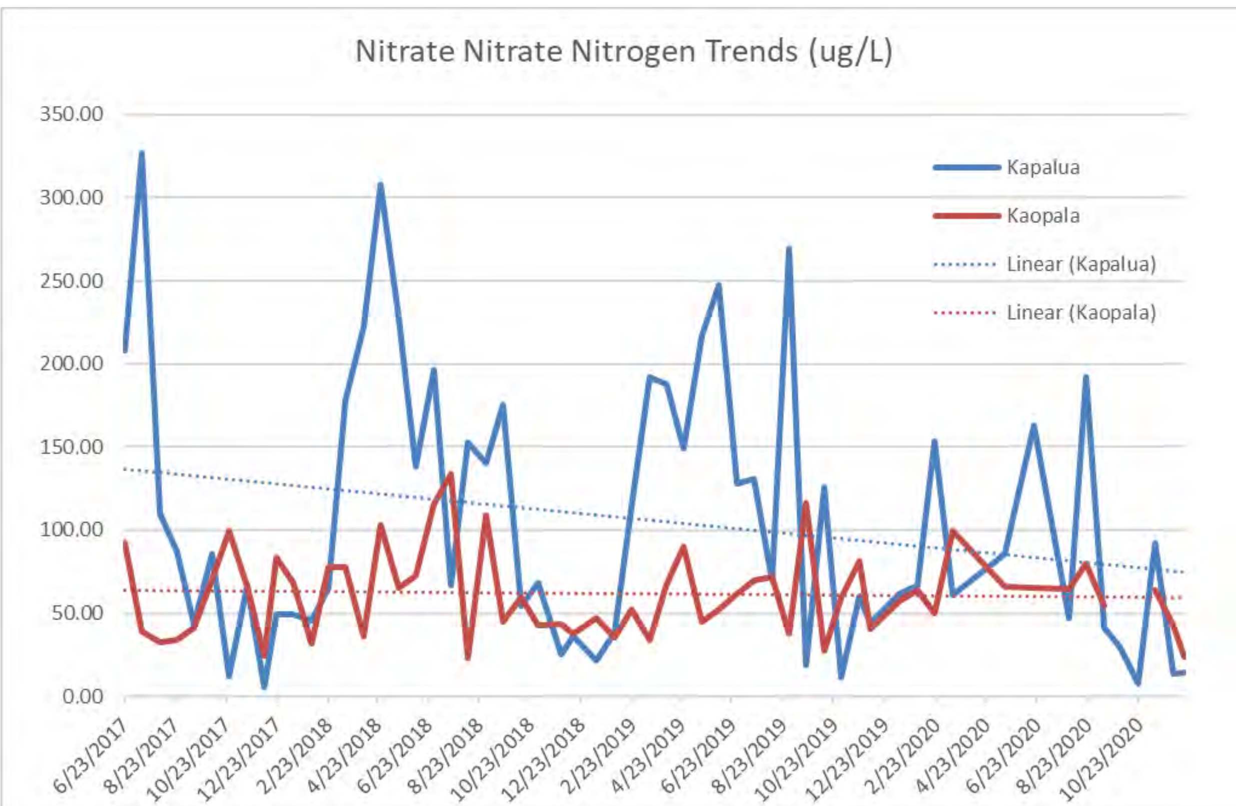


Figure 2- 15 Trend over time of NNN hotspot (Kapalua Bay and Ka'ōpala) sites in northern watersheds

There is a declining trend of NNN at Ka'ōpala and Kapalua, but most notably in Kapalua. Further investigation is needed to determine why concentrations fell around the 2020 timeframe.

Another trend observed was values for sea surface temperature increasing slightly over the past approximately five years, suggesting climate change impacts measured elsewhere in Hawaiʻi are also true for West Maui.

Given the number of sites in the West Maui R2R priority watersheds that exceed state standards for turbidity and nitrate nitrite nitrogen, it is important that land-based actions be pursued to improve water quality by reducing presence and conveyance of these land-based pollutant sources. Further research is needed to better understand nutrient dynamics.

2.3 Pollutants and Pollutant Sources

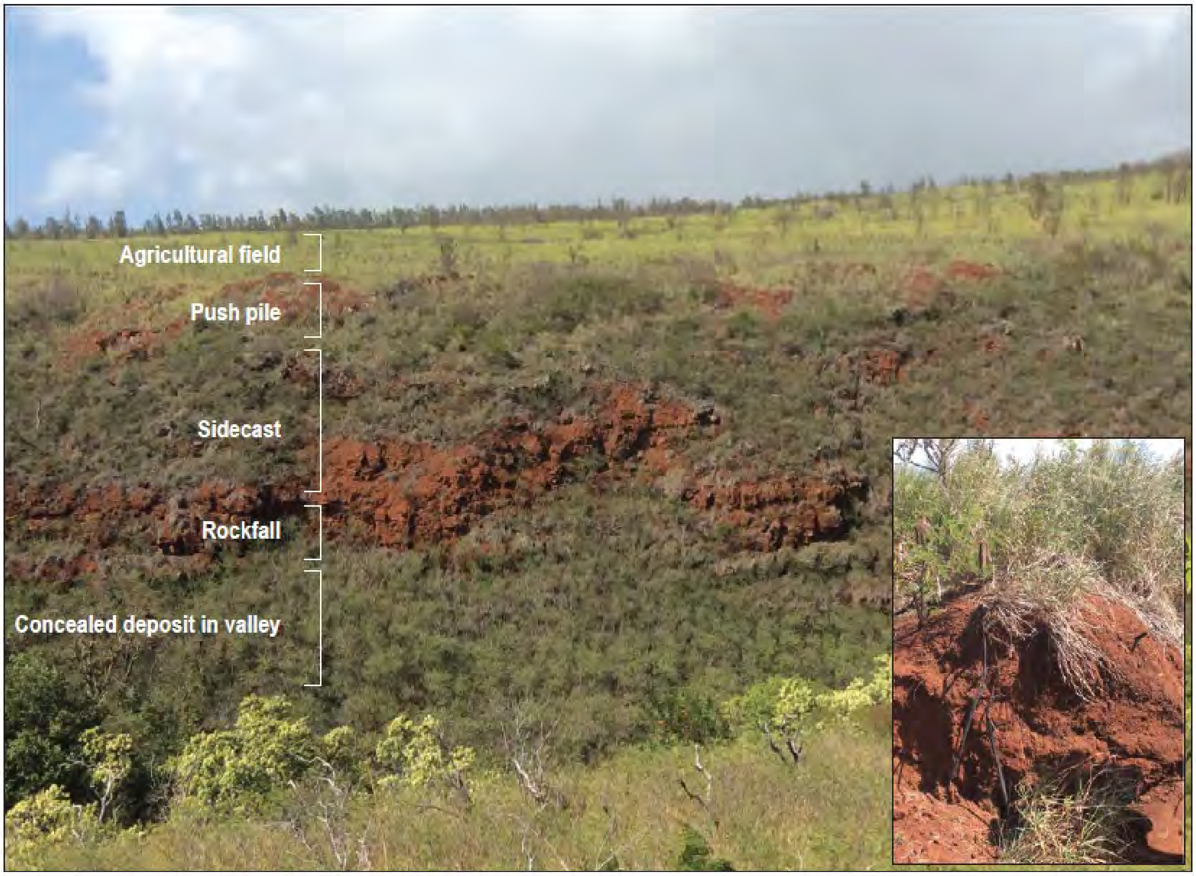


Figure 2- 16 Historic deposits of fine sediment from agricultural practices near Wahikuli Gulch. Evidence indicates undesirable sediments and debris were pushed to and over the valley margin as sidecast and now forms the stream bed and banks. (USGS, 2020)

2.3.1 Sediment

Field investigations indicate an anthropogenic layer of mixed sediment atop naturally occurring alluvial sediment in the West Maui stream valleys. Mixed cobble, gravel and large boulders that are not conducive to large-scale agriculture are found along the perimeter of the fields and adjacent to stream valleys. Red-orange silty sediment traces from the agricultural fields down the slide slopes of the adjacent valley. All evidence of sidecast material from atop the agricultural plateau to the bordering stream valleys. Investigations into the composition of the stream valley bed and banks indicate a layer of sandy silt over coarser grained deposit, some deposits featuring irrigation remnants and historical artifacts. This layer extends up the side slopes of the valleys up to the agricultural fields. These fine-grained deposits form historic fill terraces or legacy agricultural deposits that line the stream banks along much of the lower channel (Figure 2-16) (USGS, Stock, 2020).

Sediment in the Conservation District is characterized by coarse sediment and boulders, likely created by rockfalls and landslides and occupying up to a third of larger watersheds like Honolua, Honokahua, Kahana, Honokōwai, and Wahikuli. Side slope deposits of fine-grained legacy agricultural soils occur only within the Agricultural District and below, occupying up to one-fourth of the area of larger watersheds, like at Kaʻōpala. The mixed fine-grain composition atop alluvial deposits, the location only within the Agricultural District, the evidence of sidecasting and presence of agricultural artifacts supports the conclusion that the material deposited in the stream valleys are manmade and originated during and as a result of past agricultural practices (USGS, Stock, 2020).

USGS conducted pedestrian surveys starting from stream mouth up to the reach of the stream just above historic agricultural influence at four stream valleys to determine the extent of the fill terraces. Survey data was extrapolated to the remaining stream valleys to estimate fill terrace extent across West Maui watersheds. USGS found that fine-grained fill terraces account for approximately 40% of the total streambank length. These deposits vary in thickness, averaging approximately 85 cm thick, consisting of a silty loam, roughly 95 percent fine sediment (45% sand, 47% silt, and 8% clay) with a median grain size of 0.04 mm (Figure 2-17). Fill-terrace deposits are considerably siltier and finer than sediments found in agricultural fields (USGS, Stock, 2020).

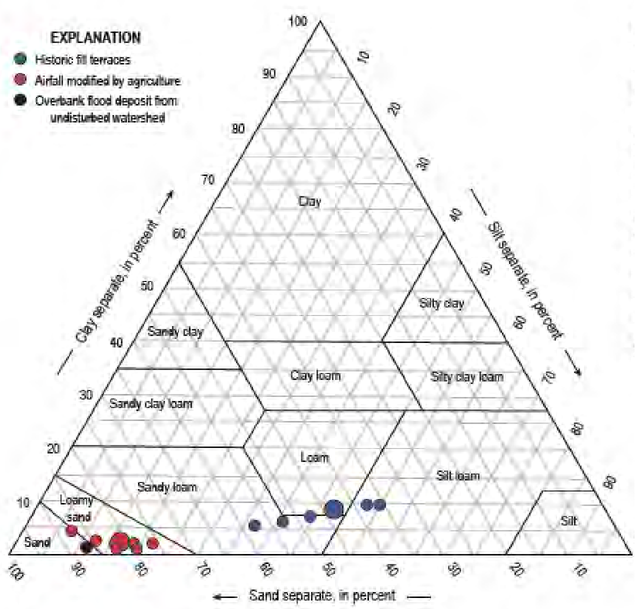


Figure 2- 17 USDA soil classification diagram of potential sediment plume sources including airfall from agricultural fields (red) and historic fill terraces (blue) in watersheds. Agricultural field airfall is characterized as a loamy sand and historic fill terrace is a silty loam (USGS, 2020)

A crude but defensible sediment budget indicates that this annual bank erosion sends a minimum of approximately 920 tons of fine sand, silt, and clay to West Maui's nearshore, the equivalent of about 93 dump-truck loads per year. Uncertainties in bank erosion rate imply that actual sediment loads could be 30–360 percent of estimated values. The sediment budget predicts that Kahana Stream produces almost a third of this total (USGS, Stock, 2020).

2.3.2 Nutrients

Data from the 2012 Volume I Watershed Characterization Report for Wahikuli and Honokōwai Watersheds identified exceedances of State water quality standards for chemical pollutants e.g. nutrients, in particular Nitrate and Nitrite, in both individual and aggregated water samples in both the dry and wet seasons (Note: the State Water Quality standards were amended in November 2014. Reference Section 2.2, above, the study areas continue to exceed the State Water Quality Standards for NNN.) Water quality monitoring at the time was discrete and limited in scope and likely did not depict the true extent of nutrient pollution across West Maui at the time. Numerous studies based on modeling suggest historic land use has the largest influence on nitrogen hotspots in West Maui. Legacy pineapple and sugar plantations relied on regular application of Nitrogen-based synthetic fertilizers. Chemical pollutants may infiltrate into groundwater—a typical transport pathway for ammonium and nitrate forms of nitrogen (Soicher and Peterson 1997).

Limited nitrogen isotope testing has taken place at the highest NNN sites. Results did not clearly indicate either fertilizer or wastewater signatures. Further testing is recommended to confirm the modeled assertion that legacy fertilizer is the main source.

2.4 Conveyance

Figure 2- 18 Sediment laden flow at Kaopala Gulch outlet after storm event observed by USGS on 7/20/14 (USGS, 2020)

2.4.1 Precipitation

Rainfall in West Maui occurs primarily via tradewind-driven orographic rain, typical of Hawai‘i’s subtropical location, carrying moist air from the sea in a westerly direction and upwards over Hawai‘i’s east facing mountain ranges. Orographic rain or the “Rain Shadow Effect” drives the climate gradient characterize by a wet windward side and a dry leeward side. In West Maui, orographic rain starts on the east side of Maui, over the summit of Pu‘u Kukui in the Conservation District and over into the Agricultural District before rain dissipates. Accordingly, the Conservation District and much of the Agricultural District in West Maui is forested and green, while the lower watershed Urban District is generally arid. While orographic rains are of moderate intensity and do not generally trigger flash floods or landslides, instead their consistent occurrence (over 70% of rain events) and relatively long duration is the primary contributor of Hawai‘i’s water supply (USGS, Stock, et. al., 2020).

