Preliminary Watershed Planning Framework for Kahoma and Kaua‘ula Watersheds in West Maui, Hawai‘i

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ACRONYMS

Acronyms/Abbreviations	Definition
AET	Apparent Effects Threshold
Ag	silver
As	arsenic
AU	Assessment Unit
BAER	U.S Department of Agriculture Burned Area Emergency Response
BMP	best management practice
Cd	cadmium
CFS	cubic feet per second
CFU	colony forming unit
Co	cobalt
Cr	chromium
Cu	copper
CWA	Clean Water Act
DLNR	Department of Land and Natural Resources
DO	dissolved oxygen
DOH	Hawaiʻi Department of Health
ERL	Effect Range-Low
ERM	Effect Range-Median
FEMA	Federal Emergency Management Agency
HAR	Hawaiʻi Administrative Rules
Hg	mercury
HOKWO	Hui O Ka Wai Ola (Association of the Living Waters)
HSG	hydrologic soil group
LTRP	Long-Term Recovery Plan
LWRF	Lahaina Water Reclamation Facility
MLRA	major land resource area
mm/hr	millimeters per hour
MPN	most probable number
Ni	nickel
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resource Conservation Service
PAH	polycyclic aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
PEL	Probable Effects Threshold
PET	potential evapotranspiration

Acronyms/Abbreviations	Definition
POC	persistent organic chemical
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
Se	selenium
SOM	soil organic matter
SQuiRTs	NOAA screening quick reference tables
STV	statistical threshold value
TEL	Threshold Effect Level
TEQ	Toxic Equivalent Concentration
TMDL	Total Maximum Daily Load
TN	total nitrogen
TP	total phosphorus
TSS	total suspended solids
V	vanadium
WQS	water quality standard
Zn	zinc

Note: *This Preliminary Planning Framework is based on the best available information at the time of development, including existing datasets, reports, and stakeholder input. Where more current or site-specific data becomes available through monitoring, assessments, ground-truthing, or additional stakeholder engagement, those findings should be used to refine or update planning and implementation efforts.*

1.0 INTRODUCTION AND WATERSHED GOALS

1.1 BACKGROUND

In early August of 2023, deadly wildfire broke out across the Island of Maui, Hawaiʻi causing widespread destruction in the town of Lahaina and in other areas of Maui. The fires impacted communities and watersheds surrounding Lahaina, including those in the Kahoma and Kauaʻula watersheds, altering watershed hydrology (e.g., increased runoff rates due to vegetation loss and impacts to soil health). Over a short-term period following the fire (1–5 years), increased storm runoff can worsen flooding, soil erosion, and delivery of sediment, nutrients, and other pollutants to freshwater streams and coastal waters (FEMA 2024).

Prior to the wildfires, a watershed-based plan was in development for the Waikapu and Waiakoa watersheds, which encompass most of the burn area in Central Maui. The plan was approved by the Hawaiʻi Department of Health (DOH) in December 2023, and projects to mitigate water quality impacts are currently in the process of obtaining subawards from DOH's Clean Water Act (CWA) Section 319(h) grant program. As for the Kahoma and Kauaʻula watersheds, there is no approved watershed-based plan or alternative plan in place that meets EPA requirements for CWA 319(h) funding eligibility.

To address short-term impacts from the Lahaina fire, Tetra Tech was tasked with developing a Preliminary Watershed Planning Framework (hereinafter Preliminary Planning Framework) to inform an alternative watershed plan for the Kahoma and Kauaʻula watersheds. This Preliminary Planning Framework was intentionally scoped to include more detailed information than typically expected from an alternative watershed plan, in order to leverage available expertise and provide a foundation for both near-term recovery and future, comprehensive watershed-based planning. While the EPA's *Nonpoint Source Program and Grants Guidelines for States and Territories* (EPA 2024) do not provide specific guidance for developing a Preliminary Planning Framework, this framework was informed by the guidelines for both alternative and nine-element watershed-based plans, which it is intended to support.

Alternative plans are developed in response to a nonpoint source pollution emergency or urgent nonpoint source public health risk, to "address the post-emergency situation (e.g., efforts to control erosion and re-establish vegetation in the immediate aftermath of a forest fire, efforts to reduce pollution affecting drinking water safety, other climate-related events) …" To ensure that a plan meets the definition of an *alternative watershed plan*, implementation, monitoring, and reporting of alternative plans for emergency response should be completed within 48 months of the event. Although this document does not serve as the official alternative watershed plan, it outlines key strategies to address post-fire nonpoint source pollution and guide long-term watershed restoration and planning.

1.2 CULTURAL CONSIDERATIONS

In recognition of Native Hawaiian history, culture, and ongoing stewardship practices, this plan acknowledges the ahupuaʻa system as a culturally grounded framework that aligns with holistic watershed management. Ahupua'a refers to the traditional subdivision of the land that typically extends from the uplands towards the mountains (mauka) down towards the sea (makai), encompassing an entire social-ecological system from ridge to reef. This holistic approach to watershed management recognizes the interconnectedness of natural resources on land and in water, emphasizing how they function together as part of a living system. Within this framework, resources are managed with the understanding that impacts in one part of the ahupua'a affect all other parts (for example, inappropriate management of forestry and agricultural uses in upland areas can negatively affect the quality of streams and coastal waters) (NSSCP 2025).

The ahupua'a is a foundational system of land and water management in Hawaiian culture that continues to serve as a relevant framework for watershed management. Native Hawaiian history, knowledge and cultural practices should continue to inform natural resource management and wildfire recovery efforts, and should be central to watershed planning moving forward. As noted locally,

> "Restoration" of Lāhainā following the August 8th, 2023, wildfires, and all that accompanies it must be informed by native history, customs and practices. The ʻike (knowledge) and voices of Native Hawaiians whose kūpuna (ancestors and elders) rest in the kulaīwi (native land) of Lāhainā need to be leaders in all discussions. There should be no room for perpetuation of "disaster capitalism" in the actions that are to follow." (Kumu Pono Associates LLC 2025)

Lāhainā has a rich history and deep cultural significance for Native Hawaiians. For centuries, the people of Hawaiʻi lived in harmony with the land and water, exemplifying sustainable systems, subsistence practices, and community-based watershed management. Agricultural lands and communities were once sustained by the free-flowing waters of the Kahoma and Kauaʻula streams.

> "However, over time, the natural waterways that made Lāhainā an ʻāina momona (abundant, fertile land) were impeded by government zoning, the rise and fall of the plantation economy, and mass development of residential subdivisions and resorts, disrupting this delicate balance" (Ferreira 2024).

These are only a few examples of ongoing impacts of colonialism in Hawaiʻi, which have had lasting effects on Hawaiian culture and sovereignty (Trask 2010). Cultural losses, environmental degradation, and the need for sustainable development in Lāhainā demonstrate how imperative it is "that we look to our past to guide our future" (Ferreira 2024).

1.3 PROBLEM STATEMENT

A significant amount of the landscape within the Lāhainā fire burn scar has been heavily impacted by past land management. Following the cessation of decades-long plantation agriculture and ranching in the islands, many of the lands became idle and unmanaged, allowing highly invasive and highly flammable nonnative grasses to spread. Varieties like guinea grass, molasses grass, and buffel grass—which originated in Africa and were introduced to Hawaiʻi as livestock forage—now occupy about a million acres across the main Hawaiian Islands. Wet winters followed by dry summers lead to exceptional grass growth in the spring before drying out in the summer and fall. These dried grasses become dense fuels ready to burn, a contributing factor in the fast moving and uncontrollable wildfire in Lāhainā that was pushed by a strong downslope windstorm (County of Maui Department of Fire and Public Safety 2024).

Another factor contributing to wildfire risk is changing weather patterns. In recent years, the state has seen long-term declines in average annual rainfall and increases in periods of drought, induced by climbing temperatures, making Hawaiʻi drier and more susceptible to wildfires. The risk of wildfire in Hawaiʻi is greater than 92% of states in the United States (USDA Forest Service 2025) and the annual area burned by wildfire in Hawaiʻi has increased by 300% in the past decades (UH News 2020). The drier leeward sides of the islands—where Lāhainā is located—are typically the most vulnerable.

Erosion and increased water flows following wildfires exacerbate nonpoint source pollution and challenge nonpoint source management programs. Recovery in the Kahoma and Kauaʻula watersheds is anticipated to take many years and require significant technical assistance, resources, and funding. This Preliminary Planning Framework outlines the scope of the effort, based on prior reports, available data, data analyses, and consultation with key stakeholders.

1.4 PLANNING FRAMEWORK GOALS

This Preliminary Planning Framework is intended to guide watershed-based planning and implementation of projects and management measures that address critical sources of nonpoint source pollution related to the 2023 fire, while also providing general guidance for long-term improvement and protection of water quality in the Kahoma and Kauaʻula watersheds. The short-term goal associated with this plan is to protect fresh and marine water quality from the effects of the Lāhainā wildfire.

Although the major focus of this framework is to address post-wildfire recovery as it pertains to water quality protection, it also establishes a long-term goal of reducing the risk of future impacts to fresh and marine water quality from wildfire. In support of this goal, the plan provides recommendations to reduce the risk of future wildfire impacts to water quality in the context of watershed restoration. Further, the plan is intended to help secure additional funding sources for watershed management in the Kahoma and Kauaʻula watersheds and improve watershed planning practices related to natural hazards statewide (i.e., funding from the Federal Emergency Management Agency (FEMA) and other hazard mitigation programs).

This framework is also intended to inform future development of a full, more comprehensive EPA nine-element plan for the Kahoma and Kauaʻula watersheds, to be developed under a separate effort, and any future watershed recovery and management planning pursuant to the Lāhainā Long-Term Recovery Plan (LTRP) currently being drafted by the County of Maui (Maui Recovers 2024). In this regard, this Preliminary Planning Framework also establishes a long-term goal to restore and protect fresh and marine water quality from pollutants generated by historic and current land uses. Potential measures and practices in support of this goal are identified in this framework, but further watershed evaluation is needed to fully address EPA's guidance for watershed-based planning, such as estimating pollutant loads from individual source types and estimating pollutant reductions from water quality protection practices.

2.0 WATERSHED CHARACTERIZATION

2.1 PROJECT AREA DESCRIPTION

The Kauaʻula hydrologic unit (code 200200000702) and Kahoma hydrologic unit (code 200200000703) are located on the western part of the Hawaiian island of Maui, each lying on the flanks of Pu'u Kukui Mountain. Kauaʻula and Kahoma hydrologic units are straddled by the town of Lāhainā. The Kauaʻula hydrologic unit is 8.34 square miles on the southwestern flank of Pu'u Kukui Mountain and includes Kauaʻula Stream and its tributaries. One mainstem and two headwater tributaries flow in response to rainfall runoff, with some perennial flow supported by dike-impounded groundwater discharge in the upper reaches of Kauaʻula Stream (State of Hawaiʻi 2018a). The Kahoma hydrologic unit is 8.41 square miles on the western flank of Pu'u Kukui Mountain and includes Kahoma Stream, which flows from its headwaters to Lāhainā Harbor in a westerly direction (from higher elevations). Kahoma Stream has two branches, Kahoma and Kanahā streams, and one main tributary, Halona Stream. Kahoma Stream flows naturally to the ocean 95% of the time, with smaller tributaries flowing intermittently in response to rainfall runoff. Dike-impounded groundwater in the upper reaches supports baseflow with two tunnels augmenting spring flow (State of Hawaiʻi 2018b). Higher elevations support native ohia- and koa-dominated forests, while lower elevations are dry and occupied by a mixture of grasses, shrubs, and trees—many of which are non-native invasive species. In August 2023, a series of wildfires burned parts of Maui, with devastating impacts to the community of Lāhainā (Rafferty 2025). The impact of such fires can cause fundamental changes to watershed hydrology, especially in a short-term period (1-5 years after a disaster). Peak flow increases and faster water arrival times can increase flood risk post-wildfire (FEMA 2024).

Figure 1 shows the location of the Kauaʻula and Kahoma watersheds within the island of Maui, Hawaiʻi.

Figure 2and Figure 3 depict the Kauaʻula and Kahoma HUC-12 watersheds and associated streams.

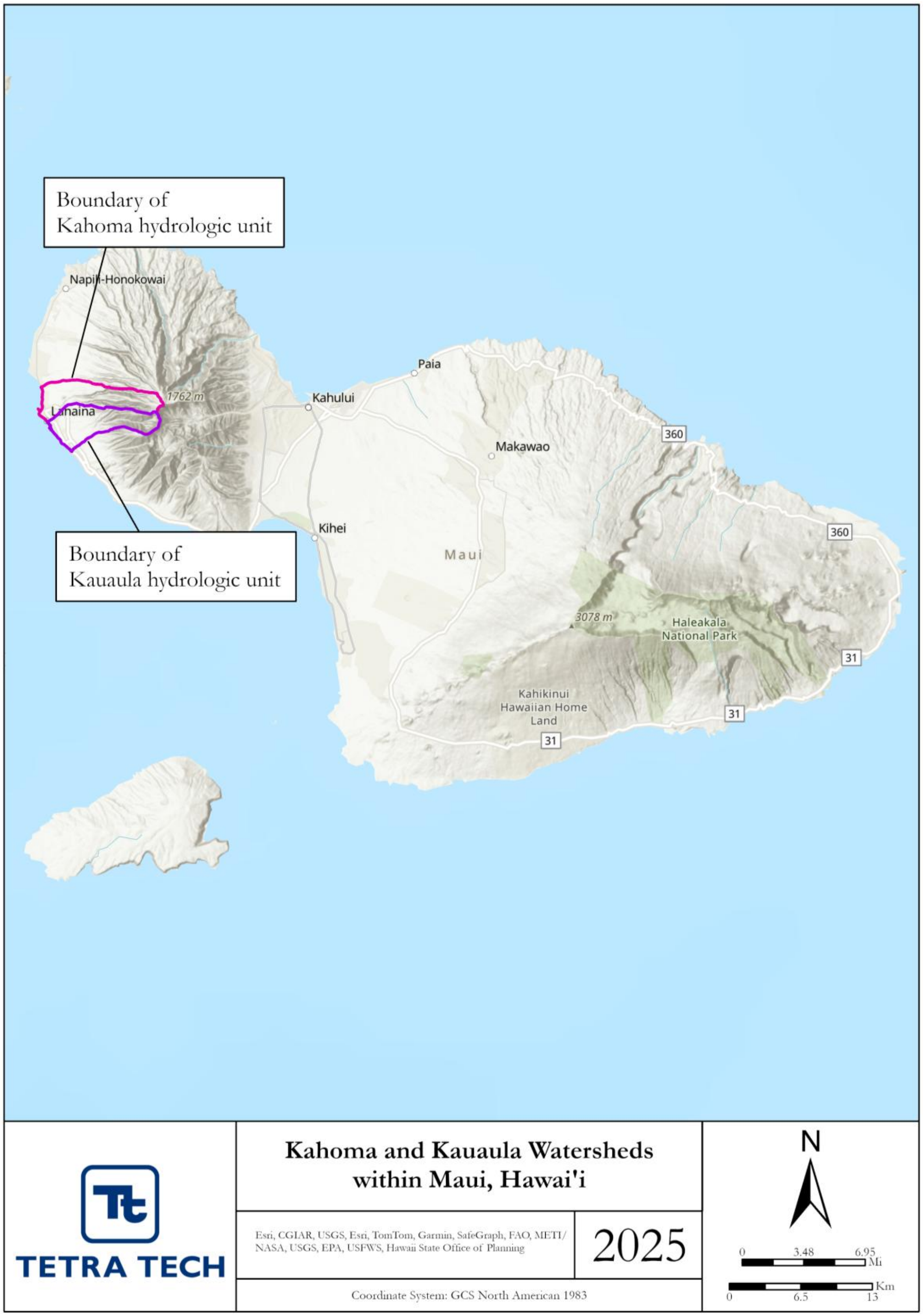

Figure 1. Location of the Kaua'ula and Kahoma watersheds in and around Lāhainā on Maui, Hawai'i.
(*Source: Hawai'i Statewide GIS Program 2025*)

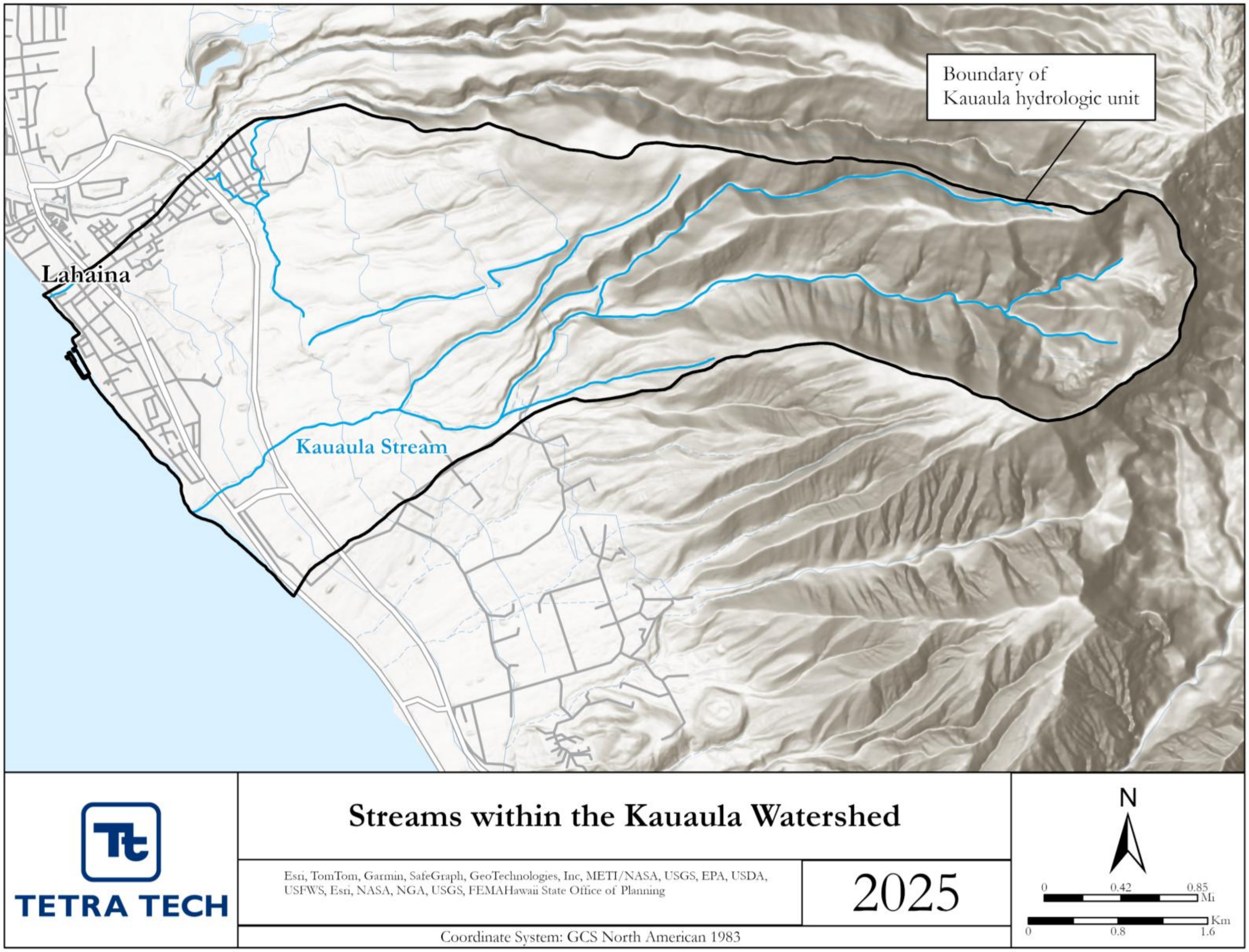

Figure 2. Kauaʻula HUC-12 watershed and associated streams. (*Source: Hawaiʻi Statewide GIS Program 2025*)

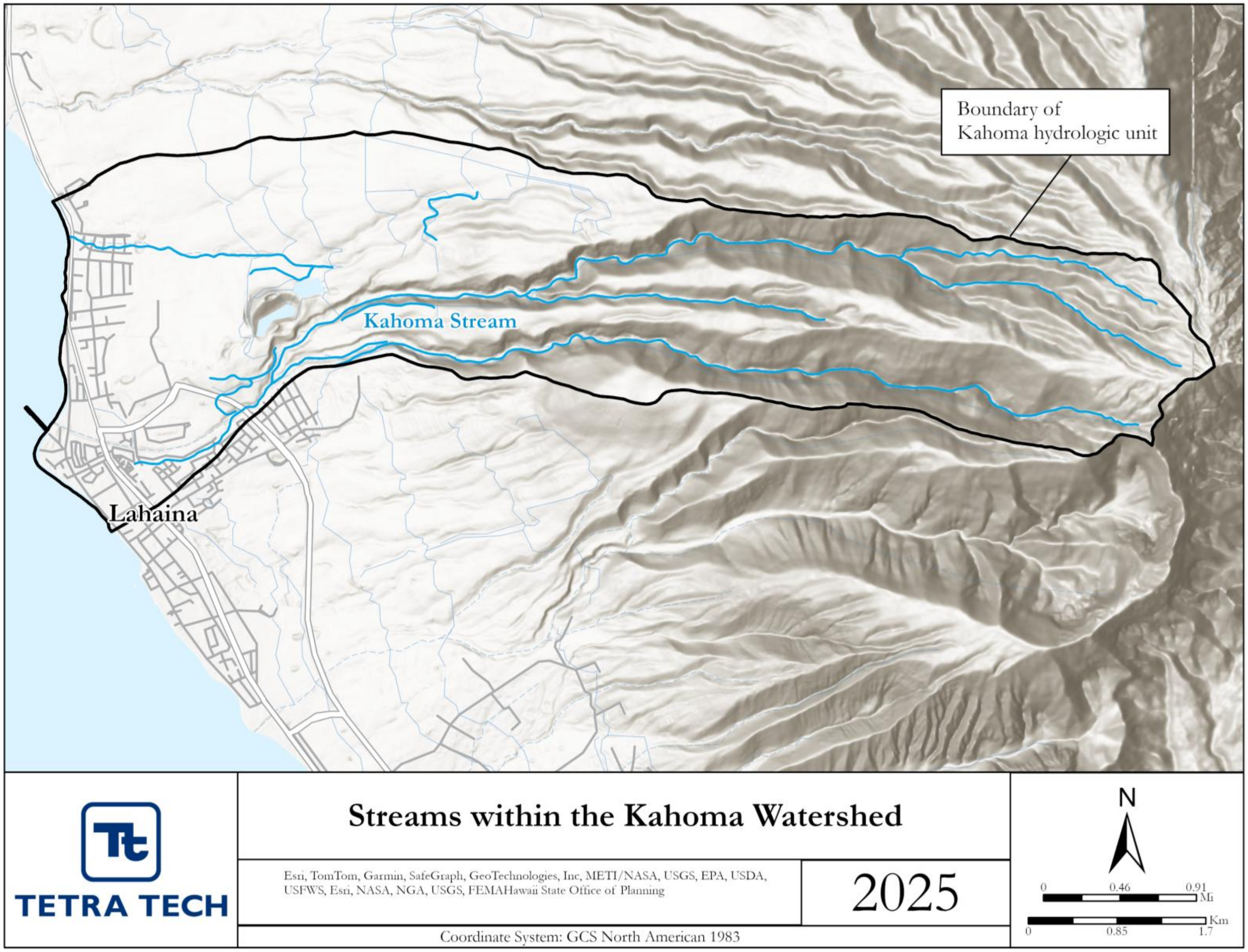

Figure 3. Kahoma HUC-12 watershed and associated streams. (*Source: Hawaiʻi Statewide GIS Program 2025*)

2.2 POPULATION

Most of the population in the Kauaʻula and Kahoma watersheds is located in and around the town of Lāhainā on the island of Maui. Lāhainā, a census designated place in the County of Maui, is located along the northwest coast of the island of Maui and had a total population of 12,702 people in 2020 (U.S. Census Bureau 2022a). Lāhainā encompasses both Lāhainā town and the Kāʻanapali and Kapalua beach resorts (State of Hawaiʻi 2018a). It makes up less than 8% of the population of the County of Maui, which was estimated to have a total population of 164,754 people in 2020. Between 2010 and 2020, Lāhainā grew in population from 11,704 people (an increase of 998 people or approximately 8.5%) (U.S. Census Bureau 2022b). The State of Hawaiʻi estimates that due to the fires in 2023, the total population of Maui has fallen by at least 1,000 people due to relocations out of state or to other counties in Hawaiʻi (Hawaiʻi Department of Taxation 2025).

2.3 SOCIOECONOMIC CONDITIONS

Between 2018 and 2022, there were 3,562 households in Lāhainā, and the average household size was 3.53 people. The median household income in Lāhainā between 2018 and 2022 was $83,443 and 91.1% of the population attained a high school education or higher and 24.8% of the population attained a bachelor's degree or higher. The main industries in Lāhainā are arts, entertainment, recreation, and accommodation, followed by educational services, health care and social assistance, and retail trade (U.S. Census Bureau 2022c).

The Hawaiʻi Department of Taxation estimates that the observed relocation of residents in Maui due to the 2023 fires may have significant implications for the economic conditions and revenues of both the county and state. They estimate that nearly $60 million in annual income was lost in Maui due to changes in the migration of people in and out of Maui caused by the fires. They also estimate that the impacts to the incomes of the people who remained in Maui after the fires are quite likely to be much greater in magnitude than the relocation data reported to the Department of Taxation (Hawaiʻi Department of Taxation 2025).

2.4 TOPOGRAPHY

The elevation in the Kauaʻula watershed ranges from 0 feet (where it discharges to the ocean) to a maximum elevation of 5,220 feet in the mountains at the headwaters of the watershed, with a mean basin elevation of 2,220 feet and a mean basin slope of 75.4% (State of Hawaiʻi 2018a). Slopes of greater than 30% are apparent for a large portion of the basin (~70%). Similarly, the elevation in the Kahoma watershed ranges from 0 feet (where it discharges to the ocean) to a maximum elevation of 5,764 feet at the headwaters of the watershed, with a mean basin elevation of 2,390 feet and a mean basin slope of 71.2% (State of Hawaiʻi 2018b). Slopes of greater than 30% are apparent for a large portion of the basin (~70%).

Figure 4 depicts elevation ranges across the Kauaʻula and Kahoma watersheds on the island of Maui, Hawaiʻi.

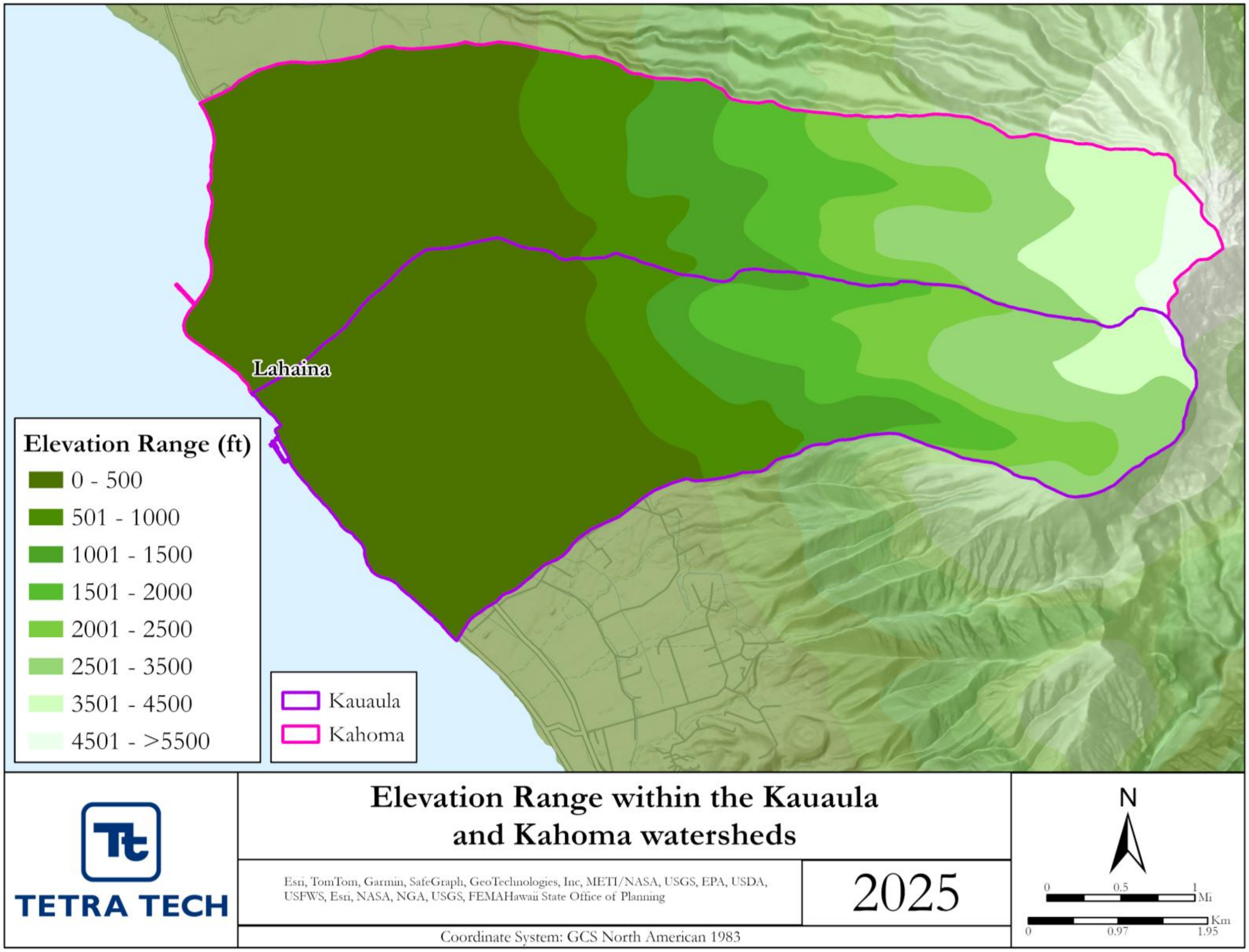

Figure 4. Elevation ranges (feet) within the Kauaʻula and Kahoma watersheds. (*Source: Hawaiʻi Statewide GIS Program 2025, USGS 2018*)

2.5 SOILS AND GEOLOGY

2.5.1 Major Land Resource Areas

Major land resource areas (MLRAs) are geographic areas characterized by similar soils, climate, water resources, and land uses (USDA 2022a). The Kauaʻula and Kahoma watersheds fit within three MLRAs, shown in Figure 5, including *Semiarid and Subhumid Low Mountain Slopes*, *Humid and Very Humid Steep and Very Steep Mountain Slopes*, and *Very Stony Land and Rock Land* (USDA 2022a).

The *Semiarid and Subhumid Low Mountain Slopes* area (MLRA 158), which makes up approximately 550 square miles, is located on the leeward, drier side of the older Hawaiian Islands and has moderately steep slopes that are dissected by gulches. MLRA 158 has a distinct boundary with the highly dissected, steep and very steep mountain slopes of MLRA 164 and a diffuse boundary with the alluvial fans and coastal plains of MLRA 163; as well as the intermediate or high mountain slopes of MLRAs 160 and 167. Dominant soil orders include Oxisols, Mollisols, and Aridisols. Soils are very deep, well drained, and very fine textured, with the MLRA having significant acreage of non-soil areas. Most of the land use on this MLRA is farms and ranches, but some small areas are used for dry-farmed pasture, urban development, and military installations. Crops grown include irrigated sugarcane, truck crops, and pineapples (USDA 2022a). In the Kauaʻula and Kahoma watersheds, MLRA 158 makes up a large portion on the western sides near the ocean (USDA 2022a).

The *Humid and Very Humid Steep and Very Steep Mountain Slopes* area (MLRA 164), which makes up approximately 760 square miles, has low to intermediate elevations in the older Hawaiian Islands and mountainous areas dissected by gulches and canyons. It has very few populated areas and has a distinct boundary with the arid and semiarid climates of MLRAs 158 and 163, as well as the rolling slopes of the volcanic mountains in MLRAs 159A, 160, 165, and 167. Dominant soil orders are Inceptisols, Andisols, and Spodosols. Soils generally are deep, poorly to well drained, and fine, very fine, medial, or hydrous textured. Forest and rangeland make up most of MLRA 164. Forestland is used mainly for watershed, wildlife, and recreation related uses, while some small areas are used for crops or pasture (USDA 2022a). MLRA 164 makes up a small portion of the Kauaʻula and Kahoma watersheds and is located upslope from MLRAs 158 and 166.

The *Very Stony Land and Rock Land* area (MLRA 166), which makes up approximately 490 square miles, is on arid and semiarid, low- to high-elevation, volcanic mountain slopes on the older Hawaiian Islands. Dominant soil orders are Aridisols, Mollisols, and Entisols. Soils are dominantly shallow, well drained, and clayey. They formed in material weathered from basic igneous rocks. Rock outcrops or stones cover the surface of about 40%–50% of the MLRA. Most of this MLRA is used for rangeland, watershed, and wildlife habitat, with a small amount of acreage being used for urban development. More than one-fifth of the area is forestland (USDA 2022a). MLRA 166 makes up a large portion of the watersheds, upslope from the coast and MLRA 158.

More information about the three MLRAs in the Kauaʻula and Kahoma watersheds can be found at: https://www.nrcs.usda.gov/sites/default/files/2022-10/AgHandbook296_text_low-res.pdf (USDA 2022a).

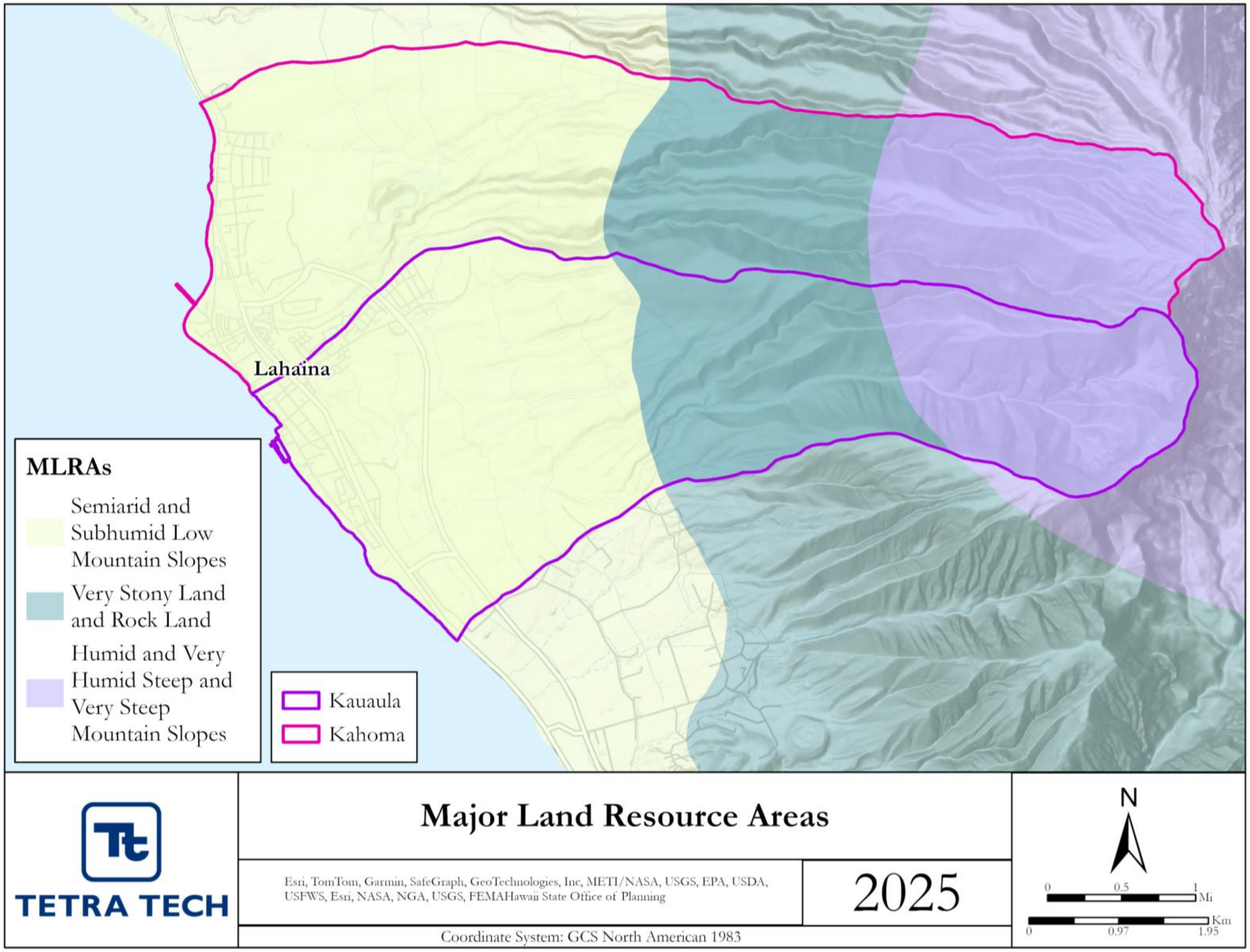

Figure 5. Major Land Resources Areas (MLRAs) in the Kaua'ula and Kahoma watersheds. (*Source: USDA 2022b*)

2.5.2 Geology

Maui was built by the formation of two volcanoes, including Puʻu Kukui, or the West Maui volcano. The Kauaʻula and Kahoma watersheds lie on the southern and western flanks of Puʻu Kukui. Three volcanic phases built West Maui: the Wailuku Volcanic Series, Honolua Volcanic Series, and Lāhainā Volcanic Series. About 97% of the volcano's volume was formed during the Wailuku Series, with Pāhoehoe and ʻAʻā flows. The first phase eventually collapsed and formed a caldera with horizontal post-caldera lava flows. The second phase formed an incomplete cap, with thick flows dominated by alkali rocks. The Honolua Volcanic Series produced several dike and vent formations with an irregular pattern. This series finished and was followed by four small eruptions that encompassed the brief Lāhainā Volcanic Series. Silica lava flows dominated this phase, followed by rapid erosion and valley incision that produced broad alluvial fans on the western and eastern slopes of West Maui (State of Hawaiʻi 2018a). The main rocks in the Kauaʻula and Kahoma watershed regions consist of older alluvium, pāhoehoe and ʻaʻā lava flows, sand and gravel, and intrusive rocks (State of Hawaiʻi 2018a, 2018b). The generalized surface geology of the Kauaʻula and Kahoma watersheds is summarized in Table 1.

Table 1. Surface geologic features for the Kauaʻula and Kahoma hydrologic units, Maui.

Watershed	Name Type	Rock Type
Kauaʻula	Wailuku Volcanics	Intrusive rocks, Caldera complex, Dike complex, Pāhoehoe and ʻAʻā lava flows
	Older alluvium	Lithified sand and gravel
	Alluvium	Sand and gravel
	Honolua Volcanics	Pāhoehoe and ʻAʻā, Conglomerate
Kahoma	Wailuku Volcanics	Intrusive rocks, Caldera complex, Dike complex, Pāhoehoe and ʻAʻā lava flows
	Lāhainā Volcanics	Lava flows
	Alluvium	Sand and gravel
	Older alluvium	Lithified sand and gravel
	Honolua Volcanics	Pāhoehoe and ʻAʻā, Conglomerate

Source: Sherrod et al. (2007) in State of Hawaiʻi (2018a, 2018b)
Note:
Generalized surface geology tables were edited from original report for consistency.

2.5.3 Soils

The main types of soils in the Kauaʻula and Kahoma watersheds are described in Table 2 and their locations are depicted in Figure 6 and Figure 7. Approximately half of the Kauaʻula watershed consists of rough mountainous land and Wainee silty clays (each makes up about 30%–31% of the watershed). Wainee soils are deep, well drained, and excellent for agriculture (State of Hawaiʻi 2018a, 2018b). Stony alluvial land and rock outcrops make up 10% and 7% of the watershed, respectively. Other soil types are noted in Table 2 and mapped in Figure 6. Similarly, roughly half of the Kahoma watershed is composed of Wahikuli silty clays and rough mountainous land (each makes up about 24%–35% of the watershed). Lāhainā silty clay makes up 11% of the watershed. Other soil types are noted in Table 2 and mapped in Figure 7**Figure 7**.

Table 2. Main soil types in the Kauaʻula and Kahoma watersheds.

Watershed	Soil Type[1]	Acres in Watershed	Percent of Watershed
Kauaʻula	Ewa	361	7%
	Lāhainā	130	2%
	Olelo	49	1%
	Pulehu	140	3%
	Rock land	193	4%
	Rock outcrop	387	7%
	Rough broken land	289	5%
	Rough mountainous land	1,582	30%
	Stony alluvial land	526	10%
	Wainee	1,678	31%
	Water > 40 acres	6	<1%
	Total	**5,340**	**100%**
Kahoma	Alaeloa	81	2%
	Beaches	2	<1%
	Ewa	174	3%
	Lāhainā	603	11%
	Olelo	237	4%
	Pulehu	98	2%
	Rock land	154	3%
	Rock outcrop	477	9%
	Rough broken land	295	6%
	Rough mountainous land	1,912	35%
	Wahikuli	1,303	24%
	Wainee	17	<1%
	Water > 40 acres	26	1%
	Total	**5,380**	**100%**

Source: NRCS (2024)
Note:
[1] Soil textures were grouped by overall soil type and differ slightly from figures below.

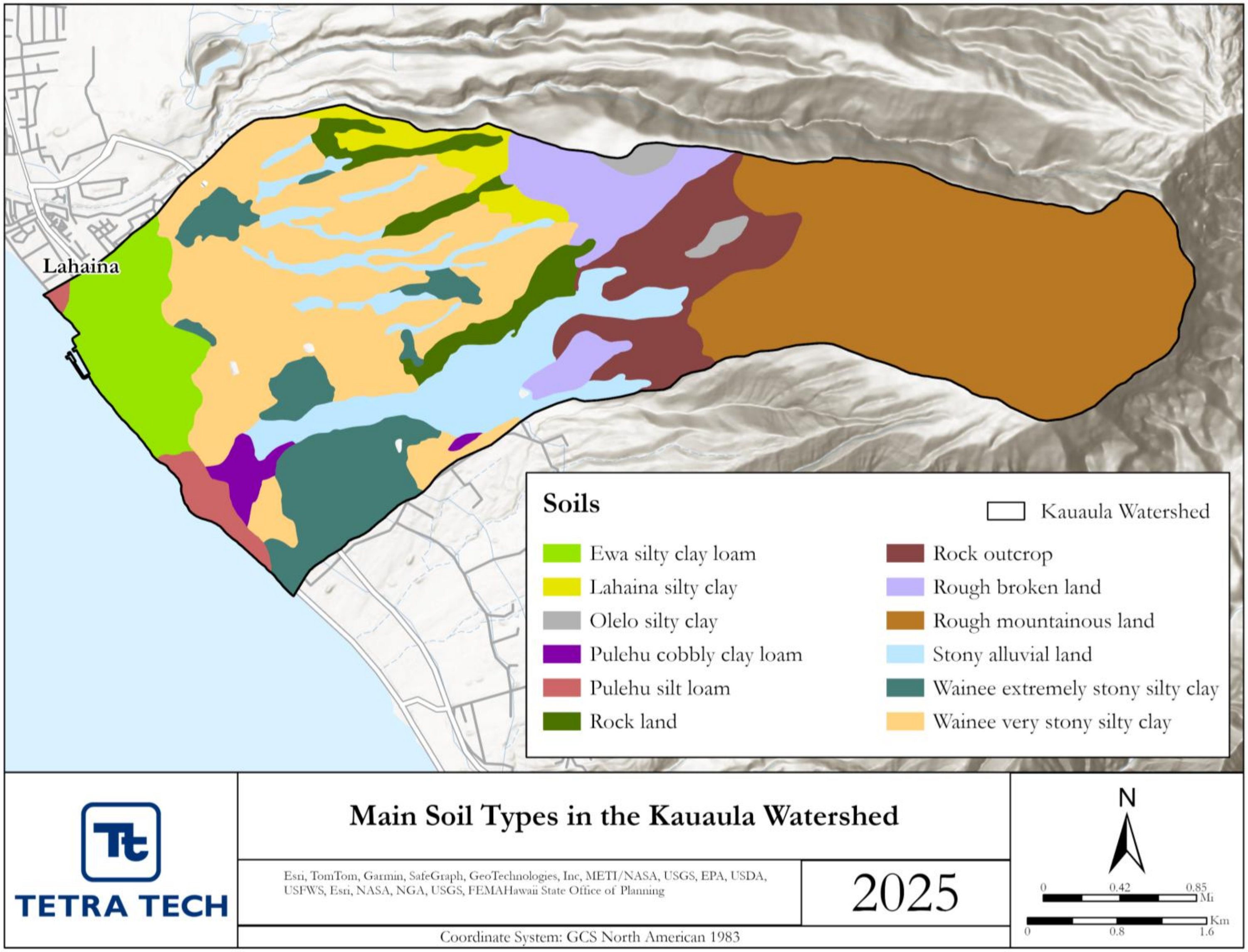

Figure 6. Map of main soil types in the Kaua'ula. (*Source: NRCS 2024*)

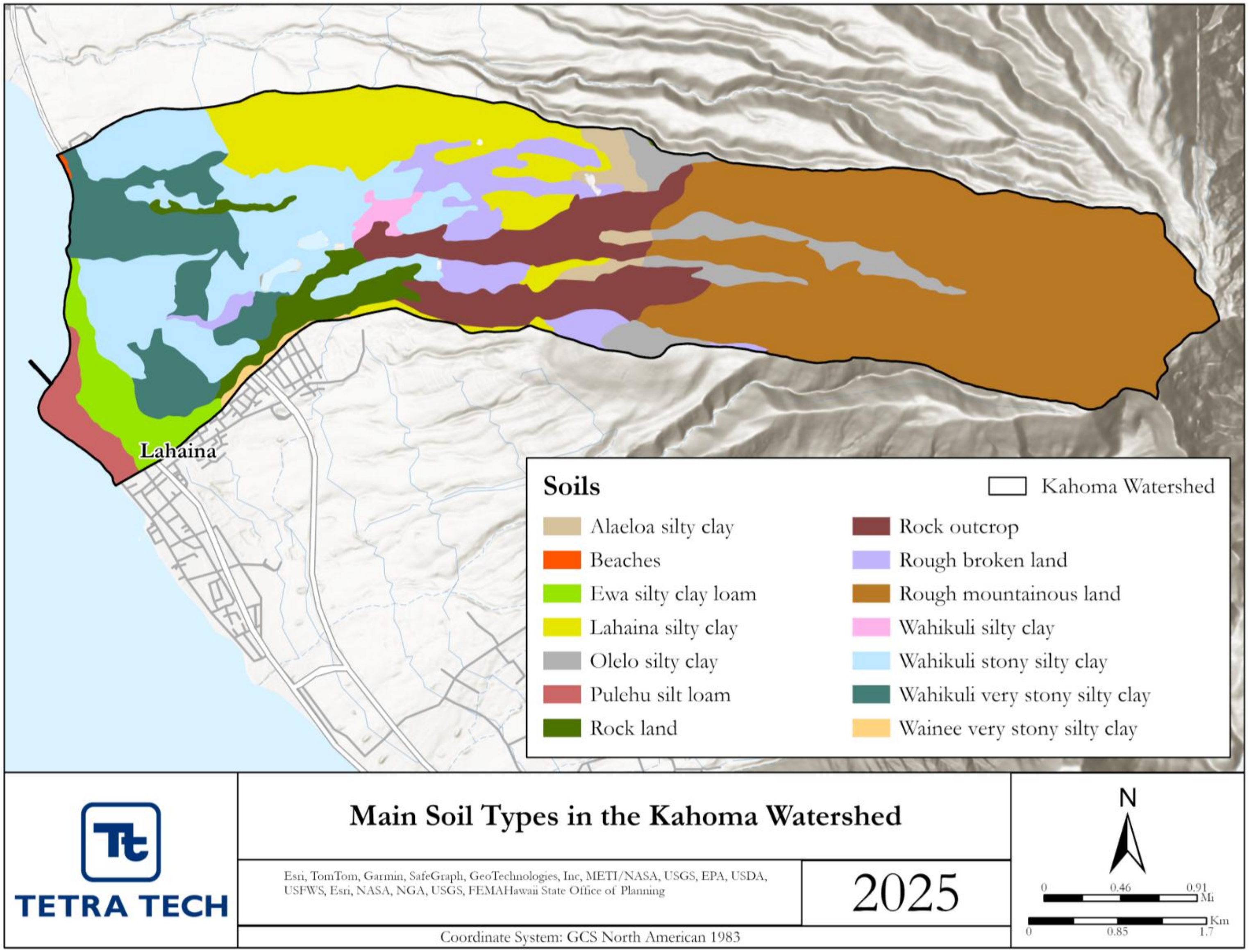

Figure 7. Map of main soil types in the Kahoma. (*Source: NRCS 2024*)

Erosion factor K indicates the susceptibility of a soil to sheet and rill erosion by water. Values of K range from 0.02 to 0.69. Other factors being equal, the higher the value the more susceptible the soil is to sheet and rill erosion by water—with values of 0.4 or greater considered to be indicative of high erodibility. Within the Kaua'ula watershed, K factor ranges from 0.05 to 0.32. Areas with K values of 0.1 or 0.2 make up over 70% of the watershed area. Only a small percentage of the watershed, at the downstream drainage area near the coast, is considered more susceptible to sheet and rill erosion (K value greater than 0.3). Similarly, within the Kahoma watershed, K factor ranges from 0.05 to 0.32. Areas with K values of 0.17 or 0.2 make up approximately 70% of the watershed area. Table 3 provides more information about the K factors observed in the watersheds. Figure 8 and Figure 9 display the spatial extent of different K factors.