Other dominant rainfall events are attributed to episodic cyclones and thunderstorms that bring higher intensity rainfall on both windward and leeward sides of Hawaiian islands. These lower frequency, higher intensity rainfall events are caused by upper-level trough, *kona* low, and cut-off low pressure systems, often exceeding 10 millimeters per hour (USGS, Stock, et. al., 2020).

Rainfall events exceeding 10–20 millimeter (mm) per hour over a minimum of two hours over watersheds that feature in-/near-stream sediment deposits generate terrestrial runoff, causing coastal plumes (Figure 2-18). Analysis of recent and historical rainfall indicates that West Maui communities can expect rainfalls of sufficient intensity and duration to generate coastal plumes to occur at least 3–5 times per year (USGS, Stock, et. al., 2020).

USGS examined historic rainfall records to determine rainfall trends over the past three decades. Historic records from West Maui stream gages in the Conservation District indicate the following: 1) annual rainfall totals have decreased, 2) cumulative hours (duration) of rainfall at intensities greater than 20 millimeters per hour (mm/hr) have decreased, 3) the frequency of storms with continuous intense rainfall has not changed. In summary, this means that although total rainfall has decreased since the 1970s, more rainfall now occurs during short, intense storms capable of causing runoff and erosion and generating coastal turbidity plumes (USGS, Stock, et. al., 2020).

2.4.2 In-Stream Erosion

During precipitation events of high enough intensity and for a long enough duration to generate in-stream erosion of fill-terrace deposits, high concentrations of silts and fine sands are shed into stream waters and transported downstream to the ocean These episodic and recurring higher intensity rainfall events of 10-20 mm/hr and lasting a minimum of 2 hours generates coastal sediment plumes at least 3-5 times per year in West Maui. Far less frequently, even greater intensity rainfall events that exceed 50mm/hr and that could mobilize agricultural sediments, occur on a decadal cycle. An analysis of saturated soil hydroconductivity in the agricultural fields and dirt roads above the stream valleys indicates infiltration rates (50 mm/hr) far exceeding rainfall rates (10-20 mm/hr) necessary to generate offshore sediment plumes, meaning that rainfall at intensities that generate sediment plumes would readily infiltrate the ground within the agricultural fields and not cause surface runoff or conveyance of agricultural sediments into the ocean. USGS concludes that the frequent coastal plumes observed in West Maui are predominately a result of in-stream sediment transport, and not agricultural runoff.

On average, the rate at which fill terraces erode range from 4 to 24 mm annually, with higher rates in streams located in wetter watersheds like Honolua Stream and Papua Gulch than streams located in drier watersheds like Mahinahina Gulch. Generalized bank erosion rates of 14 mm/yr and 5 mm/y for perennial/intermittent and ephemeral streams, respectively, were used in conjunction with eroding bank length to estimate annual sediment loads to the ocean per stream. Annual loads are divided by watershed area to determine sediment yield measured in metric tons/km^2/yr.

The annual load from bank erosion ranges from zero for watersheds without identified channels to a high of 285 metric tons/year with most values within the range of 25–62 metric tons/year (Figure 2-19). When sediment enters West Maui’s nearshore, imagery indicates that sediment is transported in three distinct along-shore cells, Northern Cell (Watersheds 1-12, starting at Lipoa Point and including Honolua Stream, Mokupea Gulch and Honokahua Stream), Middle Cell (13-33, starting at Napili 2-3 and including Honokeana, Kaʻōpala Gulch, Kahana and Honokōwai Streams) and Southern Cell (34-35, starting at Black Rock and ending at Wahikuli Gulch). Sediment loads from each activated stream channel combine within and per cell. For example, Kahana Stream, which has the highest value eroding bank length at 55 km and also the highest annual bank erosion load of 285 metric tons/year, combines with Kaʻōpala Gulch, which transports the second highest sediment yield in West Maui at 26 metric tons/km2/yr to generate synergistically worse adverse effects within the Middle Cell (Figure 2-20). The high annual load and high sediment yield within the same cell makes Kahana and Ka'ōpala prime targets for mitigation.

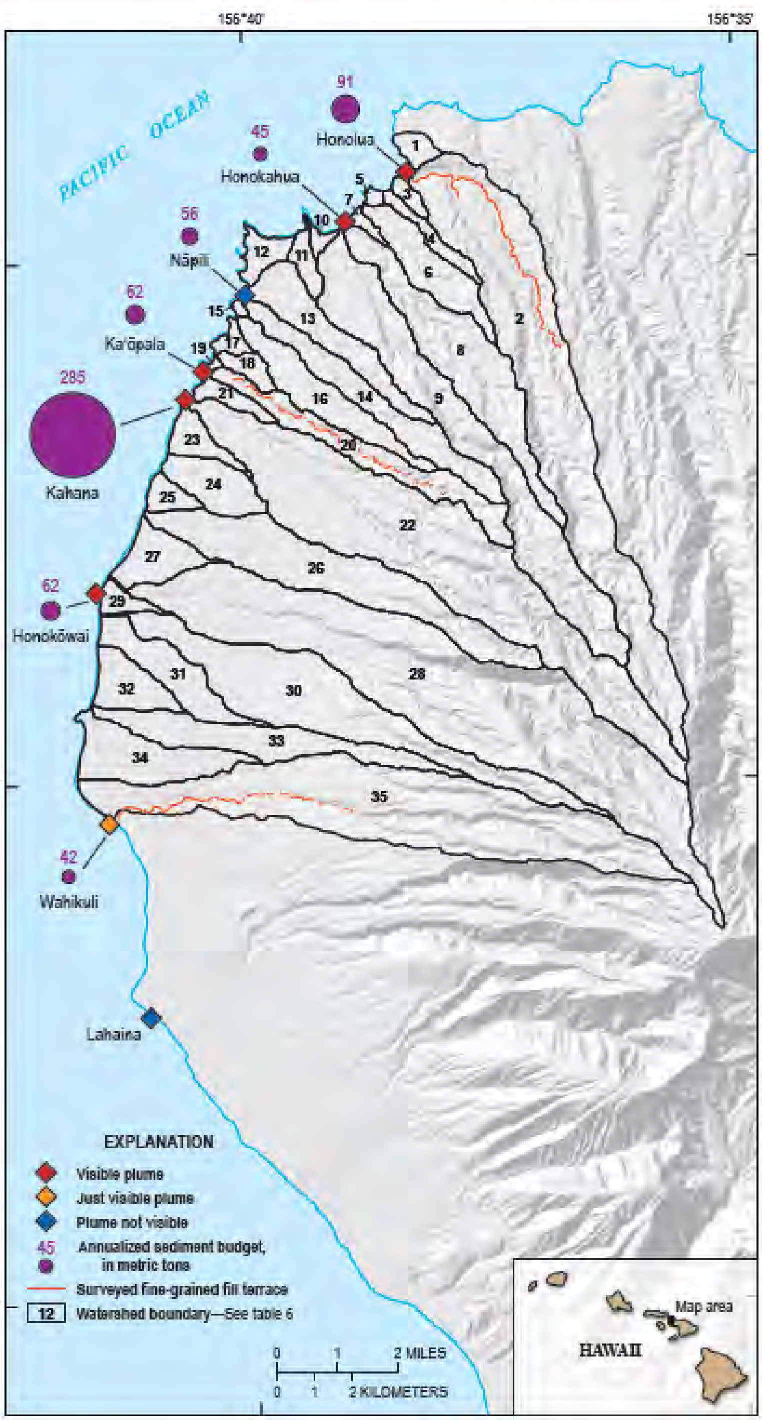


Figure 2- 19 Map of West Maui. Major watersheds and sub-watersheds are numbered. Surveyed historic field terraces (red line); all fill terraces occur within and downstream of agricultural areas. Purple circles proportionate to sediment budget in metric tons per year (USGS, 2020)

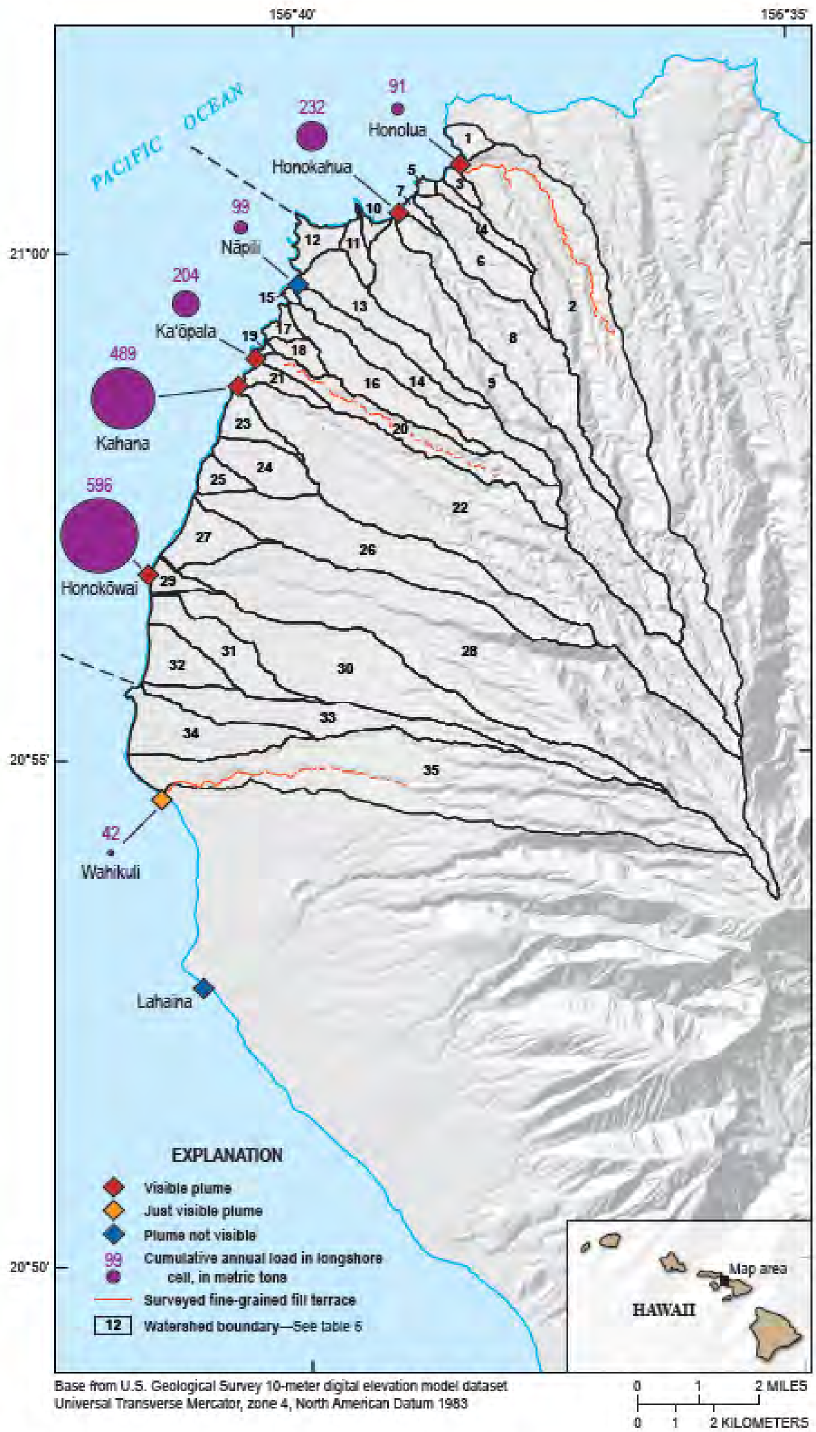


Figure 2- 20 Map of West Maui. Major watersheds and sub-watersheds are numbered. Longshore sediment transport cells (black dash). Purple circles show longshore accumulation of annual load in metric tons based on plume behavior (north to south, per cell) e.g. Honokōwai contributes 62 metric tons/year, however, due to longshore plume behavior, ocean fronting Honokōwai is exposed to a cumulative 596 metric tons/year from all outlets within middle cell, USGS, 2020

2.4.3 Coastal Erosion

West Maui faces wave exposure from both the north and the south, on the west-facing coast, contributing to exceptionally high seasonal variations in beach width. Overall, the West Maui region is considered "sand starved," with a limited sand supply prior to transition to terrigenous soil (as opposed to extensive sand dunes in Kihei and parts of Maui's north shore which act as a buffer for retreating shorelines) (COM, 2018). Data from Hui O Ka Wai Ola shows that over the past five years or so, coastal turbidity is trending slightly upwards at sample locations known to be impacted by coastal erosion. Continuing to test in the coming years is needed to better understand this trend.

Figure 2- 21 Costal erosion and water quality degradation fronting Ka'anapali Beach club (COM, 2021)

The USGS Atlas of Natural Hazards in the Hawaiian Coastal Zone (Fletcher et al. 2002) study showed that areas in the West Maui region (Olowalu, Lahaina, Nāpili, and Honolua) and including the study area, has an overall hazard assessment level of moderate to high (5 out of 7), due in large part to the low coastal slope, which increases susceptibility to impacts from high waves, storms, high tides, coastal erosion, tsunami, and flooding. Dense development of the West Maui coastline and in low-lying areas increases vulnerability to these natural hazards (Figure 2-21). Climate change and sea level rise will increase the frequency and severity of impacts. A 3-foot rise in sea level is the predicted intermediate scenario and 8+ feet of sea level rise as a worst-case scenario by the end of this century (Figure 2-22) (Sweet, et. al., 2017). Further, sea level rise is projected to be higher than global averages around tropic regions, including Hawaiʻi. Flooding events during seasonal or extreme high tides will be experienced decades before the projected global sea levels are reached as is already occurring in West Maui. Long-term community and development planning should consider adaptive and innovative solutions that provide multiple benefits and that make the West Maui community resilient to the projected impacts of climate change and sea-level rise.

Figure 2- 22 Sea Level Rise Projections, Pacific Islands Ocean Observing System, Sea Level Rise Viewer, Hanakaoʻo, West Maui. (COM, 2018)

2.4.4 Groundwater

Groundwater seeps convey freshwater to the ocean and in effect, lowers pH of the water at and near the seep. Ocean acidification lowers pH on a global scale, as the ocean absorbs increasing amounts of CO_2 from the atmosphere. Lower pH (greater acidity) slows calcification, the process by which corals and other marine species make their skeletons out of the mineral calcium carbonate. It also increases rates of coral bioerosion—the breakdown of coral by other organisms—and it can cause carbonate skeletons and sand to dissolve. A recent study by USGS shows evidence of local stressors such as freshwater and nutrient inputs compounding upon global climate change effects of ocean acidification and accelerating coral reef health decline (USGS, 2018). While well established that corals require clean, clear, low nutrient water to thrive, recent research more clearly illustrates the mechanisms and extent to which elevated sources of nitrogen can undermine coral health.

At Kahekili reef in the Wahikuli Watershed, treated wastewater effluent originating from the Lahaina Wastewater Reclamation Facility travels through submarine groundwater (confirmed through dye tracing) seeps onto nearshore reefs, transporting freshwater, lowering pH and creating a constant loading of nitrogen, on the order of 50x the normal nitrate concentration (USGS, 2018). Coral cores obtained from Kahekili reef indicate chronic exposure to polluted, low-pH groundwater resulted in bioerosion 8x higher than coral reefs without these influences (Prouty, et. al., USGS, 2017). Bioerosion is so active that the thin layer of coral that is alive is growing on a structure that can collapse, losing many benefits coral reef ecosystems provide such as providing habitat for fish and other marine biota and coastal protection. An additional Hawaiʻi based study demonstrated that nutrient pollution could make reefs more vulnerable to global changes associated with ocean acidification and accelerate the predicted shift from net accretion to net erosion (Silbiger et.al., 2018).

While more recent water quality sampling by the seeps in Kahekili suggest that nitrate-nitrate-nitrogen concentrations in the injected wastewater have lowered due to improvements at the treatment plan, the documented significant degree of impact from elevated nutrients on coral reef structure supports continuing efforts to address nutrient pollution of coastal waters. Understanding the concerted impact of global and local stressors on local coral reef ecosystems supports measures that address local, land-based pollution inputs into the nearshore environment to improve coral reef health.

3 - WATERSHED MANAGEMENT RECOMMENDATIONS

The Watershed Management Plan was prepared to guide current and future planning decisions and investments in the West Maui watershed and that comprehensively addresses problems within the watershed, while achieving the watershed objectives outlined in Section 1.5 of this plan. Planning for the future of the watershed is crucial to decrease conveyance of land-based pollutants to the marine environment and improve coral reef health. For this watershed management plan, the PDT developed a list of management measures to address the most pressing resource needs as identified in collaboration with the West Maui R2R Initiative, the West Maui community and our study partner. Recommended management measures that propose structural, engineered solutions were transmitted to the USGS to model the marine transport dynamics i.e. to which coral reefs are in-stream sediments transported to and deposited.

3.1 Management Measures.

A measure is a specific structural or non-structural action that could contribute to the plan objectives by reducing or eliminating the identified problems. Management measures may address one or more study objectives and are the “building blocks” for conceptual alternatives or recommendations (USACE, 2015). All management measures are considered to have an approximate 50-year period of analysis for individual projects, or in combination with other management measures.

3.1.1 Measures Recommended by the 2012 and 2016 Volume II Strategies and Implementation Plans

An initial list of structural and non-structural management measures was derived by combining recommendations generated in Volume II of the 2012 and 2016 Strategies and Implementation Plans that investigated a wide range of problems and solutions. Relevant measures i.e. not overcome by events or data, or not yet implemented to address a persistent problem, were carried forward in this watershed management plan.

The table below briefly discusses the current status and relevancy of the previously recommended measures and accordingly, a decision to advance or eliminate. Detailed descriptions of these measures are found in the sources identified below. Measures proposed at a later date and currently being pursued by the West Maui R2R and independently by organizations within the West Maui R2R are also added to this list and a determination to advance or eliminate made. Descriptions of these measures are provided below.

Table 3-1 Management Measures Recommended by 2012 and 2016 West Maui Strategies and Implementation Plans

Measure	**Source**	**Status** *(Complete or Ongoing, Irrelevant or Relevant)*	**Decision** *(Eliminate /Advance)*
~~Road and Trail Inventory Assessment and Pollution Source Minimization Practices~~	~~Wahikuli, Honokōwai Vol. II, 2012~~	~~Completed more or less; Should prioritize gulch buffers and road crossings~~	~~Eliminate~~
~~Fallow Agricultural Field Inventory Assessment and Pollution Source Minimization Practices~~	~~W-H Vol. II, 2012~~	~~Irrelevant; rains came and filled in the fields~~	~~Eliminate~~
Lāhaina Wastewater Reclamation Facility Alternate Disposal e.g. Increase production of R-1 water for reuse	W-H Vol. II, 2012	Ongoing (through COM investment mostly)	Advance
Engineering Analysis and Retrofit Design at Honokōwai Structure #8	W-H Vol. II, 2012	Ongoing- have concept, need more modeling, then full engineering design and permitting	Advance
Engineering Analysis and Stabilization Designs at Wahikuli Gulch	W-H Vol. II, 2012	Ongoing, Relevant	Advance
~~Fertilizer Management Plan~~	~~W-H Vol. II, 2012~~	~~Ongoing (perpetual)~~	~~Eliminate~~
Ocean-Friendly Landscaper Outreach Program	West Maui R2R (Kumuwai) Ongoing	Ongoing	Advance
Burn Area Emergency Response Plan	W-H Vol. II, 2012	Complete; updates needed periodically	Advance-
Wildland Fire Management Measures e.g. Fire breaks	West Maui R2R, Ongoing	Recommend pursuit	Advance
~~Urban Pollution Control: Baffle Box~~	~~Wahikuli, Honokōwai Vol. II, 2012~~	~~Irrelevant (location sited was not feasible)~~	~~Eliminate~~
Urban Pollution Control: Bioretention Cell e.g. Rain Garden	W-H Vol. II, 2012	Complete (locations sited; maintenance needs and additional locations)	Advance
Policy Measure: County Storm Water Management Plan	Kahana, Honokahua and Honolua Vol. II, 2016	Ongoing	Advance

Table 3-1 Management Measures Recommended by 2012 and 2016 West Maui Strategies and Implementation Plans			
Policy Measure: Enforcement of Temporary Construction Storm water BMPs	K-H-H Vol. II, 2016	Ongoing; Perpetual need to enforce	Advance
Post Construction Storm water Ordinance: Drainage Master Plan Requirement	K-H-H Vol. II, 2016	Complete. Needs update.	Advance
Policy Measure: Requirement for BMP Management Plans and Reporting by Large Scale Nutrient and Pesticide Users	K-H-H Vol. II, 2016	Ongoing	Advance
Policy Measure: Water Quality Monitoring Program	K-H-H Vol. II, 2016	Ongoing	Advance
Community Water Quality Monitoring Program	Hui O Ka Wai Ola, ongoing	Ongoing	Advance
Policy Measure: Agricultural Conservation Plan Requirement for Ag Lands	K-H-H Vol. II, 2016	Ongoing (managed by WMSWCD)	Advance
Policy Measure: Establish Storm Water Fees	K-H-H Vol. II, 2016	Ongoing	Advance
Policy Measure: Low Impact Development Requirement for development, redevelopment and improvement projects > 1 acre (State, County and private sector) to incorporate LID measures into design and construction	K-H-H Vol. II, 2016	Ongoing	Advance
Policy Measure: Golf Courses and Landscaping BMP Management Plans	K-H-H Vol. II, 2016	Ongoing (landscaping BMPs ongoing, need golf course BMPs)	Advance
Policy Measure: Pool and Vehicle Wash Water Discharge Policy	K-H-H Vol. II, 2016	Ongoing Pool complete	Advance
Policy Measure: Storm Water Management Asset Mapping	K-H-H Vol. II, 2016	Ongoing (mapping complete for COM assets, but missing for private lands)	Advance
Policy Measure: Regional Drainage Analysis	K-H-H Vol. II, 2016	Ongoing	Advance
Stop sediment from entering streams and gulches via Push pile assessment and stabilization Stream crossings stabilization Access road improvements	K-H-H Vol. II, 2016	Ongoing	Advance
~~Stop future sediment sources via~~ ~~Construction best management practices (BMPs)~~ ~~Grazing BMPs~~ ~~"Go Time" Wildfire Plan~~	~~K-H-H Vol. II, 2016~~	~~Complete~~	~~Eliminate~~

Table 3-1 Management Measures Recommended by 2012 and 2016 West Maui Strategies and Implementation Plans

Stop existing in-stream sediment deposits from transporting sediments downstream to the ocean via Identification of sediment terraces in streams and gulches Researching, piloting and implementation of stream/gulch bank management measures Restoration of traditional lo‘i kalo	K-H-H Vol. II, 2016	Ongoing	Advance
Address current in-stream sediment movement via Kahana desilting basin maintenance Desilting basin monitoring and analysis Desilting basin retrofits Potential new desilting/sediment basins	K-H-H Vol. II, 2016	Ongoing	Advance
Measures to address in-stream sediment deposits and prevent transport downstream: Microbasins in Ka‘ōpala or Wahikuli Lo’i terraces in Honolua or Honokōwai Basin modifications at Ka‘ōpala, Kahana and Honokōwai	USACE, ongoing	Ongoing	Advance
Increase groundwater recharge and slow surface flows via Conservation boundary fencing Active ungulate & invasive weed management Landscape restoration	K-H-H Vol. II, 2016	Ongoing	Advance
Monitor and assess roadside erosion at Honoapiilani Highway and Lower Road	K-H-H Vol. II, 2016	Ongoing	Advance
~~Cesspool Identification and Conversion~~	~~K-H-H Vol. II, 2016~~	~~Complete (minor source of nutrient)~~	~~Eliminate~~
Urban Storm Water Management Retrofits	K-H-H Vol. II, 2016	Ongoing	Advance
Continue to fund existing outreach initiatives and outreach coordinators	K-H-H Vol. II, 2016	Ongoing	Advance
Multiple Sediment Capture and Groundwater Recharge Basins at Wahikuli and Hahakea Gulches	Stream Restoration Technical Solution Report – Wahikuli and Honokōwai Watersheds, CORAL, 2017	Ongoing	Advance
Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch	Stream Restoration TSR – Wahikuli and Honokōwai Watersheds, CORAL, 2017	Ongoing	Advance

Table 3-1 Management Measures Recommended by 2012 and 2016 West Maui Strategies and Implementation Plans			
Gulch buffers adjacent to Wahikuli Gulch and Hahakea Gulch	Stream Restoration TSR – Wahikuli and Honokōwai Watersheds, CORAL, 2017	Ongoing	Advance
Gulch Buffer Stacked Practices via optimal combinations of the following: Ripping, Terraforming, Micro-basins, Key lining/ripping on contour, Vetiver eyebrows in kickouts, Contour planting vetiver, Native plant establishment, Hydro-mulching and Check dams	West Maui R2R, 2020	Ongoing	Advance

Table 3- 1 Management Measures Recommended by 2012 and 2016 West Maui Strategies and Implementation Plans

Community Water Quality Monitoring Program. This measure is actively implemented and managed by Hui O Ka Wai Ola. For full description, see Section 2.2.

Measures to address in-stream sediment deposits and prevent transport downstream e.g., Microbasins in Ka'ōpala or Wahikuli, Lo'i terraces in Honolua or Honokōwai, Basin modifications at Ka'ōpala, Kahana and Honokōwai. These measures were furthered to conceptual design by USACE. For full description, see Section 3.1.2.

Multiple Sediment Capture and Groundwater Recharge Basins at Wahikuli and Hahakea Gulches. Capturing and retaining sediment to prevent it from being conveyed downstream to the shoreline is a key strategy to protect coral reefs. This technical solution was identified in the Wahikuli- Honokōwai Watershed Management Plan. Unlike other west Maui watersheds, there are no existing sediment retention basins in Wahikuli watershed (PIFSC, 2017).

A design consideration: USEPA recommends that sediment basins be designed to capture runoff from the 2-year, 24-hour rainfall event. The USEPA also cautions, “Do not put sediment traps or basins in or immediately adjacent to flowing streams or other waterways.” (USEPA, 2007).