Table 3. Erosion factor K value in the Kaua'ula and Kahoma watershed.

Watershed	K factor	Acres	Percent of Watershed
Kaua'ula	0.05	366	7%
	0.1	2320	43%
	0.17	270	5%
	0.2	1582	30%
	0.28	49	1%
	0.32	361	7%
	No Rating	394	7%
	Total	**5340**	**100%**
Kahoma	0.05	2	<1%
	0.1	548	10%
	0.17	2004	37%
	0.2	1912	36%
	0.28	237	4%
	0.32	174	3%
	No Rating	504	9%
	Total	**5380**	**100%**

Source: NRCS (2024)
Note:
Acreage and percent coverage of watershed were geospatially determined for the Kahoma and Kaua'ula watersheds.

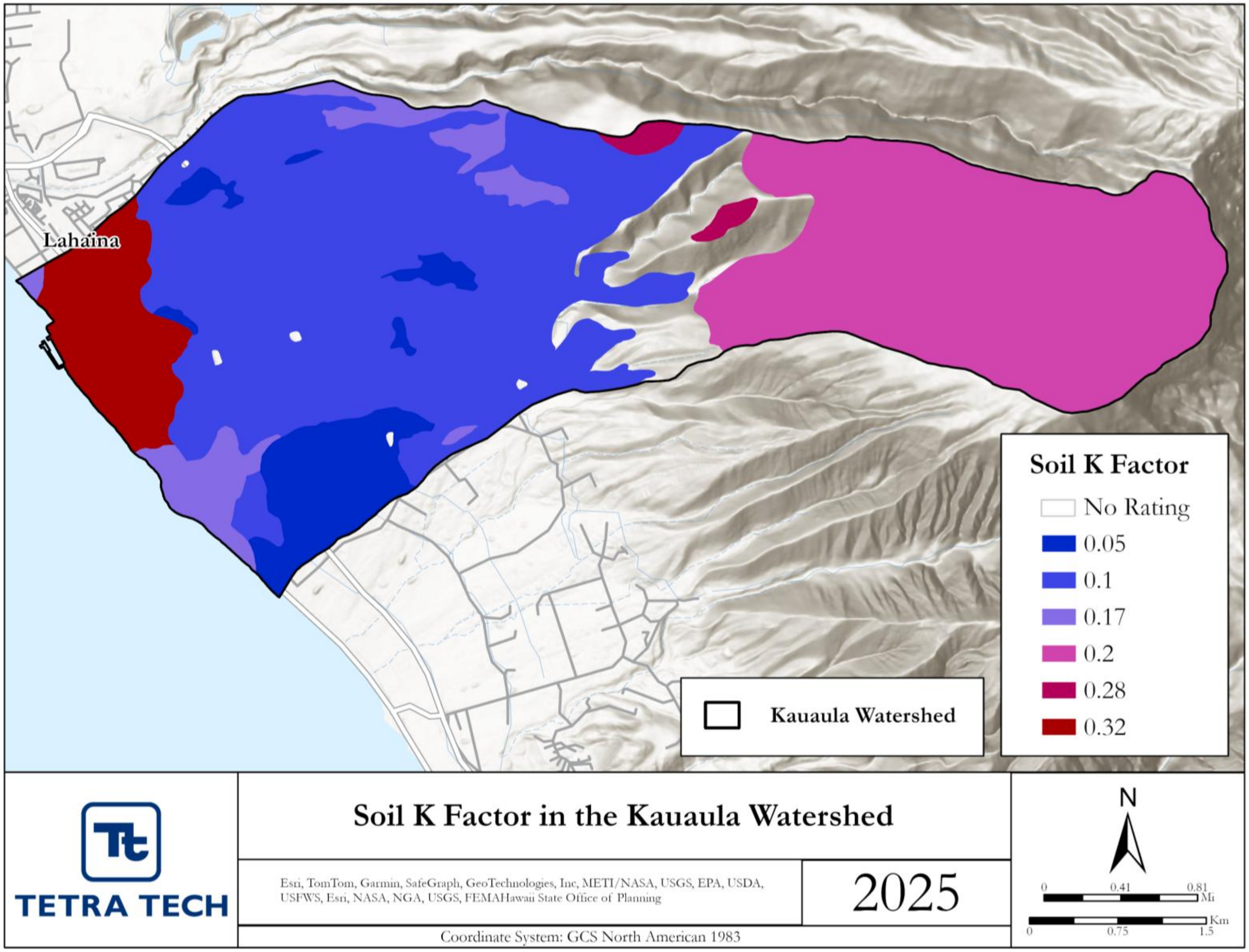

Figure 8. Soil K factor in the Kaua'ula watershed. (*Source: NRCS 2024*)

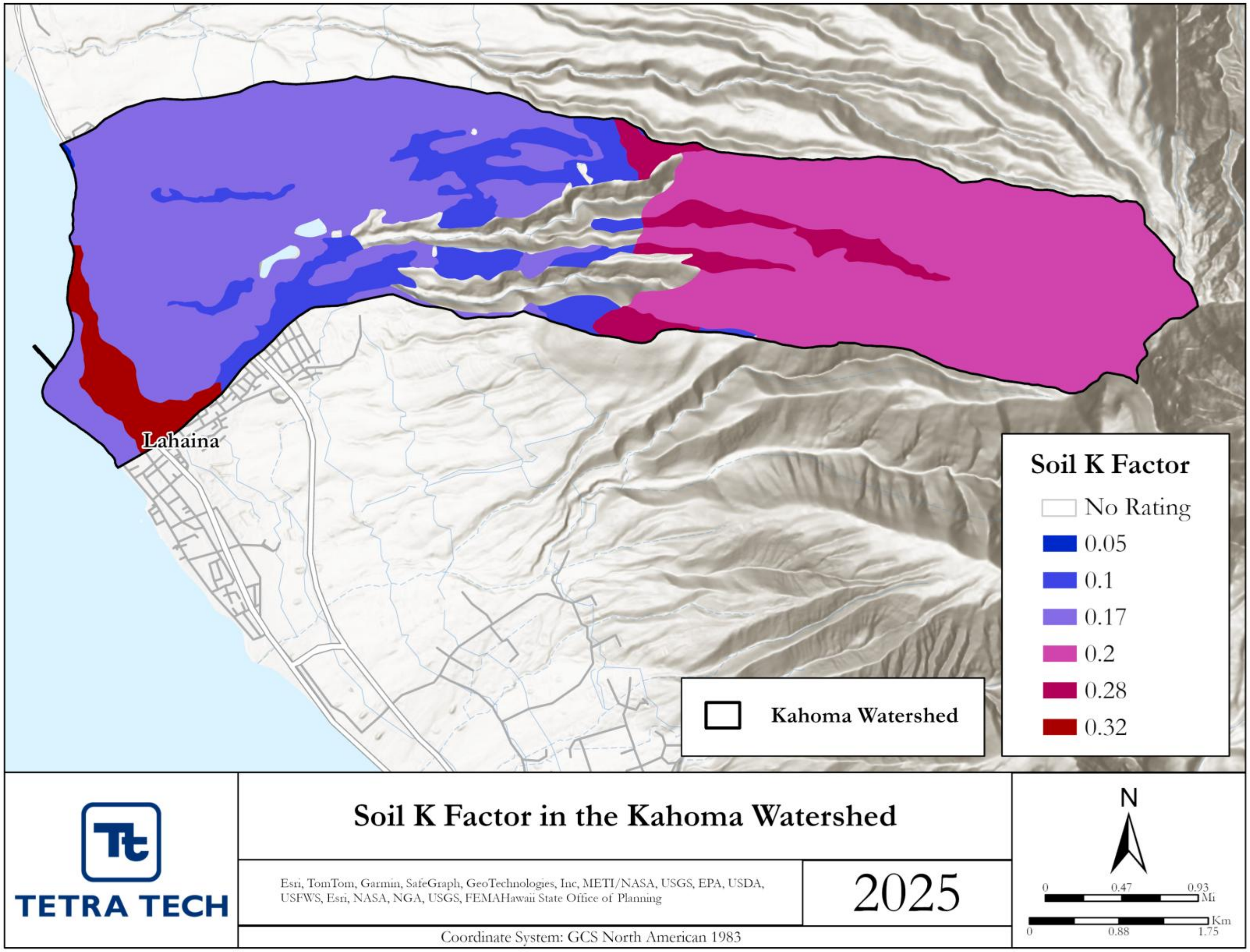

Figure 9. Soil K factor in the Kahoma watershed. (*Source: NRCS 2024*)

Hydrologic soil groups (HSGs) are groups of soils that have similar runoff potential under similar storm and cover conditions. A higher infiltration rate means that water is absorbed faster into the ground and there is less water to flow as surface runoff. Figure 10 shows the spatial extent of HSGs in the Kauaʻula watershed, while Table 4 summarizes the breakdown of HSGs. Group B (moderate infiltration) covers the largest amount of the watershed area, followed by group A (high infiltration). Areas covered by a dual group (A/D) are also present in the watershed, as well as minimal areas covered by groups C and D. The spatial extent of HSGs in the Kahoma watershed is shown in Figure 11, while the breakdown of HSG type is summarized in Table 5. The largest amount of the watershed is covered by group B (moderate infiltration), followed by group C (slow infiltration). Areas covered by group A and D soils are also present in the watershed.

Table 4. Area and coverage of each hydrologic soil group in the Kauaʻula watershed.

Hydrologic Soil Group Type	Coverage (%)
A – High Infiltration	31%
A/D – High/Very Slow Infiltration	10%
B – Moderate Infiltration	41%
C – Slow Infiltration	5%
D – Very Slow Infiltration	5%
No Hydrologic Soil Group*	8%
Total	100%

Source: NRCS (2024)
Note:
* The remainder of the watershed is made up of land uses (beaches, cinder land, rock outcrop, rough broken and stony land, water) with no hydrologic soil group type.

Table 5. Area and coverage of each hydrologic soil group in the Kahoma watershed.

Hydrologic Soil Group Type	Coverage (%)
A – High Infiltration	<1%
B – Moderate Infiltration	52%
C – Slow Infiltration	31%
D – Very Slow Infiltration	7%
No Hydrologic Soil Group*	10%
Total	100%

Source: NRCS (2024)
Note:
* The remainder of the watershed is made up of land uses (beaches, rock outcrop, rough broken and stony land, water) with no hydrologic soil group type. Type A is a very small percentage of the watershed (less than 1%).

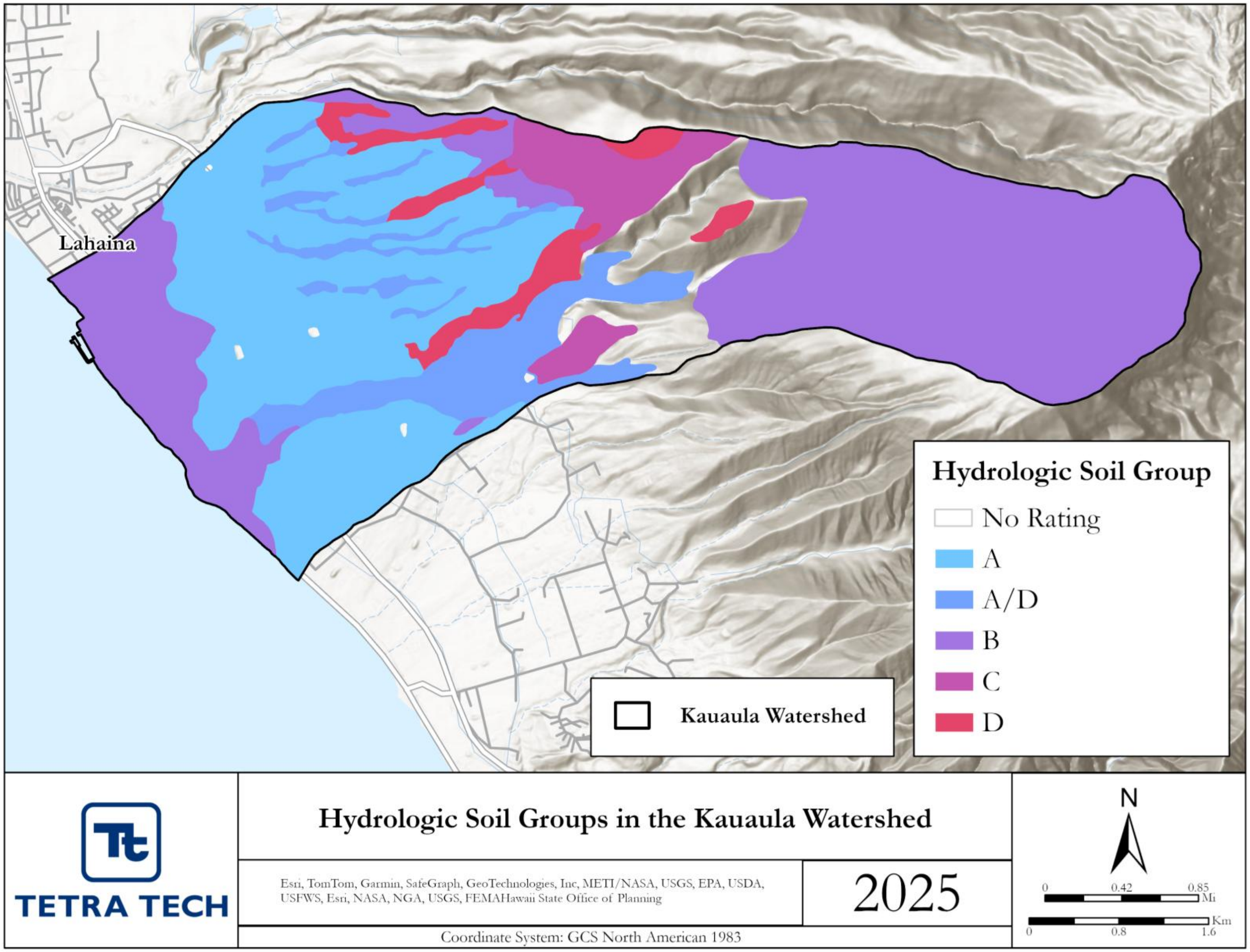

Figure 10. Map of hydrologic soil groups in the Kauaʻula. (*Source: NRCS 2024*)

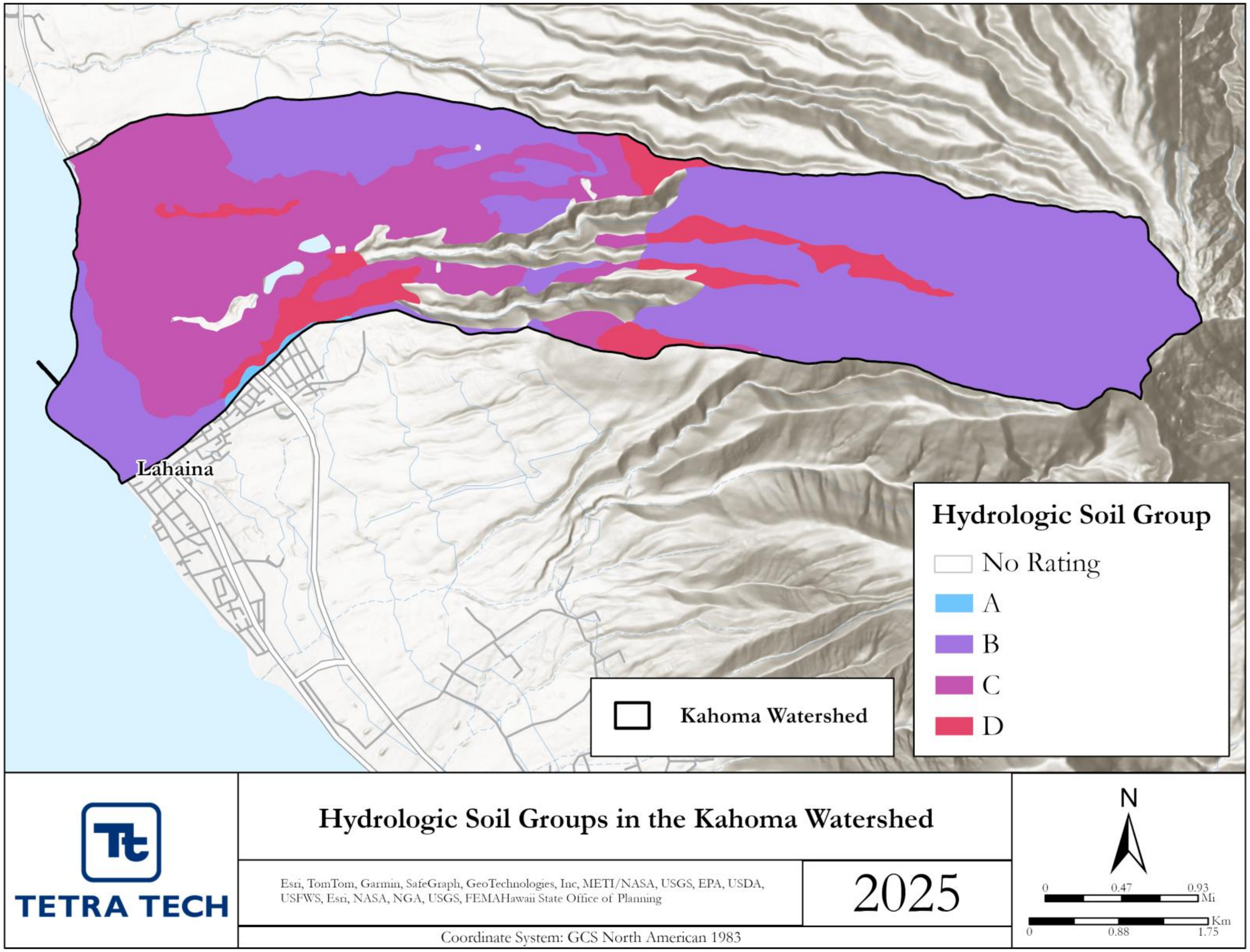

Figure 11. Map of hydrologic soil groups in the Kahoma. (*Source: NRCS 2024*)

2.6 CLIMATE

Maui's climate is characterized by tropical conditions with warm temperatures, moderate humidity, and northeasterly trade winds (State of Hawai'i 2018a). Lāhainā's monthly average high temperatures range from the low- to high-80s; monthly average low temperature range from the mid-60s to the mid-70s. Average annual high and low temperatures for Lāhainā are 85 °F and 78 °F, respectively (U.S. Climate Data 2025).

The distribution of rainfall in Kaua'ula and Kahoma is influenced by the orographic effect and rain shadow effect on the West Maui Mountains (State of Hawai'i 2018a). Orographic precipitation is when prevailing northeasterly trade winds lift warm air up the windward side of the mountains into higher elevations where cooler temperatures persist. Rainfall patterns typically follow elevation contour, where higher rainfall occurs in higher elevations and frequent and heavy rainfall occurs on the windward mountain slopes. The Kaua'ula and Kahoma hydrologic units are on the leeward flank of the West Maui Mountains. The rain shadow effect results in less orographic rainfall than on the windward slopes (State of Hawai'i 2018a). Mean monthly rainfall in the watershed is highest in January and lowest May to July (NOAA 2024).

The National Oceanic and Atmospheric Administration (NOAA) station at Pu'ukoli'i 457.1 (north of the Kahoma watershed) provides long-term data on climate. These averages vary slightly from those previously mentioned for Lāhainā. Other soil types are noted in Table 2 and mapped in Figure 7Figure **7.**

Table 6 summarizes temperature and precipitation data for the 1991–2010 climate period at the Pu'ukoli'i climate station (data from NOAA's U.S. Climate Normals Quick Access: 1991–2010 for Puukolii; NOAA 2024). The mean monthly temperature for January was 70.3 °F and 77.7 °F for August. Monthly air temperatures range from about 64.1–76.5 °F (average minimum to average maximum) in January to 70.6–84.8 °F (average minimum to average maximum) in August. Average monthly precipitation ranges from 0.64–3.41 inches at Pu'ukoli'i. Winter months are generally wetter than summer months, with monthly mean rainfall highest in November through February (NOAA 2024).

Table 6. Average temperature and precipitation measurements from Pu'ukoli'i climate station, 1991–2010.

	Pu'ukoli'i Climate Station			
Month	Average Precipitation (in.)	Average Min Temperature (°F)	Average Mean Temperature (°F)	Average Max Temperature (°F)
January	3.41	64.1	70.3	76.5
February	2.12	63.8	70.3	76.8
March	1.74	64.7	71.2	77.6
April	1.22	65.7	72.5	79.3
May	0.64	67.1	74.0	80.9
June	0.79	69.4	76.4	83.4
July	0.90	70.1	77.1	84.1
August	1.18	70.6	77.7	84.8
September	1.88	70.3	77.5	84.8
October	2.57	69.5	76.4	83.4
November	3.19	68.2	74.3	80.4
December	1.22	66.0	71.8	77.6
Summary	1.74 (total)	67.5 (mean)	74.1 (mean)	80.8 (mean)

Source: NOAA (2024)

Note:
The Pu'ukoli'I climate station is located north of the Kahoma watershed and trends vary slightly from those found for Lāhainā.

The Kauaʻula and Kahoma watersheds are located on the leeward side of the West Maui Mountains, meaning they receive little orographic rainfall. However, orographic rainfall on the windward side does contribute to higher rainfall in the upper elevations because winds blow precipitation across the peak. There is high spatial variability in rainfall from the *mauka* to *makai* across the two hydrologic units, each having a mean annual rainfall average of 81.4 inches (State of Hawaiʻi 2018a, 2018b).

Above elevations of 2,000 feet in the Kauaʻula and Kahoma watersheds, rainfall is highest during the months of December and January, where the mean monthly rainfall varies from 13.1 inches to 13.8 inches (State of Hawaiʻi 2018a). Irregular Kona storm systems may occasionally produce localized intense rainfall on southeast facing slopes for both units (State of Hawaiʻi 2018a, 2018b).

Evaporation is commonly estimated by using a relationship between potential evaporation and available water in the watershed, estimated as potential evapotranspiration (PET) (State of Hawaiʻi 2018a, 2018b). The PET in both the Kauaʻula and Kahoma watersheds averages 99.3 inches and ranges from 56.0 inches to 227.8 inches per year (Giambelluca et al. 2014 in State of Hawaiʻi 2018a, 2018b).

2.7 LAND COVER

The spatial distribution of different land cover classes within the Kauaʻula and Kahoma watersheds is displayed in Figure 12 and Figure 13, respectively. Land cover types within the watersheds were determined using NOAA's C-CAP High-Resolution Land Cover (NOAA 2015). Both the Kauaʻula and Kahoma watersheds are dominated by evergreen forest, grassland, and scrub/shrub. The remainder of each watershed is a mixture of land uses, with the coast consisting mostly of developed land and areas east of the coast consisting of multiple land uses such as cultivated crops, developed areas, wetlands, evergreen forest, and scrub/shrub.

Table 7 provides a breakdown of various land cover types within the Kauaʻula and Kahoma watersheds. The Kauaʻula watershed is dominated by grassland (28%), evergreen forest (27%), and scrub/shrub (26%). Impervious developed areas comprise 11% of the total watershed. Cultivated crops and open space for development each make up about 3% of the watershed, while bare land and open water account for 1%. Other types of land cover types make up less than 1% each and are described in Table 7.

The Kahoma watershed is dominated by evergreen forest (40%). This is followed by grassland (21%) and scrub/shrub (19%). Impervious developed areas comprise 10% of the total watershed. Open space and bare land each make up about 4% and 3% of the watershed, respectively. Cultivated crops and open water make up 1% of the watershed. Other types of land cover types make up less than 1% each and are described in Table 7.

State of Hawaiʻi (2018a, 2018b) noted that the large-scale maps might not capture small, cultivated lands or other vegetation located on small land parcels. The report also noted that land cover types could have been changed slightly since the time of map publishing, especially concerning commercial crop cultivation.

At small scales, there may be land cover types that are not picked up by the satellites such as tropical flowers, dryland (and some wetland) taro, sweet potato, banana, and papaya.

Table 7. Area and percent coverage of land cover types in the Kauaʻula and Kahoma watersheds.

Watershed	Land Cover Type	Coverage (%)
Kauaʻula	Grassland	28%
	Evergreen Forest	27%
	Scrub/Shrub	26%
	Developed, Impervious	11%
	Developed, Open Space	3%
	Cultivated Crops	3%
	Bare Land	1%
	Open Water	1%
	Palustrine Wetland	<1%
	Total	**100%**
Kahoma	Evergreen Forest	40%
	Grassland	21%
	Scrub/Shrub	19%
	Developed, Impervious	10%
	Developed, Open Space	4%
	Bare Land	3%
	Cultivated Crops	1%
	Open Water	1%
	Palustrine Wetland	<1%
	Total	**100%**

Sources: NOAA (2015), State of Hawaiʻi (2018a, 2018b)
Note:
Percent coverage for land cover type were geospatially determined for the Kahoma and Kauaʻula watersheds.

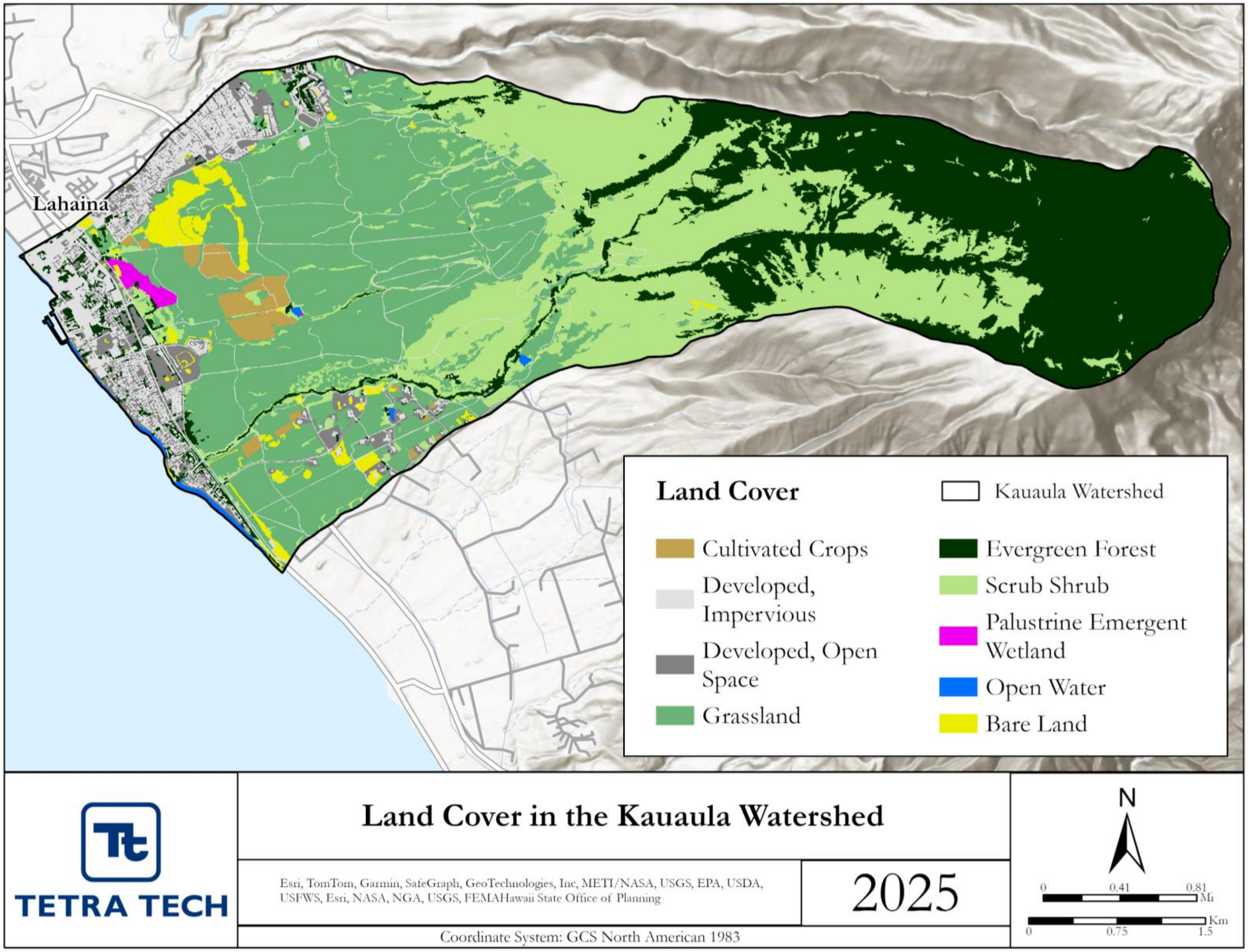

Figure 12. Spatial distribution of land cover in the Kaua'ula watershed. (*Source: NOAA 2015*)

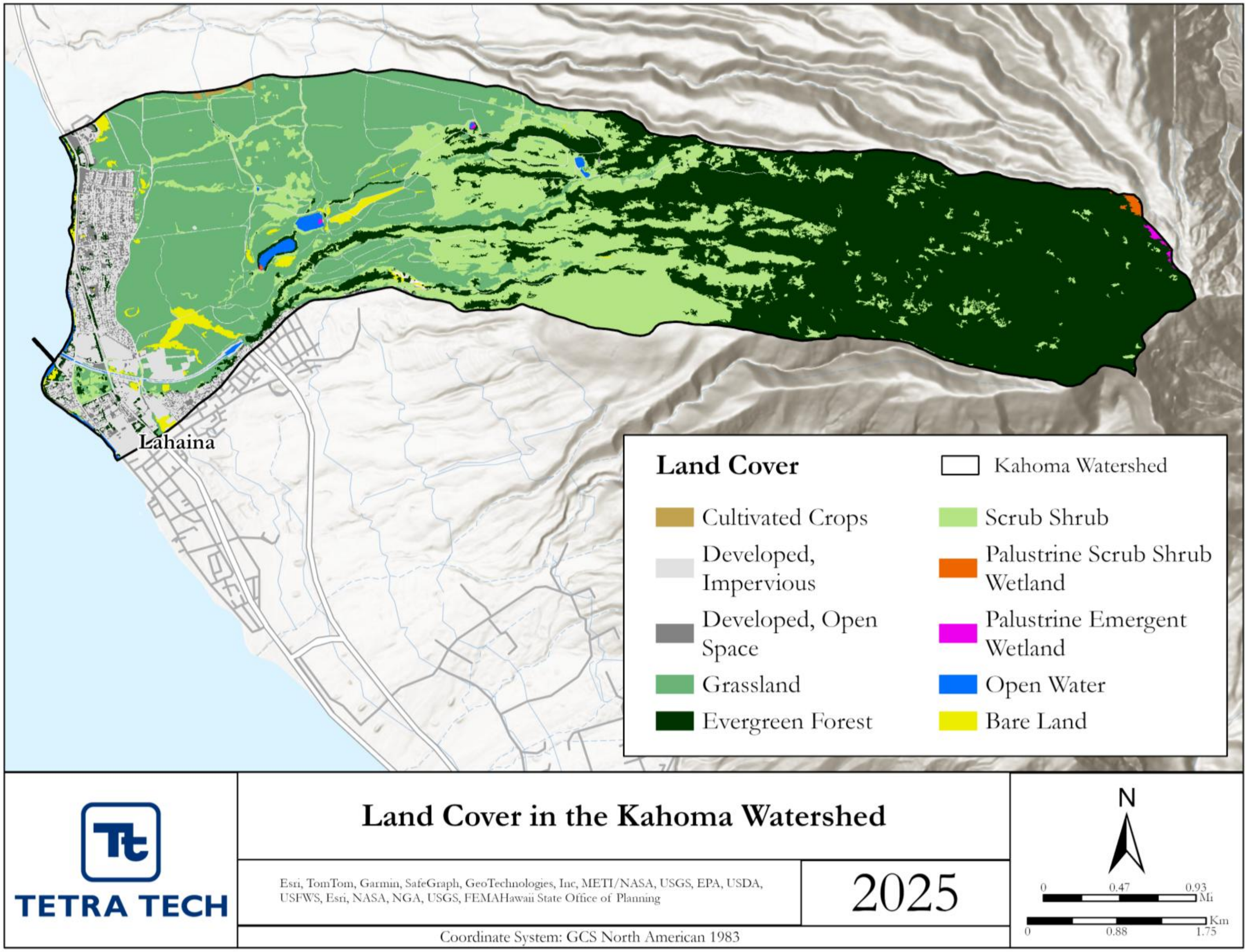

Figure 13. Spatial distribution of land use in the Kahoma watershed. (*Source: NOAA 2015*)

2.8 BIOLOGICAL AND CULTURAL RESOURCES

The Semiarid and Subhumid Low Mountain Slopes area (MLRA 158) of the Kauaʻula and Kahoma hydrologic units are naturalized scrub/shrub and grassland areas. Non-native plant species include koa haole, bermudagrass, guineagrass, and the dominating buffelgrass, which are highly invasive and flammable. Native plant species include ʻilima, pili grass, ʻuhaloa, as well as the rare shrub, ʻōhai. Dominant wildlife species in this area include non-native doves and francolins. Endangered species of Maui include Hawaiian bats, nēnē, stilts koloa ducks, and coots, whose natural habitat are wetlands and reservoirs found in this MLRA (USDA 2022a).

The Very Stony Land and Rock Land area (MLRA 166) are home to naturalized scrub/shrub vegetation and grasses. Species include guineagrass, christmasberry, bermudagrass, and natal redtop. There are areas designated as critical habitat on Maui, endangered plant species include koʻokoʻolau, *Bobea sandwicensis*, *Bonamia menziesii*, and aʻe (*Zanthoxylum hawaiiense*). Wildlife species in this area include naturalized game birds, deer, goats, and feral pigs. Pelagic bird species include albatross, shearwaters, and petrels. Endangered species on Maui include Blackburn's sphinx moth and nene (USDA 2022a).

MLRA 164 makes up the Humid and Very Humid Steep and Very Steep Mountain Slopes area (MLRA 164) of the Kauaʻula and Kahoma hydrologic units. This area is dominated by montane rainforest, *Oreobolus furcatus*, and mixed plant species. Common plants include ʻōhiʻa lehua, wet sedges, naʻenaʻe (*Dubautia waialealae*), and ʻukiʻuki. Rare and endangered plants in this MLRA on Maui include *Pteris lydgatei*, ha`iwale (*Cyrtandra munroi*), ʻōhā wai, and several pauoa and haha species. Dominant wildlife species include rare honeycreepers and other native forest birds. Naturalized species include feral pigs, exotic birds, deer, and goats (USDA 2022a).

Following the 2023 Maui fires, the Lāhainā community has started reforestation and conservation activities throughout the watershed. Planting native species such as ʻaʻaliʻi and wiliwili will help to bring endemic and culturally significant plants back to the watersheds. Several impacted species are sacred plants facing environmental stress prior to the devastation of the fires (Kamehameha Schools 2025).

3.0 Hydrologic and Water Quality Characterization

3.1 STREAMFLOW HYDROLOGY

Streams on Maui are usually flashy due to small drainage areas and steep gradients. The Kauaʻula and Kahoma watersheds have both perennial and intermittent streams, as shown in Figure 14. Streamflow consists of direct surface runoff as overland and subsurface flow that rapidly returns water to the stream, groundwater discharge as base flow, streambank storage return, direct rainfall into streams, and additional water such as excess irrigation discharged into streams (State of Hawaiʻi 2018a).

Substantial groundwater discharge from the dike complexes occurs at high elevations that contributes to the baseflow of most streams in the region (State of Hawaiʻi 2018a). Groundwater withdrawal has a significant impact on the water levels of surrounding areas streamflow, which can decrease native habitat for species and lower available water resources (State of Hawaiʻi 2018a). A more detailed discussion of groundwater and information related to stream flow in the Kauaʻula and Kahoma watersheds is available in the Instream Flow Standard Assessment Reports for hydrologic units 6007 and 6008.

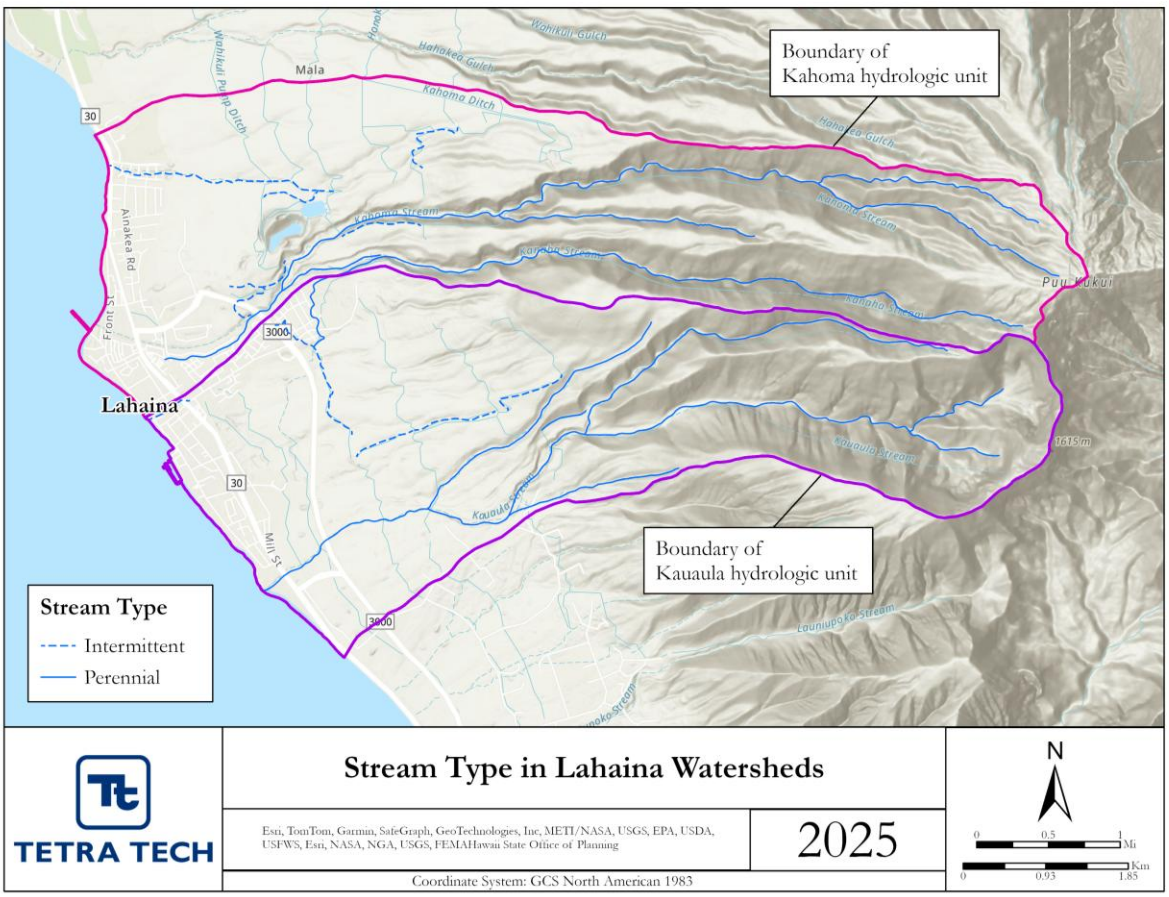

Figure 14. Stream types in the Kauaʻula and Kahoma watersheds. (*GIS layer provided by Hawaiʻi Department of Health Clean Water Branch*)

3.2 WATER QUALITY MANAGEMENT FRAMEWORK

Water quality standards (WQS) designate the “beneficial uses” to be protected (e.g., recreation, support and propagation of aquatic life, agricultural and industrial water supplies, shipping, navigation), the numeric and narrative “criteria” for their protection (e.g., the pollutant concentration that can be present in a waterbody without impairing its beneficial uses), and “antidegradation” provisions (intended to protect water quality in waterbodies meeting standards). Total Maximum Daily Loads (TMDLs) are developed to meet applicable WQS, which may be expressed as numeric water quality criteria or narrative criteria for the support of beneficial uses. However, TMDLs have not been developed for the Kahoma and Kauaʻula watersheds.

3.2.1 Applicable Water Quality Standards

Hawaiʻi Administrative Rules (HAR) Title 11, Department of Health Chapter 54 establishes WQS for the waters of Hawaii, as summarized below (Hawaiʻi DOH 2021). State WQS are defined for both inland and marine waterbodies. Both inland and marine WQS apply to the Kauaʻula and Kahoma watersheds.

3.2.2 Beneficial Uses

Beneficial uses in inland receiving waters are Class 1 or Class 2, depending upon underlying land use designations and regulations. Beneficial uses for marine waterbodies are classified as Class A or Class AA based on marine conservation areas. These beneficial uses for both inland and marine waters are described below.

3.2.2.1 Inland Waters

Class 1 It is the objective of Class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these waters is prohibited. Any conduct which results in a demonstrable increase in levels of point or nonpoint source contamination in Class 1 waters is prohibited (Hawaiʻi DOH 2021).

> *Class 1.a.* The uses to be protected in Class 1.a waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other non-degrading uses which are compatible with the protection of the ecosystems associated with waters of this class (Hawaiʻi DOH 2021).
>
> *Class 1.b.* The uses to be protected in Class 1.b waters are domestic water supplies, food processing, protection of native breeding stock, support and propagation of aquatic life, baseline references from which human-caused changes can be measured, scientific and educational purposes, compatible recreation, and aesthetic enjoyment. Public access to these waters may be restricted to protect drinking water supplies (Hawaiʻi DOH 2021).

Class 2 The objective of Class 2 waters is to protect their use for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in this class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class. No new treated sewage discharges shall be permitted within estuaries (Hawaiʻi DOH 2021).

Kauaʻula Stream, Kahoma Stream, and their tributaries fall within Class 1.a, Class 1.b, and Class 2 designations for inland waters. Class 1.a applies to the headwaters streams that are within the West Maui Natural Area Reserve or the West Maui Forest Reserve. Class 1.b applies to headwater streams outside of the West Maui Natural Area Reserve and the West Maui Forest Reserve. Class 2 waters include all streams segments in the watershed downstream of the Class 1 waters (Hawaiʻi DOH 2021).

3.2.2.2 Marine Waters

Class A waters include embayments and marine waters. Class A waters are protected for recreational purposes and aesthetic enjoyment, as well as protection of fish, shellfish, and wildlife. Class A waters for both the Kauaʻula and Kahoma watersheds are the marine waters located at the mouths of each of the watersheds (State of Hawaiʻi 2017, 2018a, 2018b). Class AA waters are not located on the western side of Maui where the Lāhainā watersheds discharge (Figure 15).

Class A It is the objective of class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Any other use shall be permitted if it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class. No new sewage discharges will be permitted within embayments. No new industrial discharges shall be permitted within embayments (Hawaiʻi DOH 2021).

Figure 15. Marine water classes along the coast of the Lāhainā watersheds. (*Source: Hawaiʻi Statewide GIS Program 2025*)

3.2.3 Numeric and Narrative Criteria

HAR Title 11, Department of Health Chapter 54 establishes WQS and specific water quality criteria for all waters of the state. Numeric water quality criteria for conventional parameters in fresh waters and coastal waters of Hawaiʻi are summarized below in Table 8 and Table 9 (Hawaiʻi DOH 2021). The tables identify the geometric mean components of the criteria, although all conventional criteria also have numeric criteria not to be exceeded more than 10% of the time and numeric criteria not to be exceeded more than 2% of the time. Source: Hawaiʻi DOH (2021)

Note:
Parameter table adapted from those presented in HAR Title 11.

Table 10 summarizes recreation criteria for all state waters for *Enterococci* (colony forming unit [CFU] per 100 mL) for geometric mean and statistical threshold value (STV) (Hawaiʻi DOH 2021).

Table 8. Inland Water Quality Criteria for Conventional Parameters.

Parameter	Wet Season			Dry Season		
	Geometric Mean Not to Exceed the Given Value	10%	2%	Geometric Mean Not to Exceed the Given Value	10%	2%
Total Nitrogen (µg/L)	250	520	800	180	380	600
Nitrate + Nitrite (µg/L)	70	180	300	30	90	170
Total Phosphorus (µg/L)	50	100	150	30	60	80
Total Suspended Solids (mg/L)	20	50	80	10	30	55
Turbidity (NTU)	5	15	25	2	5.5	10

Source: Hawaiʻi DOH (2021)
Note:
Parameter table adapted from those presented in HAR Title 11.

Table 9. Open Coastal Water Quality Criteria for Conventional Parameters.

Parameter	Wet Season			Dry Season		
	Geometric Mean Not to Exceed the Given Value	10%	2%	Geometric Mean Not to Exceed the Given Value	10%	2%
Total Nitrogen (µg/L)	150	250	350	110	180	250
Nitrate + Nitrite (µg/L)	5	14	25	3.5	10	20
Ammonia Nitrogen (µg/L)	3.5	8.5	15	2	5	9
Total Phosphorus (µg/L)	20	40	60	16	30	45
Turbidity (NTU)	0.5	1.25	2	0.2	0.5	1

Source: Hawaiʻi DOH (2021)
Note:
Parameter table adapted from those presented in HAR Title 11.

Table 10. Recreation Criteria for *Enterococci* for All State Waters.

Parameter	Criteria	
	Geometric Mean Not to Exceed the Given Value over any 30-day period	STV Not to be Exceeded more than 10% over 30-day period
Enterococci (CFU/100 mL)	35	130

Source: Hawaiʻi DOH (2021)
Note:
Parameter table adapted from those presented in HAR Title 11.

Section 11-54-4 Basic water quality criteria applicable to all waters (Hawaiʻi DOH 2021).

a) All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including:

b) Materials that will settle to form objectionable sludge or bottom deposits;

c) Floating debris, oil, grease, scum, or other floating materials;

d) Substances in amounts sufficient to produce taste in the water or detectable off-flavor in the flesh of fish, or in amounts sufficient to produce objectionable color, turbidity, or other conditions in the receiving waters;

e) High or low temperatures, biocides, pathogenic organisms, toxic, radioactive, corrosive, or other deleterious substances at levels or in combinations sufficient to be toxic or harmful to human, animal, plant, or aquatic life, or in amounts sufficient to interfere with any beneficial use of the water;

f) Substances or conditions or combinations thereof in concentrations which produce undesirable aquatic life; and

g) Soil particles resulting from erosion on land involved in earthwork, such as the construction of public works; highways; subdivisions; recreational, commercial, or industrial developments; or the cultivation and management of agricultural lands.

b(c)(2) Narrative toxicity and human health standards.

a) Acute Toxicity Standards: All state waters shall be free from pollutants in concentrations which exceed the acute standards listed in Appendix E dated OCT 22 2021, entitled "Numeric Standards for Toxic Pollutants Applicable to All Waters", located at the end of this chapter. All state waters shall also be free from acute toxicity as measured using the toxicity tests listed in section 11-54-10, or other methods specified by the director.

b) Chronic Toxicity Standards: All state waters shall be free from pollutants in concentrations which on average during any twenty-four-hour period exceed the chronic standards listed in Appendix E dated OCT 22 2021, entitled "Numeric Standards for Toxic Pollutants Applicable to All Waters", located at the end of this chapter. All state waters shall also be free from chronic toxicity as measured using the toxicity tests listed in section 11-54-10, or other methods specified by the director.

c) Human Health Standards: All state waters shall be free from pollutants in concentrations which, on average during any thirty-day period, exceed the "fish consumption" standards for non-carcinogens in Appendix E dated OCT 22, 2021, entitled "Numeric Standards for Toxic Pollutants Applicable to All Waters", located at the end of this chapter. All state waters shall also be free from pollutants in concentrations, which on average during any twelve-month period, exceed the "fish consumption" standards for pollutants identified as carcinogens in Appendix E dated OCT 22 2021, entitled "Numeric Standards for Toxic Pollutants Applicable to All Waters", located at the end of this chapter.