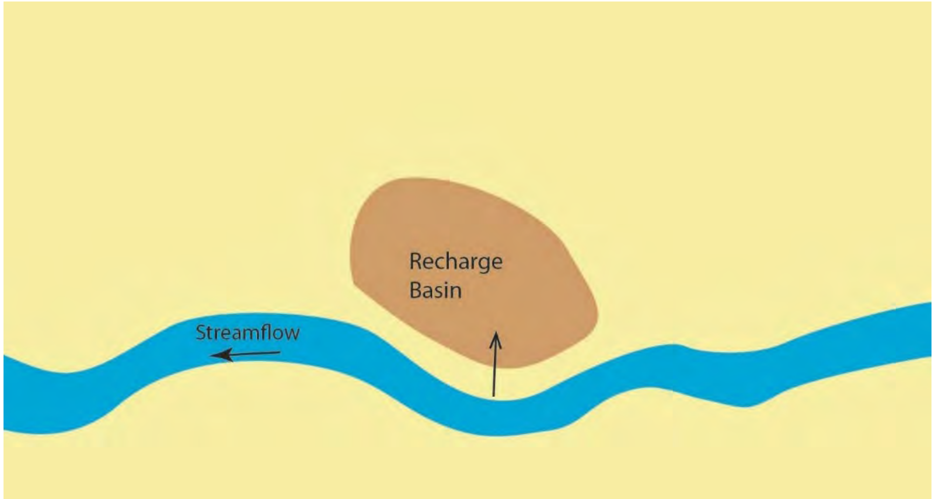


Figure 3- 1 Multiple Sediment Capture and Groundwater Recharge Basins at Wahikuli and Hahakea Gulches Concept Sketch

This measure could be implemented along Wahikuli Gulch and Hāhākea Gulch where the topography and channel conditions are naturally conducive to flow movement and storage. Ideally, existing boulders or logs would form natural weirs. Rather than one large sediment retention basin (as has been done in other west Maui watersheds), a series of smaller basins would be more feasible within the project timeline and regulatory environment (Figure 3-1).

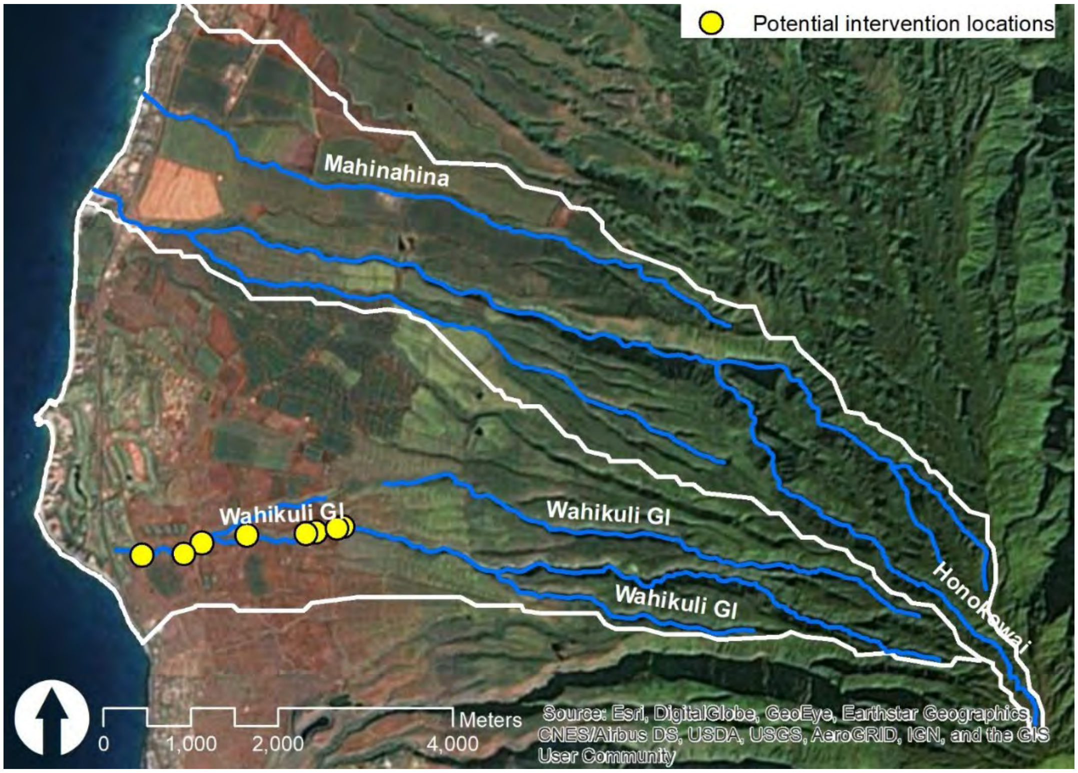


Figure 3- 2Potential Intervention Locations for Multiple Sediment Capture and Groundwater Recharge Basins at Wahikuli and Hahakea Gulches

Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch. This technical solution would combine sediment capture and groundwater recharge with recreational elements (e.g. open space with trails/walk-run paths, native and regional vegetation for cultural and subsistence use, shade trees that are drought-tolerant, community garden, seating, play areas, etc.). The recharge and recreation area would be approximately 250 meters (820 feet) long and 50 meters (160 feet) wide and located on the south overbank, parallel to Wahikuli Gulch from the railroad trestle to Honoapiʻilani Highway (Figure 3-2). The first overflow to the pond system would be located upstream end on the left bank (looking downstream) of Wahikuli Gulch to divert flood water into the upstream pond. There would be a second overflow located downstream. There would be an overflow spillway. The upstream ponds would function as sediment settling basins, and access for heavy equipment for sediment removal would be incorporated into the design.

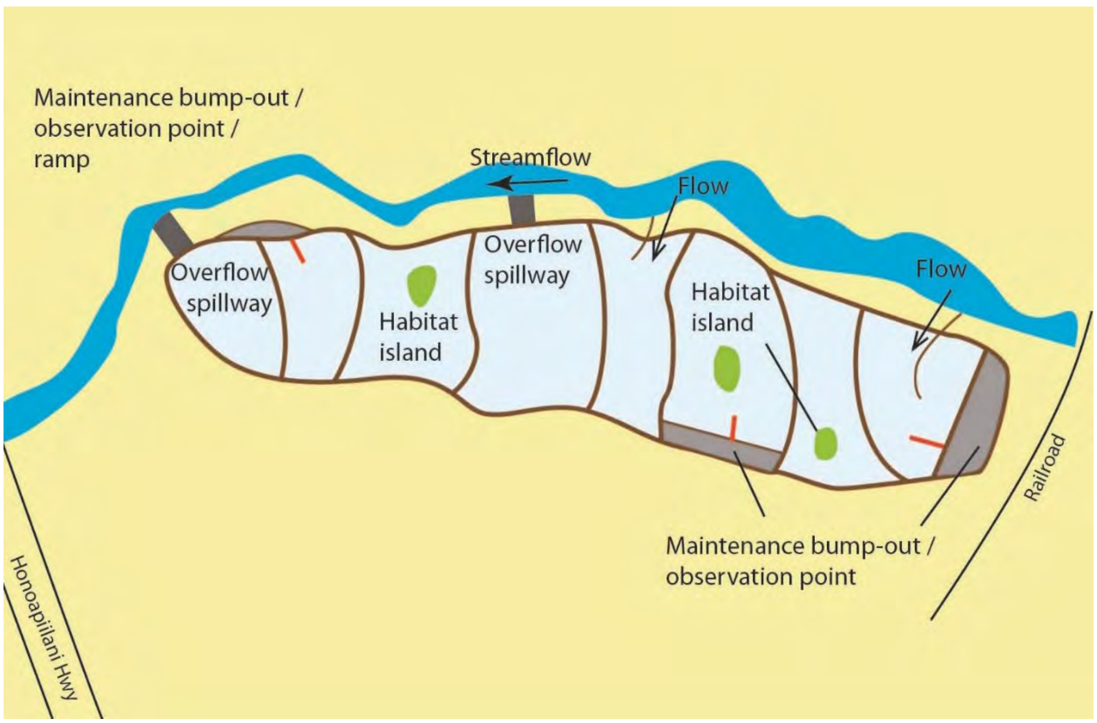


Figure 3- 3 Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch Concept Sketch

This measure could be implemented along Wahikuli Gulch and Hāhākea Gulch (Figure 3-3). It would be preferable because this measure does not include construction, only excavation up to four feet in depth may be necessary to optimize the site's recharge capabilities. From a cursory site investigation, it appears that the top three feet of sediment is silt, with gravels below. It may be advantageous to remove this layer of silt to improve recharge, however, the benefits of additional flow storage will have to be balanced against the risk of disturbing the existing loose soils. Currently, there are existing homeless encampments in this area.

Figure 3- 4 Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch Concept Sketch over Aerial Photo

This measure would need regular inspection and maintenance of the inlet and outlet works, as well as the sediment basins. Typical maintenance activities would include trash and debris removal, vegetation management, and removal of accumulated sediment. Paid staff would likely need to perform tasks requiring heavy equipment, but volunteers could potentially conduct vegetation management and trail maintenance.

Gulch buffers adjacent to Wahikuli Gulch and Hahakea Gulch. The West Maui R2R proposes measures to be implemented in the agricultural fields and above areas surrounding stream valleys. The following erosion control measures are intended to create a buffer around the gulches, intended to reduce transport of sediments and other pollutants from the agricultural fields up above into the adjacent stream valleys below. In particular, these measures have been proposed in the mid-watershed areas of Wahikuli and Honokōwai and could potentially be proposed at additional watersheds to the north.

- Ripping: Deep tilling roads and fields to three feet to remove compaction and increase infiltration.
- Terraforming: Re-shape the contours of the land to optimize hydrology in favor of keeping runoff on the land.
- Micro-basins: Series of small depressions positioned to receive and settle out sediment from runoff.
- Key lining/ripping on contour: Deep plowing to remove soil compaction and direct water from wetter to drier parts of the landscape.

- Vetiver eyebrows in kickouts: Planting tight arcs of vetiver on contour in the channels directed off of a series of practices designed to clear water from roads during rainfall.
- Contour planting vetiver: Working across the topographic lines of the landscape, close planting vetiver slips to create a living check dam for water and sediment.
- Native plant establishment: Planting species native to Hawaiʻi adapted to the conditions and likely to thrive without maintenance after establishment.
- Hydro-mulching: Coating bare landscapes with a sprayed-on combination of seeds, fertilizer and tackifier to achieve coverage of large areas in a relatively short time period.
- Check dams: A small dam that can be created by various materials including debris, sandbags, coconut coir logs etc. to reduce the velocity of water and therefore rain-driven erosion.

Gulch Buffer Stacked Practices via optimal combinations of the aforementioned erosion control measures. The West Maui R2R needs to determine the optimal suite of actions to take within the 100-foot gulch buffer zones of the mid-elevation lands in the Wahikuli and Honokōwai watersheds that will best meet the objectives of keeping sediment on the land, deliver some community benefit, improve water retention, and increase ecosystem integrity. Ideally, once the best suite of actions is determined, this decision will form the path forward, and only require updating when there is new science or lessons learned that would prompt a course correct. Decisions on awarding of grants and which actions to pursue is spread between non-profit organizations and agencies. There is urgency around determining the best suite of erosion control actions to take, because the coral reefs receiving the turbid water from these drainages are in rapid decline, and this has resulted in a temporary focus on priority grant funding for the area.

3.1.2 Structural Measures Developed by USACE to Address In-Stream Erosion of Historic Fill Terraces

3.1.2.1 Strategies.

Strategies were formulated that provide a means to address the watershed problem and meet the study objectives. The main problem is land-based pollution conveyance via streamflow to nearshore coral reefs. The study objective is to propose measures that reduce pollution sources and conveyance to coral reefs, the implementation of which increases coral reef resistance and resiliency. To guide development of management measures, strategies to address the problem could be implemented at the following general locations throughout the West Maui watershed:

- Upstream of the source
  - Hold or slow storm flows
  - Divert storm flows
- At the source
  - Stabilize sediments in place
  - Remove sediment source
  - Modify the pollutant
- Downstream of the source
  - Capture sediments in transport

3.1.2.2 Strategy: Structural Measures Proposed Upstream of the Source

Addressing the conveyance of fine-grain sediments to the ocean above the source would involve management of flows i.e., slow/entrain or divert storm flows, that erode the historic fill terraces and mobilize sediments for transport to West Maui's coral reefs. The following strategies derived measures proposed to address the problem upstream of the source:

- Upstream Detention Basin/Dam
- Retrofit Existing Irrigation Pipe System

Upstream Detention Basin/ Dam. The upstream detention basin/dam measure features a holding structure of concrete or earthen construction intended to capture flows in the upper watershed and lower flow conditions in the channel, which could minimize in-stream erosion. An upstream detention basin could be constructed at one or multiple upstream locations across the study area. The more water the basin can hold, the more effective the basin is at slowing stream velocity downstream. Greater holding capacity equates to greater structural footprint (either individually or in series). This measure would meet the study objective to reduce conveyance of pollutants. Construction of a new detention basin or dam would be a challenge for buildability due to limited accessibility(most of the upper watershed is inaccessible), incredible costly due to size (capable of holding back storm flows), would be challenging to permit, and meet both USACE and State of Hawai'i dam safety criteria, could result in significant adverse environmental effect, and likely would not be acceptable to the West Maui community, some of whom are against any type of water diversion due to historic and current strife related to water diversion in West Maui. When presented to the FAST, the R2R Working Group and the West Maui community, this measure received no positive feedback. Construction of an Upstream Detention Basin/Dam was ultimately eliminated and "not recommended" for further consideration as a management measure.

Figure 3- 5 Retrofit Existing Irrigation Pipe System. USACE concept illustration.

Retrofit Existing Irrigation Pipe System. The utilization of existing irrigation pipe system measure proposes to modify the existing and extensive agricultural irrigation system to re-route flow across multiple watersheds into a single stream during large flow events (Figure 3-5). This measure would effectively and efficiently address sediment conveyance by concentrating the problem to a single culmination point. New construction would be focused at the central flow point which could be a sedimentation basin and would require modifications to existing infrastructure to route to the central basin. Similar to the aforementioned proposed measure, retrofitting the existing irrigation system and rerouting flow from multiple sub-watersheds to a central sedimentation basin would be costly, very large in scale, would also be challenging to permit and likely would result in significant adverse direct and indirect environmental effects by significantly altering the flow and sediment regime across multiple drainage basins. Likewise, when presented to the stakeholders, this measure received no positive feedback. Retrofitting the existing irrigation system and rerouting flows to a central sedimentation basin was ultimately eliminated and not recommended for further consideration as a management measure.

3.1.2.3 Strategy: Structural Measures Proposed at the Source

Addressing the pollutant and conveyance of pollutants at the source would involve stabilization of the sediments in place, removal of the source in its entirety or modification of the pollutant. This strategy would completely and effectively prevent mobilization of fine-grade sediments to the ocean that have the potential to degrade coral reef health. The following strategies derived measures proposed to address the problem at the source:

- Bank stabilization

- Manually excavate or remove sediment source
- Flocculation

Bank stabilization. The primary source of in-stream sediment pollution, as identified by USGS, is historic fill terraces deposited by agricultural practices during the plantation era (USGS, Stock, 2020). In situ stabilization of the fill terraces that comprise the bed and banks of streams and gulches in West Maui would prevent sediments from being conveyed by stream transport out to West Maui coral reefs. Stabilization techniques could involve environmentally acceptable alternatives such as planting or the less desirable hard alternative: armoring. However, the magnitude of this proposed solution is reflective of the pervasiveness of the problem throughout the study area and would likely render implementation of this measure infeasible. These deposits are extensive, comprising the bed and banks of approximately 40% of the stream length of streams and gulches (over 247 meters or 154 miles of total stream length) throughout the Agricultural District across all five watersheds of the study area (USGS, Stock, 2020). Even if the West Maui community proposed to target stabilization of the stream with the greatest sediment budget, Kahana Stream—annual load of 285 metric tons, the effort would require planting or armoring 54,992 meters or 34 miles of stream length (doubled, to account for left and right banks, and perhaps tripled to account for the stream bed).

When presented to the FAST, the R2R Working Group and the West Maui community, this measure received mixed reviews. Addressing the pollutant at the source rather than managing flows once sediment is mobilized was preferred. It was estimated that the initial cost to construct would likely be less than the measures proposing new construction above the source, however, the maintenance requirements would be significant and the scale of this effort in areas where much of the fill terraces are inaccessible could quickly inflate costs. Planting, as a means of stabilizing the sediment, was the preferred, environmentally acceptable alternative, however plantings across such a vast area would generate discussion of potential adverse secondary impacts regarding ecology and biodiversity. Due to the uncertainty of the practicality of implementing this measure, stabilization of fill terraces in place was ultimately eliminated and not recommended for further consideration as a management measure.

Remove sediment source. The study group considered manual excavation or removal of the sediments from its source. Manually removing in-stream sediments would eliminate the pollutant from the equation. However, similar to the proposed stabilization of sediments in situ, the magnitude of this effort would likely render implementation of this measure infeasible. According to USGS' sediment budget for the study area, West Maui contributes 922 metric tons of sediment every year. This is a massive amount that must also overcome the issue of limited accessibility. Options of excavation would require use of many, large heavy machinery and equipment or pneumatic removal by shovels and buckets or a vacuum apparatus e.g. "dry dredging" to overcome limited access to these areas. The extent of the total volume of sediment that would need to be excavated is unknown. Additionally, once excavated, the disposition of the excavated material would need to be decided. Options for disposition include upland disposal, ocean disposal or beneficial reuse. Regardless of the selected disposition, the volume of excavated material is significant and would likely require a combination in order to handle all excavated material. When presented to members of the West Maui R2R and West Maui community, this measure received mixed reviews from the stakeholders. Addressing the pollutant at the source and removing it from the equation was a preferable strategy to managing flows before or after sediment is mobilized. However, this management measure was eliminated from further consideration based on feasibility concerns.

Flocculation. Fine sediment, such as clays and fine silts, require a long time to settle. Accordingly, targeting clay and fine silts is generally not practical. Coarse to medium size silt particles settle more quickly and can be realistically targeted for sediment trapping. However, these fine particles that are suspended in the water can be encouraged to stick together with the help of a coagulant chemical. Flocculation, a gentle mixing stage, further increases the particle size and thereby also reducing the time required for settlement. This measure compliments previously proposed measures that rely upon capturing sediment through detention.

When initially proposed at the public meeting in August 2018, there was some uncertainty regarding the impact that coagulant chemicals would have on the environmental system. Coagulation and flocculation are commonly used in water treatment facilities but has a limited performance history in Hawaii for addressing sedimentation issues in natural river systems. The measure was generally met with hesitancy by the public.

However, since the time of the public meeting, further research has revealed there are sources of biodegradable, natural flocculants that perform on a wide array of soil types and pH ranges; and have demonstrated no harm to aquatic organisms based on toxicity testing at recommended dosages (Dober). One example of this is Chitosan, a natural biopolymer derived from chitin, recycled from the shells of crustaceans like shrimp, crabs, and lobsters.

Flocculants would prove a challenge to implement singularly as a management measure given flashy, high velocity flow events characteristic of West Maui, potential for labor-intensive operations and maintenance demand, and dosing requirements. Accordingly, this management measure was eliminated from further consideration based on feasibility concerns. However, flocculants show promise as an additive measure used in conjunction with another management measure to increase efficiency of trapping fine sediments by inducing aggregation and promoting fallout.

3.1.2.4 Strategy: Structural Measures Proposed Downstream of the Source

Addressing the conveyance of pollutants downstream of the pollutant source would involve capturing diverting or filtering streamflow to reduce conveyance or volume of conveyed sediments from the stream channel. This strategy would prevent mobilization or minimize volume of conveyed fine-grade sediments and filter or slow down stream velocity. The following strategies derived measures proposed to address the problem downstream of the source:

- Improve existing sedimentation measures
- Send flows offshore, past coral reefs
- Filter sediment-laden flow
- Offset Micro Basins
- Lo‘i Terraces

Retrofit/re-design existing sedimentation basins. Ka‘ōpala Gulch, Kahana Stream and Honokōwai Stream all contain a sediment retention or desilting basin along their stream channel. The purpose of a desilting basin is to temporarily store storm flow, thereby increasing slowing velocity and increasing residence time, allowing for sediment to settle out within the basin. A portion of the sediment in suspension is removed from the stream flow prior to conveyance downstream and out to the ocean. The study team, the West Maui R2R Watershed Coordinator and USGS discussed at great length the variation in settling rates among different size sediments, with large boulders, gravel and coarse grain sands settling out immediately to within minutes, and fine clay particles settling out in hours, under still water conditions. During a storm event, continuous stream flow agitates the water column suspending and resuspending fine-grained sediments throughout the water column. Water that spills over the basin (by design) and flows downstream carries with it fine sediments that were not able to settle out in the basin. Sedimentation basins reduce, but do not necessarily eliminate in-stream pollution conveyance. With every flow event, sediment is captured in the basin and accumulates over time, requiring maintenance by the landowner to routinely remove accumulated sediments and restore the holding capacity of the basin.

This measure proposes improvements to the existing sediment retention basins at the 3 aforementioned locations. Kahana Stream and Kaʻōpala Gulch basins, as constructed, are undersized. Honokōwai Stream basin is not operating at full capacity. The basin improvements measure proposes modifying existing detention basins to improve their effectiveness in capturing sediment. Improvements to the existing basins would meet the study objective to effectively and efficiently reduce pollutant conveyance. The reduced footprint associated with modification to existing structures is preferable to new construction and likely would cause no more than minimal environmental effects. The proposed measure, improve existing basins, received positive feedback from stakeholders. The measure proposing to improve existing basins completely, effectively, efficiently and acceptably met the study objective to reduce conveyance of land-based pollutants to the ocean and accordingly, was carried forward.

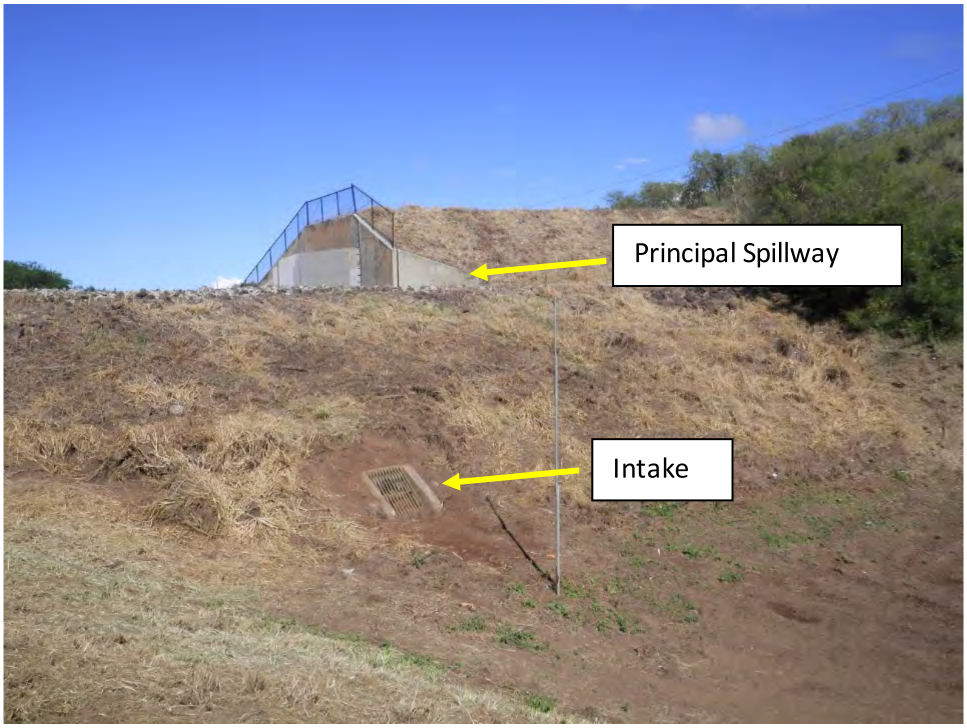


Figure 3- 6 Principal Spillway and Intake, Kaʻōpala Dam Source: State Dam Inventory System, State of Hawaiʻi

The primary deficiency with the Kaʻōpala, Kahana, and Honokōwai basins is the inability to control the pool elevation and sediment retention time. The open outlet pipe at Kaʻōpala allows sediment-laden waters at the bottom of the reservoir pool to be released downstream immediately (Figure 3-6).

Similarly, the open ports on the Honokōwai riser structure also allow sediment-laden water to be released immediately (Figure 3-7). The intake for the Kahana basin was recently uncovered. The modified intake, which was intended to have a sluice gate that opened and closed automatically, was left in the "open" position due to inoperability. Previously, the buried intake prevented the basin from properly draining. While this did significantly increase the retention time for smaller floods, the non-federal sponsor could not effectively remove these sediments from the basin as it was nearly always saturated. Larger storms likely reactivated these particles, carrying them over the riser structure and downstream.

Providing dam owners and operators with a means to control the release of water downstream would also significantly reduce the amount of sediment transported downstream. However, controlled release of water comes with the risk of not maintaining flow continuity in the river system and may increase flood risk downstream.

Figure 3- 7 Open ports at the riser structure, Honokōwai Dam (2017)

Figure 3- 8 Riser structure and saturated conditions, Kahana Dam (2017)

Two examples of a detention basin effective at sediment retention are Mahinahina Basin and Napili 4-5 Basin. Mahinahina Basin has a small outlet pipe like Kahana Basin (Figure 3-9). However, it was designed to include a butterfly closure valve and is located halfway up the embankment rather than near the embankment toe. The concentration of sediment at this elevation is less than it would be if the outlet pipe were located at the reservoir bottom.

Figure 3- 9 Intake for the outlet pipe, Mahinahina Dam

At Napili 4-5, the outlet modification installed on the embankment provides the dam operator with controlled release of flow from the top-down (Figure 3-10). The modification consists of a series of sluice gate panels that are manually opened by the dam operator to allow flow to enter the original, underground outlet pipe (Figure 3-11).

Figure 3- 10 Outlet Modification at Napili 4-5 (2017)

The following sections include proposed modifications for the ineffective basins that are based on observations and design concepts described above.