Refer to Appendix E of Hawaii's water quality standards for numeric criteria for specific metals, persistent organic chemicals (POCs)—for example polychlorinated Biphenyls (PCBs)—and other chemicals (Hawaiʻi DOH 2021).

3.2.4 Antidegradation

Section 11-54-1.1 General policy of water quality antidegradation (Hawaiʻi DOH 2021).

a) Existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

b) Where the quality of the waters exceed levels necessary to support propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the director finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the director shall assure water quality adequate to protect existing uses fully. Further, the director shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control.

c) Where existing high quality waters constitute an outstanding resource, such as waters of national and state parks and wildlife refuges and waters of exceptional recreational or ecological significance, that water quality shall be maintained and protected.

d) In those areas where potential water quality impairment associated with a thermal discharge is involved, the antidegradation policy and implementing method shall be consistent with section 316 of the Act. [Eff 11/12/82; am and comp 10/6/84; am and comp 04/14/88; am and comp 01/18/90; am and comp 10/29/92; am and comp 04/17/00; am and comp 10/2/04; comp 06/15/09; comp 10/21/12; am and comp 12/6/13; comp 11/15/14; am and comp OCT 22 2021 (Auth: HRS §§342D-1, 342D-4, 342D-5, Ch. 342E; 40 C.F.R. §131.12) (Imp: HRS §§342D-4, 342D-5, Ch. 342E)

3.3 HYDROLOGIC DATA ANALYSES

Continuous flow measurements were available for Kahoma and Kauaʻula streams at two U.S. Geological Survey (USGS) flow gages (USGS station 16638500, altitude 50 ft, and USGS station 16641000, altitude 1,550 ft—see Figure 16). Continuous flow data have been obtained for these stations from the USGS National Water Information System for 1963 to 2024. No other discharge data was available for the watersheds.

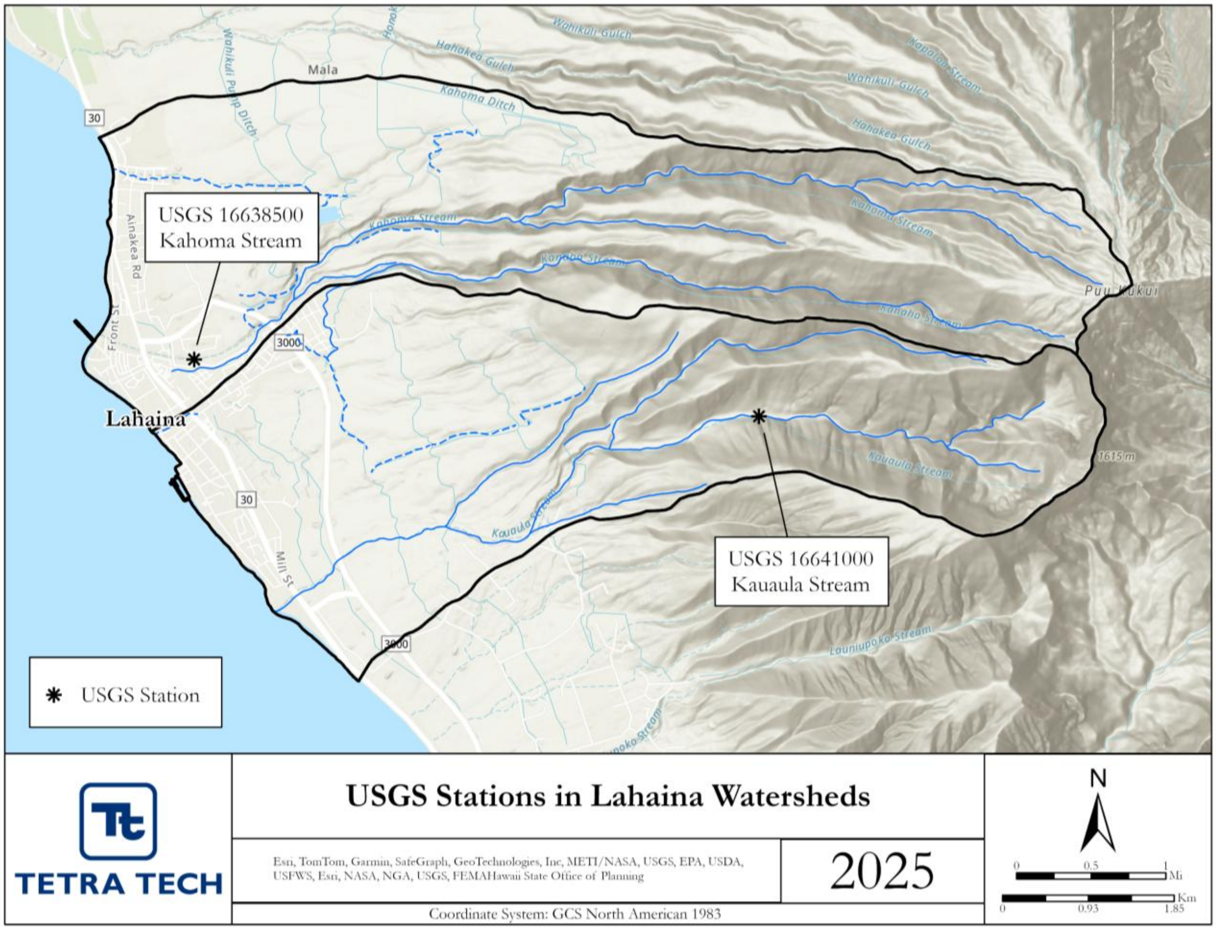

Figure 16. USGS Stream Stations on Kahoma and Kaua'ula Streams. (*Source: USGS 2019*)

Twenty-seven years of average daily flows at the USGS gage Kahoma Stream Lāhainā, Maui (USGS station 16638500; altitude 50 ft) were evaluated to characterize temporal patterns over a range of hydrologic conditions. The station has a contributing drainage area of 5.01 square miles (see Figure 16) and is the only USGS flow gage with an extensive historical period of record in the Kahoma watershed. Annual mean daily discharge for 1963 through 1989 is shown in Figure 17.

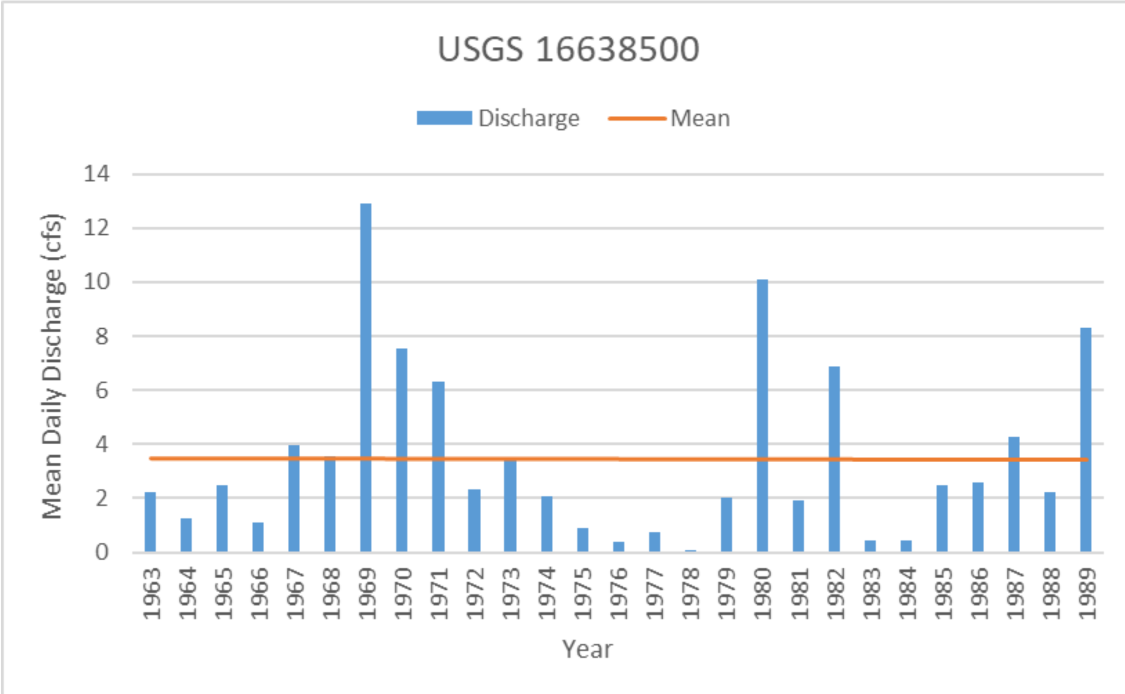

Figure 17. Kahoma stream mean daily discharge by year. (USGS: Kahoma Stream at Lāhainā, Maui, HI)

Monthly minimum, maximum, and mean discharge were calculated based on daily measurements. These summary statistics are presented in Table 11. The HAR defines the wet season in Hawaiʻi as November 1 through April 30 and the dry season as May 1 through October 31 (Hawaiʻi DOH 2021). Table 11 shows that November through April have higher mean flows than May through October, which is consistent with the HAR definitions of wet and dry seasons. The minimum flows for each month are the same (0 cubic feet per second [cfs]) and, as expected, the maximum flows exhibit much wider variability over the 12-year period. In general, November through April have higher maximum flows than the other months.

Table 11. Monthly Discharge Statistics at USGS Station 16638500 (Kahoma Stream), 1963–1989.

Month	Discharge (cfs)		
	Mean Minimum	Mean Maximum	Mean
January	0	91.8	5.5
February	0	60.2	3.5
March	0	113.5	8.1
April	0	85.4	7.1
May	0	30.9	1.9
June	0	14.7	0.7
July	0	47.1	2.6
August	0	37.1	1.6
September	0	16.9	0.7
October	0	24.0	0.7
November	0	72.7	4.0
December	0	65.5	4.3

Source: USGS (2019)
Note:
Monthly statistics summarized for available years.

Peak flow measurements at USGS station 16638500 are available from 1960 to 2020 and are displayed in Figure 18. A peak flow measurement of 7,750 cfs was recorded on May 13, 1960. Most peak flows occurred during the wet season.

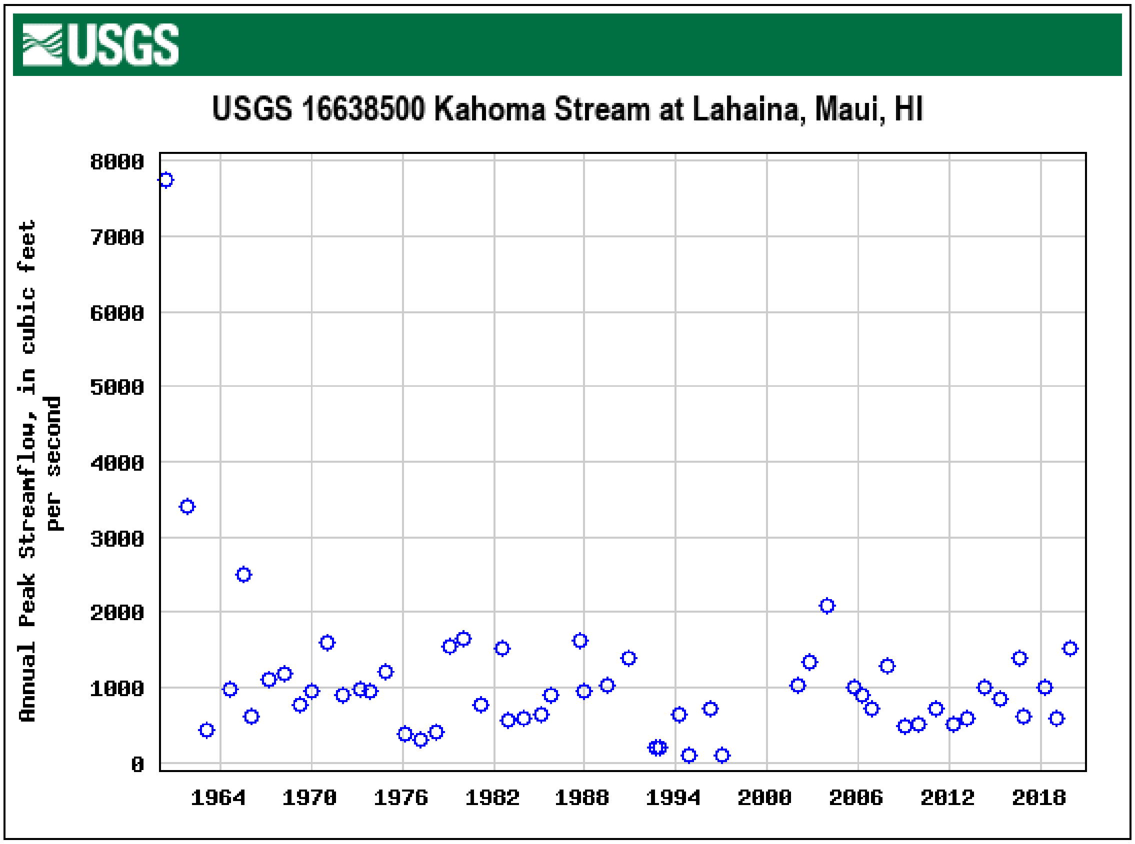

Figure 18. Annual peak discharge from 1960 to 2020 at USGS station 16638500.

Four years of average daily flows at the USGS gage Kauaʻula Stream, Maui (USGS station 1664100; altitude 1,550 ft) were evaluated to characterize temporal patterns. The station has a contributing drainage area of 1.84 square miles (see Figure 16) and is the only USGS flow gage with historical period of record in the Kauaʻula watershed. Annual mean daily discharge for 2020 through 2024 is shown in Figure 19 and Table 12.

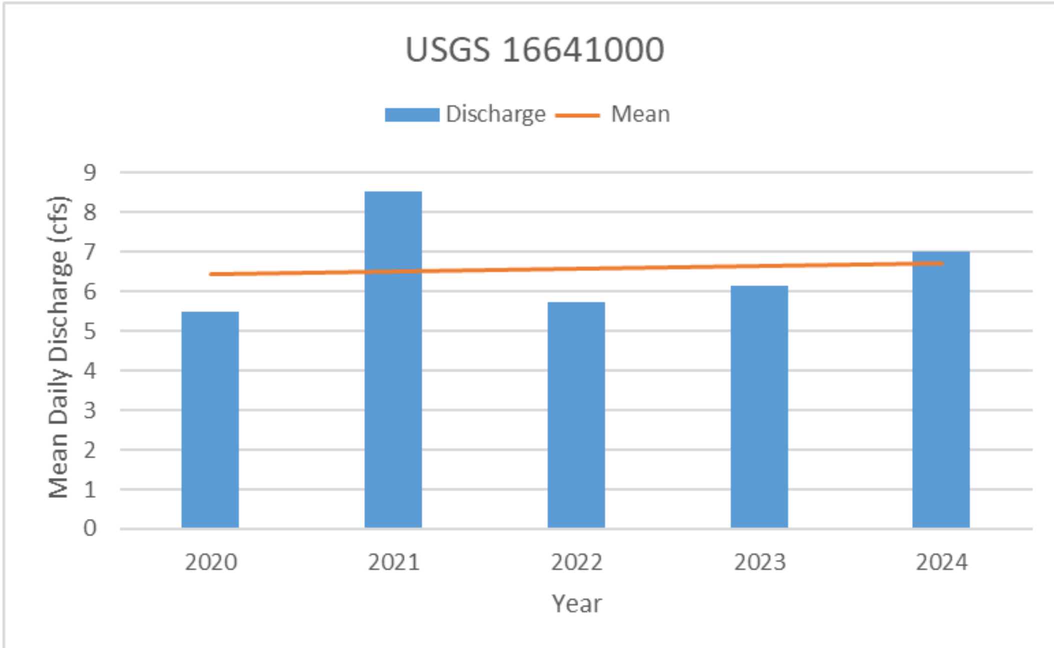

Figure 19. Kauaʻula stream mean daily discharge by year. (USGS: Kauaʻula Stream, Maui, HI)

Table 12. Mean Daily Discharge at USGS 16641000, Kauaʻula Stream, Maui, HI (altitude 1,550 ft).

	Mean Daily Discharge (cfs) by Month, 2020–2024											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	10	9.7	10	9.6	10	10	11	10	9.8	10	14	13

Source: USGS (2019)
Note:
Mean daily discharge statistics summarized for available years.

Peak flow measurements at USGS station 16641000 are available from 2020 to 2022 and are displayed in Figure 20. A peak flow measurement of 783 cfs was recorded on December 12, 2022.

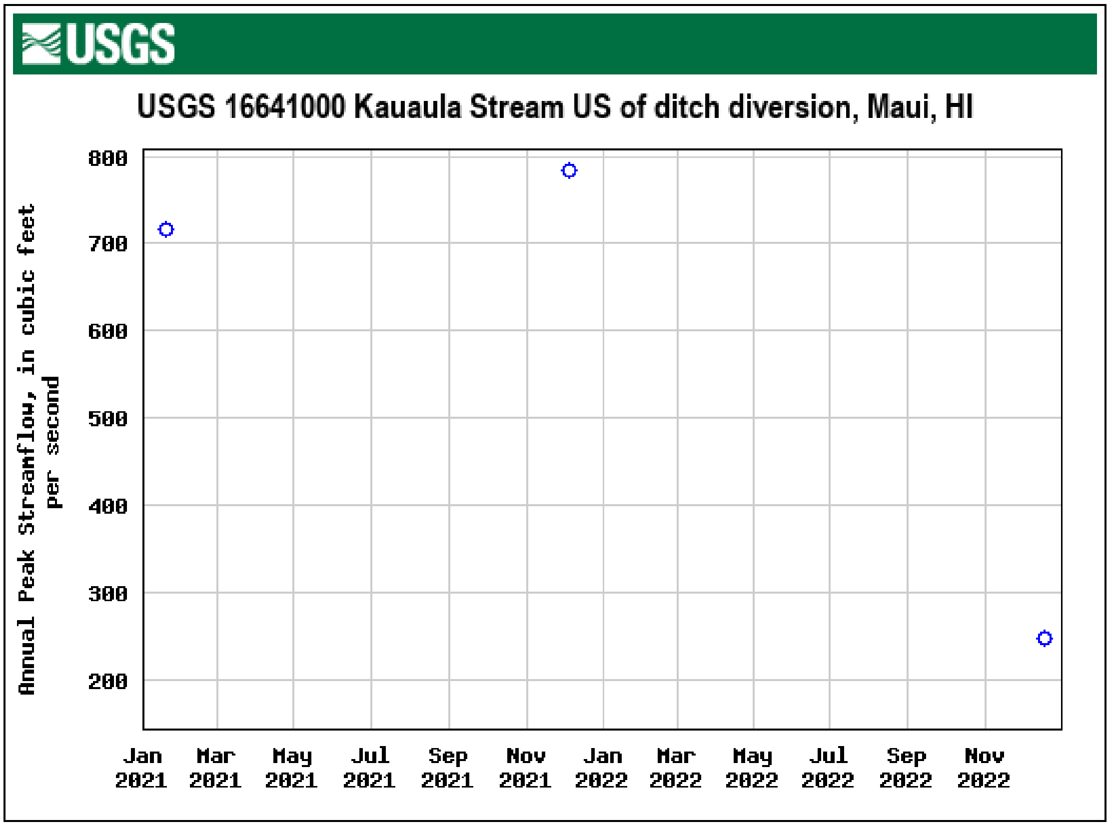

Figure 20. Annual peak discharge from 2021 to 2022 at USGS station 16641000.

3.4 WATER QUALITY DATA SUMMARY

This section provides a summary of available data for metals, conventional parameters (e.g., turbidity, *Enterococci* bacteria, nutrients), and TEQ (Toxic Equivalent Concentration) Dioxins. Additional data for a variety of POCs, including polycyclic aromatic hydrocarbons (PAHs) and PCBs, are not summarized here but can be located on the DOH website (Hawai‘i DOH 2025b); the vast majority of sample values for POCs were below method detection limits. An analysis of the available data relative to Hawai‘i water quality standards and sediment quality guidelines can be found in Section 4: Causes and Sources of Water Quality Degradation. Water quality monitoring data for the Kahoma and Kaua‘ula watersheds were obtained from the Hawai‘i Department of Health Clean Water Branch, USGS, and other Hawaii-based organizations.

Following the Maui wildfires in August 2023, DOH and partners monitored the environment and water in and around Lāhainā to assess risks and understand the impact of the fires. Public data is available for several focus areas, including coastal sediment and coastal waters. Additionally, pre-fire data for conventional parameters is also available, most of which dates back to 2016 (Callender et al. 2024), but also includes *Enterococci* data dating back to 2005 (Hawai‘i DOH 2025c) and USGS data for Kahoma stream dating back to 1977 (although the pre-2000 data is not summarized here).

Coastal water quality data was summarized for sites located within the Kahoma Nearshore (HIW20009), Kauaʻula Nearshore (HIW20012), and Lāhainā Harbor (HIW00137) Assessment Units (AUs) (Table 13 and Figure 21).

Table 13. Assessment Units and Associated Monitoring Sites for Kahoma and Kauaʻula.

Assessment Unit	Waterbody ID	Water Quality Monitoring Sites	Latitude	Longitude
Kahoma Stream	6-1-05	Kahoma Stream Gage (16638500)	20.88444	-156.67345
		Kahoma Stream Lower Reach	20.88454	-156.68362
		Kahoma Stream Upper Basin	20.88607	-156.67128
Kahoma Nearshore	HIW20009	Māla Wharf	20.88555	-156.687119
		Māla Ramp	20.885373	-156.686429
		Māla Tavern	20.887449	-156.685048
		Offshore Kahoma Stream	20.88558	-156.68832
		Pāpalaua Street	20.876911	-156.681359
		Pu'unoa (Baby) Beach	20.883903	-156.687658
		Wahikuli Beach	20.904476	-156.685931
Kauaʻula Nearshore	HIW20012	505 Front Street	20.867320	-156.676050
		Kamehameha Iki Park	20.869439	-156.678011
		Lāhainā Town (#202)	20.863560	-156.672970
		Lindsay Hale	20.864850	-156.673740
		Offshore Lāhainā Harbor	20.8727	-156.68218
		Outfall K	20.87384	-156.67862
		Outfall O	20.87523	-156.67984
		Outfall R	20.8696	-156.67683
		Puamana	20.856984	-156.665846
		Shark Pit (Puamana/Lāhainā Town)	20.864961	-156.673886
Lāhainā Harbor	HIW00137	Lāhainā Harbor	20.871933	-156.678624
		Inshore Ferry Dock	20.87214	-156.67909
		Inshore Lāhainā Harbor	20.87163	-156.67865

Source: Hawai'i DOH (2025b)
Note:
Geospatial analysis was used to determine coordinates for various monitoring sites available on the DOH Maui Wildfire Data website.

Figure 21. Maui Nearshore Assessment Units. (GIS layer provided by Hawaiʻi Department of Health Clean Water Branch)

3.4.1 Coastal Sediment

Following the Maui wildfires, ash entered sediment in ditches, streambeds, and along the shore. This ash may have settled from the air or may have been carried by stormwater runoff. Fire-related particles may eventually settle into sediment with the Kahoma and Kauaʻula watersheds (Hawaiʻi DOH 2025b).

DOH collected samples from nine nearshore sites in May, August, and November 2024. Geospatial analysis showed that four of these sites fell within the Kahoma Nearshore (Māla Wharf and Pu'unoa Beach) and Kauaʻula Nearshore (Kamehameha Iki Park and Shark Pit – Puamana) AUs (Figure 22).

A summary of results for metals tested from coastal sediment samples taken by DOH for the four sample sites in Kahoma Nearshore and Kauaʻula Nearshore AUs is provided in Table 14 and Table 15. Results for each parameter represent the average for individual samples taken during the May, August, and November 2024 sampling events. More detailed information regarding DOH coastal sediment sampling can be found on the Hawaiʻi DOH Website.

Table 14. Average Values for Metals in Coastal Sediment in Kahoma Nearshore AU (May–November 2024).

Parameter	Māla Wharf (mg/kg)[1]	Pu'unoa (Baby) Beach (mg/kg)[2]
Aluminum	14,300	5,680
Antimony	ND	ND
Arsenic	10	20
Barium	6	6
Beryllium	ND	ND
Cadmium	ND	ND
Chromium	43	19
Cobalt	21	9
Copper	25	10
Iron	32,367	13,200
Lead	4	5
Mercury	ND	ND
Molybdenum	ND	ND
Nickel	166	76
Selenium	2	1
Silver	ND	ND
Thallium	ND	ND
Titanium	2,080	805
Vanadium	64	30
Zinc	49	26

Source: Hawaiʻi DOH (2025b)
Notes:
mg/kg = milligrams per kilogram; equivalent to parts per million (ppm)
ND: Non-detect
[1, 2] Represents the average of individual sample values at Māla Wharf and Pu'unoa (Baby) Beach from May, August, and November 2024 sampling events, rounded to the nearest whole number.

Table 15. Average Values for Metals in Coastal Sediment in Kauaʻula Nearshore AU (May–November 2024).

Parameter	Kamehameha Iki Park (mg/kg)[1]	Shark Pit - Puamana (mg/kg)[2]
Aluminum	5,070	12,000
Antimony	ND	ND
Arsenic	18	22
Barium	6	7
Beryllium	ND	ND
Cadmium	ND	ND
Chromium	36	40
Cobalt	18	17
Copper	13	17
Iron	23,280	22,400
Lead	2	2
Mercury	ND	ND
Molybdenum	ND	ND
Nickel	155	89
Selenium	ND	ND
Silver	1	2
Thallium	ND	ND
Titanium	911	1,880
Vanadium	42	58
Zinc	28	32

Source: Hawaiʻi DOH (2025b)

Notes:

mg/kg = milligrams per kilogram; equivalent to parts per million (ppm)

ND: Non-detect

[1, 2] Represents the average of individual sample values at Kamehameha Iki Park and Shark Pit - Puamana from May, August, and November 2024 sampling events, rounded to the nearest whole number.

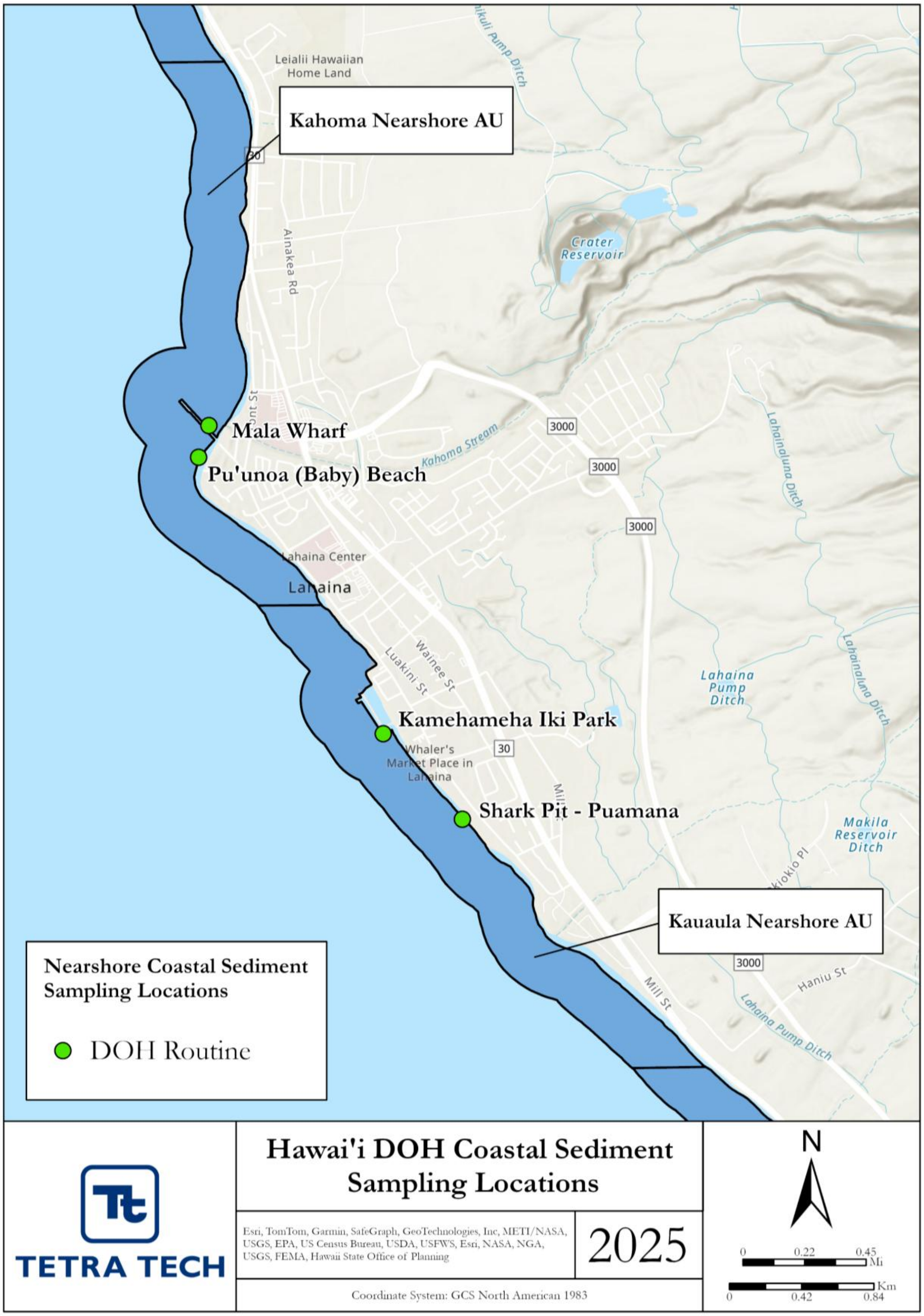

Figure 22. Hawaiʻi DOH Coastal Sediment Sampling Locations. (*Source: Hawaiʻi DOH 2025b*)

Following the fires, the Department of Land and Natural Resources (DLNR) collected 20 sediment samples from 17 sites at the Lāhainā Small Boat Harbor on November 16, 2023 (Figure 23). The Lāhainā Small Boat Harbor falls within the Lāhainā Harbor AU. Individual samples taken at the Lāhainā Small Boat Harbor were averaged for each parameter of interest and are shown in Table 16. More detailed information about DLNR coastal sediment data can be found on the Hawaiʻi DOH Website.

Table 16. Average Values for Select Parameters in Coastal Sediment in the Lāhainā Small Boat Harbor November 2023.

Parameter	Average Sample Value[1] (mg/kg)
Total Organic Carbon	43,320.0
Antimony	2.4
Arsenic	18.7
Beryllium	0.9
Cadmium	1.0
Chromium	56.9
Copper	475.6
Lead	30.2
Mercury	0.204
Nickel	82.8
Selenium	ND
Silver	ND
TEQ Dioxins	.0000115
Thallium	ND
Zinc	209.5

Source: Hawaiʻi DOH (2025b)
Notes:
ND: Non detect
mg/kg = milligrams per kilogram; equivalent to parts per million (ppm)
[1] Represents the average of individual sample values taken at Lāhainā Small Boat Harbor on November 16, 2023.

Figure 23. DLNR Sample Locations in the Lāhainā Small Boat Harbor. (*Source: Hawaiʻi DOH 2025b*)

From 2023–2024, USGS sampled numerous locations for a wide range of substances, including potentially fire-related substances in coastal sediment. Marine sediment samples were collected in December 2023 and January/February 2024. Lāhainā area sampling locations are associated with four AUs: the Kahoma Nearshore AU, Kahoma Stream AU, Kauaʻula Nearshore AU, and Lahaina Harbor AU (Figure 24). USGS analyzed sediment samples for metals and other parameters of interest. Average values (ppm) for results from individual samples taken within each AU are shown in Table 17. More detailed information regarding USGS coastal sediment sampling and interpretation of results can be found on the Hawaiʻi DOH Website.

Table 17. Average Values for Coastal Sediment Samples Taken by USGS in December 2023 and January/February 2024.

Parameter	Kahoma Nearshore AU[1]	Kahoma Stream AU[2]	Kauaʻula Nearshore AU[3]	Lāhainā Harbor AU[4]
	Results (mg/kg)			
Antimony	0.4	0.5	5	12
Arsenic	8	ND	38	46
Chromium	1,162	834	4502	489
Cobalt	62	67	60	36
Copper	136	147	307	662
Lead	8	7	191	99
Nickel	224	329	295	126
Vanadium	443	431	426	229
Zinc	162	178	682	851
TEQ Dioxins	1.2E-06	4.1E-06	5.5E-05	1.5E-05

Source: Hawaiʻi DOH (2025b)
Notes:
Grab sample sediment data provided by USGS; sampling locations are listed as presented by USGS as "marine sediment." ND: Non-detect
TEQ Dioxins: "Toxic equivalent concentration" that allows the reporting of multiple dioxin/dioxin-like chemicals as a single value based on their relative toxicities. mg/kg = milligrams per kilogram; equivalent to parts per million (ppm)
[1, 2, 3, 4] Represents the average of individual sample values taken at locations within the Kahoma Nearshore AU, Kahoma Stream AU, Kauaʻula Nearshore AU, and Lāhainā Harbor AU in ppm.

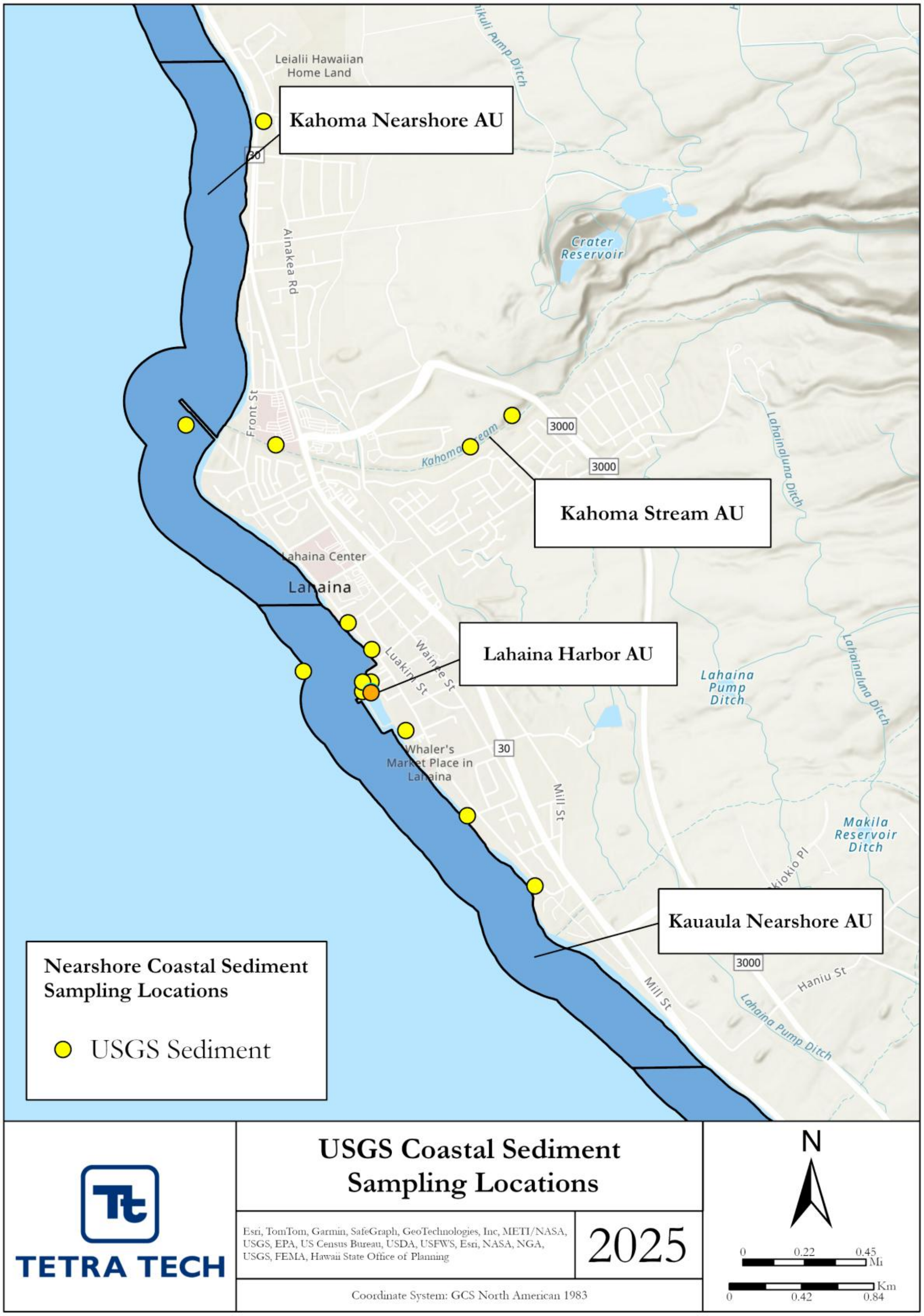

Figure 24. USGS Coastal Sediment Sampling Locations. (*Source: Hawaiʻi DOH 2025b*)

3.4.2 Nearshore Coastal Waters

Following the Lāhainā wildfires, ash and sediment may have entered coastal waters through wind erosion and surface water runoff, potentially impacting water quality within the Kahoma and Kauaʻula Nearshore AUs (Hawaiʻi DOH 2025b).

DOH and partners have monitored turbidity, nutrients (nitrogen and phosphorus), metals, and *Enterococci* bacteria in nearshore coastal waters around Lāhainā, providing pre- and post-wildfire data for coastal waters. Water quality data is available for several sites within the Kahoma and Kauaʻula Nearshore AUs. DOH, Hui O Ka Wai Ola (HOKWO), and the Surfrider Foundation's Maui Chapter have collected coastal water samples from various locations from 2016–2025. The DOH dataset for *Enterococci* dates back to 2005. More detailed information regarding nearshore coastal water sampling post-fire and routine monitoring can be found on the Hawaiʻi DOH Website.

3.4.2.1 Dissolved Metals

DOH and Surfrider collected coastal water samples for analysis of total recoverable and dissolved metals in nearshore coastal waters around Lāhainā. Only post-fire data was available for samples taken within the Kahoma, Kauaʻula, and Lāhainā Harbor AUs. Surfrider collected grab ocean water samples in January 2024 and June 2024. DOH conducted routine seawater sampling in April 2024, August 2024, and November 2024. Data was downloaded from the DOH website and sampling event results were combined for both DOH and Surfrider water quality data. Geospatial analysis showed that five sites fell within the Kahoma Nearshore AU (*Pāpalaua Street, Puʻunoa (Baby) Beach, Māla Ramp, Māla Tavern, and Māla Wharf*), five sites fell within the Kauaʻula Nearshore AU (*505 Front Street, Kamehameha Iki Park, Lāhainā Harbor, Shark Pit (Lāhainā Town), Shark Pit – Puamana*), and one site (*Lāhainā Harbor*) fell within Lāhainā Harbor (Figure 25**Figure 25**). Results for dissolved metals of interest at each site within each AU were then graphically plotted; total recoverable metals data are not included here since Hawaii's water quality criteria are applicable to dissolved metals only. The following metals are shown in the figures below:

- Arsenic (As)
- Chromium (Cr)
- Copper (Cu)
- Mercury (Hg)
- Nickel (Ni)
- Selenium (Se)
- Silver (Ag)
- Vanadium (V)

Figure 26 through Figure 47 display dissolved metals levels for sites within the Kahoma, Kauaʻula, and Lāhainā Harbor AUs. Time plots were produced for several parameters of interest and include reference lines for acute and chronic saltwater standards for aquatic life, per Hawaiʻi Water Quality Standards.

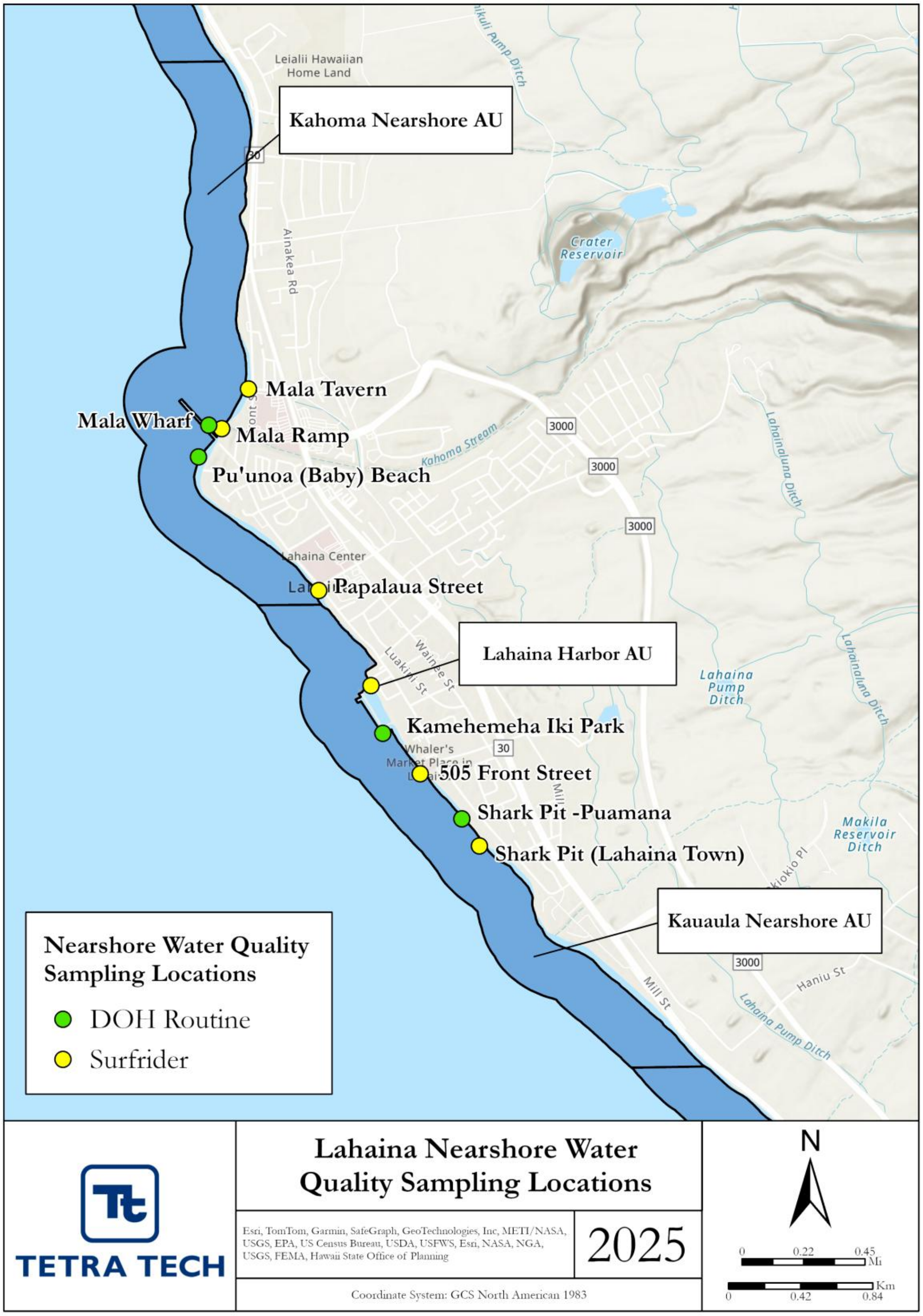

Figure 25. Nearshore Water Quality Dissolved Metal Sampling Locations.
(*Source: Hawaiʻi DOH 2025b*)

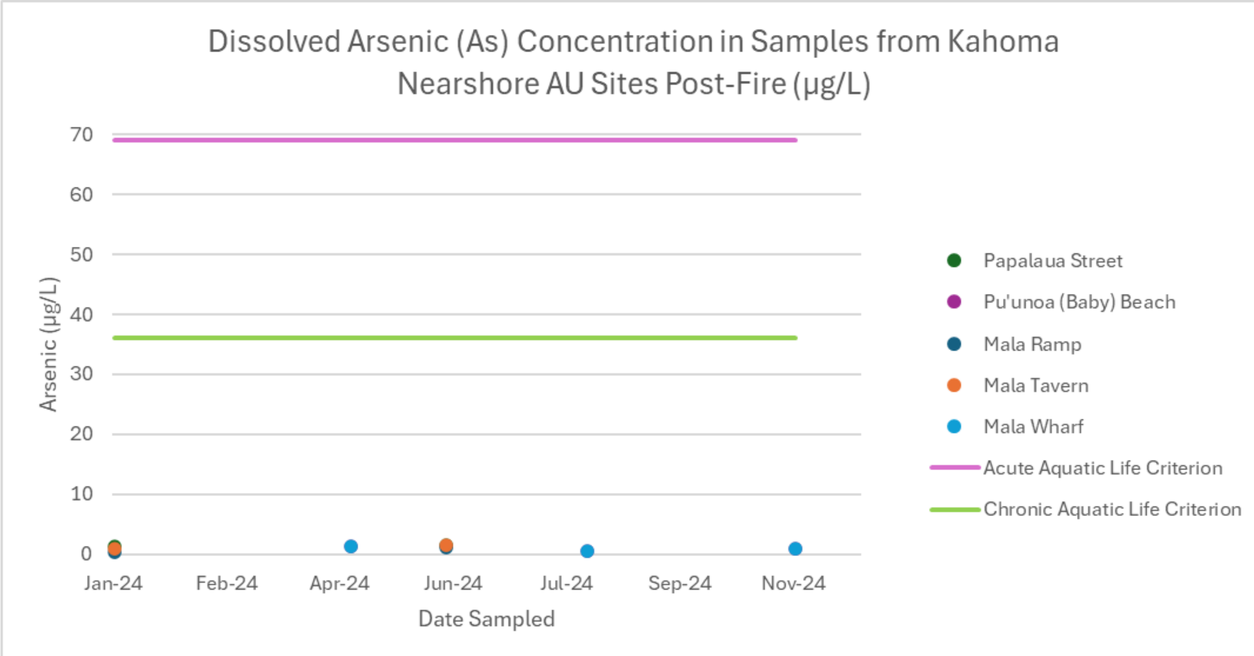

Figure 26. Post-Fire Dissolved As Concentrations within the Kahoma Nearshore Marine AU.

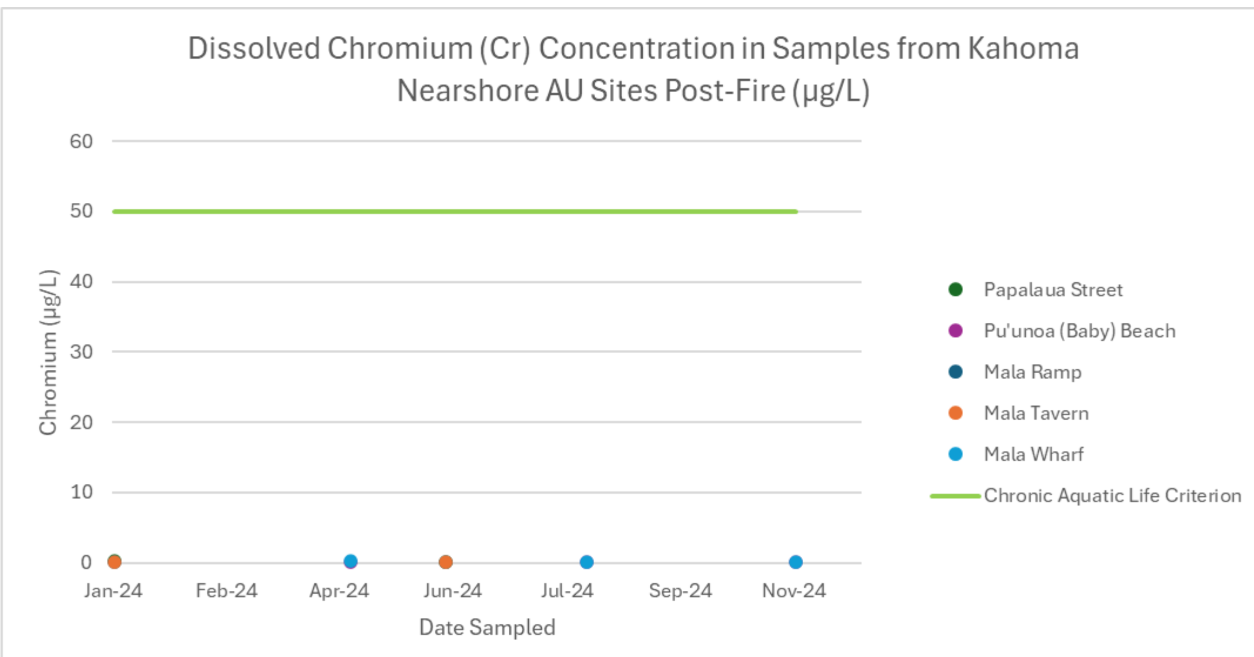

Figure 27. Post-Fire Dissolved Cr Concentrations within the Kahoma Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

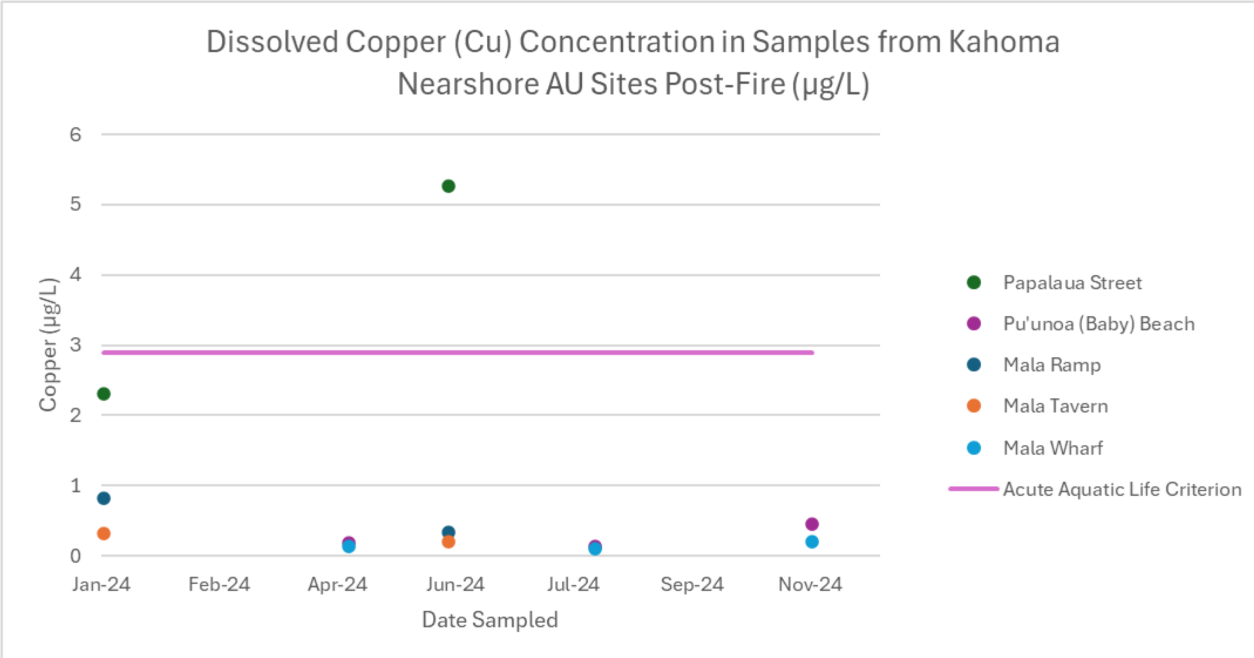

Figure 28. Post-Fire Dissolved Cu Concentrations within the Kahoma Nearshore Marine AU.

Note: Acute and chronic criteria are the same value and displayed as one color.

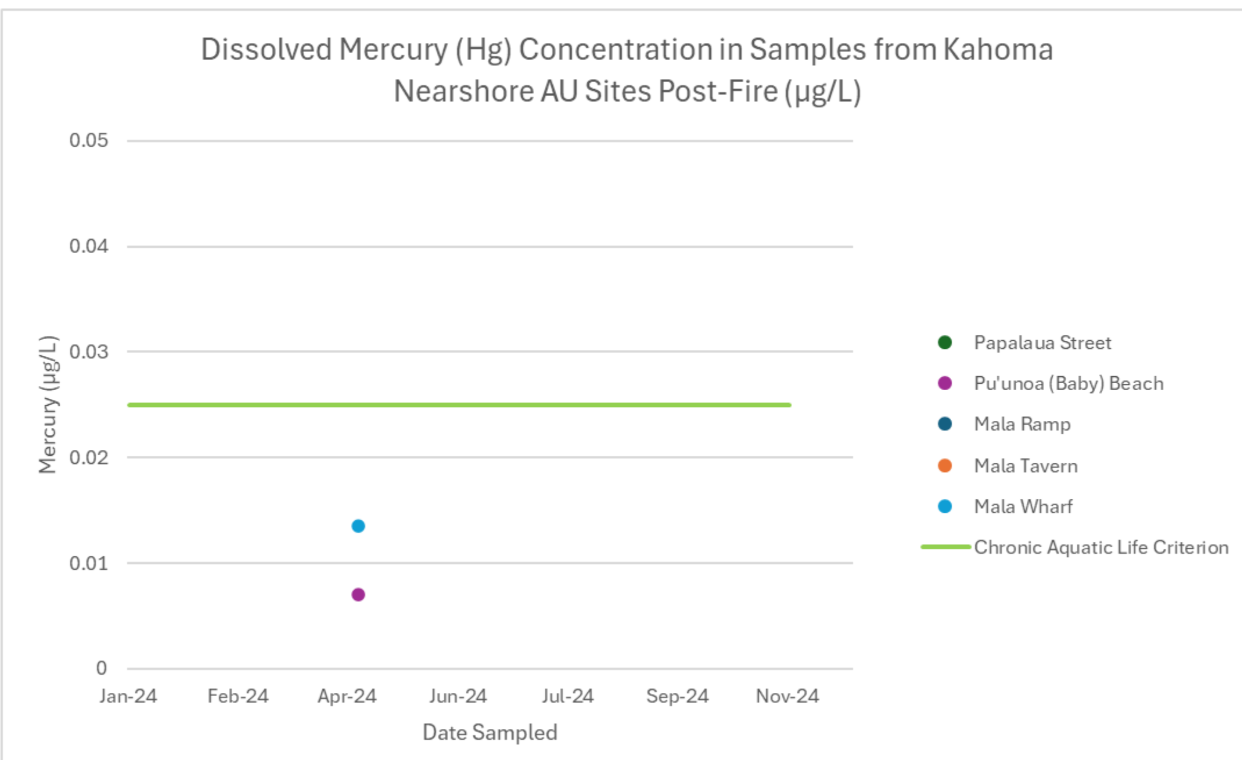

Figure 29. Post-Fire Dissolved Hg Concentrations within the Kahoma Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

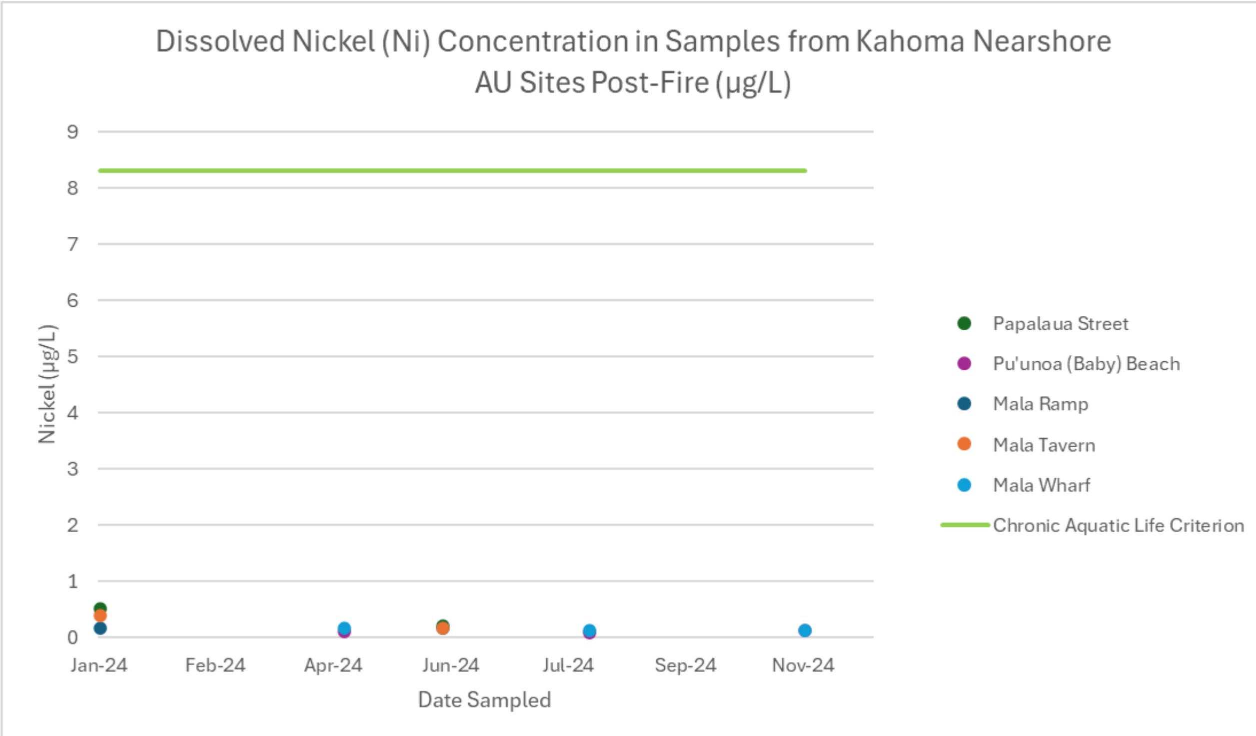

Figure 30. Post-Fire Dissolved Ni Concentrations within the Kahoma Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

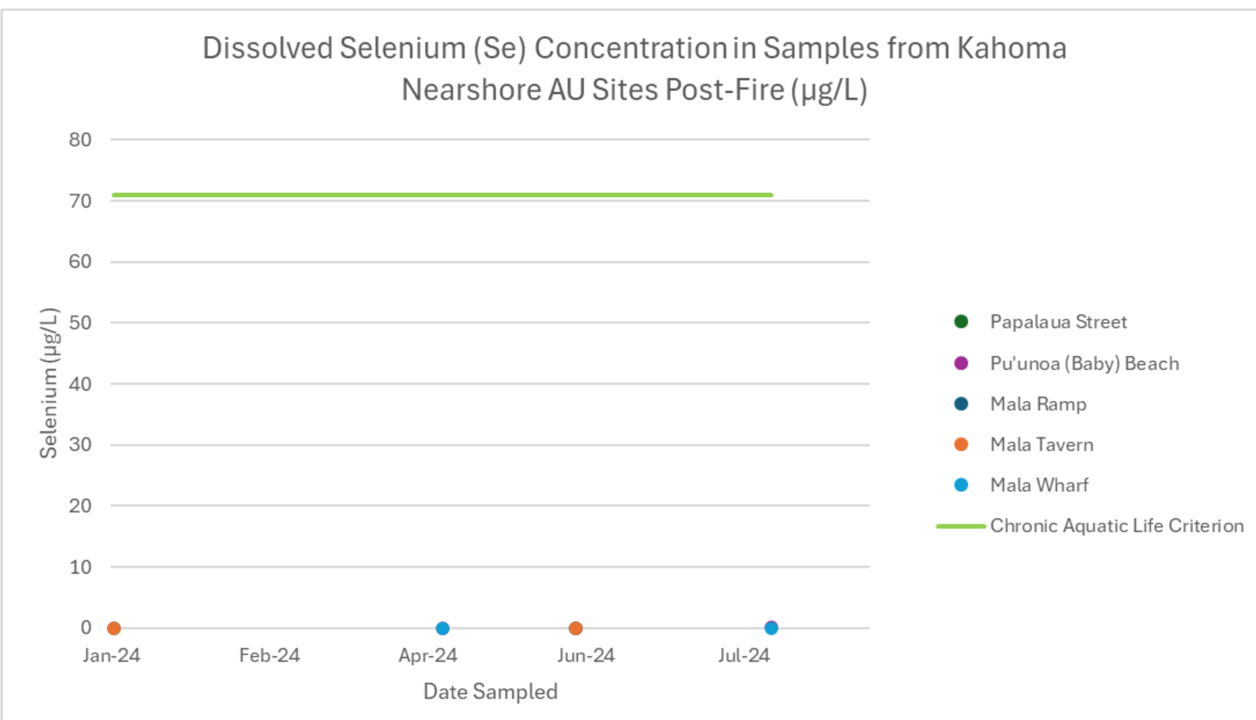

Figure 31. Post-Fire Dissolved Se Concentrations within the Kahoma Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

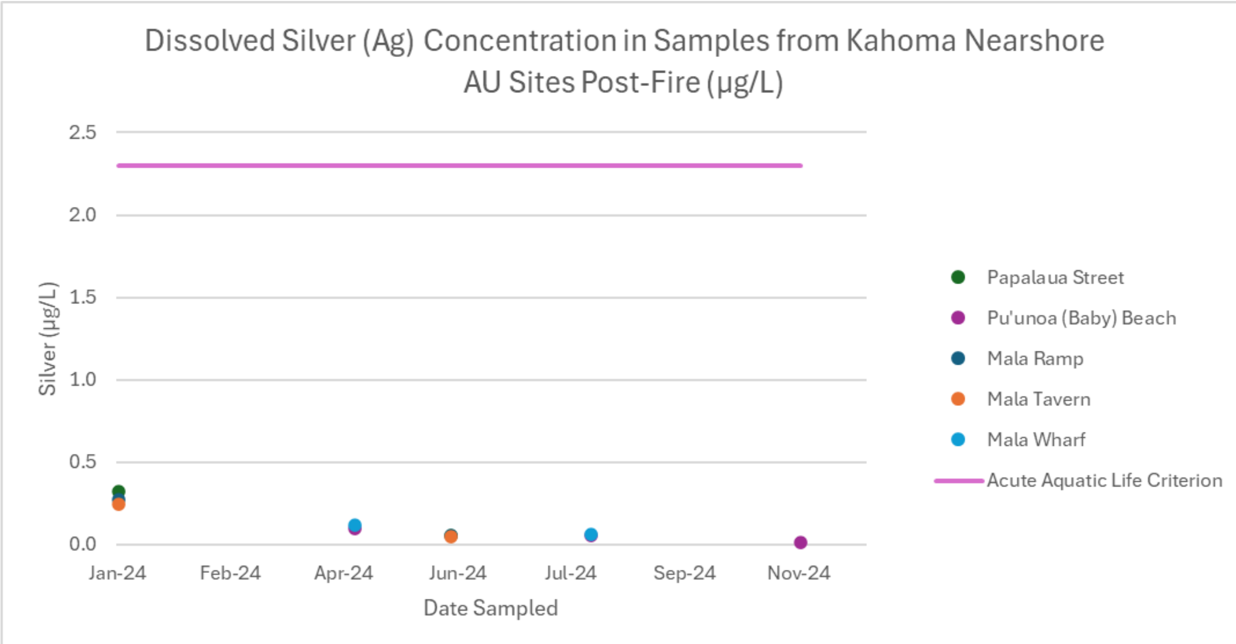

Figure 32. Post-Fire Dissolved Ag Concentrations within the Kahoma Nearshore Marine AU.

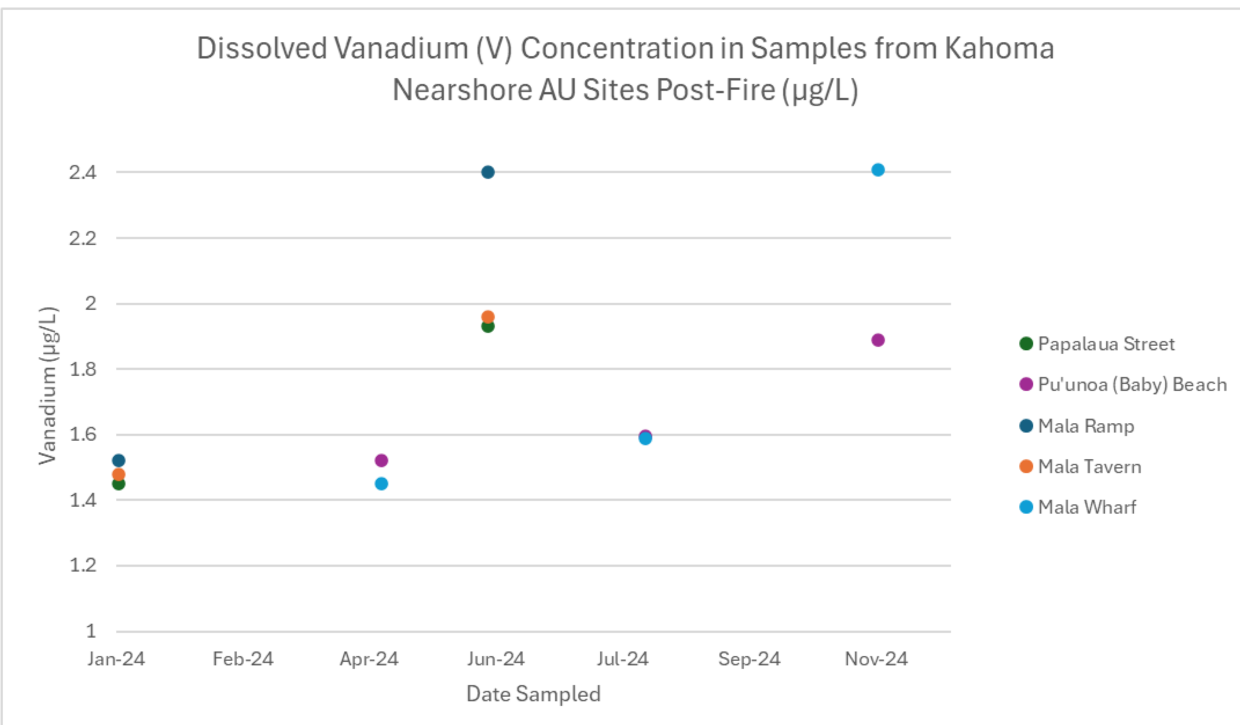

Figure 33. Post-Fire Dissolved V Concentrations within the Kahoma Nearshore Marine AU.

Note: Hawai'i Water Quality Standards do not contain criteria for Vanadium.

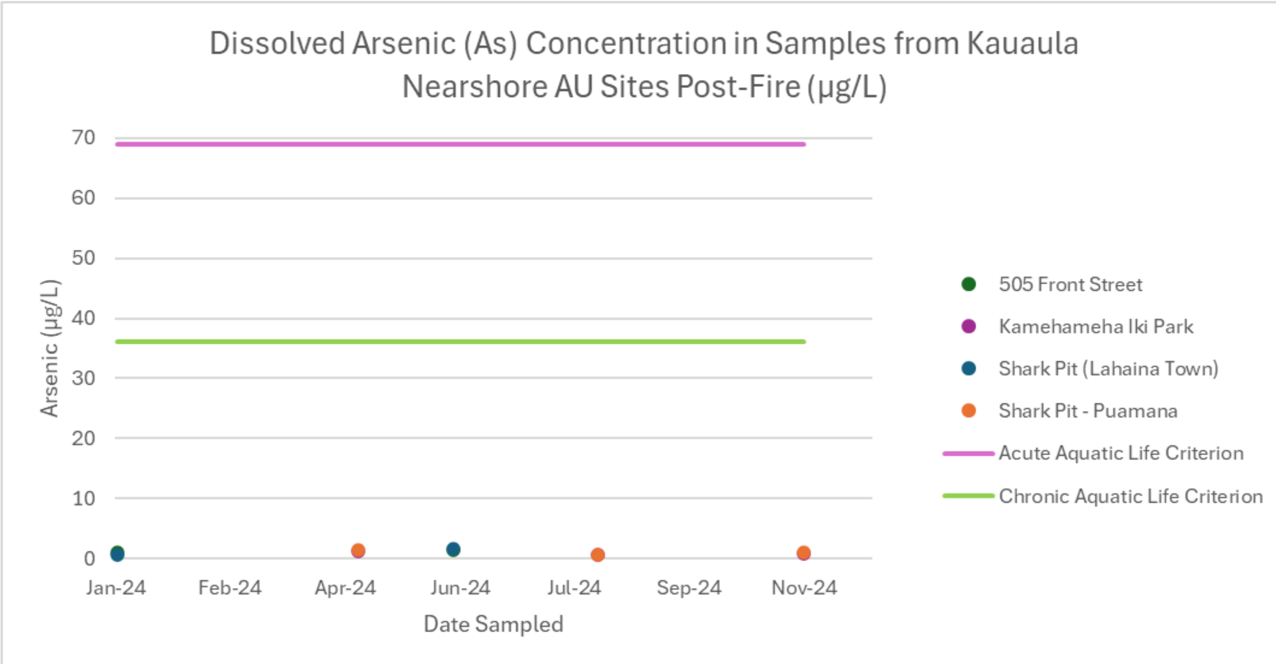

Figure 34. Post-Fire Dissolved As Concentrations within the Kaua‘ula Nearshore Marine AU.

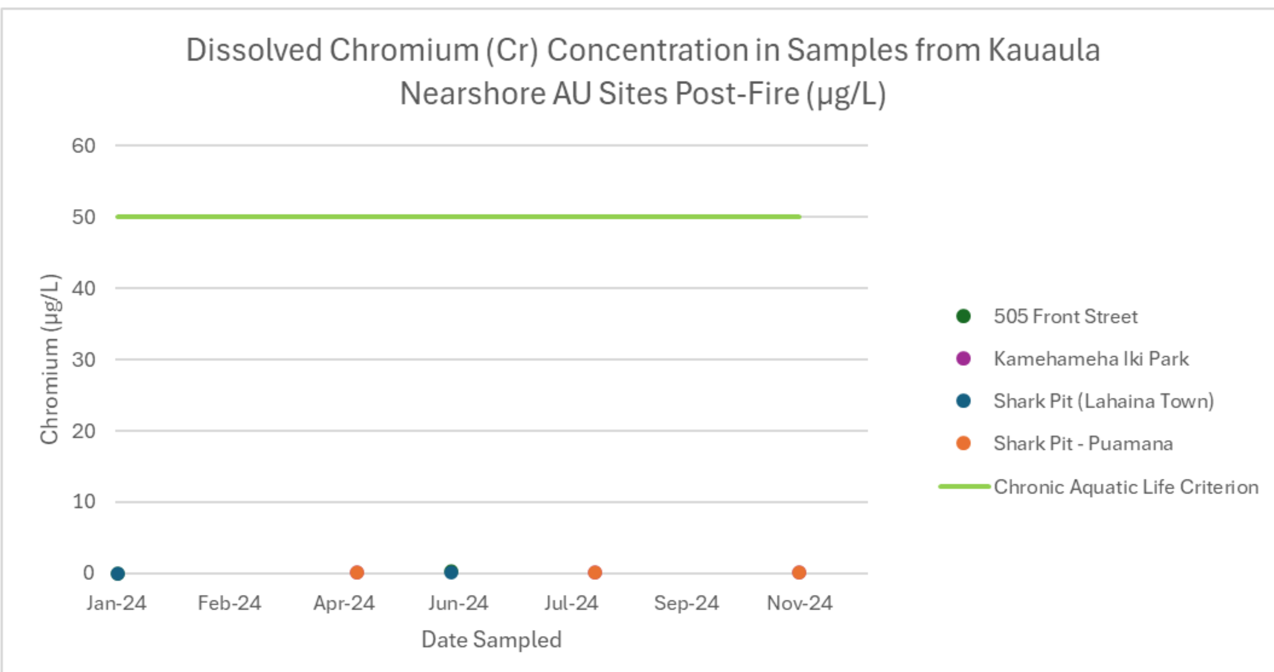

Figure 35. Post-Fire Dissolved Cr Concentrations within the Kaua‘ula Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

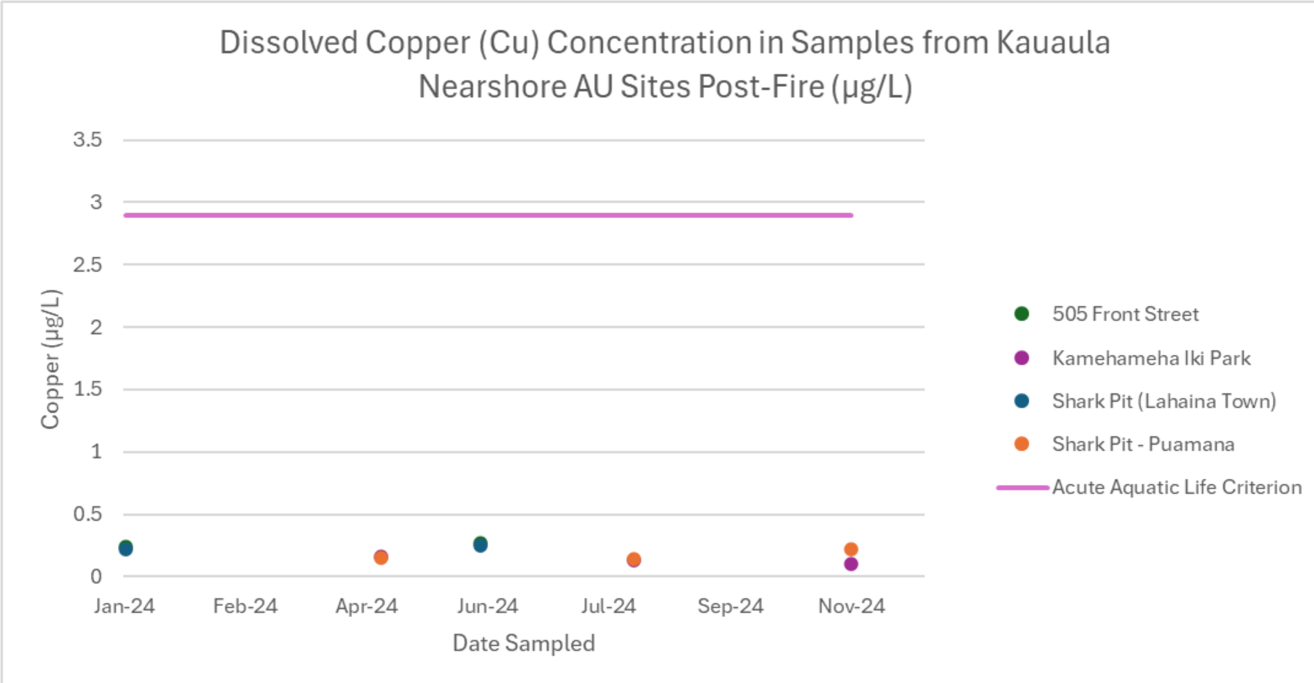

Figure 36. Post-Fire Dissolved Cu Concentrations within the Kauaʻula Nearshore Marine AU.

Note: Acute and chronic criteria are the same value and displayed as one color.

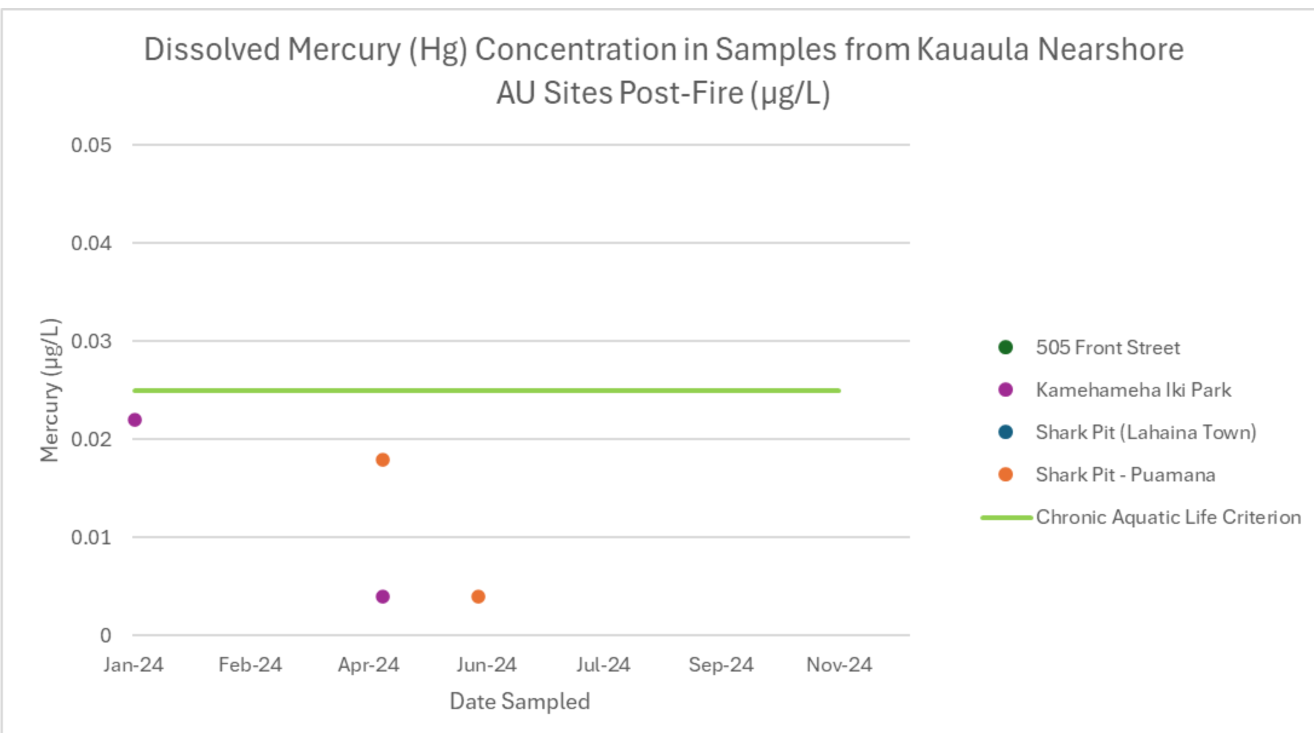

Figure 37. Post-Fire Dissolved Hg Concentrations within the Kauaʻula Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

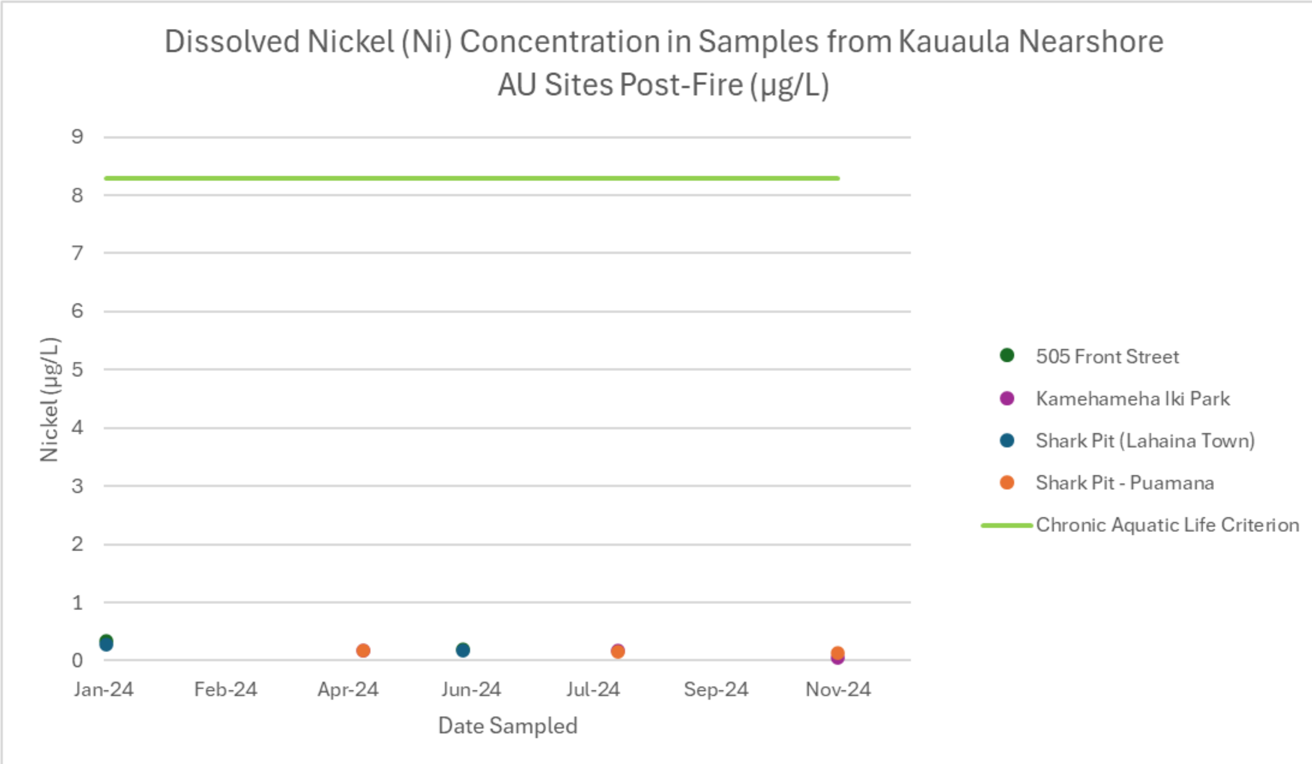

Figure 38. Post-Fire Dissolved Ni Concentrations within the Kauaʻula Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

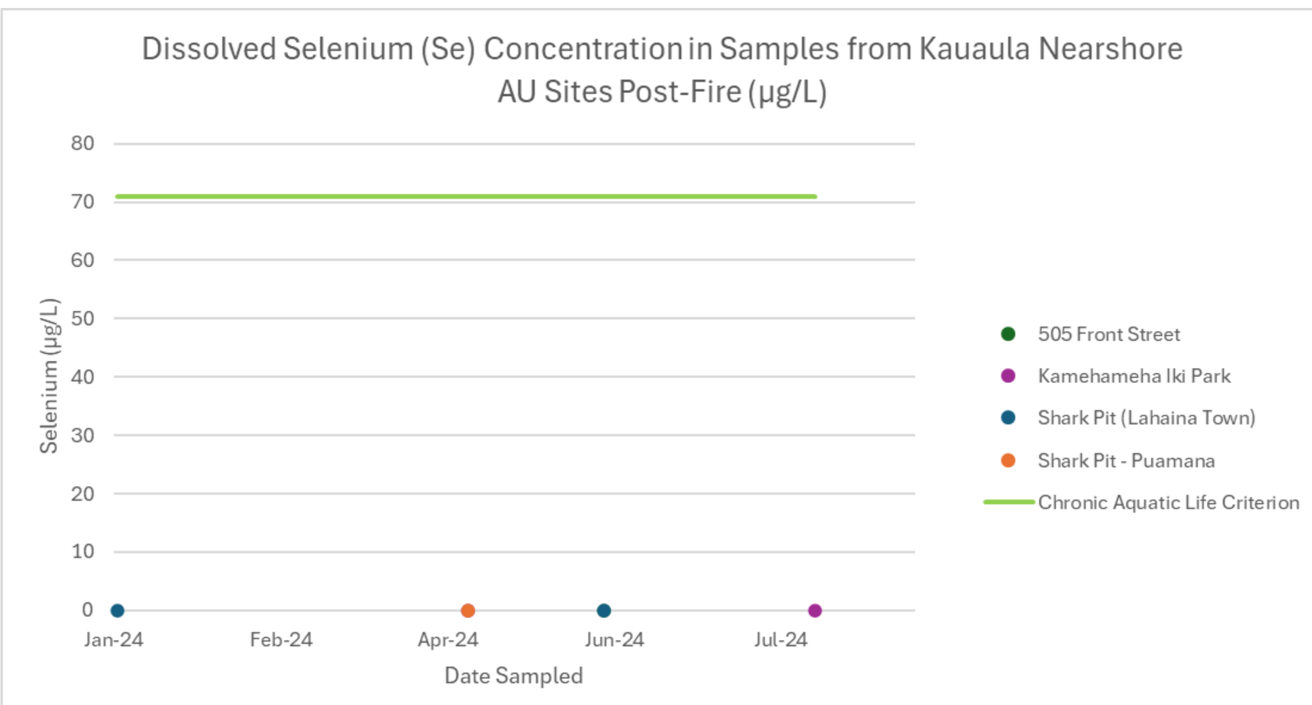

Figure 39. Post-Fire Dissolved Se Concentrations within the Kauaʻula Nearshore Marine AU.

Note: Acute criterion not displayed for visual purposes.

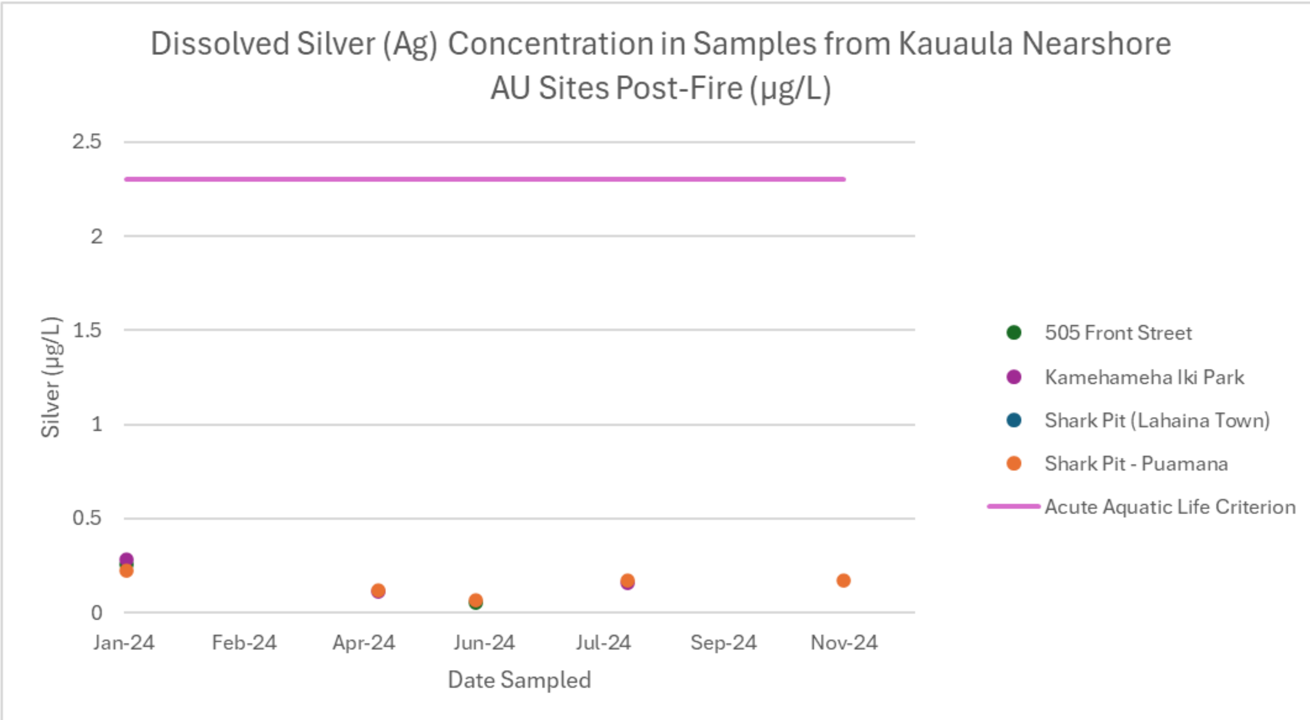

Figure 40. Post-Fire Dissolved Ag Concentrations within the Kauaʻula Nearshore Marine AU.

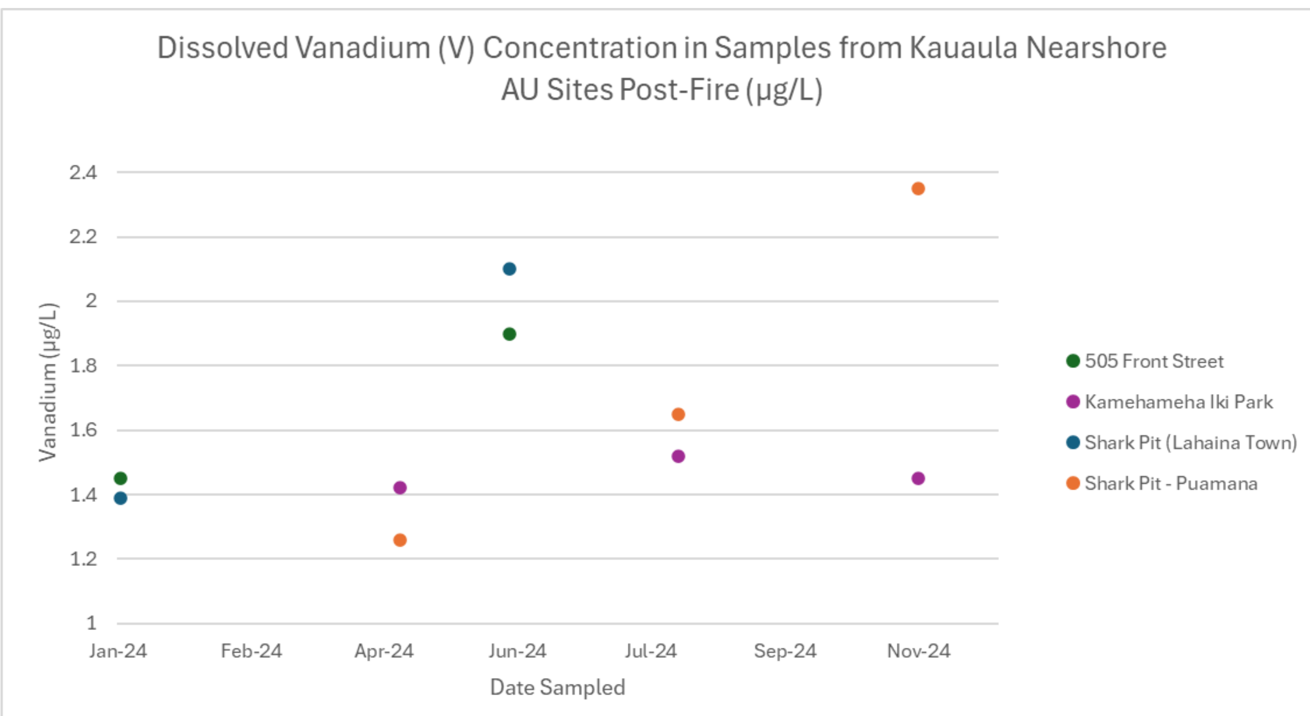

Figure 41. Post-Fire Dissolved V Concentrations within the Kauaʻula Nearshore Marine AU.

Note: Hawaiʻi Water Quality Standards do not contain criteria for Vanadium.

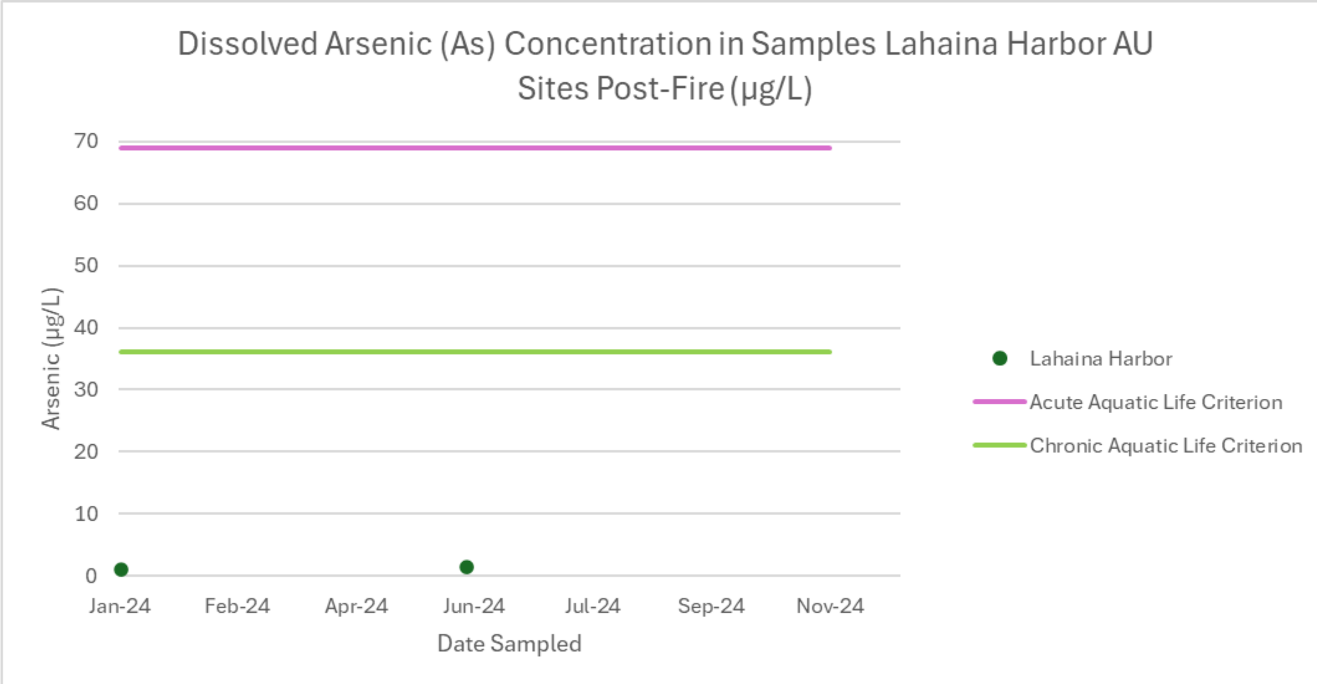

Figure 42. Post-Fire Dissolved As Concentrations within the Lāhainā Harbor Marine AU.

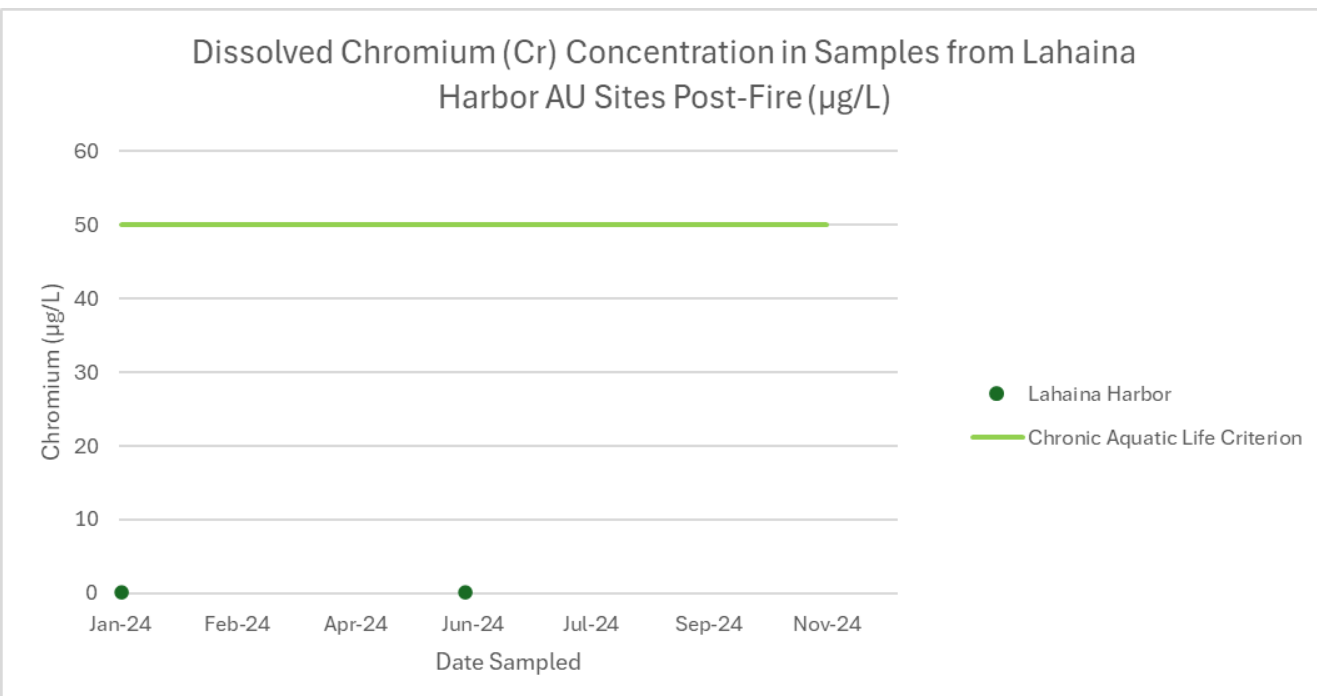

Figure 43. Post-Fire Dissolved Cr Concentrations within the Lāhainā Harbor Marine AU.