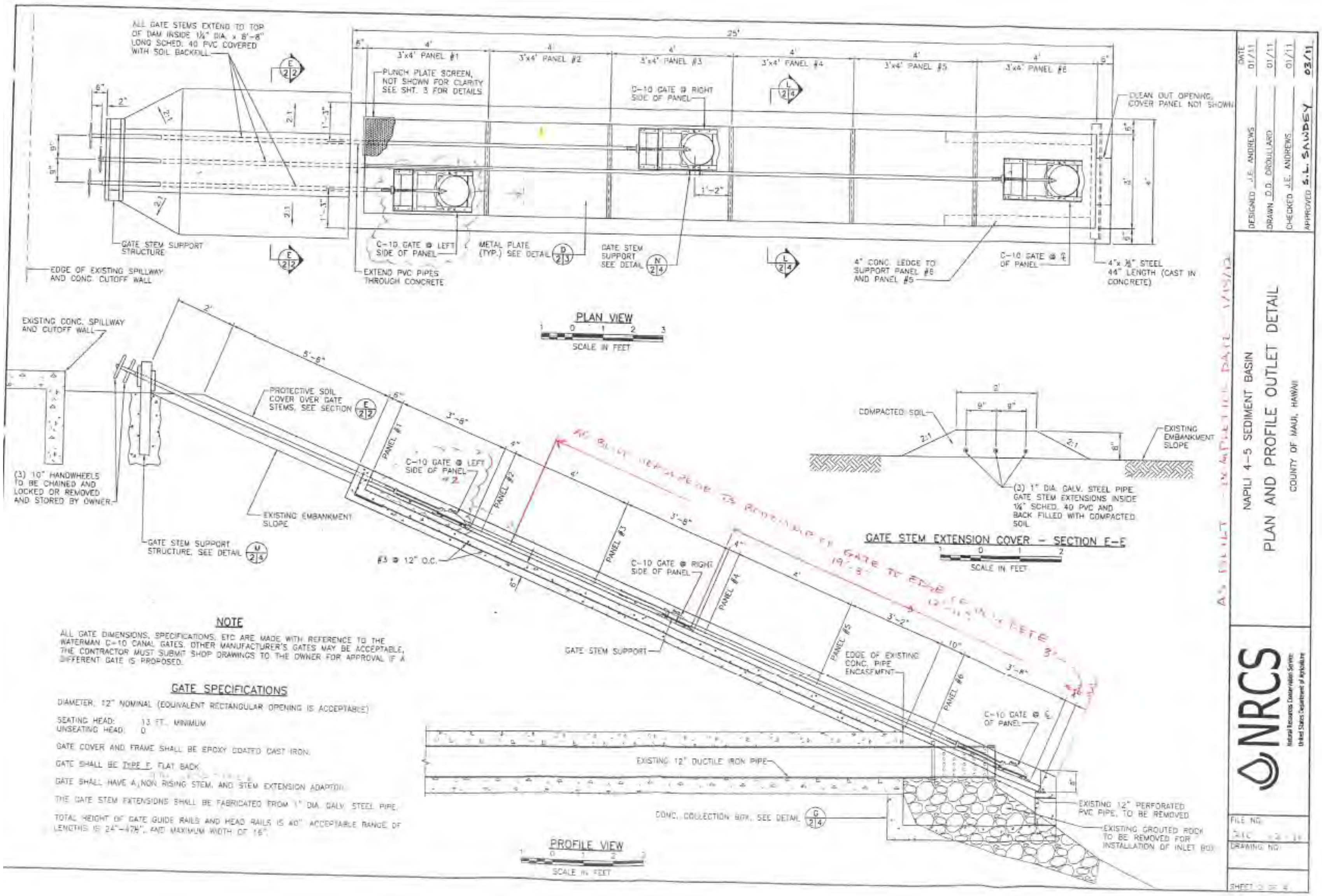


Figure 3- 11 Napili 4-5 Outlet Modification Detail

Excavate Kahana Basin. In lieu of raising the existing outlet pipe at Kahana Basin, the reservoir bottom can be lowered by over-excavation to achieve a similar function. Runoff volume captured in the excavated area would have a 100% trap efficiency when the runoff volume is less than the excavated volume. However, the amount of excavation required to accommodate the volume produced by the typical plume-triggering event (0.50 AEP flood) would be approximately 89.2 ac-ft. Assuming an approximate basin surface area of 2.00 ac, the additional depth required is about 20 ft. Based on an annual sediment load of 285 metric tons and bulk density of 1,300 kg/m3, it would take approximately 225 years to fill with captured sediment (excluding extreme events). This also assumes the inoperable outlet works is restored and able to be "closed" by the dam operator. Extreme care would have to be taken to preserve the stability of the existing dam and concrete riser structure.

This modification, however, would likely cause the reservoir to be continuously ponded or saturated. The nonfederal sponsor responsible for maintenance has expressed frustration with continuously saturated conditions as it inhibits their ability to perform maintenance (i.e. excavate captured fine sediments before they are re-activated by a larger storm event). To address this, this measure can be paired with the measure proposed in Section 1.3.1.3.2 to provide the dam operator with some ability to control flows entering the basin.

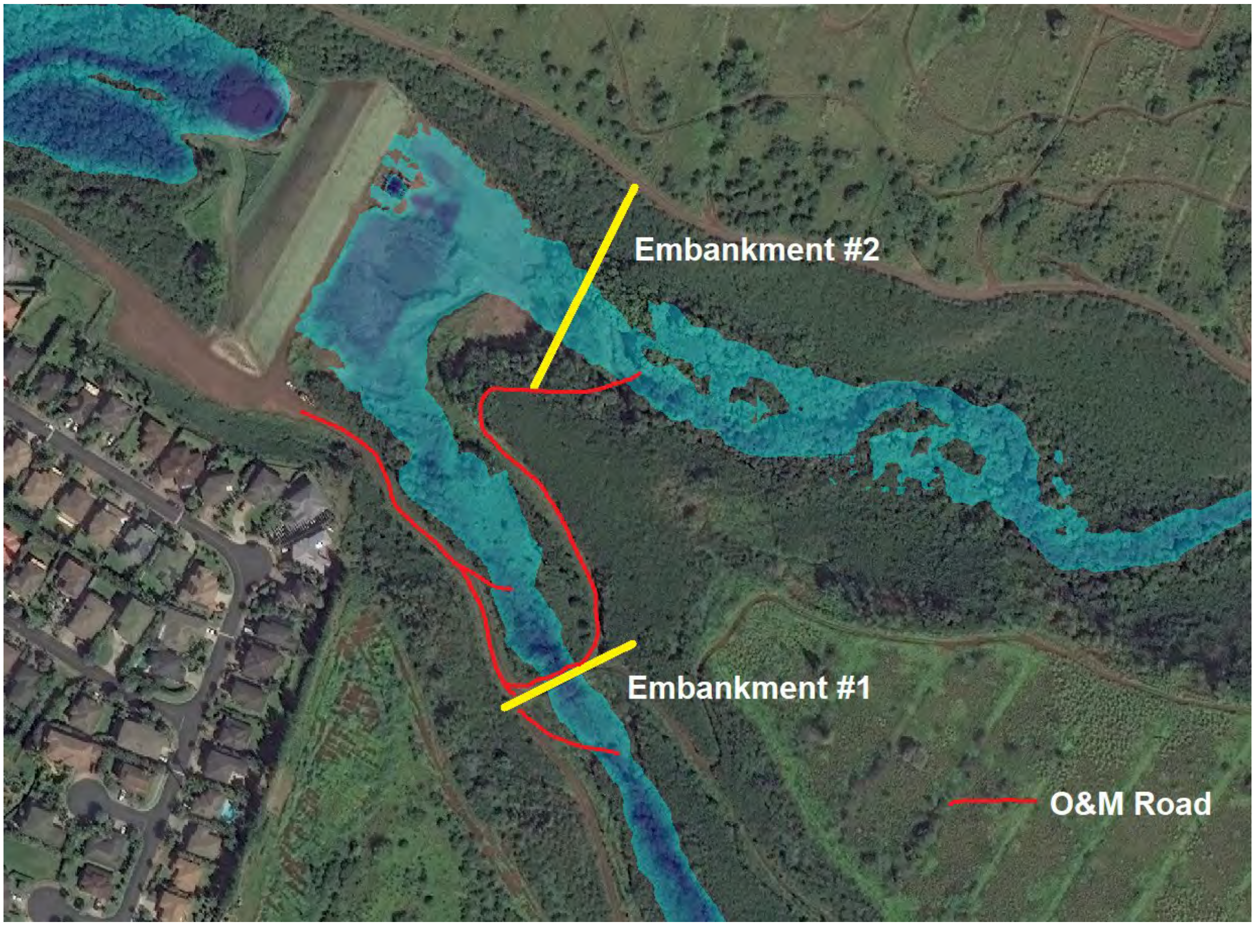


Figure 3- 12 Proposed Embankments upstream of Kahana Basin

Flow Regulation Embankments Upstream of Kahana Basin. Two additional embankments are proposed upstream of Kahana Basin to provide the dam operator with some control over flows entering the basin (Figure 3-12). The nonfederal sponsor responsible for maintenance of the dam is unable to effectively remove captured sediments from the basin due to continuously saturated conditions.

Each earthen embankment would have a large 96-inch diameter culvert and sluice gate control structure. Generally, these culverts would be left open until the dam operator wishes to remove captured sediments from the main basin and requires conditions in the main basin to be dry (unsaturated).

While the embankments can be sized within the limitations of being considered “low hazard” by general dam safety standards – less than 25 ft in height, less than 50 ac-ft in storage capacity, and no probable loss of human life as a result of a breach – the State of Hawaiʻi may still consider the two newly constructed basins as part of the larger, regulated Kahana Basin if they are sited too close to each other or are connected by an uncontrolled conduit. General dimensions and characteristics are provided in Table 3-2.

	Embankment #1	Embankment #2
Embankment Height	15 ft	15 ft
Upstream (US) Slope	3H:1V	3H:1V
US Cover	Grass	Grass
Downstream (DS) Slope	3H:1V	3H:1V
DS Cover	Grass	Grass

Table 3- 2 Kahana Basin Embankment General Dimensions and Characteristics

Honokōwai Riser Structure with Stop Log Panels. The existing Honokōwai concrete riser could be modified to allow for controlled release of flow from the top-down via stoplog panels (Figure 1-5). These panels could be installed over the existing, open ports. The modification would include eight panels, 4 ft wide by 3 ft high. An elevated work platform would also be necessary to provide operation and maintenance personnel access to the control structure during flooded conditions. As the Honokōwai Dam is a regulated dam, any modification would require further evaluation to verify there is no increased flood risk downstream.

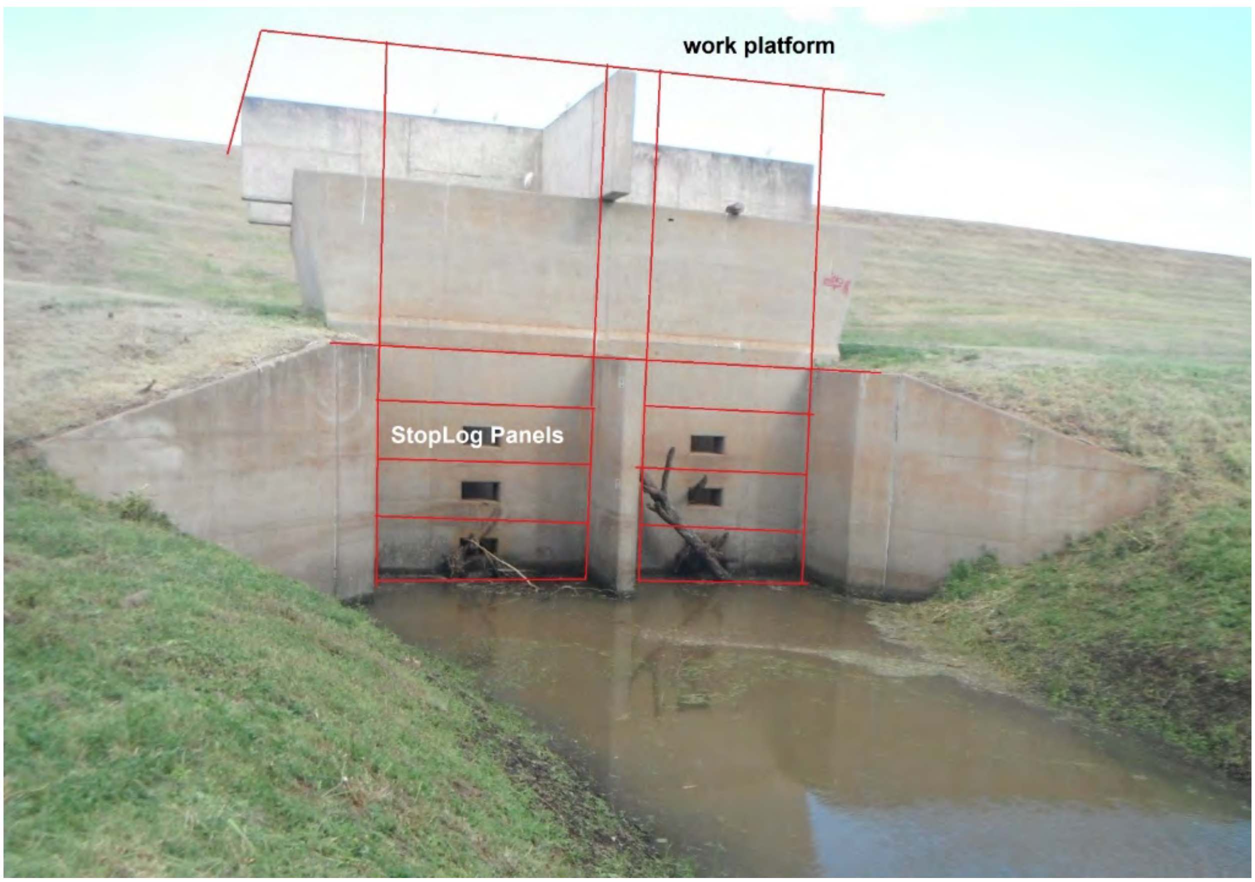


Figure 3- 13 StopLog Panels and Work Platform at Honokōwai Riser

Construction of the stoplog panels would slightly increase the surface area of the reservoir, but most importantly reduce the rate of flow leaving the reservoir. Increased retention time allows for increased settlement and a greater trap efficiency.