Note: Acute criterion not displayed for visual purposes.

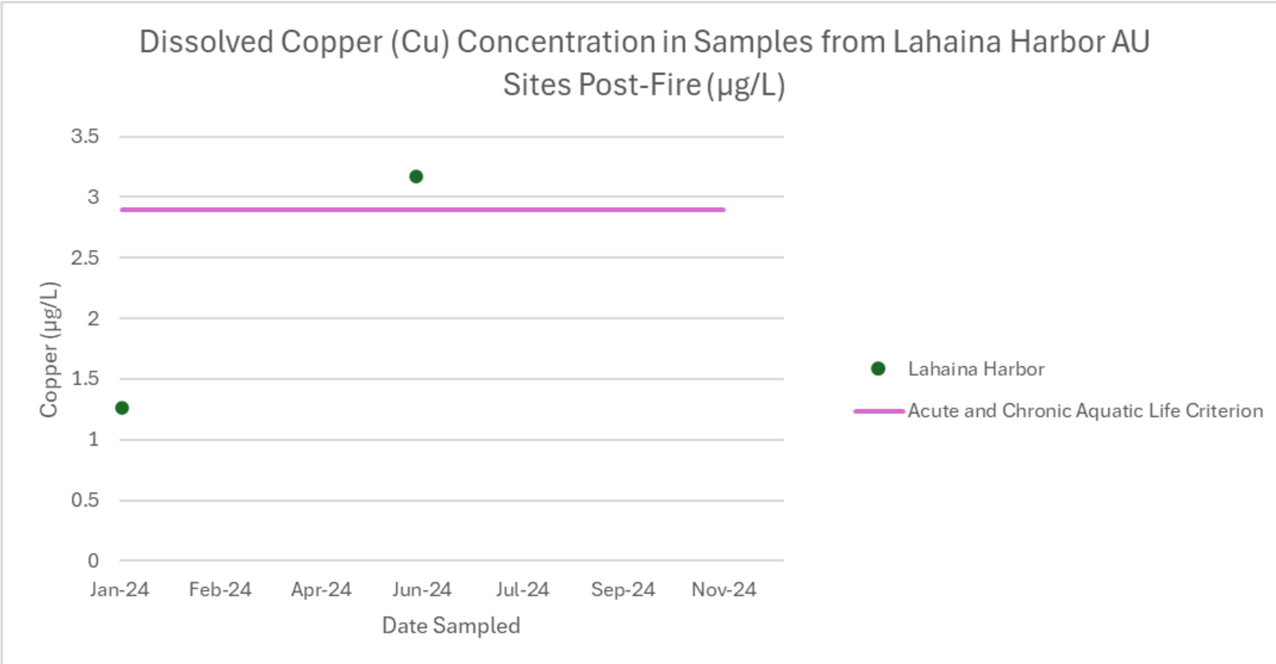

Figure 44. Post-Fire Dissolved Cu Concentrations within the Lāhainā Harbor Marine AU.

Note: Acute and chronic criteria are the same value and displayed as one color.

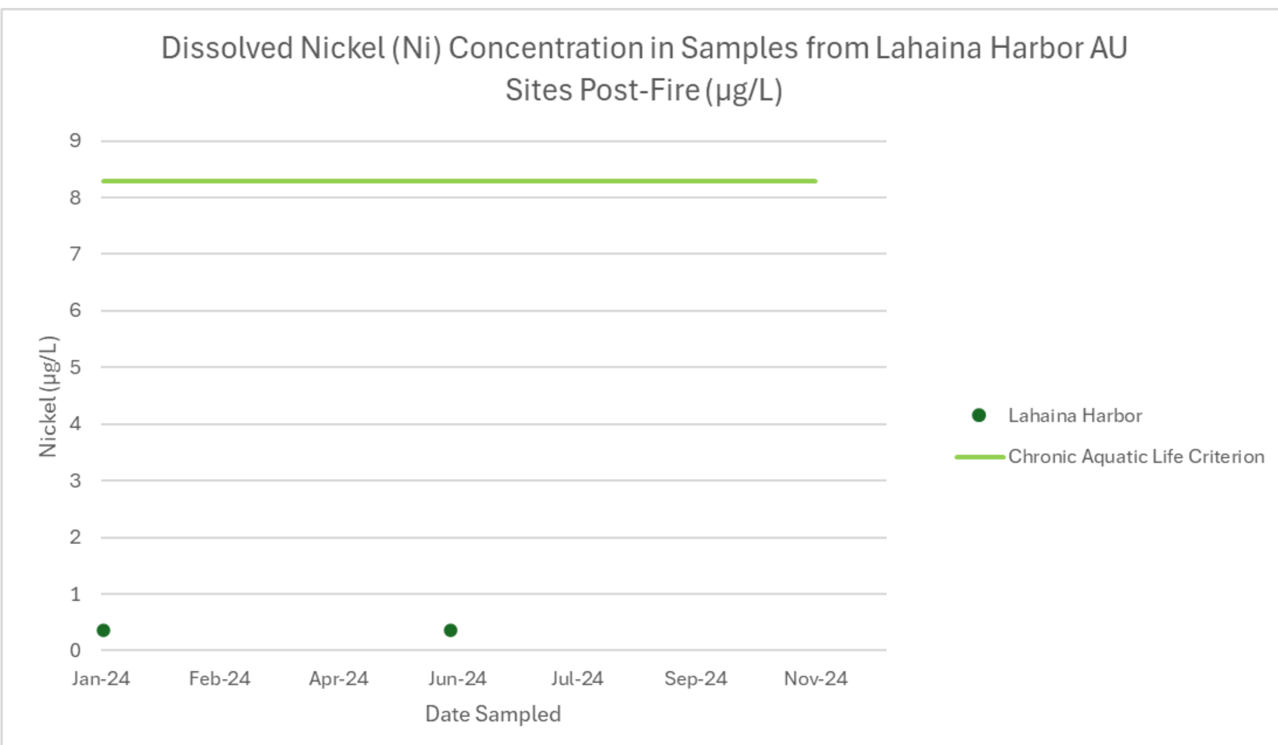

Figure 45. Post-Fire Dissolved Ni Concentrations within the Lāhainā Harbor Marine AU.

Note: Acute criterion not displayed for visual purposes.

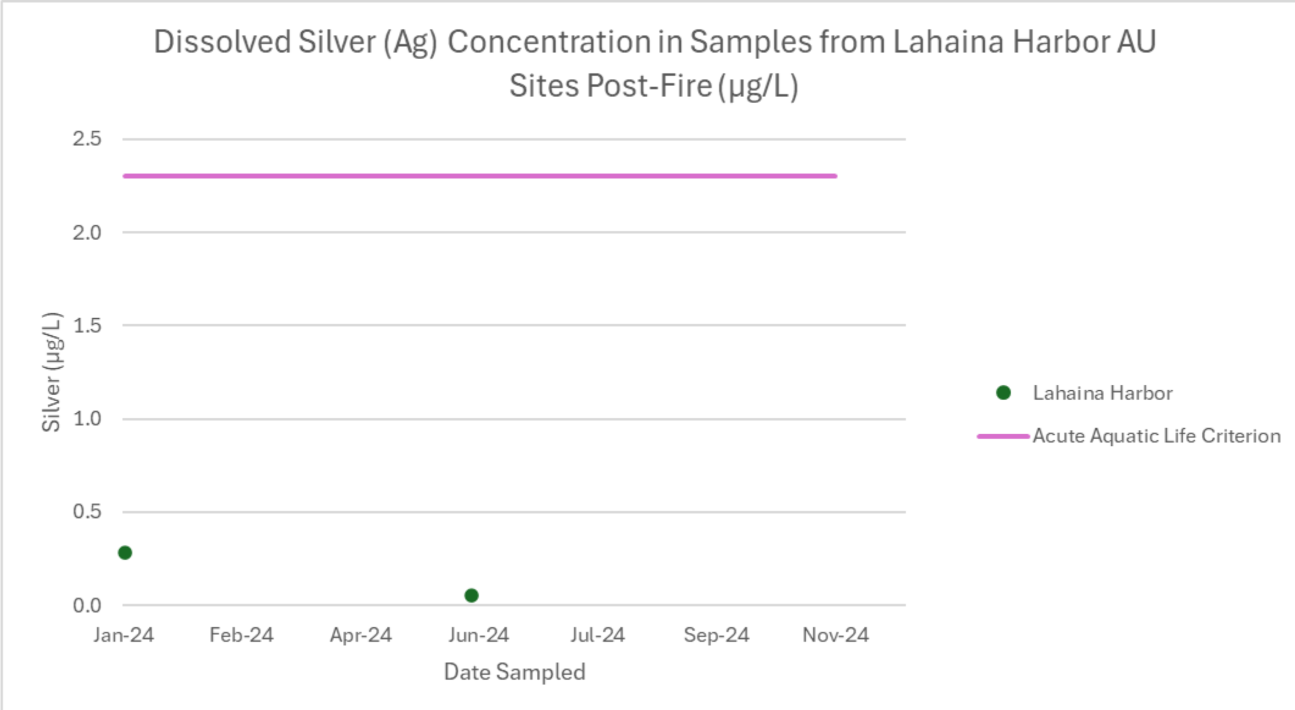

Figure 46. Post-Fire Dissolved Ag Concentrations within the Lāhainā Harbor Marine AU.

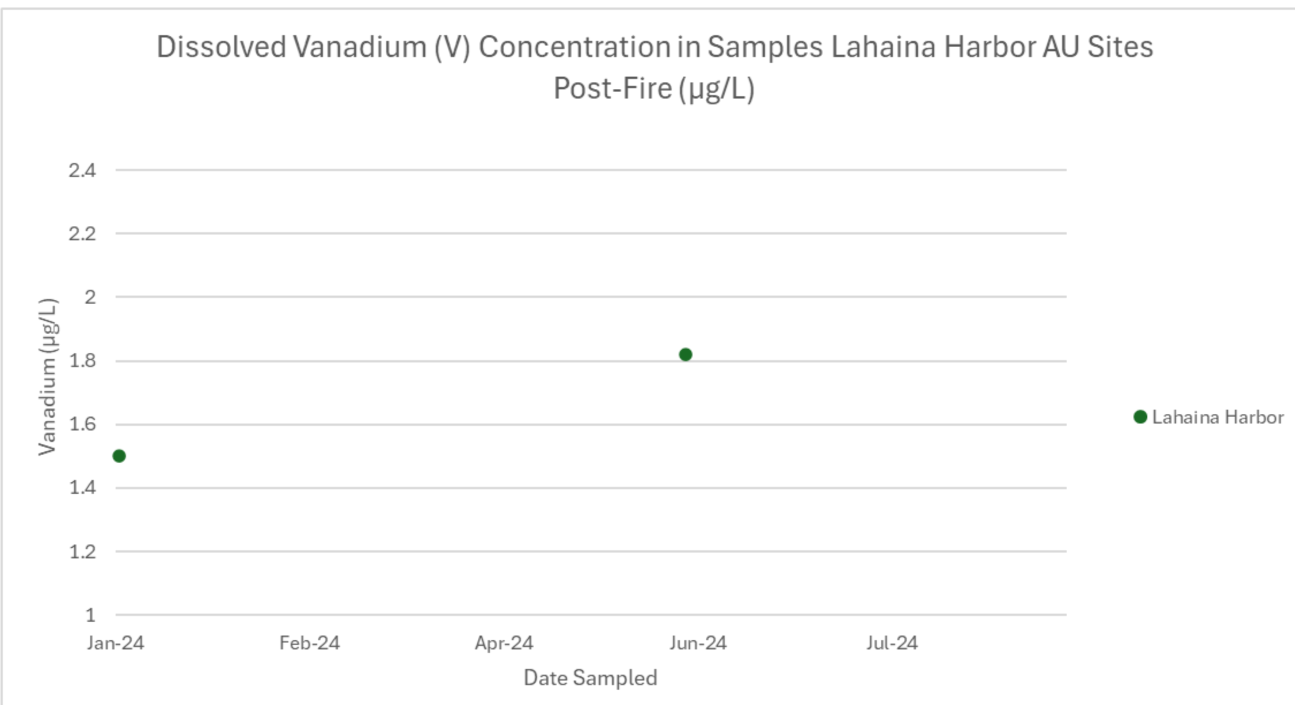

Figure 47. Post-Fire Dissolved V Concentrations within the Lāhainā Harbor Marine AU.

Note: Hawaiʻi Water Quality Standards do not contain criteria for Vanadium.

3.4.2.2 Conventional Parameters

Coastal water samples taken by DOH and HOKWO provide context to conventional parameters in nearshore coastal waters around Lāhainā (Hawaiʻi DOH 2025b, Callender et al. 2024). Data was available for pre- and post-fire samples within the Kahoma, Kauaʻula, and Lāhainā Harbor AUs. HOKWO has twelve monitoring locations around Lāhainā that provided data from November 2016 to December 2024. DOH conducted sampling at ten monitoring locations that provided data from August 2022 to March 2024. Data was downloaded from the DOH website and sampling event results were combined for both DOH and HOKWO water quality data. Data was separated by pre- and post-fire date and further by wet and dry season. Geospatial analysis showed that five sites fell within the Kahoma Nearshore AU (*Wahikuli, Puʻunoa Beach, Māla Ramp, Māla Tavern, and Pāpalaua Street*), four sites fell within the Kauaʻula Nearshore AU (*505 Front Street, Lāhainā Town, Lindsey Hale, and Mākila Point)* and one within the Lāhainā Harbor AU (Figure 48). Results for conventional parameters of interest at each site within each AU were then graphically plotted. The following conventional parameters are shown in the figures below:

- Ammonia Nitrogen (NH_4-N)
- Nitrate+Nitrite as N
- Total Phosphorus (TP)
- Total Nitrogen (TN)
- Turbidity

Figure 49 through Figure 78 display conventional parameters for sites within the Kahoma, Kauaʻula, and Lāhainā Harbor AUs. Time plots were produced and include reference lines for wet and dry season water quality criteria, per Hawaiʻi Water Quality Standards.

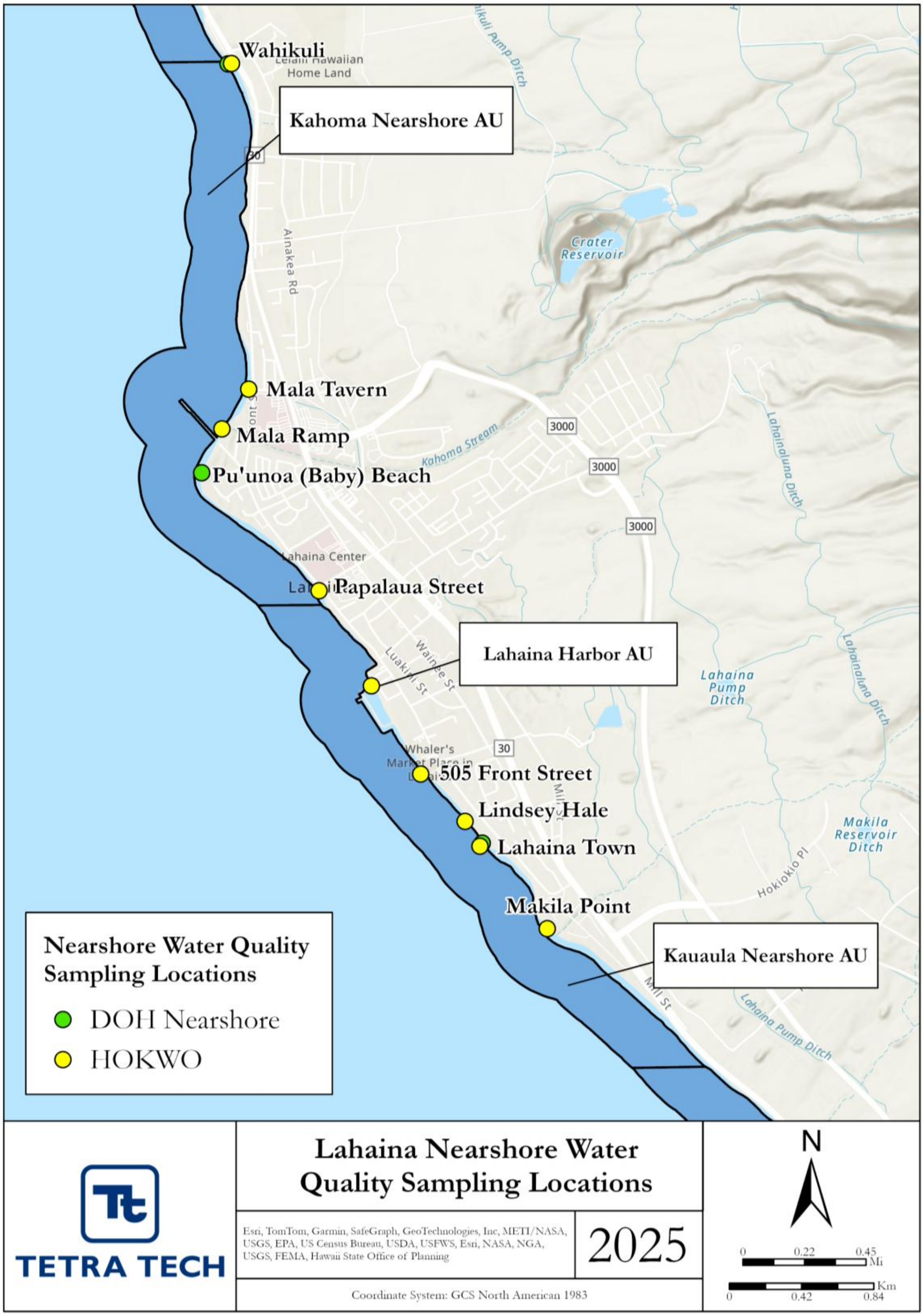

Figure 48. Nearshore Water Quality Conventional Parameter Sampling Locations.
(*Source: Hawaiʻi DOH 2025b*)

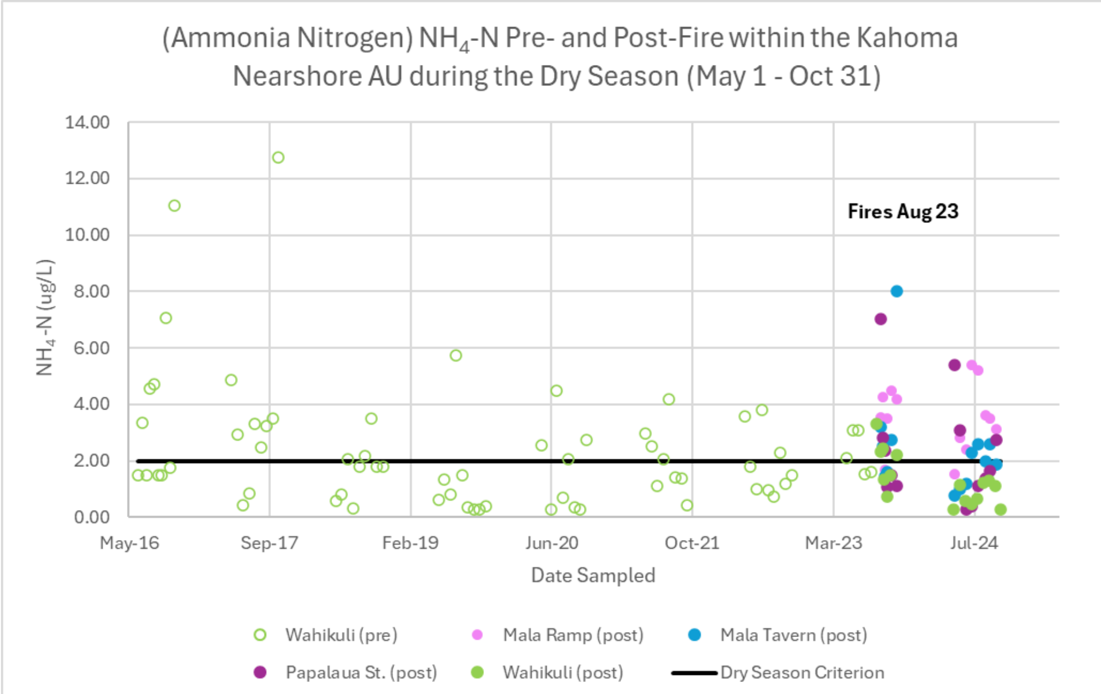

Figure 49. Ammonia Nitrogen (µg/L) Pre- and Post-Fire during the Dry Season in the Kahoma AU.

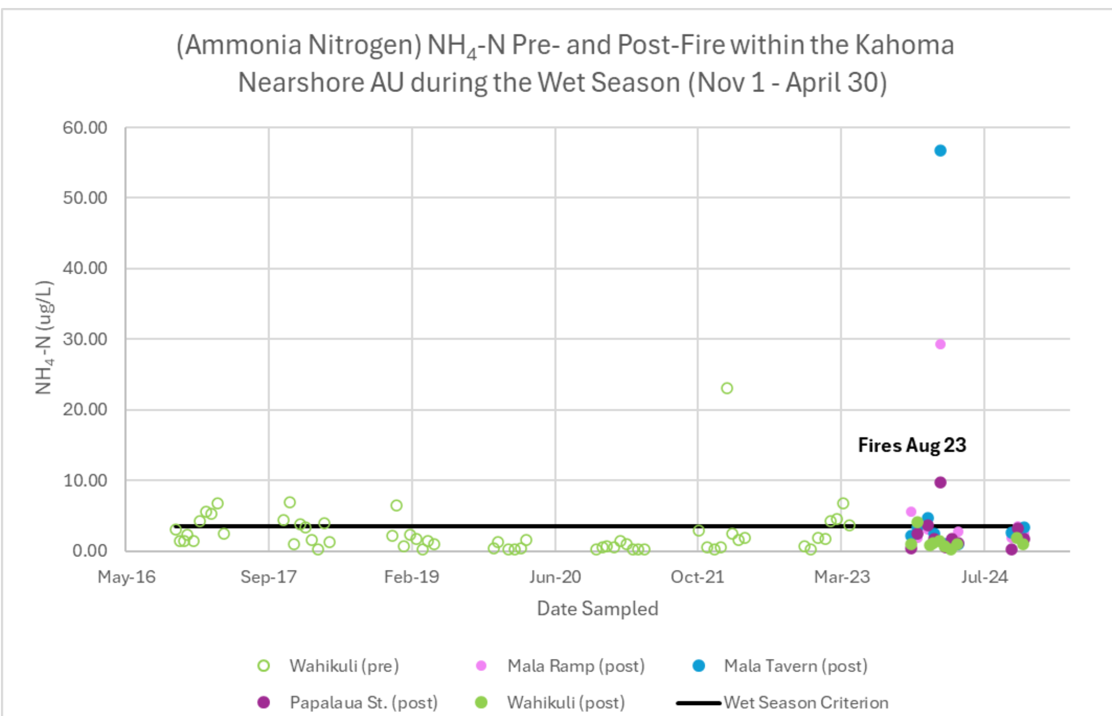

Figure 50. Ammonia Nitrogen (µg/L) Pre- and Post-Fire during the Wet Season in the Kahoma AU.

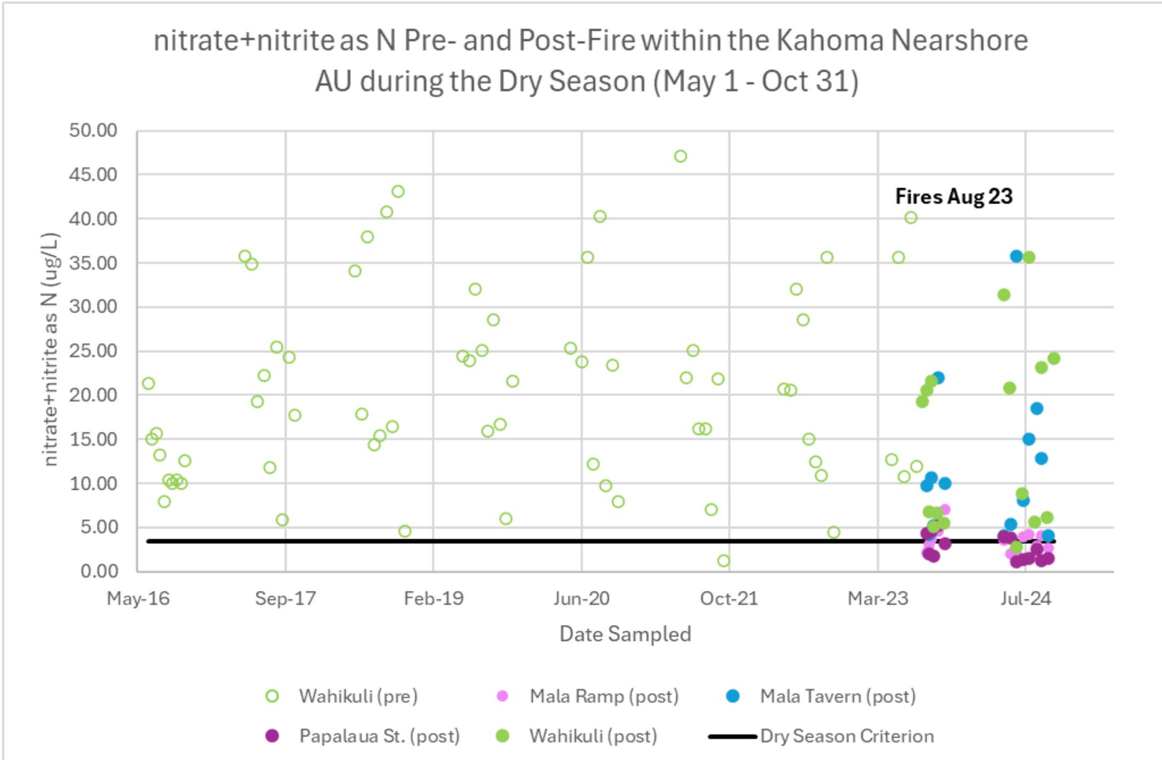

Figure 51. Nitrate+Nitrite as N Pre- and Post-Fire during the Dry Season in the Kahoma AU.

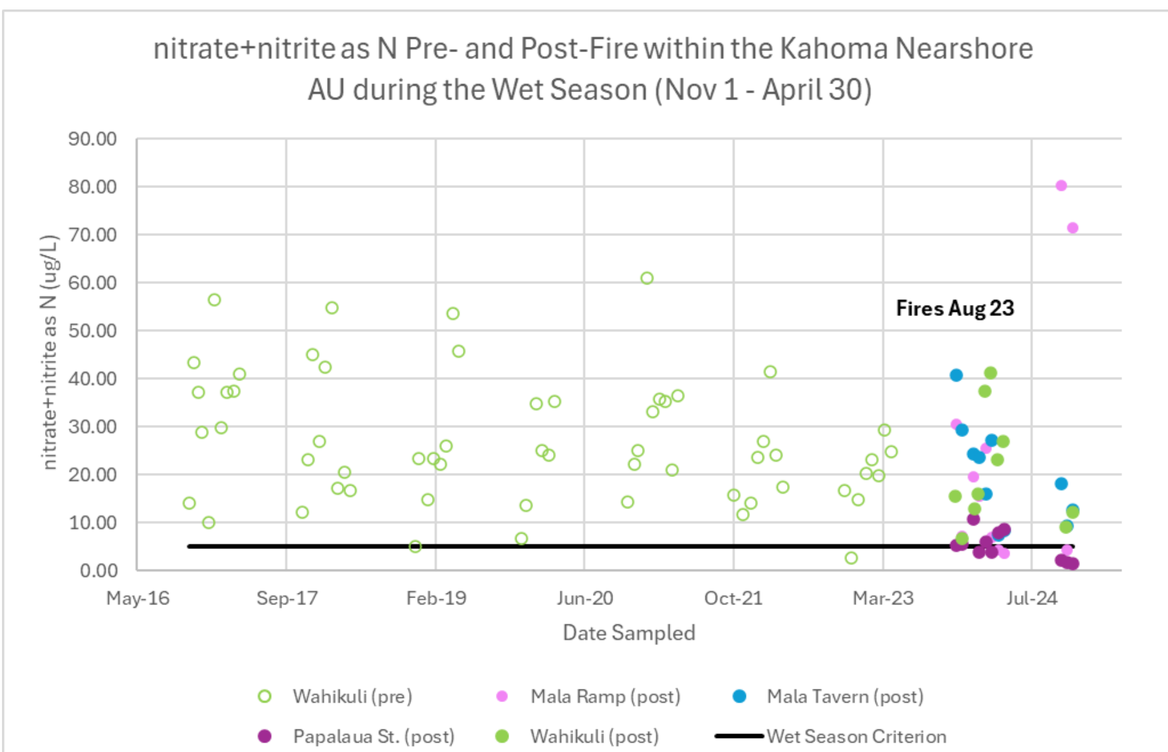

Figure 52. Nitrate+Nitrite as N Pre- and Post-Fire during the Wet Season in the Kahoma AU.

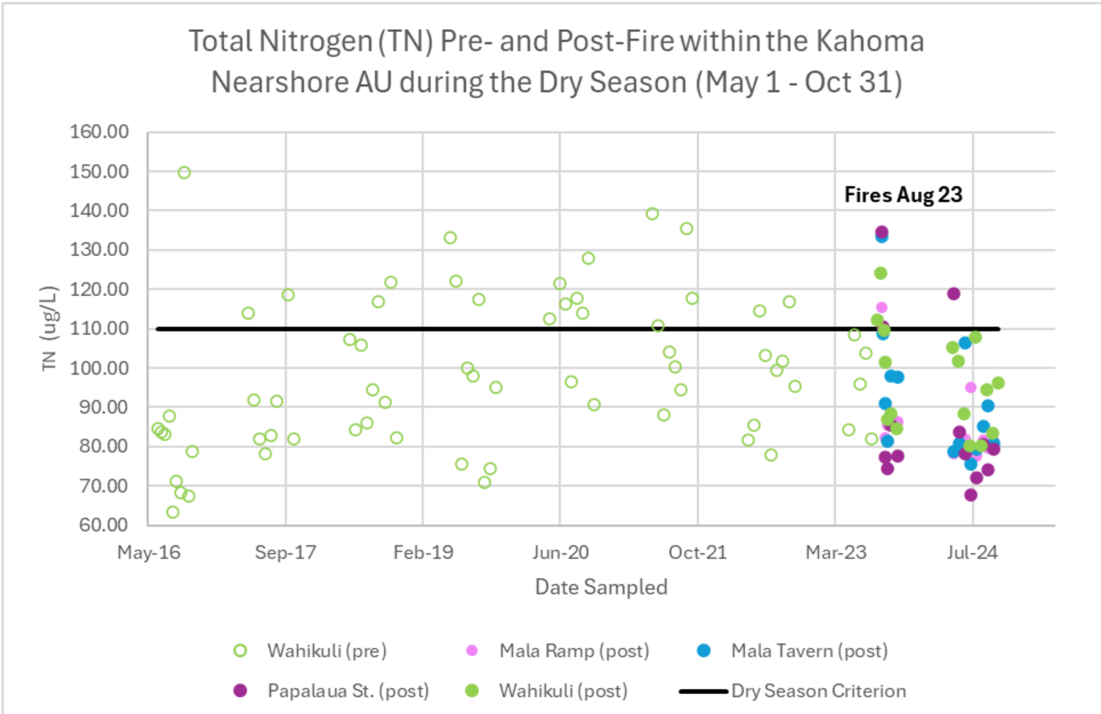

Figure 53. TN (µg/L) Pre- and Post-Fire during the Dry Season in the Kahoma AU.

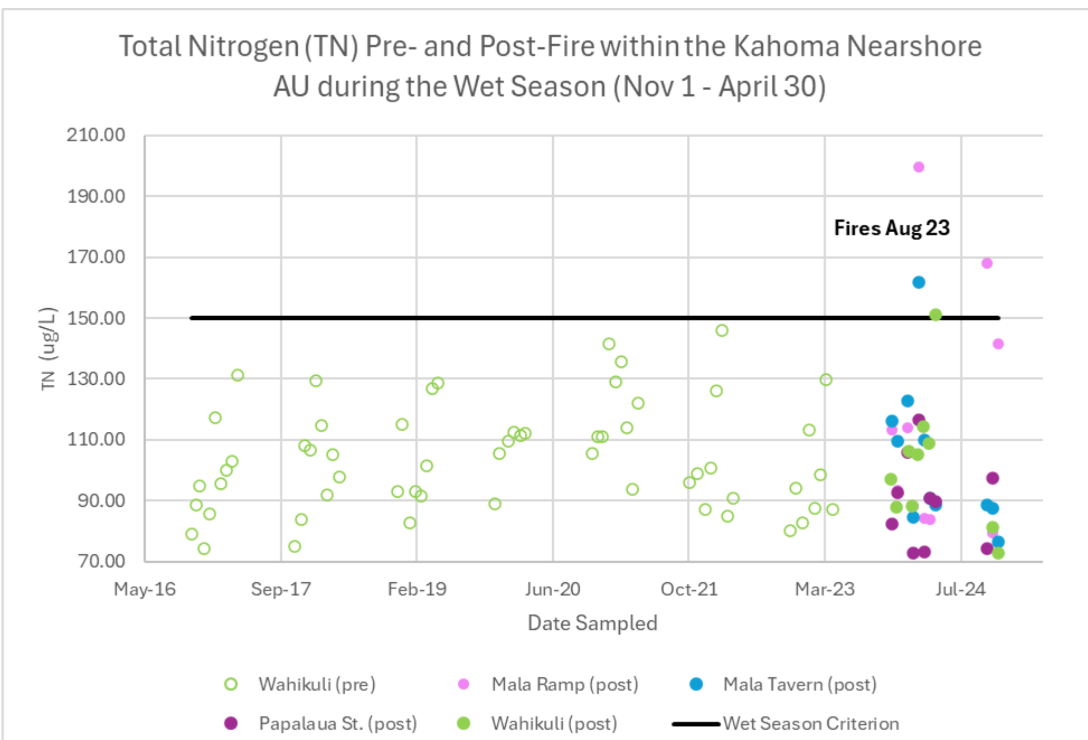

Figure 54. TN (µg/L) Pre- and Post-Fire during the Wet Season in the Kahoma AU.

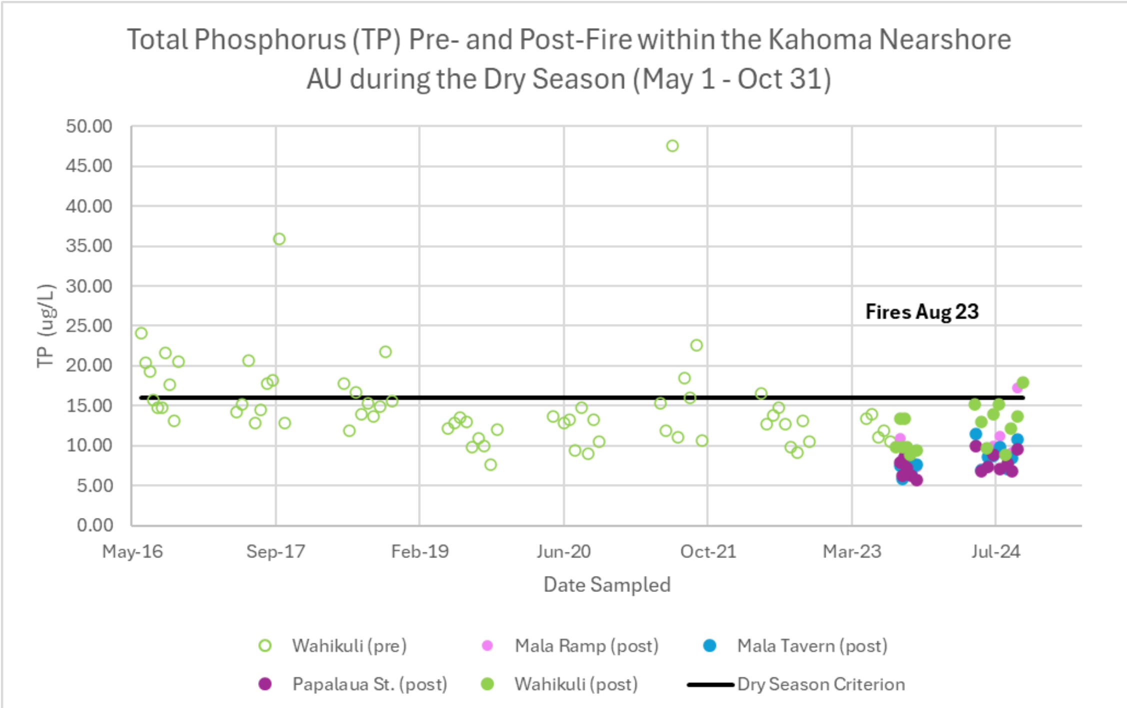

Figure 55. TP (µg/L) Pre- and Post-Fire during the Dry Season in the Kahoma AU.

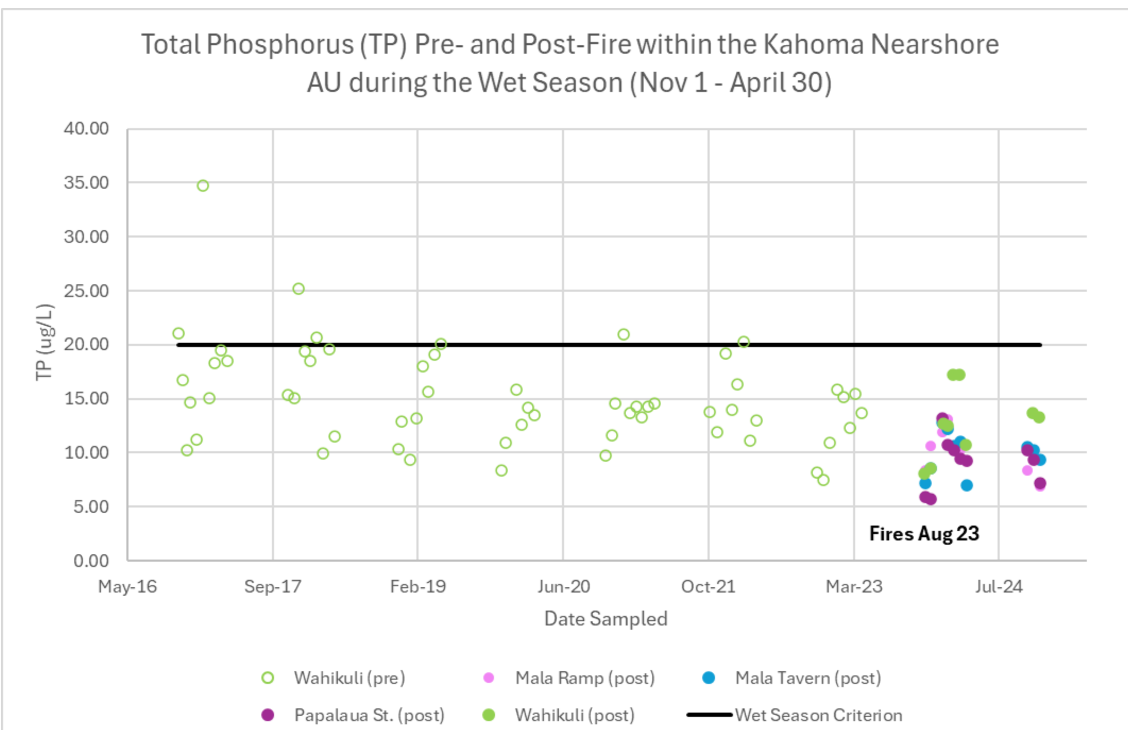

Figure 56. TP (µg/L) Pre- and Post-Fire during the Wet Season in the Kahoma AU.

Note: TP values for 4/26/24 were excluded since they were apparently in error—see Section 4.2.1.11.2 for explanation.

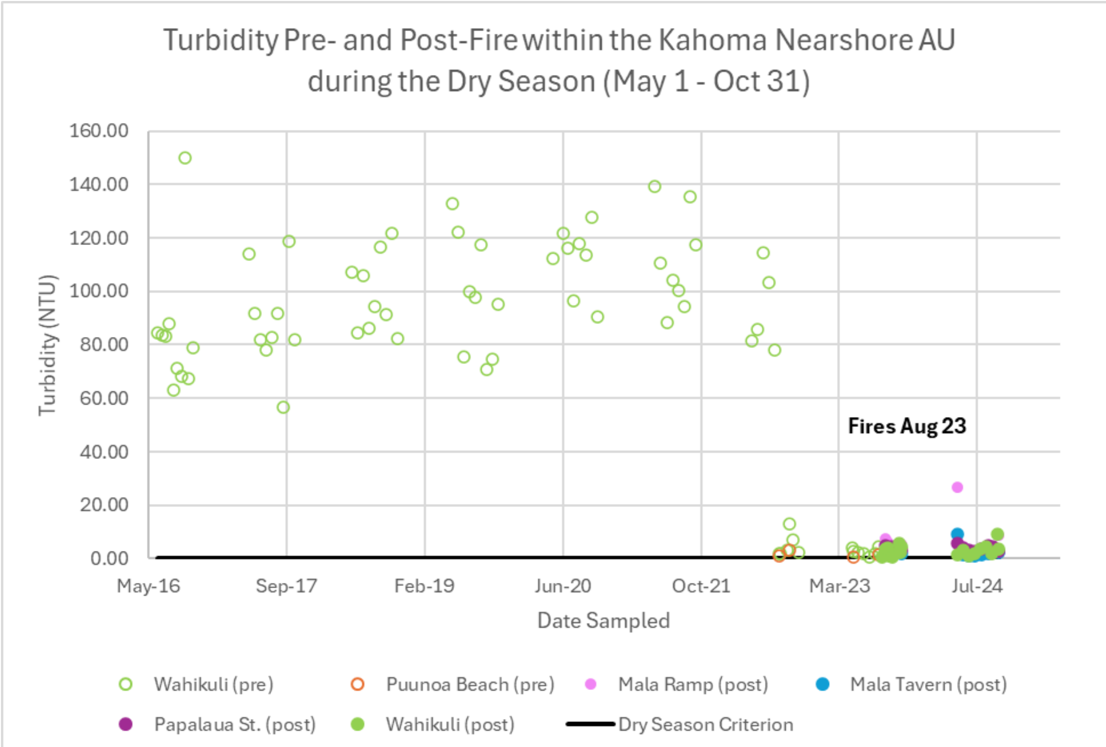

Figure 57. Turbidity (NTU) Pre- and Post-Fire during the Dry Season in the Kahoma AU.

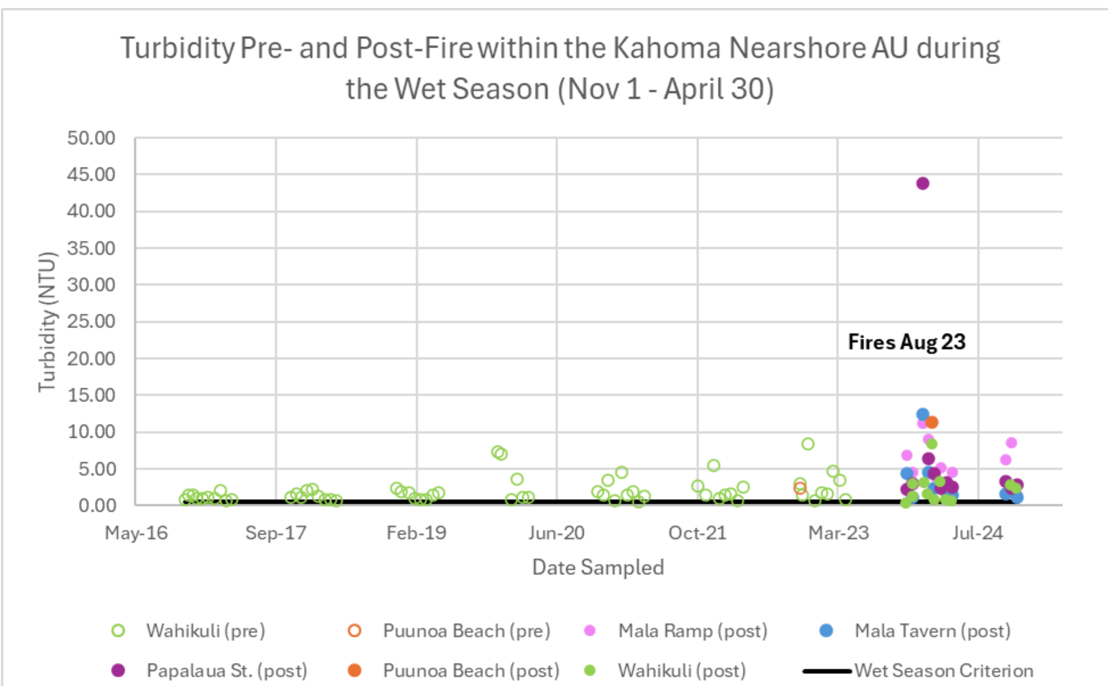

Figure 58. Turbidity (NTU) Pre- and Post-Fire during the Wet Season in the Kahoma AU.

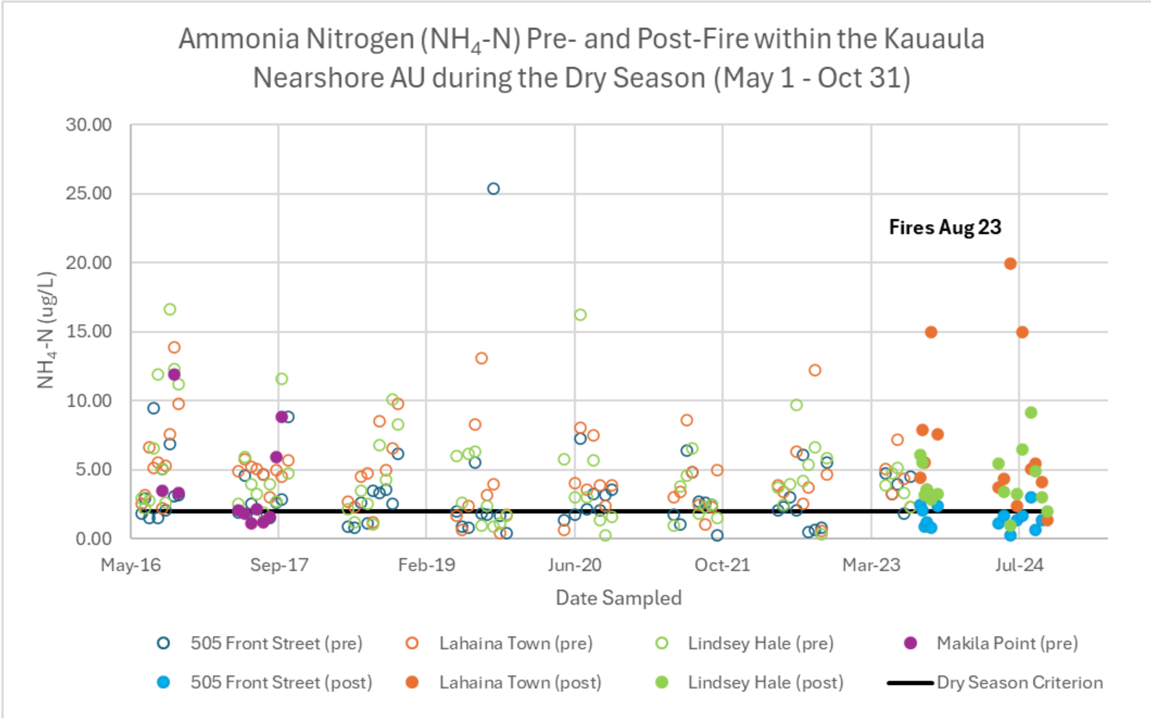

Figure 59. Ammonia Nitrogen (μg/L) Pre- and Post-Fire during the Dry Season in the Kauaʻula AU.

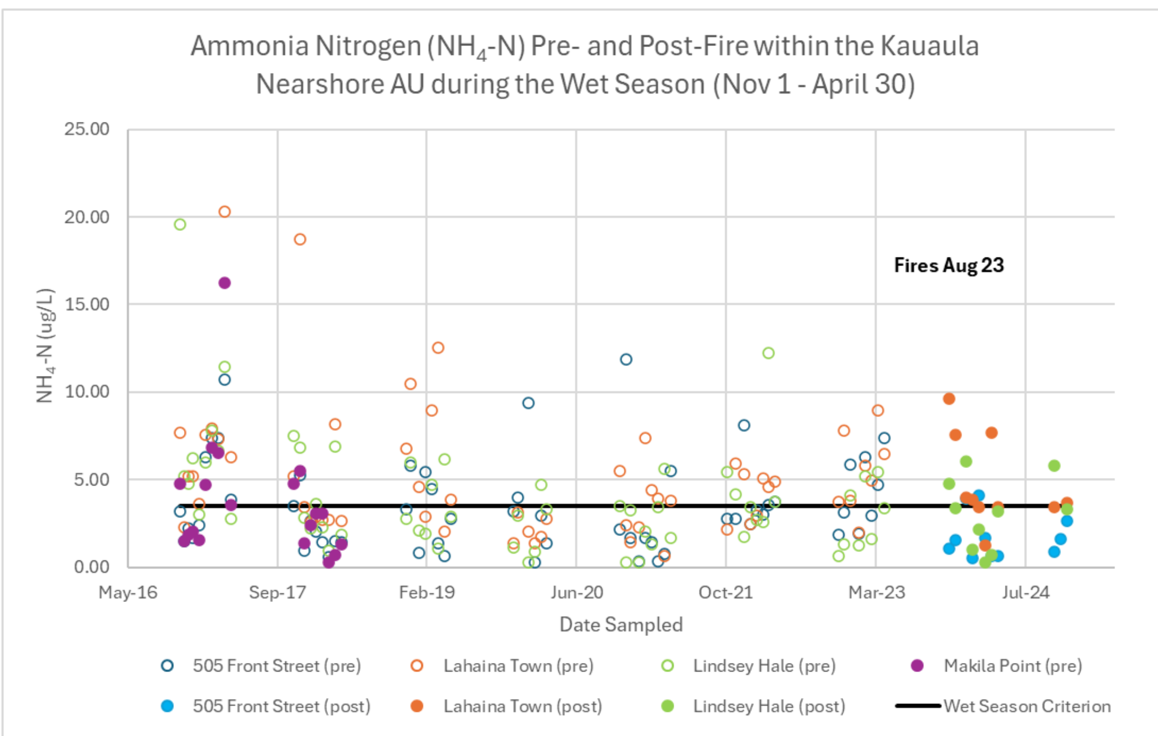

Figure 60. Ammonia Nitrogen (μg/L) Pre- and Post-Fire during the Wet Season in the Kauaʻula AU.

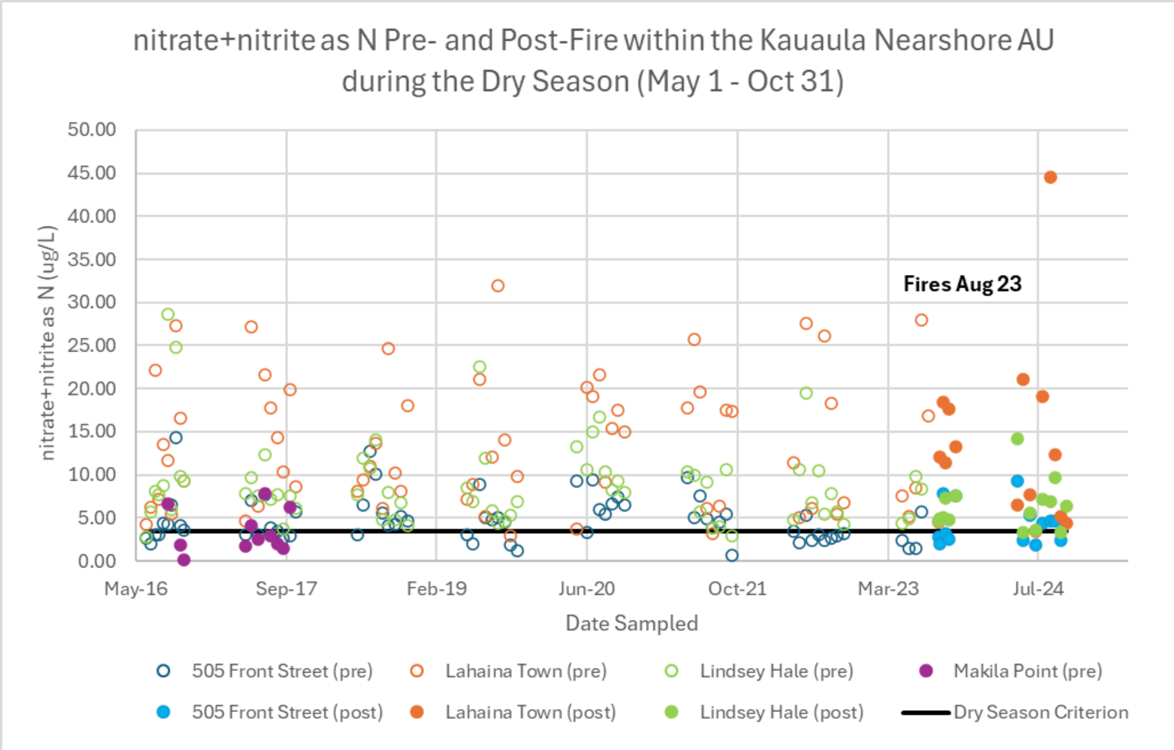

Figure 61. Nitrate+nitrite as N Pre- and Post-Fire during the Dry Season in the Kaua'ula AU.

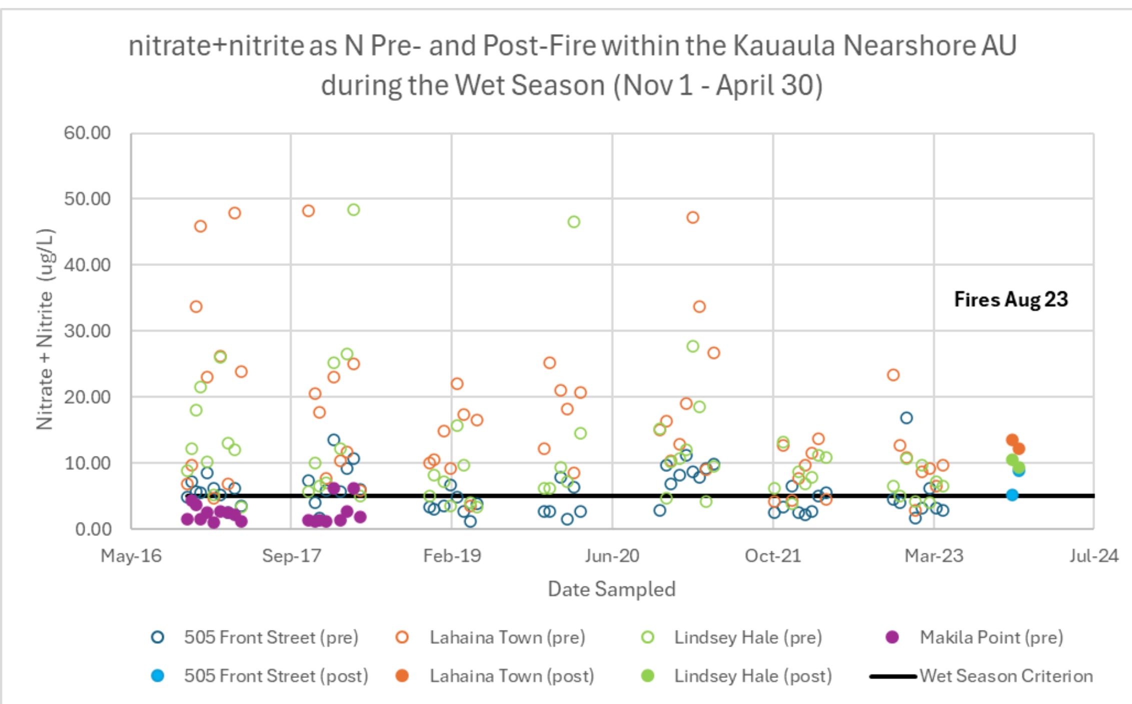

Figure 62. Nitrate+Nitrite as N Pre- and Post-Fire during the Wet Season in the Kaua'ula AU.

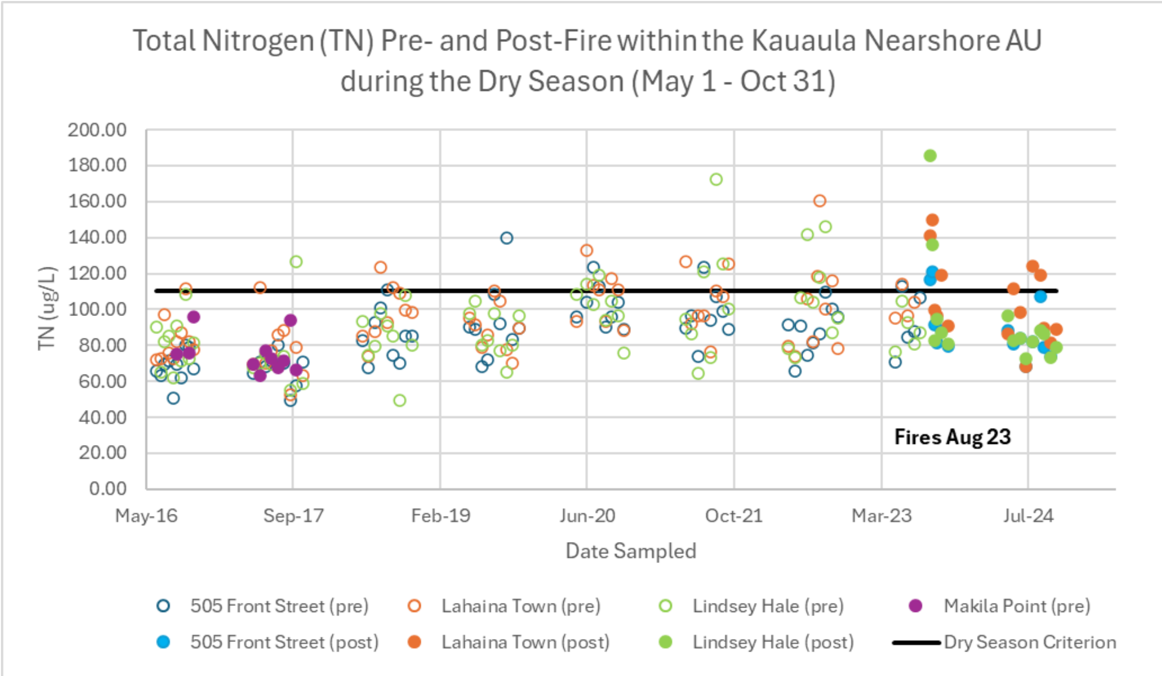

Figure 63. TN (µg/L) Pre- and Post-Fire during the Dry Season in the Kauaʻula AU

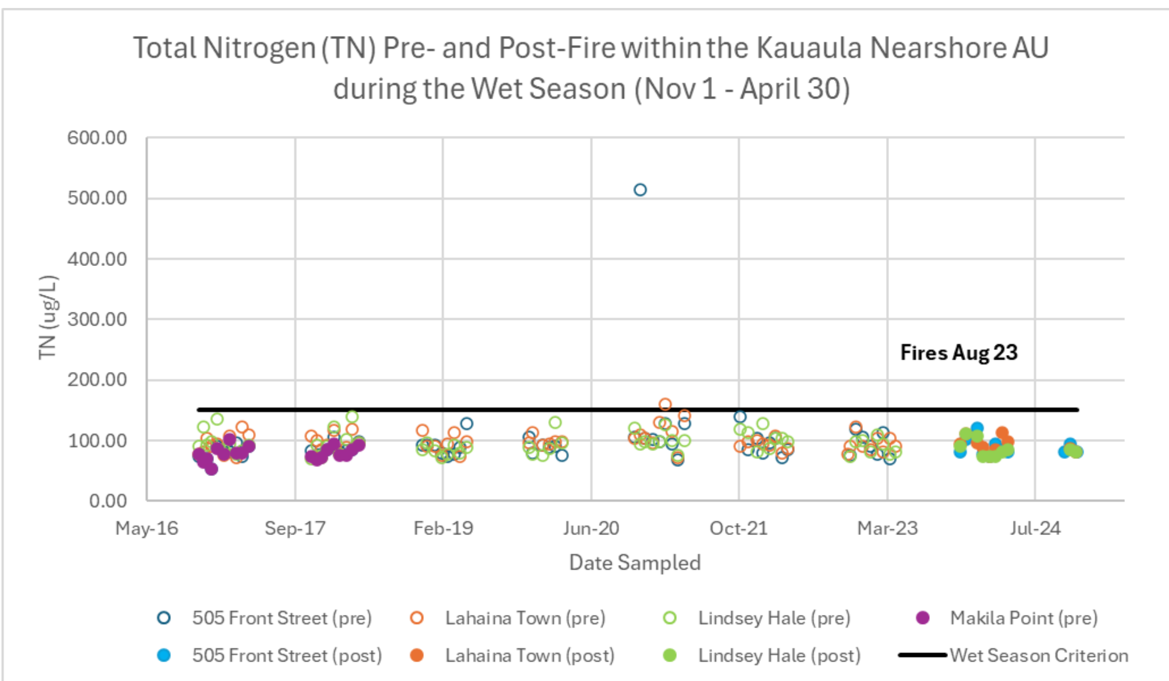

Figure 64. TN (µg/L) Pre- and Post-Fire during the Wet Season in the Kauaʻula AU.

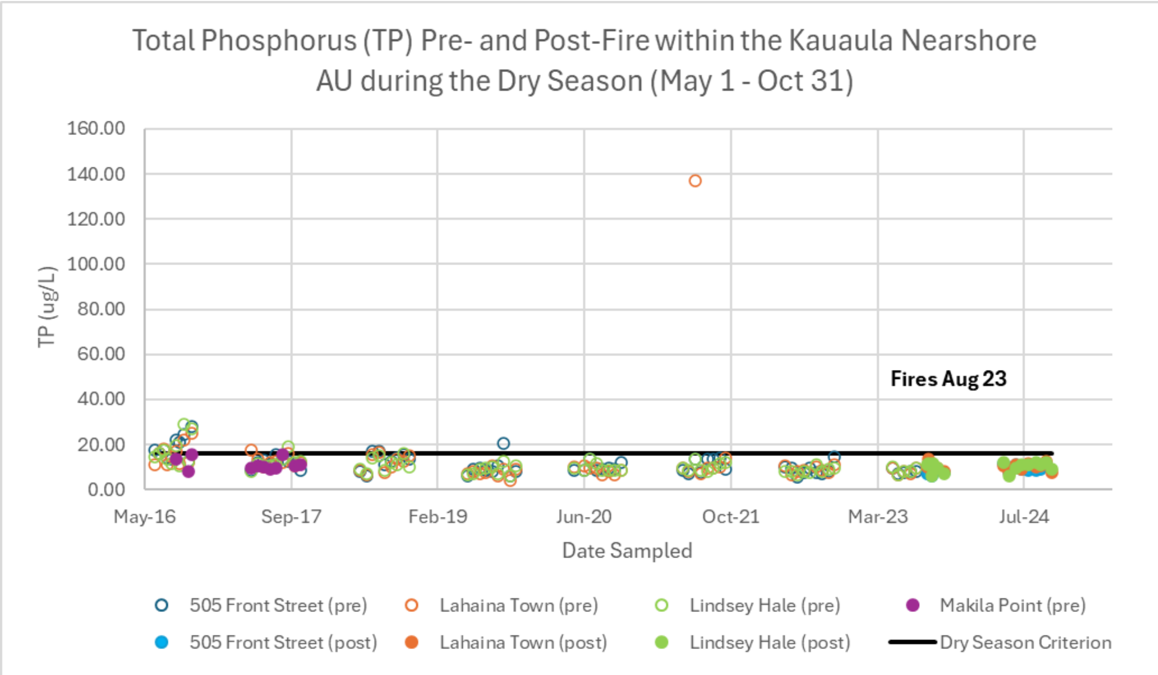

Figure 65. TP (µg/L) Pre- and Post-Fire during the Dry Season in the Kauaʻula AU.

Note: The high value for 6/30/21 at Lāhainā Town may be in error—see Section 4.2.1.11.2 for explanation.

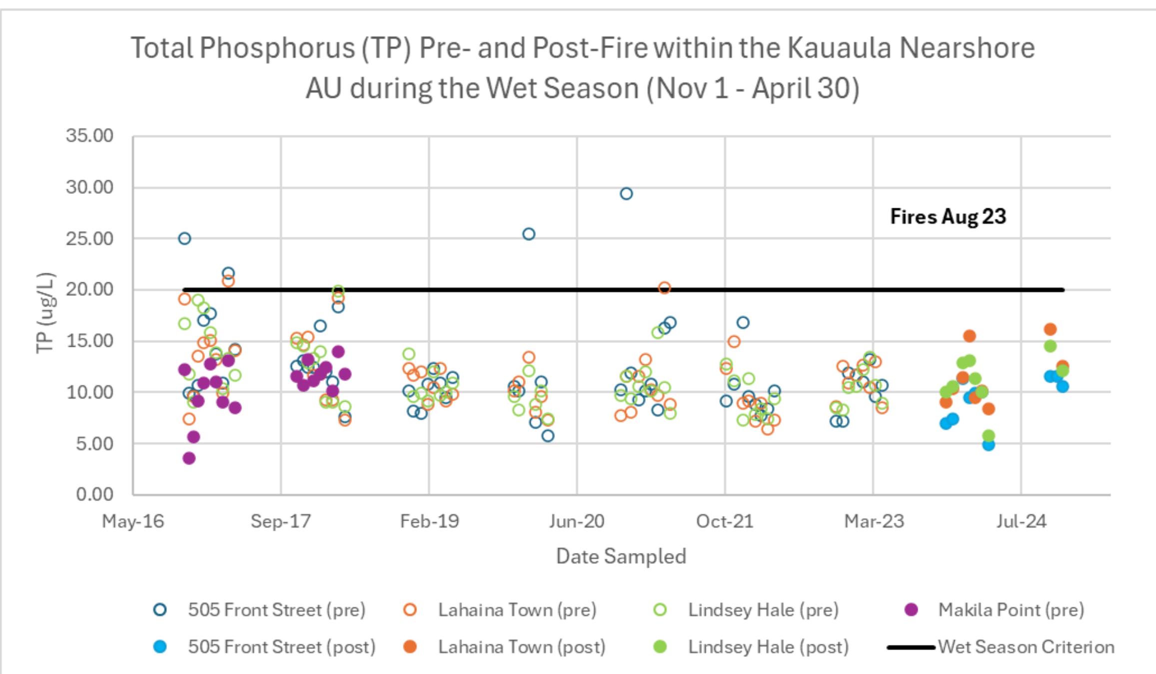

Figure 66. TP (µg/L) Pre- and Post-Fire during the Wet Season in the Kauaʻula AU.

Note: TP values for 4/26/24 were excluded since they were apparently in error—see Section 4.2.1.11.2 for explanation.

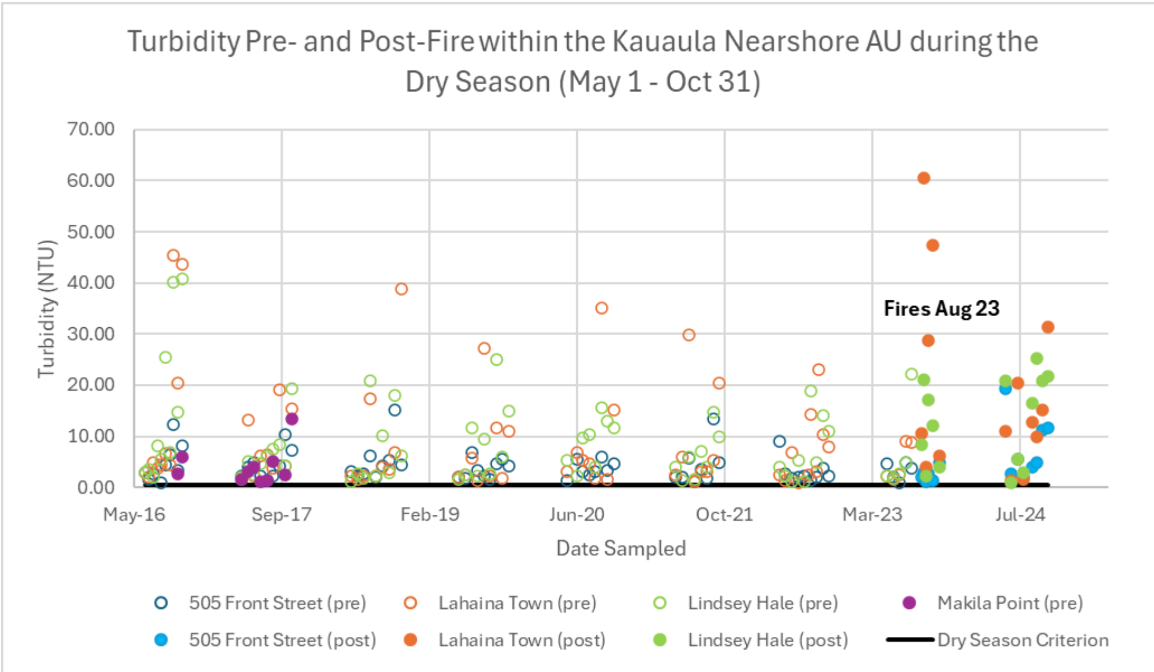

Figure 67. Turbidity (NTU) Pre- and Post-Fire during the Dry Season in the Kauaʻula AU.

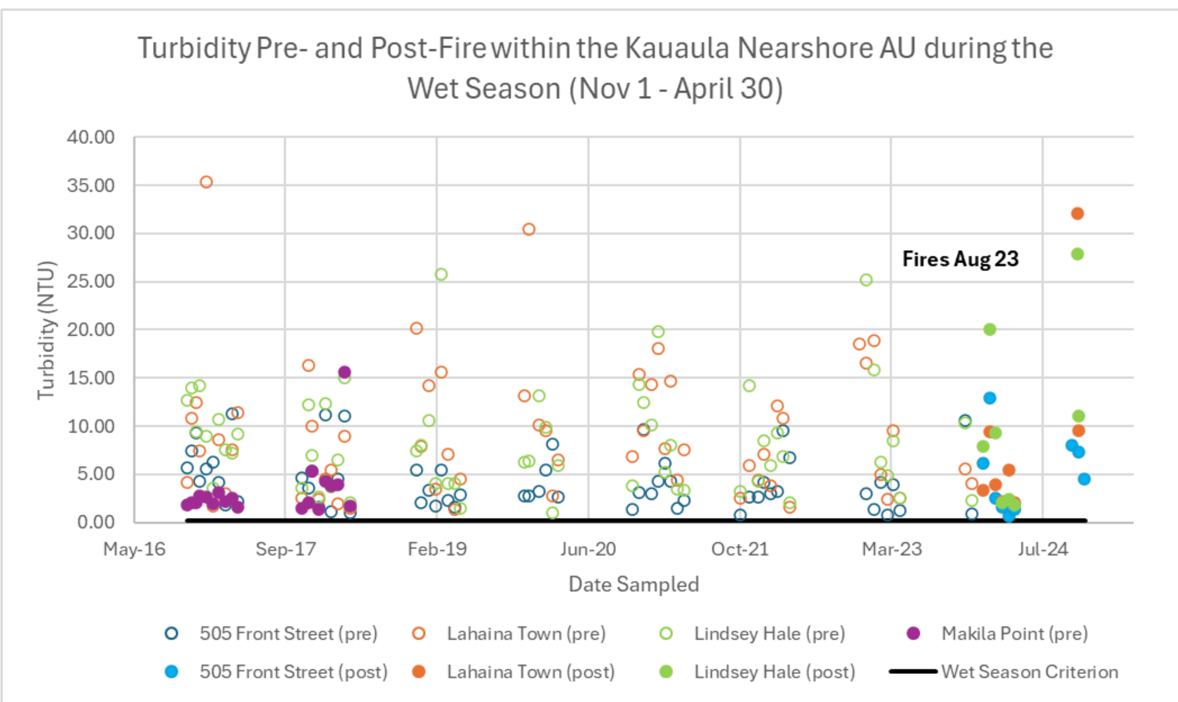

Figure 68. Turbidity (NTU) Pre- and Post-Fire during the Wet Season in the Kauaʻula AU.

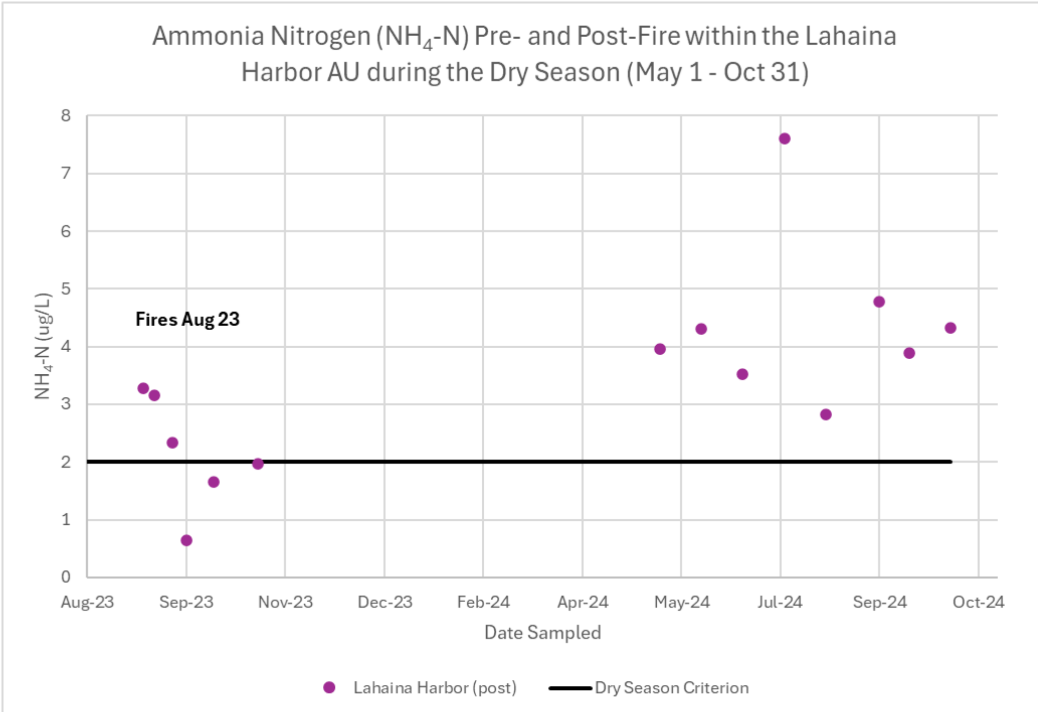

Figure 69. Ammonia Nitrogen (µg/L) Pre- and Post-Fire during the Dry Season in the Lāhainā Harbor AU.

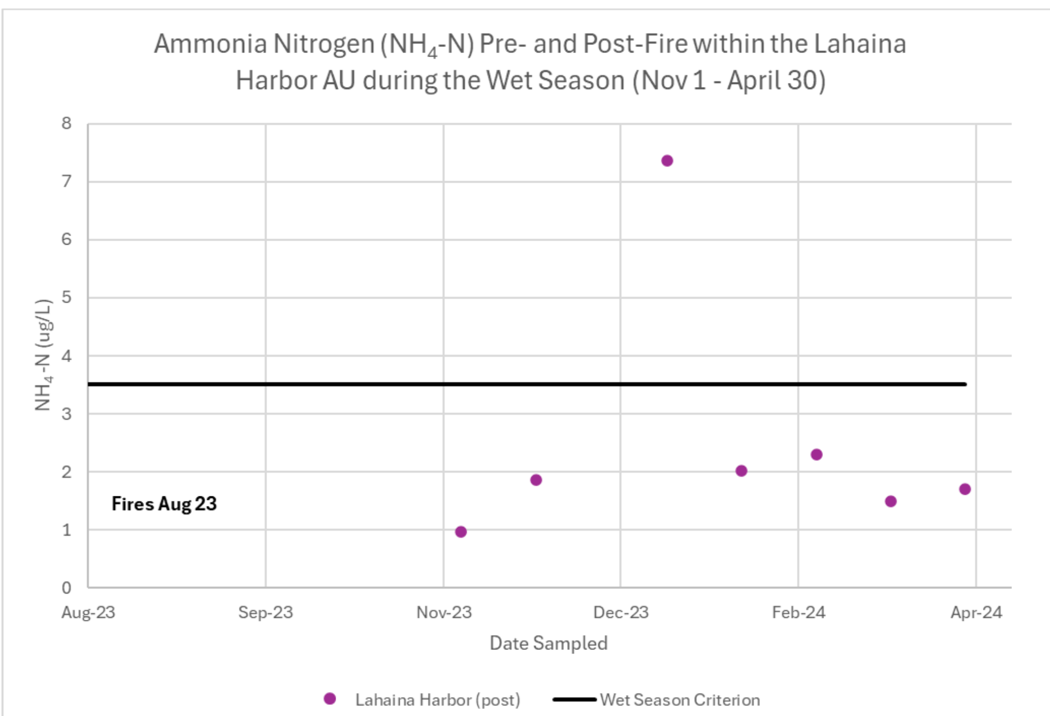

Figure 70. Ammonia Nitrogen (µg/L) Pre- and Post-Fire during the Wet Season in the Lāhainā Harbor AU.

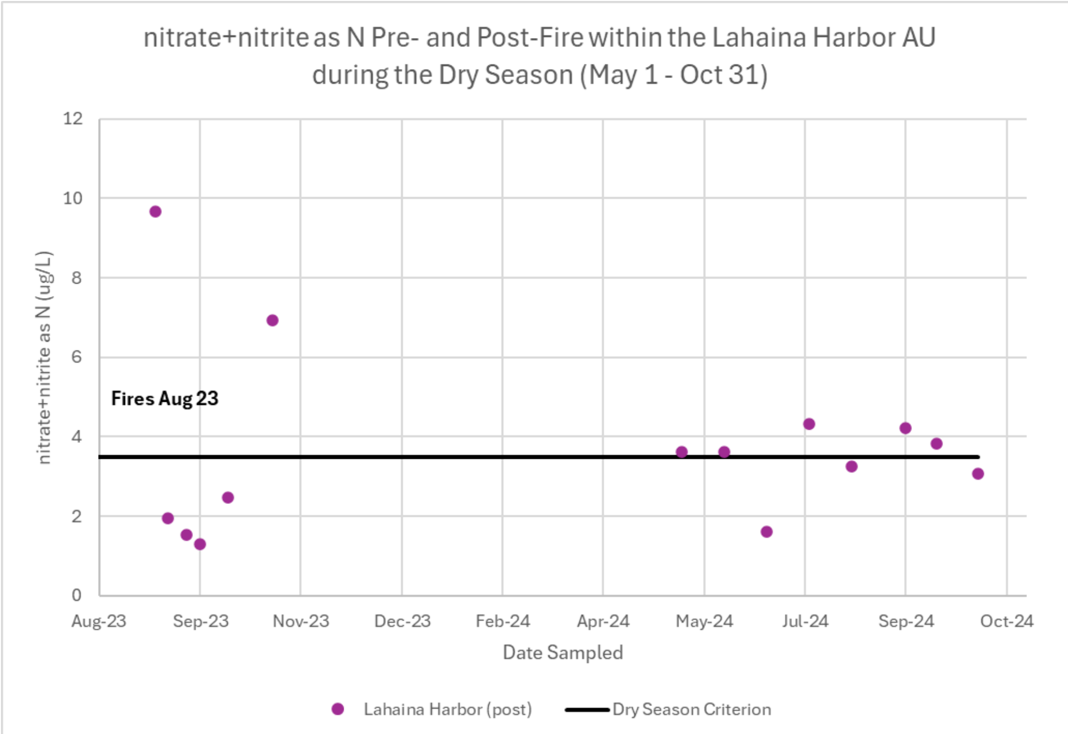

Figure 71. Nitrate+nitrite as N Pre- and Post-Fire during the Dry Season in the Lāhainā Harbor AU.

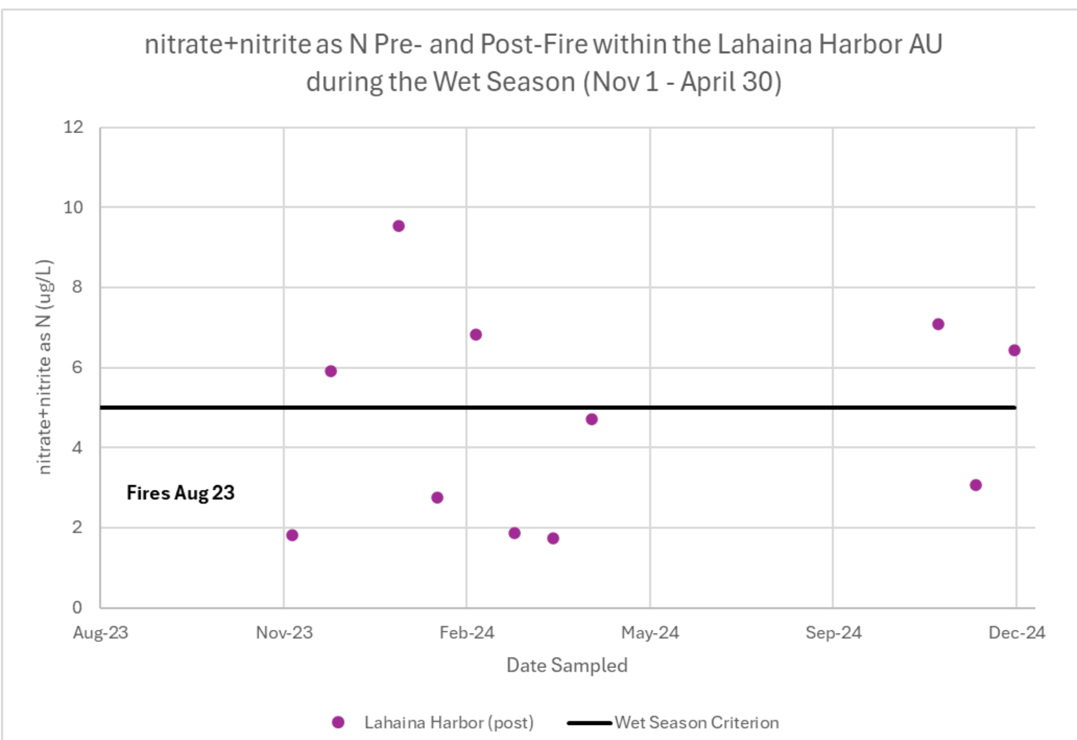

Figure 72. Nitrate+nitrite as N Pre- and Post-Fire during the Wet Season in the Lāhainā Harbor AU.

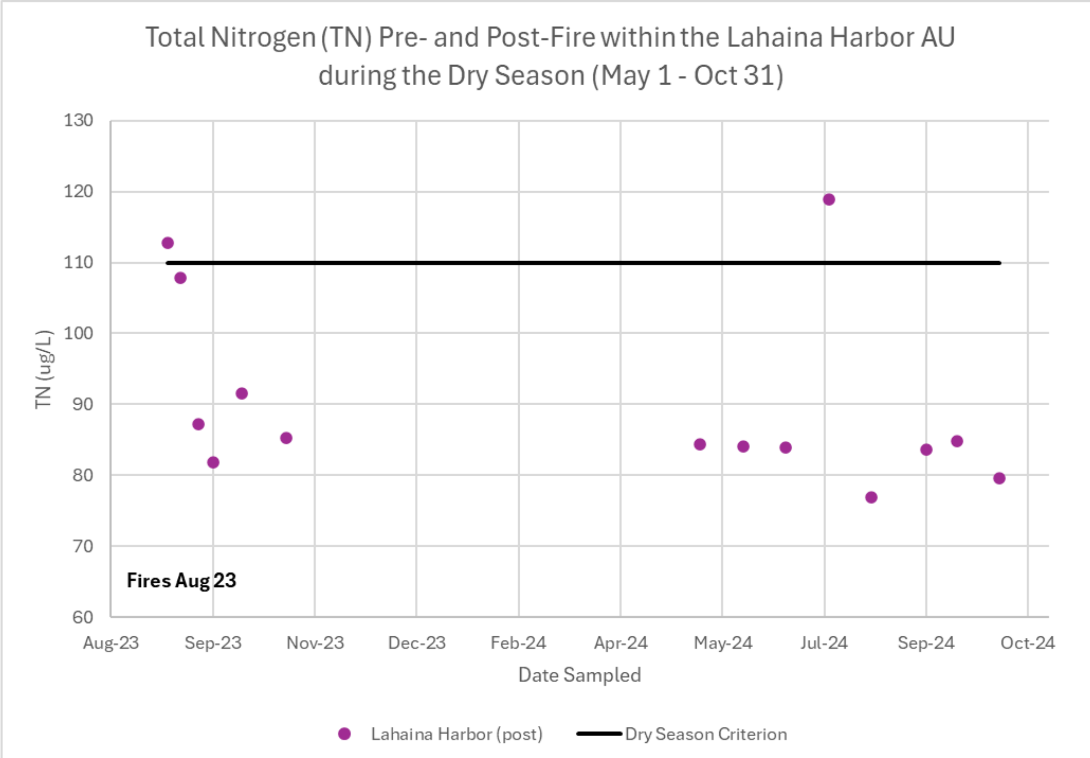

Figure 73. TN (µg/L) Pre- and Post-Fire during the Dry Season in the Lāhainā Harbor AU.

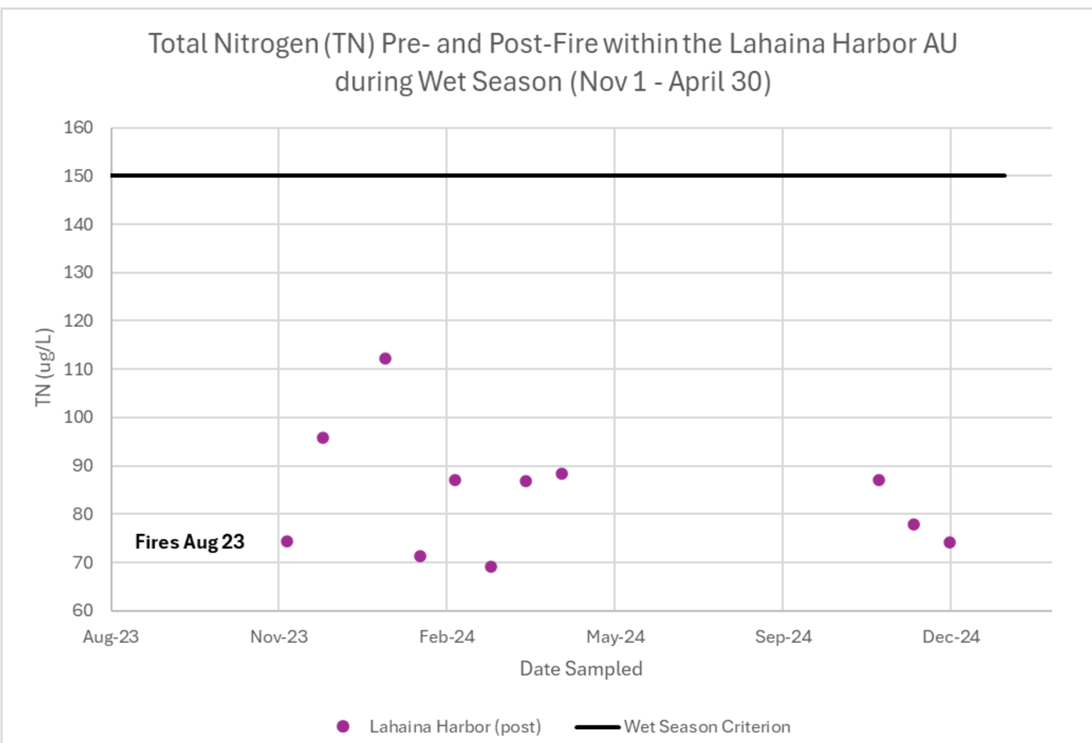

Figure 74. TN (µg/L) Pre- and Post-Fire during the Wet Season in the Lāhainā Harbor AU.

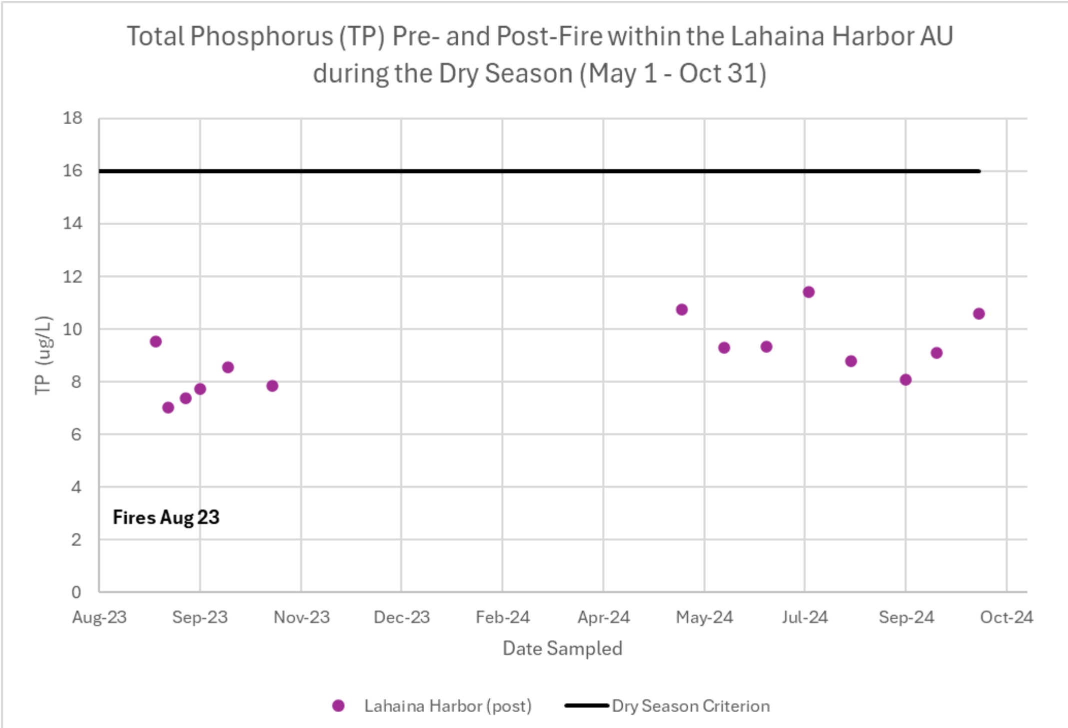

Figure 75. TP (µg/L) Pre- and Post-Fire during the Dry Season in the Lāhainā Harbor AU.

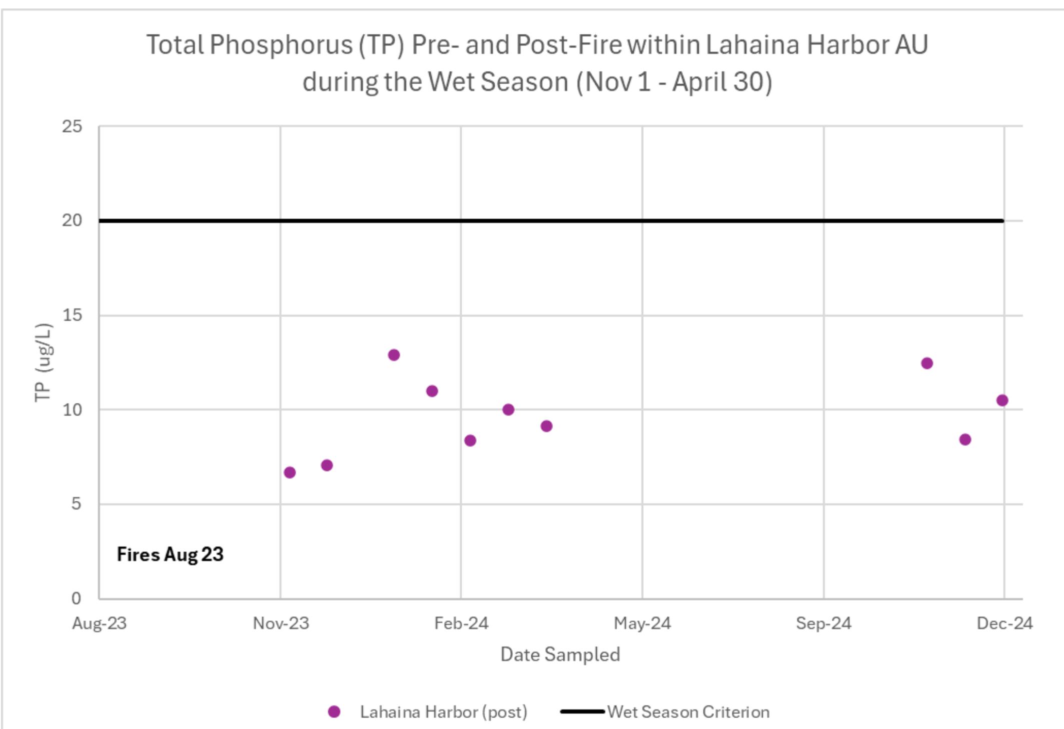

Figure 76. TP (µg/L) Pre- and Post-Fire during the Wet Season in the Lāhainā Harbor AU.

Note: TP values for 4/26/24 were excluded since they were apparently in error—see Section 4.2.1.11.2 for explanation.

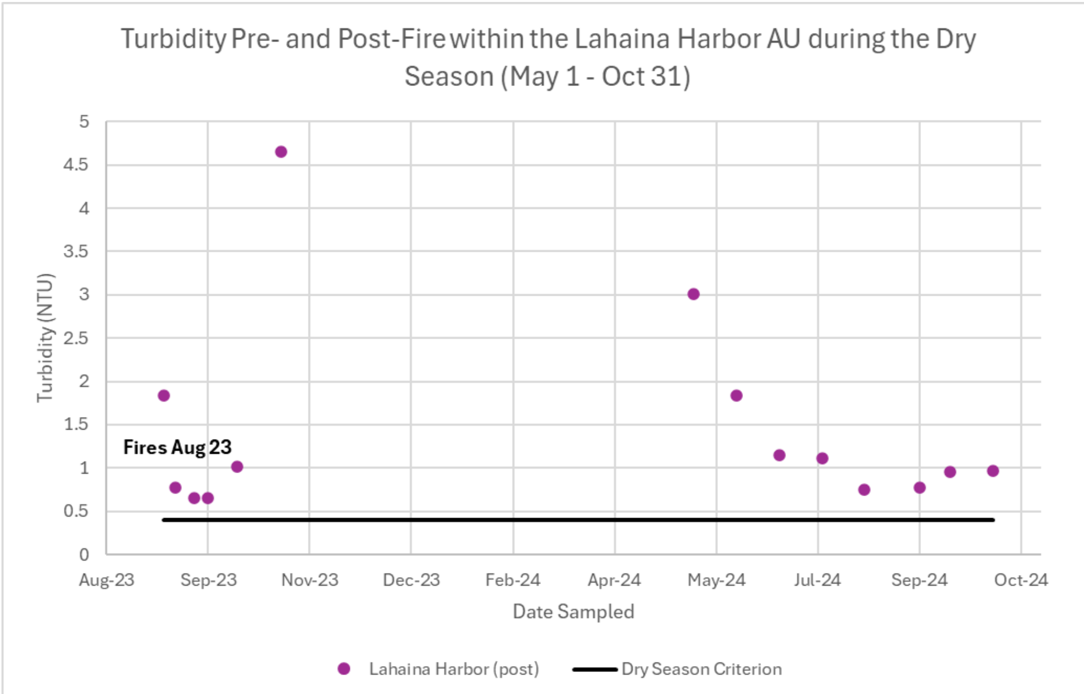

Figure 77. Turbidity (NTU) Pre- and Post-Fire during the Dry Season in the Lāhainā Harbor AU.