Name of soil separate	Diameter limits (mm)	Original Trap Efficiency (%)	New Trap Efficiency (%)
Clay	< 0.002	0.32	0.92
Silt	0.002 – 0.05	> 100	> 100
Very fine sand	0.05 – 0.10	> 100	> 100
Fine sand	0.10 – 0.25	> 100	> 100
Medium sand	0.25 – 0.50	> 100	> 100
Coarse sand	0.50 – 1.00	> 100	> 100
Very coarse sand	1.00 – 2.00	> 100	> 100

Table 3- 3 Trap Efficiency for StopLog Panels, Honokōwai Basin, 0.50 AEP Flood

Outlet Modification at Kaʻōpala Basin. The proposed modification at Kaʻōpala Basin (Figure 3-6) is a replication of the outlet modification that was done at Napili 4-5 (Figure 3-11). Both basins are similar in size. The flow and runoff volume entering both basins are also similar. The outlet pipe at Kaʻōpala Basin currently permits sediment-laden waters to leave the reservoir at a very low elevation (where sediment concentration is the highest).

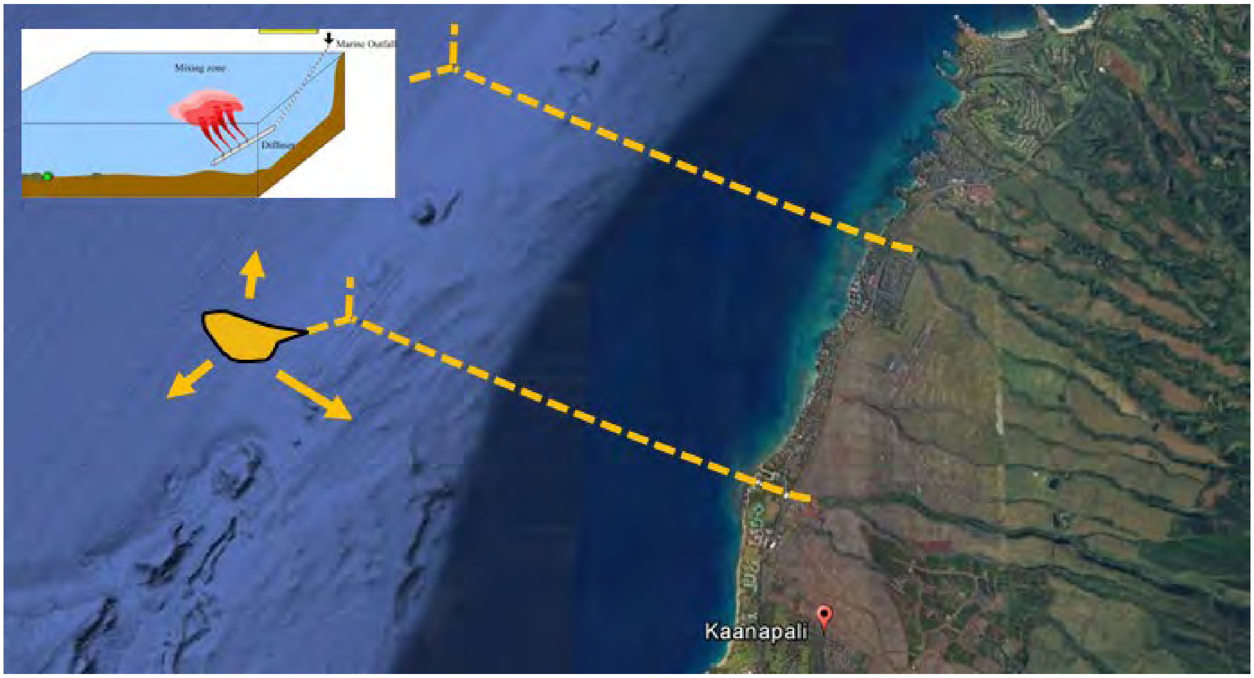


Figure 3- 14 Offshore Discharge Pipe. USACE concept illustration.

Offshore stormwater discharge pipe. The stormwater discharge pipe measure proposes the construction of a pipe large enough to convey and discharge sediment laden stormwaters past nearshore coral reefs. In-stream erosion would continue through natural processes before being captured and diverted into the deep ocean. This measure does not reduce sediment load that reaches the ocean, rather it relocates the discharge point so that the impact to West Maui coral reefs is eliminated. The size of pipe needed to capture and carry storm flows over such a long distance and likely subsurface for a portion of the alignment, would be relatively large and likewise very costly both for the initial cost to construct and the cost of future maintenance. In addition to construction impacts, transferring the problem away from the nearshore coral reef resources to an offshore ecosystem would encounter likely significant adverse environmental effect, including, but not limited to, groundwater recharge on land and pollution of the deep ocean. Construction would be technically challenging and require extensive permitting. Similar to other projects similar in structural concept, but differing in purpose e.g., Sea Water Air Conditioning, Wastewater Injection, etc., this measure generated strong opposition by stakeholders. When presented to the FAST, the R2R Working Group and the West Maui community, this measure received no positive feedback. Construction of an Offshore Stormwater Discharge Pipe was ultimately eliminated and "not recommended" for further consideration as a management measure.

Figure 3- 15 Geotextile Filtration. USACE concept illustration. Example of current application to the right. Potential location (yellow polygon).

Geotextile Filtration/Silt Bags. USACE proposed installation of pumps upstream of existing sedimentation basins to divert flows into temporary geotextile bag structures that would effectively filter storm flow to remove fines and pass through stream flow to the downstream basin. This measure would require minimal new construction and expansion of the existing maintenance plan to remove filtered sediments and operate and maintain the pump system. Geotextile filtration bags are versatile and used for may application, however, large scale, long-term use for this purpose would be novel and without precedent locally. Diversion of flow into the filtration system would also pose potential adverse environmental effects associated with entrainment, aquatic life movements, etc. This measure received mixed reviews when presented to the FAST, the R2R Working Group and the West Maui community. While the overall footprint appeared minimal and the concept sounded promising, increasing maintenance demands on the County's underfunded and undermanned maintenance program was undesirable and the uncertainty of the practicality and secondary impacts was questionable. Due to the uncertainty associated with this measure, installation of a Geotextile Filtration System was ultimately eliminated and not recommended for further consideration as a management measure. However, geotextile filtration shows promise as an additive measure used in conjunction with another management measure to increase efficiency of trapping fine sediments prior to flow into siltation basins.

Figure 3- 16 Micro Basins at Wahikuli Stream. Concept design by Coral Reef Alliance (CORAL, 2018).

Micro Basins. The offset micro basins measure proposes the construction of new micro basins adjacent to streams and gulches. Rather than one large sediment retention basin positioned within the stream channel, excess streamflow i.e., above a set stage height, would be diverted during a storm event into a series of smaller basins sited adjacent to the main channel. Flow into the micro basin system would enter on the upstream end and follow natural topography overflowing downstream into the next micro basin in series. Continuous streamflow in the main channel would be maintained. These basins would be designed to slow flows and increase residence time to allow settling of sediment out of suspension for a portion of stormwater flow before confluence with the main channel downstream. The greater the holding capacity, the more successful this measure would be at trapping sediment. In addition, earthen basins would promote groundwater recharge. This concept was proposed by the 2016 Watershed Plan since Honokōwai and Wahikuli watersheds lack sedimentation basins. Proposal for a series of smaller basins would allow for greater versatility in site selection. The Coral Reef Alliance (CORAL) furthered this measure to conceptual design at Wahikuli Stream, upstream of Honoapiilani Highway, incorporating recreational, cultural and educational opportunities (Figure X). This measure was not formally presented to the West Maui community by USACE. The high potential for success in meeting the study objective, opportunity to provide multiple secondary benefits and likelihood for less than significant adverse environmental impacts may outweigh the anticipated relatively moderate to high construction and operation/maintenance costs. For these reasons, the study partners recommend Micro Basins for further consideration and was carried forward.

As demonstrated in the Design Appendix, it is not possible to capture 80% of fine sediments with this measure alone (especially without flocculation). Engineering judgment was used to site and size practical sediment basins at Ka'ōpala and Wahikuli. A detention basin that is 5-ft deep, has a 1,000 ft^2 surface area, and outflow of 3 ft^3/s, is approximately 30% effective at trapping fine sediments.

Figure 3- 17 Project Malama Honokōwai Lo'i Restoration in Honokōwai Valley (Source: Maui Cultural Lands, Maui No Ka Oi Magazine, 2006)

Lo'i Terraces. Traditional Hawaiian cultivation of taro or *kalo* (*Colocasia esculenta*) involved use of a connected, terraced, wetland agricultural system called lo'i, typically located adjacent to a flowing stream. This concept, as it relates to sediment retention, is akin to the micro basins concept. While lo'i successfully traps sediment, they are not engineered to withstand storm flows. This measure would differ in that it would focuses on the cultivation of flooded agriculture, requiring continuous flow of water and heavy soil capable of impounding water without much loss through percolation. This measure proposes the restoration at historical sites or new lo'i strategically placed within the study area. Restoration of historic lo'i and construction of new lo'i were considered "feasible" because of the community support behind its implementation. Construction costs would be relatively low. Daily operation and maintenance costs and post-storm repairs, in terms of manpower, would be high i.e. labor intensive. Restoration of cultural sites and practices would benefit the West Maui community. There is a history of lo'i in Honolua and Honokōwai, where this measure is being proposed. This measure was well received by the FAST agencies, the R2R Working Group and the West Maui community and accordingly was recommended for further consideration as a management measure and carried forward.

From the 2019 Instream Flow Standard Assessment Report on Honokōwai by CWRM, the reach segment below the Honokōwai diversions (where historical lo'i were previously sited) the stream is dry for more than 50% of the year. While some flow is diverted to the Kaanapali Coffee Farm and to meet the landscaping demands for the agricultural subdivision (approximately 9 mgd), some flow is also lost through seepage (approximately 1.1 mgd). For this reason, Honokōwai is only recommended as a potential site for this management measure if minimum flow standards are established by the State and continuous flow is maintained from *mauka* to *makai*.

At Honolua, surface water may be used for small diversified agriculture and landscape irrigation, but no commercial agriculture is practiced. Honolua Stream and its tributary in Papua Gulch are flowing in the upper watershed but have discontinuous flows below the Honokohau Ditch to the ocean, with most reaches losing surface water due to seepage (approximately 1.3 mgd). While the Honokohau Ditch was originally designed to remove water from the Honolua Stream to supply irrigation water for sugarcane land, the diversion has been inactive since 2003 (CWRM). It was estimated by CWRM that there was continuous stream flow from *mauka* to *makai* about 83% of the time with a mean flow of 7.6 mgd. Differences in discharges between historic and current periods are due to differences in climate from differing years of record. Honolua still has potential for this management measure to be implemented. Its impact in reducing the amount of sediment transported to the ocean, however, would be limited to addressing sediment carried by the base flow (persistent low flow in the stream) rather than the larger, flood-induced flows. Analysis of the effectiveness of this management measure by the Churchill method indicates that it is able to remove approximately 90% of fine silt and clay, but only from a small fraction of the total hydrograph: 0.3 – 0.6 ft^3/s of flow from Honolua and Honokōwai, respectively. Typical design assumptions are summarized i3-4. As presented in the Hydrology and Hydraulics Appendix, the 50% AEP (2-yr) peak flow for Honolua and Honokōwai are 227 and 646 ft^3/s, respectively.

Parameter/Assumption	Honokōwai	Honolua
Approx. Number of Lo‘i	10	5
Surface Area (ac)	2	1
Surface Area (ft^2)	87,120	43,560
Water Depth (ft)	1.25	1.25
Capacity, C (ft^3)	108,900	54,450
Daily Inflow Rate, I (ft^3/s)	0.6	0.3
Mean velocity (ft/s)	0.0008	0.001
Time of Retention, R (s)	181,500	181,500
Time of Retention, R (hr)	50.4	50.4
Sediment Index, SI (s^2/ft)	157,837,184	157,837,184
Percent of Fines Passing (%)	7.7	6.3
Trap Efficiency (%)	92.3	93.7

Table 3- 4 Lo‘i Design Parameters and Assumptions

3.1.3 Formulation of USACE engineered measures

In August 2019, the USACE Committee on River Engineering (CRE) visited several sites in West Maui to provide recommendations on effective management strategies for reducing in-stream erosion, technical modeling, and next steps in the planning process.

They recommended the creation of hydrologic and hydraulic (H&H) models to develop a water and sediment budget. Their initial recommendations to combat in-stream erosion included the following: stabilizing the problematic banks, removing erosive bank material, capturing the sediment with an in-stream feature, diverting, all or some portion of the flow to a side-channel feature, altering the flow regime (or reducing the amount of flow in the channel with an upstream feature), and flocculation. Capturing the sediment with an in-stream feature or diverting the flow to a side-channel feature appeared to be the most promising of the recommendations listed above. These recommendations refined the USACE recommended Microbasins and lo'i terraces. Removal of the erosive bank material, altering the flow regime, and flocculation were ultimately not recommended as stand-alone management measures.