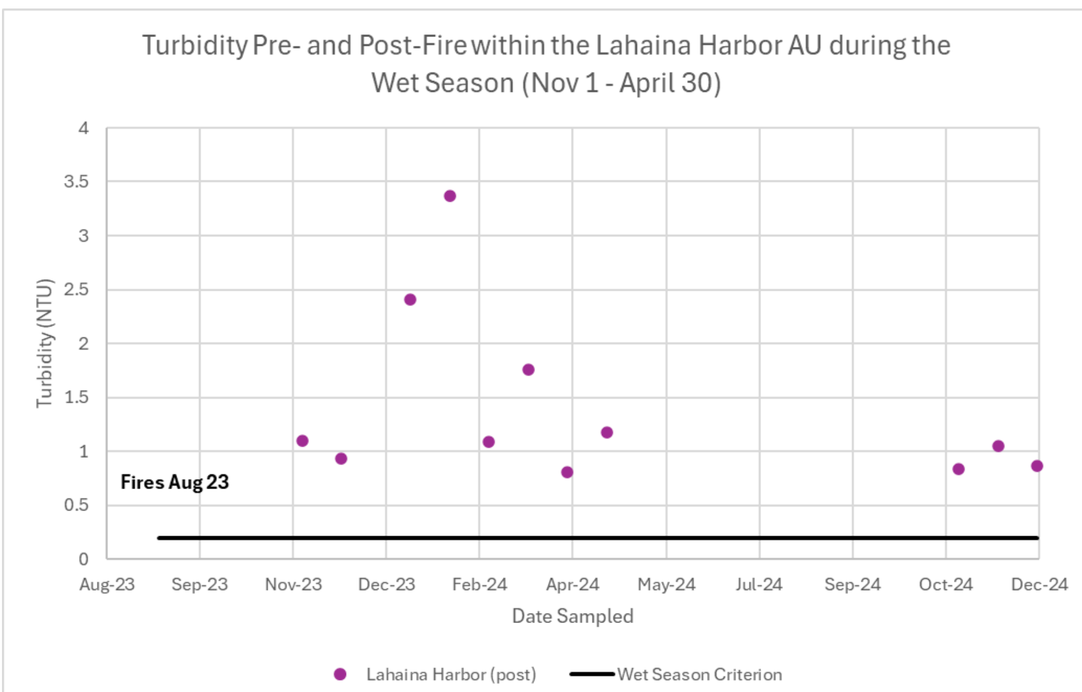

Figure 78. Turbidity (NTU) Pre- and Post-Fire during the Wet Season in the Lāhainā Harbor AU.

3.4.2.3 Bacteria

Coastal water samples taken by DOH provide context to *Enterococci* in nearshore coastal waters around Lāhainā (Hawaiʻi DOH 2025b, Callender et al. 2024). Data was available for pre- and post-fire samples within the Kahoma and Kauaʻula AUs. DOH conducted sampling at four monitoring locations that provided data from August 2005 to January 2025. Data was provided by DOH and separated by pre- and post-fire date. Geospatial analysis showed that two sites fell within the Kahoma Nearshore AU (*Wahikuli Beach and, Puʻunoa (Baby) Beach*) and two sites fell within the Kauaʻula Nearshore AU (*Lāhainā Town (#202) and Puamana)* (Figure 79). Results for *Enterococci* at each site within each AU were then graphically plotted.

Figure 80 and Figure 81 display *Enterococci* results for sites within the Kahoma and Kauaʻula AUs. Time plots were produced and include reference lines for recreational *Enterococci* criteria in all state waters, per Hawaiʻi Water Quality Standards. The reference lines are included for the sole purpose of comparing the relative magnitudes of sample values and do not represent whether criteria were attained or not attained. Evaluation of criteria attainment is based on comparing the criteria to summary statistics derived from multiple sample values (e.g., geometric mean and the 90th percentile value) rather than by comparing individual sample values to the numeric criteria.

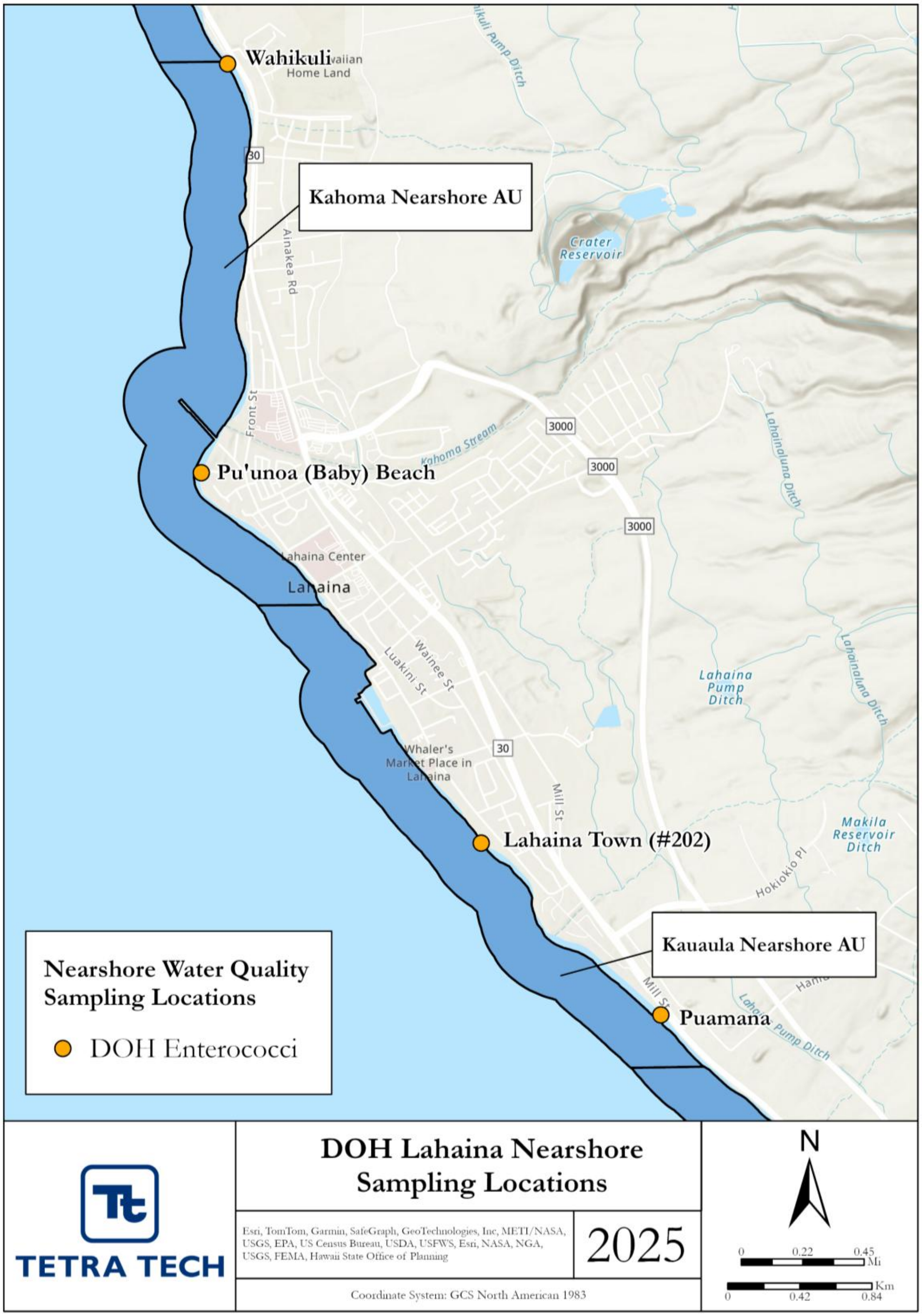

Figure 79. Nearshore DOH *Enterococci* Sampling Locations. (*Source: Hawai'i DOH 2025c*)

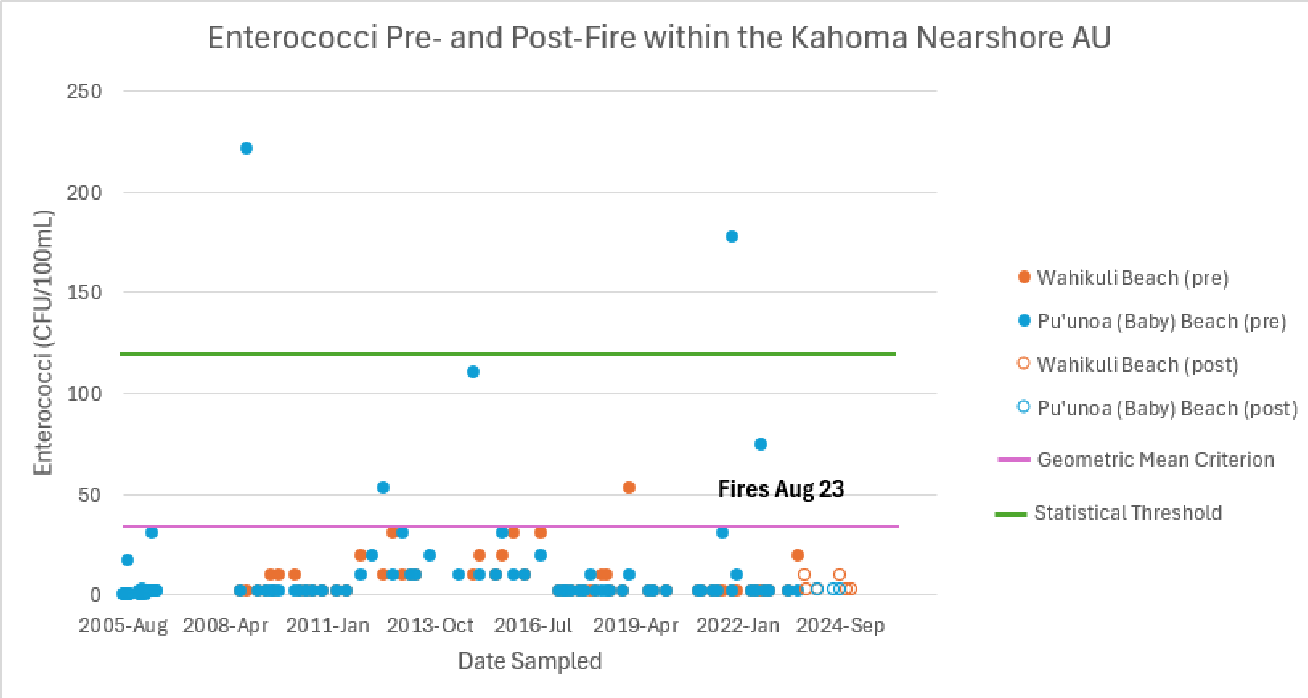

Figure 80. ***Enterococci*** **(CFU/100 mL) Pre- and Post-Fire in the Kahoma Nearshore AU.**

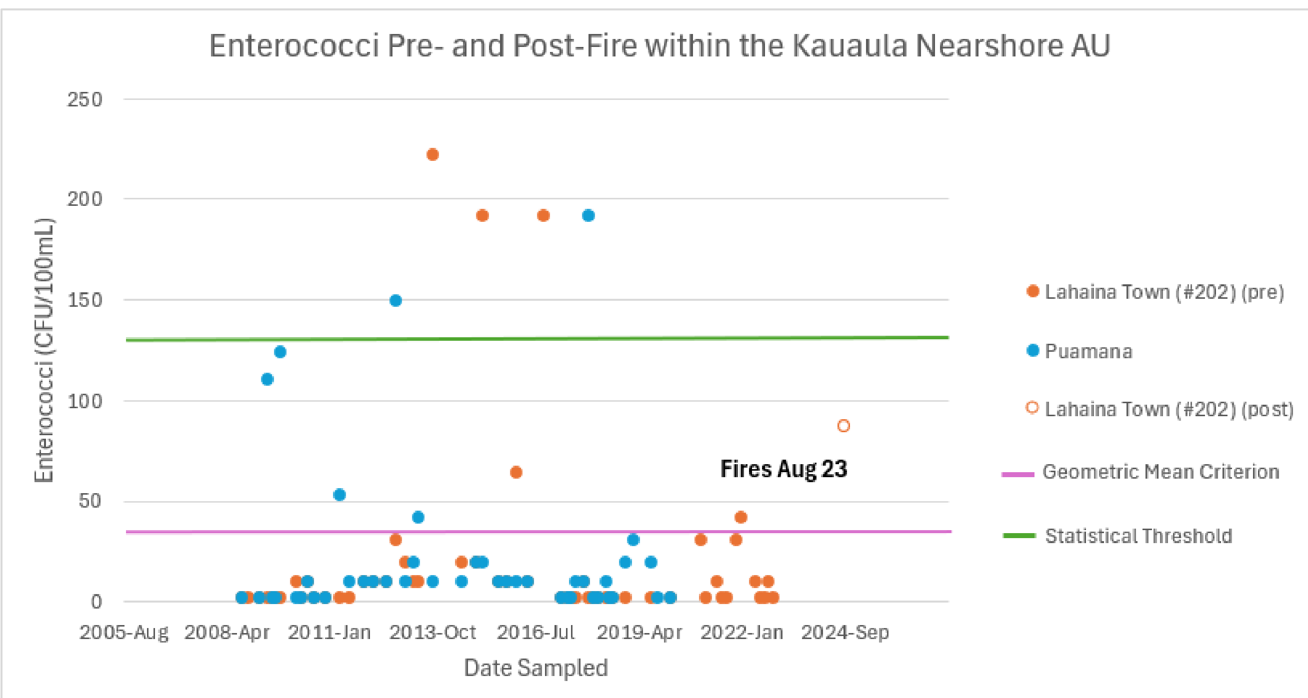

Figure 81. ***Enterococci*** **(CFU/100 mL) Pre- and Post-Fire in the Kauaʻula Nearshore AU.**

4.0 CAUSES AND SOURCES OF WATER QUALITY DEGRADATION

This section evaluates potential causes and sources of freshwater and marine water quality degradation associated with the Lāhainā wildfire as well as historical and ongoing land use and land management practices in the Kahoma and Kauaʻula watersheds. In this regard, both documented and potential causes of impairment to the designated uses of waterbodies in the Lāhainā area are addressed. Documented causes are those parameters (e.g., turbidity, total nitrogen) cited by DOH in CWA Section 303(d) impairment listings in the 2024 *State of Hawaii Water Quality Monitoring and Assessment Report* (Hawaiʻi DOH 2024a).

A potential cause of impairment in this plan is a pollutant for which DOH has not made a water quality standards attainment determination, yet recent data and information indicates that the pollutant may be causing impairment of a designated use. This evaluation addresses a variety of pollutants, some of which have associated data and information indicating that there is not a problem, while other pollutants have associated data and information suggesting that there may be a problem. These latter pollutants are referred to as potential causes of impairment in this plan and are summarized in Section 4.1.2.6.

Causes and Sources of Degradation

Water quality degradation in this section refers to a reduction in water quality due to the presence of one or more pollutants. When the level of a pollutant in a waterbody exceeds a water quality standard for a specific beneficial use (e.g., recreation), the impacted use of the waterbody is referred to as being *impaired*. *Causes* of water quality degradation can include pollutants such as bacteria, metals, nitrogen and phosphorus as well as parameters that provide an indication of water quality such as turbidity or DO. *Sources* of water quality degradation are the human-caused or natural conditions result in pollutants being delivered to waterbodies such as streambank erosion, cesspool discharges, urban stormwater runoff, and other types of sources.

The identification of potential causes of impairment in this plan is based on the precautionary principle. As applied in this plan, the precautionary principle holds that when there is scientific uncertainty about the potential harm from a pollutant, it is better to act to address the pollutant than to wait for conclusive evidence of harm (Kriebel et al. 2001). The identification of potential causes of impairment is used to guide the selection of relevant water quality protection management measures and practices. If further evaluation determines that a potential cause of impairment identified in this plan is not causing actual impairment, the selected measures and practices do not become irrelevant as they would remain applicable for preventing future impairment from that pollutant and potentially other pollutants.

In addition to available monitoring data for the Kahoma and Kauaʻula watersheds and their nearshore marine waters, data and information from studies and plans associated with nearby West Maui watersheds were used to help identify potential causes of impairment and probable pollution sources for water bodies of the Lāhainā area. This is because the Kahoma and Kauaʻula watersheds and their nearshore marine waters are similar to nearby watersheds and marine waters but have not been studied to the same extent as other West Maui watersheds and marine waters. The studies from other

West Maui watersheds and marine areas provide a reasonable basis for identifying potential causes and probable sources in the Lāhainā area due to general comparability regarding climate, geology, topography, soils, hydrology, vegetation communities, and land use history.

4.1 CAUSES OF WATER QUALITY IMPAIRMENT

The first subsection below identifies the documented cause of water quality impairment as determined through the DOH 303(d) listing process. This is followed by a subsection that identifies additional potential causes of water quality degradation.

4.1.1 Documented Causes of Impairment

DOH uses readily available water quality data and other information to assess whether water quality standards (i.e., designated uses, numeric/narrative criteria, and antidegradation policies) are attained in Hawaii's fresh and marine waters (Hawaiʻi DOH 2024a). Determinations of whether water bodies are meeting water quality standards are reported to the Environmental Protection Agency every two years in a document called the *Integrated Report*, which is part of the *2024 State of Hawaii Monitoring and Assessment Report* cited above. The 303(d) list is the portion of the report that identifies waterbodies whose designated uses (e.g., recreational use, aquatic life use) are impaired by pollutants.

The results of the 2024 Integrated Report for fresh and marine waters that have been assessed in the Kahoma and Kauaʻula watersheds are summarized below in Table 18. This is followed by brief discussions of the documented water quality impairments.

Table 18. Waters in the Lāhainā area with 303(d) listed impairments

Assessment Unit	Waterbody ID	Wet/Dry Seasonal Criteria	Cause of Impairment[1]
Kahoma Stream	6-1-05	N/A	Turbidity
Kahoma Nearshore	HIW20009	Dry	Chlorophyll-a, $NO_3 + NO_2$, NH_4, Turbidity
Māla Wharf-West Maui Coast[2]	HIW00123	Dry	Chlorophyll-a, Turbidity
Pu'unoa Beach[2]	HI373055	Dry	Turbidity
Wahikuli State Wayside Park[2]	HI169380	Dry	Chlorophyll-a, $NO_3 + NO_2$, Turbidity
Kauaʻula Nearshore	HIW20012	Dry	$NO_3 + NO_2$, NH_4, Turbidity
Lāhainā Beach[3]	HI407363	Dry	$NO_3 + NO_2$, NH_4, Turbidity
West Maui-Puamana[3]	HIW00080	Dry	Chlorophyll-a, Turbidity
Lāhainā Harbor	HIW00137	Dry	Turbidity

Notes:
[1] $NO_3 + NO_2$ = Nitrate plus Nitrite; NH_4 = Ammonia
[2] Individual waterbodies associated with the Kahoma Nearshore Assessment Unit.
[3] Individual waterbodies associated with the Kauaʻula Nearshore Assessment Unit.

4.1.1.1 Freshwaters

There is limited water quality data and information for the Kahoma and Kauaʻula watersheds. Kahoma Stream is included on Hawaii's 2024 section 303(d) impaired waters list due to turbidity. The listing originally dates back to visual assessments completed between 2001 and 2004 (Hawaiʻi DOH 2024a) that determined noncompliance with the water quality criteria at HAR Section 11-54-4 (a)(3):

> *All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including: substances in amounts sufficient to produce taste in the water or detectable off-flavor in the flesh of fish, or in amounts sufficient to produce objectionable color, turbidity, or other conditions in the receiving waters*
> (Hawaiʻi DOH 2021)

According to the 2024 Integrated Report, there is insufficient data to assess potential impairment due to *Enterococci* and nutrients (i.e., Total Nitrogen [TN], Nitrite + Nitrate [NO_2 + NO_3], Total Phosphorus [TP]) for the Kahoma watershed (Hawaiʻi DOH 2024a).

Kauaʻula Stream (Waterbody ID 6-1-04) does not have any identified 303(d) impairment listings in Hawaii's 2024 Integrated Report. This is not necessarily due to an absence of water quality problems, as DOH has determined that there is insufficient data/information to assess Kauaʻula Stream for impairment due to *Enterococci*, nutrients, turbidity, or total suspended solids (TSS) (Hawaiʻi DOH 2024a).

4.1.1.2 Marine Waters

There are three main marine AUs associated with the Kahoma and Kauaʻula watersheds: the Kahoma nearshore marine AU, the Kauaʻula nearshore marine AU, and the Lāhainā Harbor AU. DOH is in the process of consolidating individual marine waterbodies (e.g., Puʻunoa Beach) into larger marine AUs (i.e., the Kahoma nearshore marine AU and the Kauaʻula nearshore marine AU). Pending completion of the consolidation, the 303(d) list contains listings for the larger nearshore marine AUs as well as their associated waterbodies.

DOH has identified nutrients (Nitrate plus Nitrite [NO_2 + NO_3], Ammonia [NH_4]), chlorophyll-a, and turbidity as causes of water quality impairment for nearshore marine waters in the Lāhainā area (Hawaiʻi DOH 2024a). These listings are the result of routine marine water quality monitoring undertaken by DOH and its partners (e.g., Surfriders, HOKWO).

4.1.2 Potential Causes of Impairment

In addition to the documented water quality impairments identified above, other pollutants may cause or contribute to water quality impairments in the Lāhainā area. The following subsections evaluate readily available data and information to determine if the Recreational and Aquatic Life designated uses of fresh and marine waterbodies in the Lāhainā area are potentially impacted by pollutants not currently identified as impairments on Hawaiʻi's 303(d) list. The evaluation addresses sediment, nutrients (e.g., nitrogen and phosphorus), *Enterococci* bacteria, heavy metals (e.g., As, Cu, Pb, Ni), and POCs (e.g., PAHs, TEQ Dioxins). The evaluation does not address contaminants in groundwater relative to drinking water quality standards or marine organism tissue relative to water quality standards for human consumption of fish and shellfish.

4.1.2.1 Sediment

This section focuses on potential impairment of aquatic life designated uses in fresh and marine waters by sediment (i.e., sedimentation, the benthic accumulation of fine sediment particles in waterbodies).

Although sedimentation and turbidity are often related, they can affect aquatic life in different ways and are therefore typically assessed separately. Turbidity is addressed in the previous section on documented causes of impairment. Section 4.2.1.11 includes an evaluation of the effects of the fire upon turbidity levels in the nearshore marine AUs.

The Hawaiʻi narrative water quality criteria relevant to sediment pollution is HAR Section 11-54-4 (a)(6):

> *All waters shall be free of substances attributable to domestic, industrial, or other controllable sources of pollutants, including: Soil particles resulting from erosion on land involved in earthwork, such as the construction of public works; highways; subdivisions; recreational, commercial, or industrial developments; or the cultivation and management of agricultural lands* (Hawaiʻi DOH 2021)

The U.S. Army Corps of Engineers (USACE) and the USGS have identified sediment as a cause of coral reef ecosystem degradation throughout West Maui nearshore marine waters (USACE 2023, Storlazzi et al. 2023). Sedimentation generally occurs within sheltered areas harboring coral reefs, whereas turbidity and suspended sediment tend to be more problematic along the open coastline (Storlazzi et al. 2023). When "brown water" events occur periodically along the West Maui coastline, a portion of the materials responsible for creating the turbid water is deposited on the surface of the ocean floor and coral reefs. Information presented by USACE indicates that clay and silt cause more stress to coral reefs than sand because sand is easier for corals to remove from their bodies and does not resuspend and block sunlight (USACE 2023). As discussed later in the Sources section, USGS sediment budgets for neighboring watersheds suggest that anthropogenic sediment loads delivered to marine waters from Kahoma and Kauaʻula streams may be in excess of 42 metric tons per year for each stream (Stock and Cerovski-Darriau 2021).

There is a lack of data and information addressing sedimentation as a cause of impairment to aquatic life in streams of the Kahoma and Kauaʻula watersheds. However, erosion of anthropogenic sediment deposits in stream banks is a documented source of anthropogenic sediment along most low elevation stream reaches in West Maui (Stock and Cerovski-Darriau 2021). Sediment is therefore considered to be a potential cause of impairment to both Kahoma and Kauaʻula streams. Monitoring and assessment work to quantify sediment sources and in-channel sediment conditions (potentially in concert with aquatic biological community assessment) in the Kahoma and Kauaʻula watersheds would aid in evaluating sediment as a potential cause of aquatic life impairment.

4.1.2.2 Nutrients

DOH has identified $NO_3 + NO_2$ and NH_4 as causes of impairment to the Kahoma and Kauaʻula marine AUs (see Section 4.1.1) and has determined that TN and TP meet numeric criteria in both AUs (Hawaiʻi DOH 2024a). Section 4.2.1.11 includes an evaluation of the effects of the fire upon nutrient levels in the nearshore marine AUs.

DOH has not assessed the attainment of nutrient criteria in Kahoma and Kauaʻula streams (Hawaiʻi DOH 2024a). The discussion below focuses on nutrients as a potential cause of impairment to these streams.

Many of the streams along the leeward side of West Maui flow on an intermittent basis due to seasonal rainfall patterns and/or stream diversions. The only recent readily available nutrient data consists of a single post-fire sample event on Kahoma Stream in January 2024 by USGS (USGS 2025); the results were classified by USGS as provisional at the time they were accessed for this plan. The sample value for total P was 23 µg/L, which is well below Hawaiʻi's wet season (applicable Nov. 1 through April 30) geometric mean criterion of 50 µg/L for streams (Hawaiʻi DOH 2021). Kjeldahl nitrogen (NH_4 + organic nitrogen as N) and inorganic nitrogen (NO_3 + NO_2 as N) were also analyzed, with sample values of 270 µg/L and 130 µg/L, respectively. The NO_3 + NO_2 value exceeds Hawaiʻi's wet season geometric mean criterion of 70 µg/L for streams but is below the criterion of 180 µg/L not to be exceeded 10% of the time (Hawaiʻi DOH 2021). Adding the Kjeldahl nitrogen value and the NO_3 + NO_2 value together can be used to estimate the TN value at the time of the January 2024 sampling. The resulting estimated TN value of 400 µg/L exceeds Hawaiʻi's wet season geometric mean criterion for streams of 250 µg/L but is below the criterion of 520 µg/L not to be exceeded 10% of the time (Hawaiʻi DOH 2021). Since there is no recent pre-fire nutrient data, it is not possible to evaluate if these nutrient concentrations were affected as a result of the fire.

Where sufficient nutrient data exist for streams on the Hawaiian Islands, evidence of impairment of streams by nitrogen and phosphorus are a fairly widespread occurrence (Hawaiʻi DOH 2024a). Nutrient impairments appear to be more likely in watersheds with agricultural land use, urban runoff, and residential/commercial sewage cesspools. Cesspools occur in both the Kahoma and Kauaʻula watersheds (Hawaiʻi DOH 2017), and runoff from agricultural lands and urban areas also occurs (Munekiyo and Hiraga, Inc. 2003). Based on the January 2024 monitoring data (USGS 2025), NO_3 + NO_2 and TN can be considered potential causes of impairment to Kahoma Stream. Although there are no data available for Kauaʻula Stream, NO_3 + NO_2 and TN are also potential causes of impairment based on similarities in land use and potential sources to the Kahoma watershed as well as other Hawaiian streams with identified nutrient impairments. It is recommended that wet and dry season monitoring—when flow conditions permit—occur to determine if the criteria for TN, NO_3 + NO_2, and TP are being met.

4.1.2.3 Enterococci

DOH has determined that *Enterococci* bacteria levels meet criteria within the Kahoma nearshore marine AU (Hawaiʻi DOH 2024a). DOH has not determined if the Kauaʻula nearshore marine AU meets *Enterococci* bacteria levels criteria, although a determination has been made that two waterbodies within the AU (Lāhainā Beach and Puamana Beach Count Park) meet criteria (Hawaiʻi DOH 2024a). A cursory analysis of DOH beach monitoring data (Hawaiʻi DOH 2025c) associated with the Kauaʻula nearshore marine indicates that *Enterococci* meets Hawaiʻi's geometric mean (35 CFU or most probable number (MPN) per 100 mL) and STV (130 CFU or MPN per 100 mL) criteria (Hawaiʻi DOH 2021). Although *Enterococci* is not an identified cause of impairment to recreational uses of Kahoma or Kauaʻula nearshore AUs, concentrations of *Enterococci* ranging up to 178 MPN per 100 mL in the Kahoma nearshore AU and 500 MPN per 100 mL in the Kauaʻula nearshore AU have been observed since 2019 (Hawaiʻi DOH 2025c). Although the elevated levels of *Enterococci* appear to occur infrequently, bacteria management practices (e.g., urban stormwater best management practices (BMPs), cesspool conversion) are recommended to ensure that marine recreational uses continue to be protected.

There are no recent *Enterococci* sampling data available for either Kahoma Stream or Kauaʻula Stream. However, the marine sampling data showing periodic high levels of bacteria (which tend to coincide with brown water events) suggest that two streams may convey elevated loads of bacteria to marine waters. Additionally, exceedance of the recreational water quality criteria for *Enterococc*i in Hawaiian streams is a frequent enough occurrence in watersheds with cesspools located near streams that it can be considered a potential cause of impairment for both streams (Hawaiʻi DOH 2024a, Shuler et al. 2021). Cesspools are considered a probable source of impairment for Kauaʻula stream, but not Kahoma stream, based on an inventory of cesspool locations in the Kahoma and Kauaʻula watersheds (see Section 4.2.1.3) (Shuler eta al. 2021). Additional probable sources include non-native wildlife (see Section 4.2.1.8) and urban runoff (see Section 4.2.1.13). Wet and dry season *Enterococci* monitoring is needed to evaluate attainment of recreational criteria (when flow conditions allow).

4.1.2.4 Metals

Elevated concentrations of heavy metals (e.g., As, Cd, Cu, Cr, Pb) are known to cause harm to marine organisms including corals (Dal Pizzol et al. 2022, Neff 1997). The following discussion addresses potential impairment of aquatic life and recreational uses of waters from metals in the water and sediment of fresh and marine waters associated with the Kahoma and Kauaʻula watersheds.

4.1.2.4.1 Marine Sediment

DOH's monitoring and assessment of coastal sediment samples in the Kahoma and Kauaʻula nearshore AUs has determined that levels of metals do not pose a significant concern for human health resulting from contact during recreational activities (Hawaiʻi DOH 2025b). Therefore, metals levels in sediment are not considered to be a potential impairment of the recreational uses of these marine AUs. The discussion below focuses on potential impairment of aquatic life uses by metals in marine sediment.

Marine and beach sediment samples collected by DOH, Hawaiʻi DLNR, and USGS were compared to NOAA screening quick reference tables (SQuiRTs) which contain sediment quality thresholds used to identify pollutant levels that may have adverse effects upon aquatic life (Buchman 2008). The sediment quality guidelines used for comparison here are not Hawaiʻi water quality standards, nor are they indicators of toxicity, but are instead a tool to assess the risk of potential harm to aquatic life. The SQuiRTs tables were retired by NOAA in 2024; however, the Probable Effects Threshold (PEL) values used in this evaluation continue to be used to identify priority areas for nonpoint source management actions, e.g., within Canadian and Floridian sediment quality guidelines (CCME 2025, FDEP 2025, MES 1994). The Apparent Effects Threshold (AET) was used for comparison when a PEL was not available for a parameter.

Table 19 below identifies a subset of metals that were examined to determine if sample values exceeded marine PELs and AETs at marine and beach sampling sites. Note that not all sampled parameters and locations are displayed in this table.

Table 19. Coastal Sediment Metals Sampling Results, November 2023 through February 2025.

Waterbody AU ID	Site	Agency[1]	Sample Media	Do sample values exceed an aquatic life sediment quality threshold?[2]									
				Sb	As	Co	Cr	Cu	Pb	Ni	Se	V	Zn
HI643627	Kahekili Beach[3]	DOH	Marine sediment	N	N	N	N	N	N	Y	N	N	N
HIW20009	Māla Boat Ramp	USGS	Beach sediment	N	N	N	N	N	N	N	N/A	N	N
HIW20009	Māla Wharf	DOH	Marine sediment	N	N	N	N	N	N	Y	Y	Y	N
HIW20009	Offshore Kahoma Stream	USGS	Marine sediment	N	N	Y	Y	Y	N	Y	N/A	Y	N
HIW20009	Pu'unoa (Baby) Beach	DOH	Marine sediment	N	N	N	N	N	N	Y	Y	N	N
HIW20009	Turtle Rock	USGS	Beach sediment	N	N	N	N	N	N	N	N/A	N	N
HIW00137	Inshore Ferry Dock	USGS	Marine sediment	Y	Y	Y	Y	Y	N	Y	N/A	Y	Y
HIW00137	Inshore Lāhainā Harbor	USGS	Marine sediment	Y	Y	Y	Y	Y	N	Y	N/A	Y	Y
HIW00137	Lāhainā Harbor Sites (12 sites)[4]	DLNR	Marine sediment	N	N	N/A	N	Y	N	N	N	N/A	N
HIW20012	Front Street 505	USGS	Beach sediment	N	N	N	N	N	N	N	N/A	N	N
HIW20012	Kamehameha Iki Park	DOH	Marine sediment	N	N	N	N	N	N	Y	Y	N	N
HIW20012	Offshore Lāhainā Harbor	USGS	Marine sediment	N	N	Y	Y	Y	N	Y	N/A	Y	N
HIW20012	Outfall K[5]	USGS	Beach sediment	Y	Y	Y	Y	Y	Y	Y	N/A	Y	Y
HIW20012	Outfall O[6]	USGS	Beach sediment	N	N	Y	Y	Y	N	Y	N/A	Y	Y
HIW20012	Outfall R[7]	USGS	Beach sediment	N	N	Y	Y	N	N	Y	N/A	Y	Y
HIW20012	Shark Pit - Puamana	DOH	Marine sediment	N	N	N	N	N	N	Y	Y	Y	N
6-1-05	Kahoma Stream Lower Reach	USGS	Beach sediment	N	N	Y	Y	Y	N	Y	N/A	Y	N

Source: Hawaiʻi DOH (2025b)

Notes:

[1] Sampling methodology differed by agency. DOH collected composite samples of the top 2 inches of sediment using a multi-increment method; the samples were collected for the purpose of evaluating potential human health risks. DLNR samples represent individual sediment cores ranging from approximately one-half to four feet below the sea floor; the samples were collected to perform a screening-level evaluation of the suitability for sediment dredging and disposal. USGS collected a single grab sample (i.e., non-composite sample) at each site; the samples are intended to provide a screening-level indication of ecosystem contamination. The differences in sampling and analysis methodology prevent direct comparison among samples collected by different agencies, yet do not prevent their use in performing a screening level evaluation of potential harm to aquatic life uses through comparison to sediment quality guidelines.

[2] For any individual parameter in the table, a "Y" indicates that the parameter exceeded a PEL or AET in one or more samples at the corresponding site in column two. N/A means the site was not sampled for the associated parameter. Metals abbreviations: Sb = Antimony; As= Arsenic; Co = Cobalt; Cr = Chromium; Cu = Copper; Pb = Lead; Se = Selenium; V = Vanadium; Zn = Zinc.
[3] Kahekili Beach to the north of Lāhainā was used to represent sediment values at a site unimpacted by the wildfire.
[4] Results for all 12 DNLR sites associated with Lāhainā Harbor have been aggregated together.
[5] Located approximately 300 ft northwest of the intersection of Front Street and Market Street.
[6] Located near the intersection of Front Street and Lahainluna Road.
[7] Located approximately 200 ft southeast of the Lāhainā Harbor seawall.

Several metals in the Kahoma and Kauaʻula nearshore AUs and the Lāhainā Harbor AU exceed PETs and AETs used to identify potential harm to aquatic life (Table 1919). Most of the sites evaluated show slight exceedances of the non-regulatory aquatic life sediment quality thresholds for two or more metals, except for sites in Lāhainā Harbor and in the vicinity of stormwater outfalls, where concentrations of certain metals (e.g., Arsenic [As], Chromium [Cr], Copper [Cu], Nickel [Ni], Lead [Pb], Vanadium [V], and Zinc [Zn]) tend to exceed sediment quality thresholds by a greater margin. Notable exceptions are that beach sediment at Turtle Rock, Māla Boat Ramp, and Front Street 505 showed no exceedances of sediment quality thresholds for metals.

Metals concentrations tended to be greater in USGS samples than in DOH and DLNR samples. The USGS samples were collected using less rigorous protocols (grab samples representing a small area) than the DOH protocols (multi-increment sampling), which prevent their use for confirming human health risks (Hawaiʻi DOH 2025b). However, the data does have value for identifying potential impairment to aquatic life that can be addressed through additional monitoring and assessment.

Some context for these metals levels is provided by a study of metals concentrations (Silver [Ag], As, Cadmium [Cd], Cobalt [Co], Cu, Cr, Manganese [Mn], Ni, Pb, V, Zn) in marine sediments conducted by Hédouin et al. (2009), which included multiple stations at a site in Honolua Bay, Maui. Hédouin et al. (2009) compared metals concentrations to the Sediment Quality Guidelines developed by NOAA, which characterize concentrations of metals that have adverse effects on biological organisms (Buchman 2008). Within the guidelines, the Threshold Effect Level (TEL) represents the concentration below which adverse effects rarely occur; the Effect Range-Low (ERL) corresponds to concentration above which negative effects are more common, and the Effect Range-Median (ERM) corresponds to concentrations at or above which negative effects frequently occur. The evaluation found that Ni levels (up to 464 ppm) in Honolua Bay were greater than at the other two study locations on other Hawaiian Islands, exceeding the ERM (51.6 ppm) at three stations; As exceeded the ERL (8.2ppm) at two stations; Cd exceeded the TEL (0.676ppm) at one station and the ERL (1.2ppm) at two stations; and Cr levels exceeded ERL (81 ppm) at two stations. This study indicates that elevated levels of metals in nearshore marine sediment on Maui are not anomalous.

The metal concentrations in DOH marine sediment samples (Hawaiʻi DOH 2025b) are generally comparable to values observed by Hédouin et al. (2009) in Honolua Bay, Maui, except for As and Pb displaying notable differences. As values up to 25 ppm were observed by DOH, while those in Honolua Bay were all below 10ppm. Pb levels in Honolua Bay ranged up to 0.37 ppm, while in the Lāhainā area, Pb ranged up to 6.35 ppm at Māla Wharf. Metals concentrations at several sites (e.g., Inshore Ferry

Dock, Inshore Lāhainā Harbor, Outfall K, Outfall O, Outfall R) sampled by USGS (Hawaiʻi DOH 2025b) ranged much higher than those observed in Honolua Bay.

It appears that the marine sediment metals levels primarily reflect long-term conditions rather than the effects of the fire. There is no evidence that metals-laden ash transported by wind or runoff into marine waters was deposited into the sediments of nearshore waters, which are continuously mixing, although less so for the sheltered waters in Lāhainā Harbor. It seems more likely that any ash particles transported from land would be suspended in the water and carried further offshore by tidal and other currents. Metals levels at the Kahekili Beach reference site were generally lower than at sites in the fire-affected area, suggesting that the sediment metals in the Kahoma and Kauaʻula nearshore marine AUs and Lāhainā Harbor are elevated; however, tests of statistical differences were not performed. An exceedance of the aquatic life sediment PEL by Nickel at the Kahekili Beach site indicates that wildfire is not a source of elevated Nickel in the Kahoma and Kauaʻula nearshore marine AUs; the Nickel values at Kahekili may reflect a natural condition or an anthropogenic source such as urban runoff or erosion of metals-containing soils on agricultural lands. Furthermore, the absence of any sediment quality threshold exceedances in beach sand at the Turtle Rock and Māla Boat Ramp sites (Kahoma nearshore marine AU) and the Front Street 505 site (Kauaʻula nearshore marine AU) contrasts with observed aquatic life sediment threshold exceedances at nearby Lāhainā marine sediment sites. This indicates that metals levels in marine sediments display a high degree of spatial variability. When considering elevated metals in marine sediment observed by Hédouin et al. (2009), the available data and information suggest that the wildfire is not the primary source of the observed metals in the Kahoma and Kauaʻula marine sediments, although the wildfire effects may contribute to the observed metals concentrations in sediment. Further information regarding wildfire as a source of pollutants is discussed in Section 4.2.1.11.

The reason why different metals are elevated at different locations is unknown. For example, the beach sand at the stormwater Outfall K site exceeds the 95th percentile of soil background concentrations for As, Cu, Pb, and Zn (AECOM 2012). A short distance away from Outfall K, beach sand at the stormwater Outfall O site exceeded the 95th percentile of soil background concentrations for Cr, Ni, V, and Zn. The spatially variable sediment metals results may reflect a combination of the following factors:

- Insufficient representation by sampling protocols, e.g., the DOH samples were spatially composited samples, but the USGS samples were not.
- Variability in the source of the metals, e.g., spatially variable metals deposition associated with stream inputs (Hédouin et al. 2009) and urban runoff outfalls (Andrews and Sutherland 2004, De Carlo and Spencer 1997).
- Variability in hydrologic conditions, e.g., the effects of currents and waves upon sediment deposition.
- Variation in sediment particle size distribution among sites: it is known that samples of fine sediment tend to display greater concentrations of metals than coarse sediment (O'Connor 2004).

Additional monitoring and assessment work is recommended to address sediment metals levels as a potential cause of impairment to marine aquatic life within the nearshore marine AUs. Verification of sediment metals concentrations would be useful, particularly for the sites sampled by USGS. This would involve ensuring that all sites with apparently elevated metals are appropriately characterized using standard DOH protocols, which require collecting composite samples of sediments. This would also help to determine the spatial extent of any verified instances of elevated metals; if found to be a localized phenomenon within an AU, a determination that the aquatic life designated use of the AU is impaired may not be warranted. Additionally, assessment work to evaluate sediment metals toxicity to aquatic life would be valuable, because the degree of bioavailability of the different metals in the sediments under the current marine biogeochemical conditions is unknown. This type of evaluation would not only benefit water quality planning for the Lāhainā area, but for the Hawaiian Islands in general since exceedances of sediment quality thresholds by metals in marine sediment appears to be a common occurrence.

4.1.2.4.2 Marine Water

The following discussion focuses on potential impairment of marine aquatic life as DOH has determined that post-fire metals concentrations in the Kahoma and Kauaʻula nearshore marine waters are below levels of concern to human health (Hawaiʻi DOH 2025b).

Post-fire data for total recoverable and dissolved metals are available as a result of DOH and Surfrider monitoring (Hawaiʻi DOH 2025b). The dissolved fraction of individual metals analyzed were generally well below Hawaiʻi's acute and chronic saltwater criteria (Hawaiʻi DOH 2021). However, dissolved copper slightly exceeded the acute criterion (which is equal to the chronic criterion) of 2.9 µg/L at two sites. In June 2024, the concentration was 3.17 µg/L in the Lāhainā Harbor AU and 5.26 µg/L at the Pāpalaua Street site in the Kahoma nearshore AU. Based on these results, Cu can be considered a potential threat to aquatic life in the Lāhainā Harbor AU and Kahoma nearshore AU. Additional monitoring and assessment are needed to more fully evaluate copper concentrations at these two locations.

4.1.2.4.3 Freshwater Sediment

In January 2024, USGS collected sediment samples from the Kahoma stream sediment retention basin (site name Kahoma Stream upper basin) just downstream of the Lāhainā Bypass and the lower reach of Kahoma stream (Hawaiʻi DOH 2025b). In comparison to freshwater sediment quality thresholds, Cr, Co, Ni, and V exceeded the respective PELs (or AET when a PEL was unavailable) at both sites (Buchman 2008). Co exceeded the sediment quality guidelines by a slight margin, whereas the margin was greater for exceedances of Cr, Ni, and V. No samples are available from sediments in Kauaʻula stream, but it is likely that sediment metals are comparable to those in Kahoma stream. Additional monitoring and assessment are needed to more fully evaluate potential impairment of Kahoma and Kauaʻula streams by metals in sediment.

4.1.2.4.4 Freshwater

USGS analyzed total recoverable metals in a single sample collected in January 2024 from the lower reach of Kahoma stream; the results were classified by USGS as provisional at the time they were accessed for this plan (USGS 2025). Several of the metals (Ag, Cd, Cr, Cu, Zn) were below detection limits. Values for other metals (e.g., As, Ni, Pb) were below Hawaiʻi's water quality criteria for dissolved metals, indicating that the dissolved fraction for these metals could not have exceeded the criteria since total recoverable metals include both the particulate and dissolved fractions. Based on the limited data, dissolved metals are not a potential cause of impairment. However, monitoring of total recoverable metals and discharge in Kahoma and Kauaʻula streams and stormwater outfalls to marine waters would enable evaluation of metals loading into the nearshore marine AUs. Additionally, sampling of dissolved copper in the two streams and in stormwater outfalls would help address the apparent exceedance of the dissolved copper acute criterion in Lāhainā Harbor and at the Pāpalaua site in June 2024.

4.1.2.5 Persistent Organic Chemicals

This following discussion addresses potential impairment of aquatic life and recreational uses of waters from POCs in the water and sediment of fresh and marine waters associated with the Kahoma and Kauaʻula watersheds.

4.1.2.5.1 Marine Sediment

DOH's monitoring and assessment of coastal sediment samples in the Kahoma and Kauaʻula nearshore AUs determined that levels of POCs (e.g., PAHs, TEQ Dioxins) do not pose a significant concern for human health resulting from contact during recreational activities (Hawaiʻi DOH 2025b). Therefore, levels of POCs in sediment are not considered to be a potential impairment of the recreational uses of these marine AUs. The discussion below focuses on potential impairment of aquatic life uses by POCs in marine sediment.

Both DLNR and USGS have collected post-fire sediment samples for analysis of Dioxins and PAHs. DLNR monitoring focused on marine sediments in Lāhainā Harbor whereas USGS collected marine sediment and beach sediment samples more widely. PAHs were below sediment quality PEL and AET thresholds at all sites sampled. Five of 20 TEQ Dioxins sample values collected by DLNR within Lāhainā Harbor slightly exceeded the PEL of 2.15E-5 ppm (0.0000215 mg/kg). For the USGS samples, TEQ Dioxins slightly exceeded the PEL in 1 of 2 samples at the Inshore Ferry Dock site (located at the mouth of the Lāhainā Harbor). Based on these results, TEQ Dioxins may be considered a potential cause of impairment for the Lāhainā Harbor marine AU.

4.1.2.5.2 Marine Water

DOH determined that POC levels in coastal waters within the Kahoma and Kauaʻula nearshore AUs are below levels of concern to human health (Hawaiʻi DOH 2025b). Therefore, levels of POCs in marine water are not considered to be a potential impairment of the recreational uses of these marine AUs. The discussion below focuses on potential impairment of aquatic life uses by POCs in marine water.

PAHs were detected in few samples collected by Surfriders in January 2024. PAHs (e.g., Chrysene, Pyrene, Fluoranthene) were only detected at the Pāpalaua Street site and the Lāhainā Harbor site. The PAHs that were detected had concentrations between 1 ng/L and 5 ng/L, with no parameter exceeding any Hawaiʻi water quality criteria (Hawaiʻi DOH 2021).

Additional data on POCs in nearshore Maui marine waters has been collected by USGS, although the data was not collected within the Kahoma and Kauaʻula nearshore marine AUs. A USGS study documented the presence of pharmaceuticals (e.g., carbamazepine and sulfamethoxazole), two synthetic musk fragrances, a fire retardant (tris(dichloroisopropyl) phosphate), and a plasticizer compound ((tris(2-butoxyethyl)) phosphate) in water discharged from submarine springs associated with the Lāhainā Water Reclamation Facility (LWRF) wastewater plume (Hunt and Rosa 2009). Another USGS study used passive membrane samplers to evaluate the presence of a variety of organic contaminants marine water at five sites in West Maui during the dry season, including a site (near Hanakao`o Park) within 0.5 miles of the Kahoma nearshore AU boundary (Campbell et al. 2017). Pharmaceuticals (e.g., Ciprofloxacin, Triclosan, Acetaminophen, DEET) and flame retardants (Tris(2-chloroethyl) phosphate, Tris(chloropropyl) phosphate, tris(1,3-dichloro-2-propyl)phosphate)) were detected while pesticide and PCB parameters were not detected. These results from these two studies have limited utility as they were not collected in the Kahoma and Kauaʻula nearshore marine AUs and there are no applicable Hawaiʻi water quality criteria (Hawaiʻi DOH 2021) or other water quality thresholds available to make relative comparisons (although it may be feasible to devise an assessment methodology based on narrative criteria). The results from the Campbell et al. (2017) study are also of limited value since they are presented as chemical mass per sampler (sampling device) rather than a water concentration.