For the Honolua watershed, CRE proposed an alternative of lowering the floodplain and arranging boulders at constrictions to generate floodplain residence time to encourage sediment settlement. For this type of alternative, a two-dimensional (2D) hydraulic model created using the Hydrologic Engineering Center's (HEC) River Analysis System (RAS) software is recommended to compute the potential changes of this solution. For the Wahikuli watershed, two sediment stilling basins were considered. A simple sediment model could investigate the value of different configurations.

Numerous studies were conducted by the USGS in this study area and were referenced to develop the engineered measures in this study. The following reports were referenced: Open-File Report 2015-1190 *Reconnaissance Sediment Budget for Selected Watersheds of West Maui, Hawai'i* and a draft Scientific Investigation Report *Sediment Budget for Watersheds of West Maui*. These reports were used to understand the frequency of rainfall events that resulted in coastal sediment plumes, the soil distribution of historic fill terraces, and the erodibility of fill terrace material.

Climate data was collected using one available USGS, and four National Oceanic and Atmospheric Administration (NOAA) rain gages within or near the study area. These rainfall gages provided the necessary instantaneous rainfall data needed to create a hydrologic model using HEC's Hydrologic Modeling System (HMS) software. Point precipitation data for annual exceedance rainfall was obtained from the National Weather Services (NWS) NOAA Atlas 14 Precipitation-Frequency Data Server (PFDS). Point precipitation data shows rainfall frequencies from recurrence intervals of 1 to 500 years for the centroid locations of each subbasin. This data was used to determine peak flow estimates for various recurrence intervals in the calibrated HEC-HMS model.

Stream data was collected from three USGS stream gages in the study area. The following gages were used: USGS 16630200 (Honokōwai), USGS 16623500 (Ka'ōpala), and USGS 16623400 (Honokahua). These stream gages only provided peak flow data, and one of them provided usable data for a very short period of record of four years. Due to this, a stream gage adjacent to the study area was also referenced (USGS 16620000, Honokohau). This stream gage provided peak flow data with a period of record of 101 years.

Light Detection and Ranging (LiDAR) data was provided by an online GIS database under the Hawai‘i Statewide GIS program. Areas within the study area that were not covered by LiDAR were supplemented using an elevation raster from the USGS National Elevation Dataset (NED). The NED was developed by merging the highest resolution, best quality Digital Elevation Model (DEM) data available across the United States into a seamless raster format. This LiDAR and DEM data needed to be of the highest quality to ensure accuracy of the 1D and 2D models created in HEC-RAS.

3.1.4 Marine Transport Dynamics

To better understand the effectiveness of engineered measures and strategize implementation of prioritized recommendations, USGS is collaborating on this study to simulate marine transport of sediments conveyed to the ocean via streamflow. The objective of the marine transport dynamics analysis by USGS is to provide physics-based, numerical circulation and sediment dynamics model simulations of terrestrial sediment discharge from West Maui watersheds to identify the primary watersheds that impact specific coral reefs and thus more effectively prioritize recommendations for managing pollutant runoff.

USGS has maintained a co-operative agreement with Deltares, an independent institute for applied research in the Netherlands, for the past 15 years. Deltares developed Delft3D (Deltares, 2011), a physics-based numerical circulation model that incorporates meteorologic and oceanographic forcing to simulate circulation and sediment dynamics. The USGS provides Deltares observations and field data for model calibration and validation, and Deltares develops code to incorporate new physical processes and numerical modeling support. Drawing on almost a decade of experience, this team has been highly successful in describing the oceanographic characteristics of U.S. coastal waters across the Pacific and publishing their results in peer-reviewed USGS technical reports and journals (e.g. Storlazzi et al., 2010; Hoeke et al., 2011; Storlazzi et al., 2011; Warrick et al., 2013; Storlazzi et al., 2014).

The USGS provided Deltares with: (a) boundary information for the numerical model, including bathymetry, wind, wave, and tidal constituent data; (b) long time-series in situ measurements of tides, waves, currents, and turbidity for model calibration and validation; and (c) USACE-modeled water and terrestrial sediment loads emanating from the study area watersheds for both current and future scenarios. Deltares will then construct, calibrate, and validate the numerical model, including performing specified model runs to determine the influence of climate change and watershed restoration on patterns of terrestrial sediment dispersal over West Maui coral reefs. The final products include physics-based numerical model simulations of circulation and terrestrial sediment dispersal from the study area and its residence time over nearshore coral reefs for present conditions and future scenarios where water and terrestrial sediment loads discharging from the watersheds is modified due to climate change and watershed restoration.

USACE packaged the engineered solutions into two alternatives (including the No-Action alternative): 2) new construction of Lo‘i and Micro Basins at strategic locations across the watershed, and 3) a combination of Alternative 2 and improvements to existing, engineered, sediment management measures. USACE derived sediment load and rainfall/stream flow time series data for each alternative for input into Deltares’ model. The USGS-Deltares modelling effort is ongoing. The results will be compiled by USGS into a technical report for incorporation into USACE's final watershed plan for the West Maui study area by the end of 2021. In addition, USGS will provide recommendations for future modeling efforts.

3.1.5 Parametric Cost Estimates for Conceptual Structural Alternatives

Conceptual design and analysis parameters included use of record drawings, historic costs, photos, sketches, dimensions, and the H&H Appendix (Appendix A) along with Cost Engineer Rough Order of Magnitude (ROM)-level type assumptions (Google Earth, NRCS soils; cost comparison for projects similar in location and design) where various detailed engineering parameters were lacking due to the nascent stage of some of the project alternative solutions. The table below summarizes the ROM costs

	Lo'i Terrace	Modify Ka'ōpala	Modify Kahana	Modify Honokōwai	Micro Basin	Alt 2 (New Construction)	Alt 3 (New Construction + Basin Mods)
ROM	$5,113,764	$94,076	$94,076	$250,869	$11,419,134	$16,532,898	$16,971,919

Table 3- 5 Parametric Cost Estimates of USACE Recommended Engineered Management Measures and Conceptual Alternatives

The USACE will discuss this information with the study partners to inform potential strategic implementation of recommended management measures (Section 3.4.2).

3.1.6 Recommended Conceptual Alternatives/Strategies

Conceptual alternatives/strategies that met The Water Resources Council's National Evaluation Criteria: completeness, effectiveness, efficiency and acceptability were carried forward for further consideration are categorized under the following three categories: 1) Policy and Regulatory Measures (Non-structural), 2) Engineered (Structural), and 3) Education & Outreach (Non-structural). The following management measures identified across the three categories addressed the range of problems across the watershed and were formulated in consideration of current Federal, State, and local planning and environmental guidance in conjunction with laws and policies concerning ecosystem restoration, flood risk management, water supply, water quality, stakeholder collaboration, and related purposes.

`POLICY & REGULATORY:

- Support State Department of Health development of non-point source pollution management program
- Establish stormwater fees throughout West Maui
- Low impact development (LID) requirement for development, redevelopment and improvement projects >1 acre for all landowner to incorporate LID measures into design and construction
- Pool and vehicle wash water discharge policy

ENGINEERED STRUCTURAL:

- Lāhaina wastewater reclamation facility alternate disposal (e.g. Increase production of R-1 water for reuse)
- Engineering analysis/retrofit design at Honokōwai Structure #8*
- Restoration of traditional lo'i kalo

- Potential new desilting/sediment basins
- Microbasins in Ka'ōpala, Wahikuli and Papua
- Lo'i terraces in Honolua or Honokōwai
- Basin modifications at Ka'ōpala, Kahana and Honokōwai
- Conservation boundary fencing
- Active ungulate & invasive weed management
- Landscape restoration (e.g., restore native plant buffer below conservation boundary, restore native vegetation along degraded gulch edges (provide lengths)
- Gulch Buffer Erosion Control Measures/Stacked Practices (e.g. Ripping, Terraforming, Micro-basins, Key lining/ripping on contour, Vetiver eyebrows in kickouts, Contour planting vetiver, Native plant establishment, Hydro-mulching, Check dams)
- Wildland fire management measures (e.g. Plan, fund and install fire breaks at low, medium and upper elevations along agricultural district)
- Access road improvements
- Conduct analysis of urban corridor; site and propose measures for specific pollution reduction measures such as urban storm water management retrofits
- Gulch buffer stacked practices pilot program at Wahikuli, Honokōwai and Kahana
- Multiple sediment capture and groundwater recharge basins at Wahikuli and Hāhākea Gulches

PUBLIC EDUCATION AND OUTREACH:

- Continue to fund existing outreach initiatives and outreach coordinators
- Fund community outreach/education efforts
- Increase funding to and awareness of the Ocean-Friendly Landscaper Outreach Program
- Increase funding of Community Water Quality Monitoring Program

3.1.7 Preliminary Qualitative Prioritization of Recommended Engineered Strategies

The USACE collaborated with the West Maui R2R Hui to prioritize the above list of engineered recommended measures that were either combined or determined to stand alone as alternative conceptual strategies (Table 3-6). Factors considered in prioritization of the engineered structural strategies included: completeness (met study objective), effectiveness (scale of resolution across all five watersheds), efficiency (direct resolution of problem statement) and acceptability (legal, public and other social effects). Those strategies that met the study objective, could be implemented across all watersheds, directly addressed in-stream erosion of historic fill terraces and were generally acceptable received a high priority rating. Strategies are presented in order by priority; sequencing within each priority category is in no particular order. A potential implementation timeframe was assigned to each strategy on the order of 0-5 years, 5-10 years, 10-15 years and 15+ years. Some strategies could be phased and are denoted on the below table by the entirety of the timespan for implementation.

Priority	Recommended Measure	0-5 yrs	5-10 yrs	10-15 yrs	15+ yrs
High	Basin Modifications at Ka'ōpala, Kahana and Honokōwai	■			
High	Prevent agricultural soils from transport into streams and gulches by researching, piloting and implementation of stream/gulch bank management measures	■	■		
High	Address current in-stream sediment movement via* -Kahana desilting basin maintenance -Desilting basin monitoring and analysis -Desilting basin retrofits -Potential new desilting/sediment basins	■			
High	Measures to address in-stream sediment deposits and prevent transport downstream via:* -Microbasins in Ka'ōpala Wahikuli and Papua -Lo'i terraces in Honolua or Honokōwai	■	■		
High	Increase groundwater recharge and slow surface flows via -Conservation boundary fencing -Active ungulate & invasive weed management -Landscape restoration (e.g., restore native plant buffer below conservation boundary, restore native vegetation along degraded gulch edges)	■	■	■	■
Medium	Road and Trail Inventory Assessment and Pollution Source Minimization Practices	■			
Medium	Lahaina WWRF Injection Wells Alternate Disposal (Increase production of R-1 water for reuse)	■			
Medium	Burn Area Emergency Response Plan	■	■	■	■
Medium	Wildland Fire Management Measures e.g. Fire breaks		■		
Medium	Push pile assessment and stabilization		■	■	■
Medium	Urban Storm Water Management Retrofits		■	■	
Medium	Gulch Buffer Stacked Practices - optimal combinations of: Ripping, Terraforming, Micro-basins, Key lining/ripping on contour, Vetiver eyebrows in kickouts, Contour planting vetiver, Native plant establishment, Hydro-mulching and Check dams	■	■	■	■
Medium	Sediment Capture and Groundwater Recharge Basins Complex Combined with Recreational Open Space at Wahikuli Gulch and Hahakea Gulch		■	■	
Low	Urban Pollution Control: Bioretention Cell e.g. Rain Garden	■			
Low	Assess roadside erosion at Honoapiilani Hwy and Lower Rd		■		
Low	Gulch buffers adjacent to Wahikuli and Hahakea Gulch	■	■	■	■

Table 3- 6 Preliminary Prioritization and Implementation Timeline of Recommended Engineered Conceptual Alternatives/Strategies

3.2 Implementation

The USACE, in collaboration with the study partners, will continue to discuss and refine strategic implementation and prioritization of recommended non-structural and structural strategies and incorporating the results of the USGS-Deltares marine transport dynamics analysis. Implementation discussions will focus on satisfying the study objectives, strategic siting of recommendations in the watershed, identifying funding, partnering and support opportunities and responsible parties, as well as residual data gaps and synergistic implementation of recommendations for a maximized effect.

3.3 Conclusion

This comprehensive five-watershed management plan builds upon the 2012 and 2016 watershed plans prepared for West Maui. It incorporates the best available scientific information and reflects extensive collaboration with federal, state and local partners and community organizations. The prioritized list of recommendations ensures the problems are addressed, opportunities for secondary benefits are explored, study objectives are met and within the context and constraint of the study area. Targeting land-based pollution will increase the resistance and resiliency of West Maui coral reef health thereby improving the local West Maui economy.

The purpose of the watershed management plan and its prioritized list of conceptual recommendations is to assist the West Maui community and its leaders in strategic planning and future decision-making. The prioritized list of conceptual recommendations will be incorporated into an implementation strategy, to offer the West Maui community a roadmap to take each recommendation to implementation. This watershed management plan can be used to execute follow-on studies or projects in the areas that meet the community of West Maui's greatest needs and can be leveraged to secure funding sources and project opportunities to implement the recommendations.

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