Based on the available data, POC concentrations in water are not considered to be a potential cause of aquatic life impairment. Nevertheless, periodic monitoring of POCs of concern to human health and aquatic life would be beneficial.

4.1.2.5.3 Freshwater Sediment

In January 2024, USGS collected sediment samples from the Kahoma stream sediment retention basin just downstream of the Lāhainā Bypass and the lower reach of Kahoma stream (USGS 2025). PAHs were not detected in sediment in the lower reach of Kahoma stream and TEQ Dioxins were below the PEL of 2.15E-5 ppm (Buchman 2008) at both locations.

4.1.2.5.4 Freshwater

The only recent readily available data on POCs consists of a single post-fire sample event on Kahoma Stream in January 2024 by USGS; the results were classified by USGS as provisional at the time they were accessed for this plan (USGS 2025). Only two of the tested pesticide parameters were detected—Glyphosate and 2-Hydroxyatrazine (a metabolite of the herbicide Atrazine). The concentration of Glyphosate was 0.15 µg/L and the concentration of 2-Hydroxyatrazine was 7.6 ng/L. Hawaiʻi does not have numeric criteria for either chemical (Hawaiʻi DOH 2021). The Glyphosate concentration was well below guideline values (800 µg/L for long-term exposure and 27,000 µg/L for short-term exposure) used in Canada to protect freshwater aquatic life (CCME 2012). Additional monitoring of POCs in freshwater sediment would facilitate a more rigorous evaluation of POCs as a potential cause of impairment to freshwater aquatic life.

4.1.2.6 Summary of Potential Causes of Impairment

Table 20 below summarizes the findings of the evaluation of potential additional causes of impairment. These potential impairments are in addition to the documented causes of impairment identified in Section 4.1.1. All the potential causes of impairment require additional assessment by DOH to determine if designated uses are impaired by the identified pollutants.

Table 20. Potential Causes of Impairment in the Kahoma and Kauaʻula Watersheds.

Assessment Unit	Waterbody ID	Designated Use	Potential Cause of Impairment
Kahoma Stream	6-1-05	Aquatic Life	Sediment, TN, NO_2 + NO_3, Cr, Co, Cu, Ni, V
		Recreation	*Enterococci*
Kauaʻula Stream	6-1-04	Aquatic Life	Sediment, TN, NO_2 + NO_3, Cr, Co, Cu, Ni, V
		Recreation	*Enterococci*
Kahoma Nearshore	HIW20009	Aquatic life	Sediment, Cr, Co, Cu, Ni, Se, V
Kauaʻula Nearshore	HIW20012	Aquatic life	Sediment, An, As, Cr, Co, Cu, Pb, Ni, Se, V, Zn
Lāhainā Harbor	HIW00137	Aquatic life	An, As, Cr, Co, Cu, Ni, V, Zn, TEQ Dioxins

4.2 SOURCES OF WATER QUALITY DEGRADATION

Except for ash and other pollutants associated with the 2023 Lāhainā wildfire, there is limited data and information on the sources of water quality degradation that are specific to the Kahoma and Kauaʻula watersheds and the nearshore marine ecosystem in the vicinity of Lāhainā. However, findings from recent studies of nearby watersheds and coastal areas along West Maui can be extrapolated to the Lāhainā area, due to similarities in land uses, physical conditions, and environmental factors. The following discussion categorizes pollutant sources as those that are either probable sources or unlikely sources.

4.2.1 Probable Sources

The following sections identify probable sources of pollutants based on a review of readily available data and information.

4.2.1.1 Agricultural Land Management

From the 1800s through the mid-1900s, most of the dry forests and shrublands on the leeward side of Maui were cleared to facilitate farming and establishment of non-native grassland for livestock grazing (SRGI 2012a, Henshaw and Lewis 2011, Griffith 1902). By the mid-19th century, observed reductions in dry season stream flows across the Hawaiian Islands had been attributed to deforestation by logging and livestock grazing (Cannarella 2010, Henshaw and Lewis 2011). In a 1902 report on the state of Hawaiian forests, Griffith (1902) noted the effects of grazing in the Lāhainā area:

> *The forests in the Iao valley [northeast of Lāhainā] are very well protected and consequently show no signs of deterioration while the streams are maintained with a fairly even flow. The forests in the remainder of the district of Lāhainā show very plainly the effect of grazing and must be much more carefully looked after in order to conserve the all-important water supply.*

Griffith's report only briefly mentions the link between land use changes and watershed-scale hydrological effects in the Lāhainā area. However, the remainder of the report provides relevant context to the water resource issues of the Lāhainā watersheds as it documents numerous observations throughout the Hawaiian Islands that reiterate the same overall conclusion: wherever logging and livestock grazing led to deforestation, watershed-scale hydrology was altered, resulting in diminished supplies of fresh water.

Changes in land cover from native dry forest and shrubland to non-native grassland and shrubland has caused soil organic matter (SOM) depletion, soil erosion, and damage to soil structure which in turn has altered soil hydrology (Perkins et al. 2012). As mentioned previously, agricultural land use in the 1900s also involved the mechanical scraping of soil surfaces to remove rocks to facilitate the cultivation of plantation crops. This undoubtedly would have also removed topsoil and its organic matter from soils. The degradation of soil health on agricultural lands likely influences the hydrological response of the Kahoma and Kauaʻula watersheds and associated sediment and nutrient loading to the near-shore marine ecosystem.

The National Resources Conservation Service (NRCS) (2023) noted that the soils within the area burned by the Lāhainā wildfire have very little organic matter. Although some of the organic matter was likely removed through burning, the SOM deficit appears to extend to lands in the Kahoma and Kauaʻula watersheds outside of the burned area.

A comparison of pre-wildfire SOM levels in semi-arid agricultural and developed areas to levels in adjacent mid-elevation lands in the central portion of the two watersheds that are too rugged for agriculture suggests that SOM in the areas with agricultural and urban land use has become depleted. Figure 82 shows that SOM in surface soil layers in rugged, uncleared areas ranges from 3% to 6.5% (by mass), whereas the vast majority of agricultural lands has an SOM content of 0% to 2% in the soil surface layer (NRCS 2025). A similar pattern occurs for SOM within the 0-to-60-inch soil profile (weighted average, by mass) (Figure 83). Because subsurface SOM tends to have a longer residence time than SOM in the soil surface layer (Rumpel 2011), its apparent depletion relative to adjacent lands suggests that conditions promoting its loss have been occurring for a long time. It also suggests that the current vegetation communities and land use in the agricultural and developed areas are not conducive to promoting soil health. Essentially, the agricultural lands have undergone desertification.

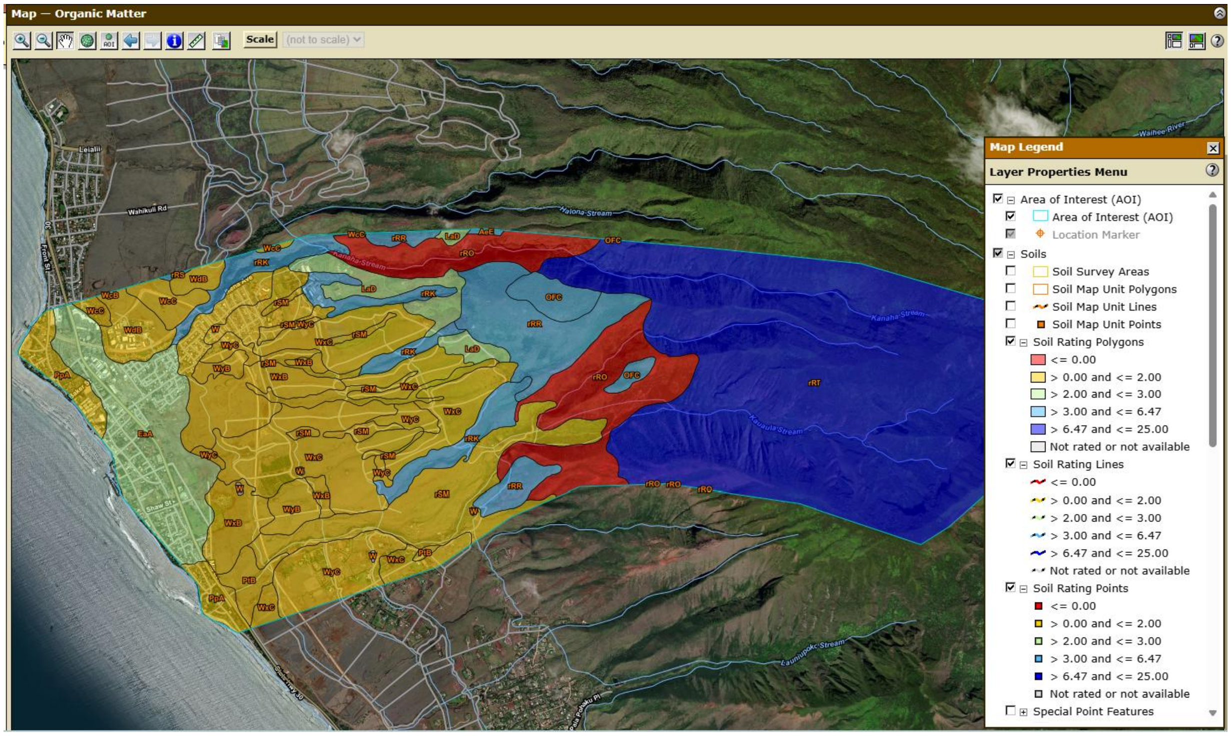

Figure 82. Percent SOM in soil surface layers of the Kahoma and Kauaʻula watersheds.

(*Source: NRCS 2025*)

Both surface and subsurface SOM are important for soil health because they mediate a variety of chemical, physical, and biological processes—including hydrologic functioning. As SOM decreases, infiltration of precipitation into soils decreases, the water-holding capacity of soils decreases, evaporation of water from soils increases, surface runoff volumes increase, and soil erosion increases (Gilbert et al. 2020, Brown and Cotton 2011, Brown et al. 2011, Evanylo et al. 2008, Gravuer et al. 2019). SOM deficits across large acreages may alter hydrology at hillslope to watershed scales (Yang et al. 2014). More specifically, SOM deficits may contribute to increased flashiness of surface runoff and streamflows, and generation of high sediment loads, which are typical of arid environments experiencing episodic heavy rains. In contrast, restoration of SOM content can make the soils and vegetation communities they support more resilient to climate variability such as drought (Lal 2020).

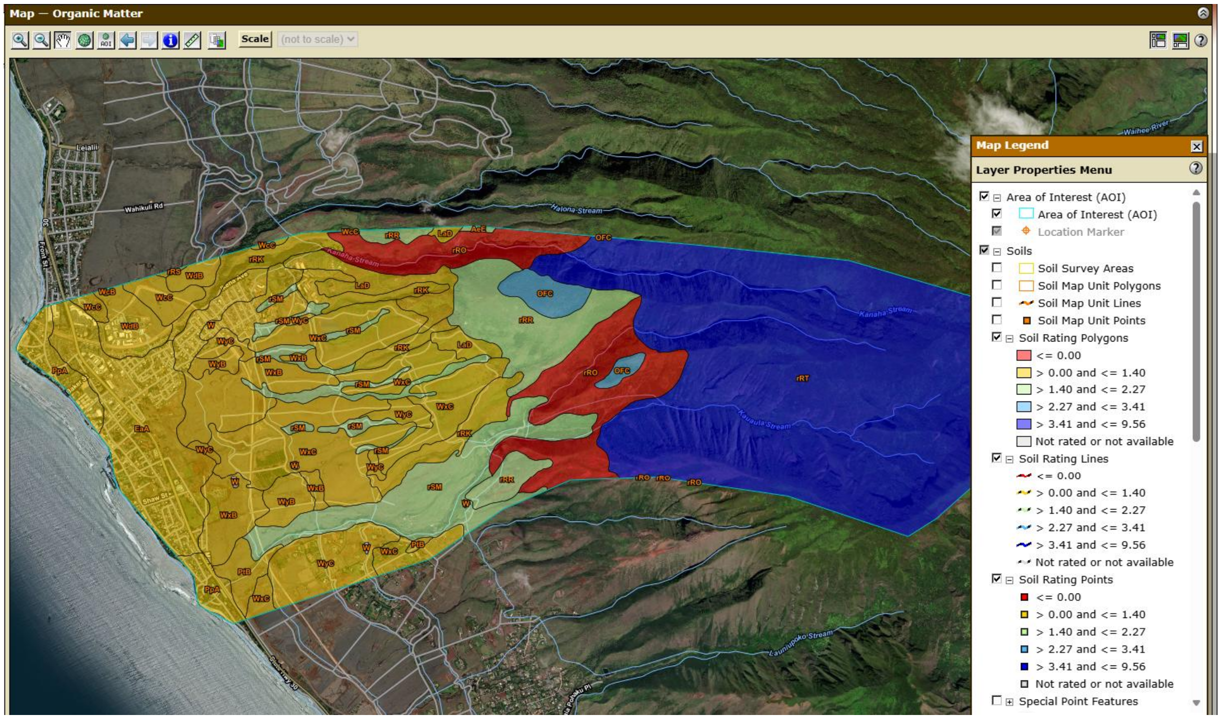

Figure 83. Percent SOM in the soils (0 to 60 in. depth) of the Kahoma and Kauaʻula watersheds. (*Source: NRCS 2025*)

At present, an insignificant acreage of agricultural lands within the Kahoma and Kauaʻula watersheds is being actively used for production of crops and livestock (Munekiyo and Hiraga, Inc. 2003). Agricultural runoff as a source of nutrients and sediment to streams and marine waters is associated with legacy effects of agricultural plantations and livestock grazing upon soils, vegetation communities, and hydrology. Runoff generated from abandoned sugar cane fields is conveyed by numerous gullies into Lāhainā where it drains into the ocean or ponds in the vicinity of Maluʻuluolele Park and commercial areas around Front and Waineʻe streets (Munekiyo and Hiraga, Inc. 2003). Additionally, it is likely that the networks of dirt roads, irrigation ditches, and firebreaks on agricultural lands convey surface runoff and contribute nutrients and sediment to gullies and streams. For example, NRCS (2023) noted one location where a ditch routes field runoff to Kauaʻula Stream, and three locations where firebreaks cross drainageways—resulting in piles of exposed soil that are susceptible to erosion by surface runoff. Most of the irrigation ditches, however, are not problematic because they were designed to route water away from gulches (NRCS 2023). Fugitive dust from bare agricultural soils was historically a problem in watersheds to the north of Lāhainā (SRGI 2012a) but does not currently appear to be a problem in the Kahoma and Kauaʻula watersheds.

The sediment budget study performed for West Maui watersheds by the USGS (Stock and Cerovski-Darriau 2021) concluded that relatively few storms have rainfall whose intensity and duration are sufficient to cause surface runoff from agricultural fields, such that the fields rarely contribute to sediment loads in observed marine plumes. This conclusion was supported by two lines of evidence.

First, marine sediment plumes were observed in the northern watersheds despite a lack of concurrent evidence that surface runoff was occurring on agricultural fields. Second, measured infiltration rates and calculated saturated hydraulic conductivities of soils and dirt roads tended to exceed the rainfall intensities estimated to trigger coastal sediment plumes. In an earlier draft of the study, it was estimated that surface runoff from the agricultural lands in the Lāhainā area lands only occurs when rainfall intensities exceed a recurrence interval of 25 years (Stock et al. 2016).

The conclusion that agricultural runoff in the Lāhainā area is rare (Stock and Cerovski-Darriau 2021) appears to contradict the information regarding agricultural land runoff provided in the Lāhainā Watershed Flood Control Project Final Environmental Impact Statement (Munekiyo and Hiraga, Inc. 2003). One aspect of the USGS study (Stock and Cerovski-Darriau 2021) that may help explain the discrepancy is that the analysis of potential storm runoff from agricultural lands was based on data for sandy loam soils in the northern watersheds whereas the agricultural soils of the Kahoma and Kauaʻula watersheds are primarily silty clays and silty clay loams. Because silty clay and silty clay loam soils tend to have lower infiltration and saturated hydraulic conductivities in comparison to sandy loam soils, it is plausible that the study underestimates the runoff potential from agricultural lands and roads in the Lāhainā watersheds. Furthermore, the runoff potential analysis performed by USGS was completed prior to the Lāhainā fire and thus does not account for the potential effects of the fire upon hydrologic conditions and responses, as discussed in the section on wildfire.

The historical use of agricultural fertilizers appears to be a significant source of nutrient inputs within the Kahoma and Kauaʻula watersheds and the Lāhainā nearshore marine waters. Measured concentrations of nitrogen and phosphorus in groundwater upgradient of agricultural areas have been found to be roughly 30 µg/L and 60 µg/L, respectively, while nitrogen and phosphorus concentrations in wells downgradient of agricultural lands have been found to range up to 2,500 µg/L and 300 µg/L, respectively (Glenn et al. 2013). Most groundwater on the Hawaiian Islands discharges to the Pacific Ocean through submarine springs (Glenn et al. 2013), yet it is likely that some also discharges into streams, including Kahoma and Kauaʻula streams. Residual nitrogen in soils and groundwater associated with the historical use of nitrogen fertilizers likely contributes directly to the identified NO3 + NO2 and NH_4 impairments in nearshore marine waters. It also likely contributes to chlorophyll-a and turbidity impairments. Growth of algae in marine waters is typically limited by the available supply of nitrogen, such that an increased supply of nitrogen often causes increased algal growth. Increased algal growth can lead to increased turbidity as algae tissue becomes suspended in turbulent nearshore waters.

Historical agricultural practices appear to be a source of elevated metals concentrations in both freshwater and marine sediments associated with the Kahoma and Kauaʻula watersheds. Soils of the Kahoma and Kauaʻula watersheds contain naturally elevated levels of metals—see also Section 4.2.1.7 (AECOM 2012). It is suspected that accelerated soil erosion on agricultural lands along with erosion of anthropogenic sediment deposits in stream terraces (see Section 4.2.1.9 Streambank Erosion) is a significant source of the heavy metal concentrations observed in the Kahoma and Kauaʻula nearshore marine waters.

Elevated levels of metals in marine sediment have been observed in other nearshore marine waters on Maui. Hédouin et al (2011) found that marine sediments in Honolua Bay and Honokohau Bay, Maui displayed high concentrations of Co, Cr, Mn, Ni, and V. Except for Mn, marine organism tissue samples (from alga, goatfish and urchin) did not appear elevated relative to areas without high concentrations of metals in sediment, suggesting that the metals in the sediment tend to be inert. Although the study found an apparent inverse relationship between coral cover and Co, Cr, Mn, Ni, V, Zn concentrations in sediments, the authors suggested that variation in coral cover was related to a combination of stressors (e.g., sediment, metals, nutrients) rather than sole effects from metals.

Hédouin et al. (2009) found evidence indicating that the spatial distribution of sediment metals concentrations in Honolua Bay reflect sediment loading from Honolua Stream, with greater concentrations close to the mouth of Honolua stream and lesser concentrations with increasing distance offshore. A similar pattern could be expected near the mouths of Kahooma and Kauaʻula streams.

The elevated metals concentrations in marine sediments of Honolua and Honokohau Bays were attributed to high natural background levels in the soils of the contributing watersheds (Hédouin et al. 2011). However, the authors did not consider that between 1926 and 1979, a substantial proportion of both watersheds were dedicated to pineapple production (USACE 2023), which has been attributed as a major source of ongoing marine turbidity and sediment problems on Maui, including in Honolua Bay (USACE 2023, Stock and Cerovski-Darriau 2021). The elevated metals concentrations in marine sediments are not a natural occurrence if they are associated with the accelerated erosion of soils on agricultural lands or erosion of streambank sediment deposits caused by the bulldozing of fields (see Section 4.2.1.9 for more information on the widespread occurrence of anthropogenic streambank sediment deposits on Maui).

Historical use of pesticides on former sugar cane lands in the Kahoma and Kauaʻula watersheds is an additional probable source of observed As and Pb in marine waters. Significantly elevated levels of As have been identified in soils at former sugar cane fields, former pesticide storage or mixing areas, and former sugar plantation camps (Hawaiʻi DOH 2018a). DOH has attributed the presence of elevated levels of soil at some historical sugar plantation areas to the widespread use of sodium arsenite (an inorganic As compound) or other As-based herbicides/pesticides in and around the cane fields in the 1920s through 1940s. Certain types of fertilizers that contained As may also be a source of contamination. Because inorganic As and Pb are stable in the environment, they remain in the soil many years after use, and can migrate as a result of soil erosion or leaching.

In addition to heavy metals (i.e., As and Pb) used in agricultural pesticides, DOH has identified additional categories of pesticides historically used on sugar cane plantations on Maui and other Hawaiian Islands (Hawaiʻi DOH 2019). However, information on the use of specific pesticides in the Kahoma and Kauaʻula watersheds is not available. Categories of pesticides and related contaminants associated with historical sugarcane cultivation include:

- Carbamates (e.g., benomyl and propiconazole)
- Chlorinated herbicides

- Dioxins/furans
- Hg (elemental)
- Organochlorine pesticides (e.g., heptachlor and trifluralin).
- Organo-phosphorus pesticides
- Triazine pesticides
- Volatile and semi-volatile organic compounds
- Total Petroleum Hydrocarbons (e.g., diesel fuel used as a base for applying some pesticides)

It is recommended that future monitoring and assessment be conducted to evaluate the presence of pesticides and related contaminants in water and sediment originating on agricultural lands.

4.2.1.2 Boat and Harbor Maintenance

Boat and harbor maintenance is a potential source of pollutants including heavy metals and persistent organic compounds (EPA 2001). Paint and wood preservatives used on boats and harbor infrastructure can contain As, Cu, Cr, and Zn. Ni is a component of brake linings and pavement material, and Cd is present in boat batteries and brake linings. These and other metals (Aluminum [Al], Iron [Fe], and Cr) are used in various components at marinas or by recreational boaters and can wash from parking lots, service areas, and launch ramps into surface waters. High levels of Zn, Cr, and Pb have been detected in the waters of some marinas (EPA 2001). Based on this information, boat and harbor maintenance likely contribute to the observed levels of heavy metals (e.g., As, Cr, Cu, Ni, and Zn) in and around Lāhainā Harbor (see Section 4.1.2.4.1). It is less certain whether boat and harbor maintenance has contributed to the levels of TEQ Dioxins in the harbor (see also Section 4.2.1.11 for information related to potential TEQ Dioxins associated with burning at the harbor). Urban runoff and atmospheric deposition of automobile exhaust may also contribute to the observed levels of heavy metals and TEQ Dioxins at the harbor.

Demolition of the remaining harbor infrastructure (not including the seawalls) began in the fall of 2024 and reconstruction is anticipated to be completed by the fall of 2026 (County of Maui 2025b). In addition to reconstruction of the infrastructure, the harbor will be dredged. This is expected to decrease the levels of metals and dioxins in the sediments of the harbor.

4.2.1.3 Cesspools, Septic Systems, and Sewers

Cesspools and septic systems are a source of nutrients, pathogens, and other pollutants (such as pharmaceuticals and household chemicals) throughout the island of Maui, including the Kahoma and Kauaʻula watersheds and nearshore marine areas surrounding Lāhainā (Hawaiʻi DOH 2017). The main challenge with cesspools is that due to the permeable nature of many Hawaiian soils and underlying rock, the effluent of many cesspools leaches into the groundwater more quickly than biogeochemical treatment of pollutants can occur in the soils. Aquifers on the Hawaiian Islands tend to be of limited extent and volume, being replenished during the annual wet season (Glenn 2013). In many areas, the flow of groundwater is not confined by geologic formations, resulting in relatively rapid discharge of groundwater—and pollutants—into streams or marine waters.

The State of Hawaiʻi maintains an inventory of cesspools and septic systems on Maui. Most cesspools in the Lāhainā area have been designated as Priority Level 1, which indicates that the cesspools have the greatest potential to impact human health and the environment and are directly adjacent to sensitive natural resources like coral reefs or drinking water aquifers (Shuler et al. 2021). Figure 84 and Figure 85**Figure 85** display the cesspool locations within the Kahoma and Kauaʻula watersheds. Note that cesspools are prioritized by census tract in these figures; a portion of the Kauaʻula watershed does not have cesspool rankings displayed because the census tract did not contain the minimum number of cesspools required for the tract to receive a priority ranking (Mezzacapo and Shuler 2022).

There are slightly more than 300 cesspools located within the Kahoma and Kauaʻula watersheds combined (Shuler et al. 2021). Approximately 280 cesspools are located in the Kahoma Stream watershed, nearly all of which are located within 0.5 miles of the Kahoma nearshore marine AU. Most of these cesspools are located within the Wahikuli subdivision, most of which were burned in the 2023 Lāhainā fire. An effort is underway to establish sewer connections for approximately 231 of the single-family home lots in the Wahikuli subdivision (AECOM 2025). Roughly 28 cesspools are located within Kauaʻula watersheds, with most of these located within 0.6 miles of Kauaʻula Stream and several other cesspools located within 0.25 miles of the Kauaʻula nearshore marine AU.

Information regarding the inventory of cesspools and septic systems in the Kahoma and Kauaʻula watersheds should be obtained from the Department of Health Wastewater Branch.

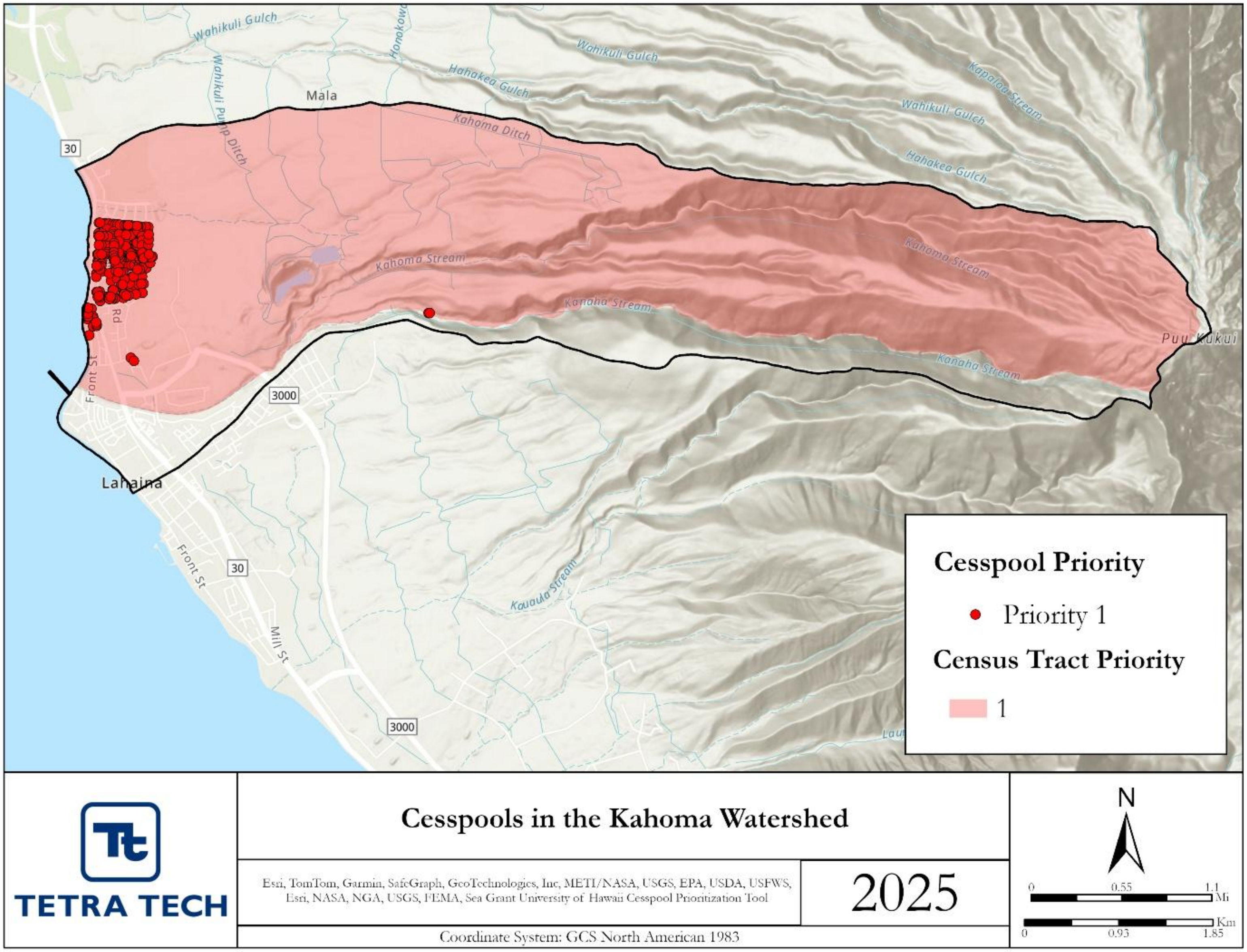

Figure 84. Cesspools in the Kahoma Watershed. (*Source: Mezzacapo and Shuler 2022*)

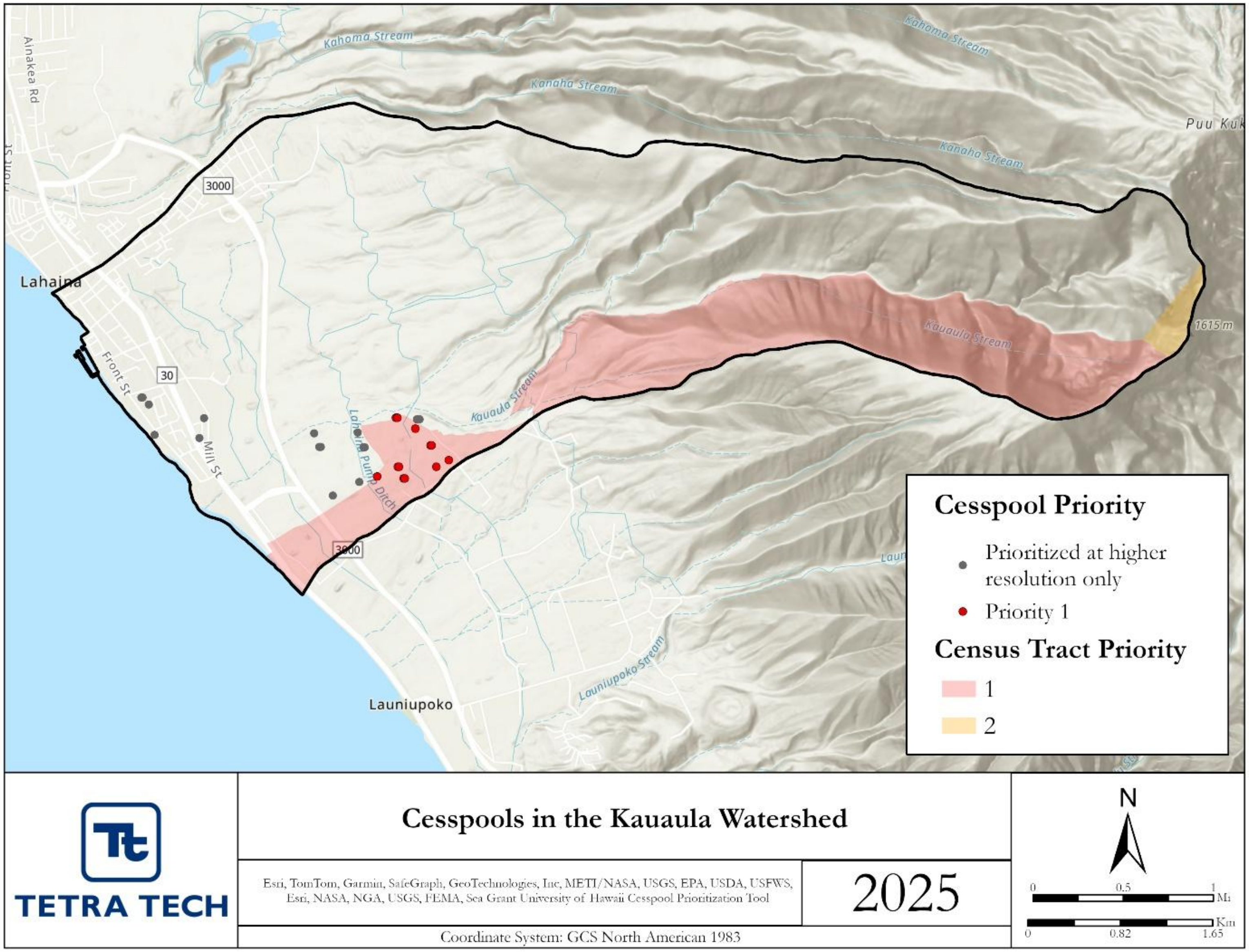

Figure 85. Cesspools in the Kaua‘ula Watershed. (*Source: Mezzacapo and Shuler 2022*)

Sewer systems can also be a potential source of nutrients, pathogens, and other pollutants. This can occur due to overflow of a combined sewer system (i.e., when sewer water and stormwater share the same conveyance system) during storm events, when there is a leak in the sewer system, or when a residential or commercial property's sewer line is incorrectly connected to a stormwater conveyance system. Combined sewer overflows are not an issue since Lāhainā does not have a combined sewer system. It is unknown whether sewer leaks or illicit wastewater discharges to the stormwater conveyances are potential issues in the Kahoma and Kauaʻula watersheds.

4.2.1.4 Climate Variability

Variability in climate is linked to the occurrence of coastal sediment plumes in the watersheds of west Maui, including the Kahoma and Kauaʻula watersheds. Unlike the West Maui watersheds to the north, the Kahoma and Kauaʻula watersheds have not experienced a decreasing trend in total annual rainfall since the 1970s (Stock and Cerovski-Darriau 2021). However, there is evidence that a greater proportion of the total rainfall is produced by brief, intense storms (e.g., rainfall intensity exceeding 20 millimeters per hour [mm/hr]) even though the frequency of these storms has not changed. Greater storm intensity is likely to translate to increased sediment loads to the nearshore marine ecosystem during these episodic events as high flows continue to erode terrace deposits in stream valleys (Stock and Cerovski-Darriau 2021).

USGS performed a rainfall analysis to evaluate the frequency of events that result in coastal sediment plumes (Stock and Cerovski-Darriau 2021). The analysis indicated that coastal sediment plumes are generated when rainfall events occur that exceed roughly 10 mm/hr to 20 mm/hr (0.4 in/hr to 0.8 in/hr) for a minimum of 2 hours. USGS estimated that coastal sediment plumes occur about once per year at Lāhainā, based on the average rainfall record at the Lāhainā climate station from 1978 to 2001; however, more recent rainfall records from nearby stations suggested that the frequency may be closer to 3 to 5 times per year. USGS researchers suggested that runoff from agricultural fields occurs when rainfall events exceed 50 mm/hr, which the agency estimated to occur about once per decade.

Additionally, a recent remote sensing study of vegetation types on the Hawaiian Islands found evidence that drought impacts on vegetation were more widespread than precipitation decline on the leeward side of Maui (Madson et al. 2023). Drought impacts increase the risk of wildfire and associated generation of pollutants including nutrients and sediment—as well as heavy metals and other toxins when homes and businesses are burned.

4.2.1.5 Commercial and Residential Landscaping Management

Turfgrass on golf courses, resort properties, recreational areas, and yards of some individual residences are typically maintained through irrigation and periodic applications of inorganic fertilizers. Nitrogen and phosphorus from fertilizers can be transported in surface runoff to streams and marine waters. In addition, nutrients can leach through soils and into the groundwater and be discharged into fresh or marine waters. Although the golf courses at Kāʻanapali are located beyond the boundary of the Kahoma nearshore marine AU, it is possible that nutrients associated with fertilizer that reach the marine waters can be transported into the Kahoma nearshore marine AU. However, the use of fertilizer on commercial and residential properties in Lāhainā is a more likely source. Landscaping fertilizer has been identified as a source of nutrient pollution in nearby Maui watersheds (Reyes 2019) and is a probable source of nutrients in the Kahoma and Kauaʻula watersheds and Lāhainā nearshore marine waters.

4.2.1.6 Loss of Coastal Estuaries, Ponds, and Wetlands

Coastal estuaries, ponds, and wetlands can play an important role in the capture and retention of sediment, nutrients, and other pollutants. Several coastal ponds and wetlands in the Kahoma and Kauaʻula watersheds, such as Loko o Mokuhinia at the present-day location of Maluʻuluolele Park, historically accumulated water from groundwater discharges and surface runoff (CH2MHILL 2013). The ponds and wetlands were destroyed through historical draining and filling associated with land development.

Additionally, it appears that channelization and adjacent development at the mouths of Kahoma and Kauaʻula streams may have destroyed estuarine and coastal wetland habitat. Historical accounts indicate that lo`i kalo (wetlands or irrigated terraces for growing taro) were maintained in the lower reaches of Kahoma stream and that a fishpond once located near the stream mouth was hydrologically connected to another pond—possibly Loko o Mokuhinia (CH2MHILL 2013). This habitat would have contributed to the protection of protecting nearshore marine water quality by harboring vegetation communities that could trap sediment and nutrients transported from the two streams.

4.2.1.7 Natural Sources

A 2012 report evaluated natural background levels of metals in soils of the Hawaiian Islands (AECOM 2012). Although characterizing the levels of individual metals is beyond the scope of this watershed plan, the report demonstrates that various heavy metals (As, Cd, Cr, Co, Cu, Pb, Hg, Ni, Se, V, and Zn) naturally occur in the soils of Maui, with considerable spatial variation in soil concentrations based on local geology and soil type.

These metals undoubtedly contribute to observed concentrations in fresh and marine water and sediments in the Kahoma and Kauaʻula watersheds. Natural soil erosion processes can deliver dissolved and mineral forms of metals to fresh and marine waters. Additionally, natural soil leaching processes can transport dissolved metals into groundwater, which may be subsequently discharged into marine waters. Levels of metals that impact designated uses (e.g., aquatic life, recreational use) and result from naturally occurring soil erosion or leaching would be considered to represent a background condition rather than a cause or source of impairment. Land use activities that increase the erosion of soils containing naturally elevated metals concentrations can accelerate the delivery of heavy metals to fresh and marine waters, thereby becoming a source of impairment. As described in Section 4.2.1.1, historical agricultural land management is likely to be increasing sediment and associated metals loading to Kahoma and Kauaʻula streams.

4.2.1.8 Non-Native Species

As noted in Section 4.2.1.1, replacement of native dry forest and shrublands with non-native grasses and shrubs across the agricultural lands in the Lāhainā area has implications for watershed hydrology and pollutant loading. At the most basic level, invasive non-native plant species on the Hawaiian Islands outcompete and displace native species (Henshaw and Lewis 2011). Interception and evapotranspiration of precipitation in dry forests may differ from that of the existing non-native vegetation communities. For example, non-native grasses may intercept less precipitation and transpire less water than native dry forest trees species and may therefore contribute to increases in the rate and volume of stormflows. Larger, flashier stormflows are more likely to erode the anthropogenically derived terrace sediments in stream valleys, leading to greater sediment loads and turbidity transported in streams and delivered to the nearshore marine ecosystem. Additionally, non-native invasive plant communities increase the risk of wildfire (Henshaw and Lewis 2011). Wildfire was historically not a major driver of Hawaiian forest ecology and as such, the native plant communities are not resilient to wildfires. When fires do occur, they therefore serve to reinforce the processes that contribute to continued degradation of soils and water quality.

The effects of altered watershed ecology are compounded by the presence of non-native, feral ungulates such as pigs and deer on agricultural and conservation lands. These animals contribute to erosion within the watersheds through denudation of vegetation communities and disturbance of soils (SRGI 2012a, Henshaw and Lewis 2011) and may also contribute fecal bacteria loads to streams. On the island of Molokaʻi, vegetation community denudation and associated soil erosion caused by feral ungulates has been linked to increased TSS and turbidity in nearshore marine waters (TNC 2019).

4.2.1.9 Streambank Erosion

USGS developed sediment budgets for 35 West Maui watersheds from Wahikuli Gulch north to Līpoa Point, based on observations and data collection between 2014 and 2016 (Stock and Cerovski-Darriau 2021). The study did not develop sediment budgets for the Kahoma and Kauaʻula watersheds, although the Lāhainā area was addressed in some of the hydrological findings. Many of the other study findings related to sediment sources are relevant to the Kahoma and Kauaʻula watersheds given their similarity in environmental conditions (i.e., geology, topography, climate, soils, vegetation communities) and land use (e.g., a history of irrigated plantation agriculture) to the studied watersheds. Three of the main differences between the Kahoma and Kauaʻula watersheds and watersheds to the north include the following:

- The lowlands of the Kahoma and Kauaʻula watersheds are drier than the lowlands of watersheds to the north.
- For a given storm recurrence interval, rainfall intensities around Lāhainā are roughly half as large as in watersheds to the north.
- Agricultural soils in the northern watersheds have a greater proportion of sand and lesser proportion of clay than the agricultural soils in the Kahoma and Kauaʻula watersheds.

USGS found that runoff causing coastal sediment plumes tended to coincide with storm events with rainfall intensities exceeding 10 mm/hr to 20 mm/hr for at least one to two hours (Stock and Cerovski-Darriau 2021). It was estimated that the recurrence interval for such storms in the Lāhainā area was less than one event per year. Sediment plumes following a small storm event were observed at the mouth of some streams with upstream sediment-retention basins, indicating that sediment basins alone are not able to sufficiently reduce sediment loads.

Overall, the evidence indicated that the primary source of turbidity and sedimentation of nearshore marine waters is streambank erosion of historical terraces composed of sand, silt, clay, and rocks (Stock and Cerovski-Darriau 2021). Historical fill terraces are found only downstream of historical agricultural fields. The terrace deposits were evidently derived from soil and rocks that were scraped off agricultural fields using bulldozers and pushed to the edge of ravines or into ravines throughout West Maui. Artifacts found embedded in the fill terraces in stream valleys suggest that the terrace sediments were deposited throughout most of the 20th century. Aerial photographs from 1951 show that side slopes of the ravines were locally covered by aprons of sediment. Field surveys of four watersheds north of Kahoma and Kauaʻula watersheds found that the fill terraces occupied roughly 40% of streambank length downstream of the forest reserve boundary.

The sediment budget for Wahikuli Gulch developed by USGS can be used to provide a rough estimate of sediment loading for the Kahoma and Kauaʻula watersheds (Stock and Cerovski-Darriau 2021). Wahikuli Gulch is the next major watershed to the north of the Kahoma and Kauaʻula watersheds, and has a similar climate, watershed size and extent, geology, and land uses. Wahikuli Gulch has roughly half its length impacted by constructed fill terraces, which roughly corresponds to the extent of agricultural land along its length. The extent of agricultural land in the Kahoma and Kauaʻula watersheds is similar to that of Wahikuli Gulch, suggesting a similar extent of fill terraces. Although data on terrace erosion rates from Māhinahina Gulch were used to characterize erosion rates for the southern watersheds with arid lowlands, this watershed is considerably smaller than Kahoma and Kauaʻula watersheds because it does not have headwaters in the mountains and its entire length is impacted by fill terraces (Stock and Cerovski-Darriau 2021).

The streambank erosion sediment load for Wahikuli Gulch was estimated to be 42 metric tons/yr, with a hypothetical natural background load estimated at 18.6 metric tons/yr. For a hypothetical decadal storm (i.e., a storm with a recurrence probability of once every 10 years), the annualized sediment load is estimated to be 70 metric tons/yr, or 700 metric tons in total. The researchers noted that their modeling indicated that the bank erosion rate for the southern arid watersheds may be 3-5 times greater than observed rate of 5 mm/yr in Māhinahina Gulch, resulting in sediment loads that may be 104% to 360% greater (44 metric tons/yr to 151 metric tons/yr) than the estimated 42 metric tons/yr for Wahikuli Gulch. This potential underestimate may be associated with the fact that Māhinahina Gulch is an ephemeral drainage that has its headwaters in the foothills; this drainage likely has lower peak discharges and thus lower stream power than the southern watersheds with mountainous headwaters, including the Kahoma and Kauaʻula watersheds (Stock and Cerovski-Darriau 2021).

Streambank erosion can also be a significant source of nutrient (nitrogen and phosphorus) loads in streams and may contribute to the levels of metals observed in nearshore marine sediments. Although data is apparently unavailable on the nutrient levels in the streambank sediments, bank erosion can be considered a source of nitrogen and phosphorus loads not only within Kahoma and Kauaʻula streams, but also within their associated nearshore marine AUs.

4.2.1.10 Stream Channel Modification

The lower reaches of both Kahoma and Kauaʻula streams flow through a concrete-lined channel. Although this may help convey large magnitude flows more effectively through the urban portions of the streams, it also results in significant ecological consequences. One consequence is that the natural capacity for in-channel and floodplain sediment storage may be reduced. In natural channels, vegetated floodplains and in-channel features such as point bars can trap and store large quantities of sediment, thereby regulating the rate of sediment load delivery to downstream water bodies. In concrete-lined channels, the intent is to prevent overbank flows, which reduces the potential for floodplain sediment storage. Additionally, in-channel sediments are mobilized more readily in concrete lined channels than in natural channels (Mohammadi 2005), which may increase the rate of sediment loading to downstream receiving waters.

For Kahoma and Kauaʻula streams, this also means that the concrete lined sections influence metals loads delivered to marine waters since the sediments contain elevated levels of metals (see Section 4.2.1.7 Natural Sources).

Concrete-lined channels can also affect nutrient dynamics in streams and their receiving water bodies. In alluvial streams there can be a back-and-forth exchange of water between the stream, hyporheic water, and groundwater. This interaction has particularly significant implications for nitrogen dynamics. The hyporheic zone can play an important role in denitrification (Merill and Tonjes 2014) whereby NO_3 (a main contributor to eutrophication) is transformed into nitrogen gas through microbiological processes and emitted into the atmosphere. Denitrification along a stream can considerably reduce the amount of NO_3 that is delivered to downstream receiving waters (Hester et al. 2018). A lack of hyporheic water exchange in concrete lined channels may therefore result in a reduced capacity for denitrification, thus increasing nitrogen loading to downstream receiving waters.

Concrete-lined channels also affect stream temperature regimes (Parrish et al. 1978). All else being equal, a concrete lined channel will have warmer water than a stream in which water exchange with the hyporheic zone and/or groundwater discharges into the stream occurs. This is important because water temperature influences chemical (e.g., chemical reactions influencing the pH of water), physical (e.g., oxygen solubility), and biological (e.g., the metabolic rate of aquatic organisms) attributes of streams (Allan et al. 2021). The warmer water in a concrete lined channel will not only affect stream ecology, but may also affect the ecology of receiving waters, such as coral reef ecosystems.

4.2.1.11 Wildfire

This section provides a discussion of the recent wildfire effects upon agricultural and urban lands as a source of pollutants to the Kahoma and Kauaʻula watersheds and associated nearshore marine waters.

4.2.1.11.1 Agricultural Lands

Within weeks after the August 2023, Lāhainā wildfire swept through the lower reaches of the Kahoma and Kauaʻula watersheds, a U.S. Department of Agriculture (USDA) Burned Area Emergency Response (BAER) team evaluated fire damage to soils and potential hydrological and water quality effects within the 2,336 acre burned area (USDA 2023).

For the undeveloped acreage within the fire perimeter, the BAER team estimated that 13% (307 ac.) experienced a very low severity or was unburned, 55% (786 ac.) experienced a low burn severity, 24% (342 ac.) experienced a moderate severity burn, and less than 1% (1 ac.) experienced a high severity burn. Note that the burned acreage estimates extend outside of the Kahoma and Kauaʻula watersheds, with no estimates currently available that are exclusive to the two watersheds. Additionally, developed areas (900 ac.) were not evaluated for soil burn severity (USDA 2023). The wildfire did not appear to significantly decrease soil surface organic matter in grassland and shrubland with low to moderate fire severity. However, in the areas with moderate to high burn severity, burning of organic materials on the soil surface and soil structure damage was more common, increasing the risk of wind and water erosion. Ash layers had been blown away in most of the areas with low to moderate burn severity and in some cases, burnt soil layers were also removed through wind erosion.

The BAER team concluded that runoff, suspended sediment, turbidity, and nutrients were likely to increase in streams within and below burned areas in response to rain events with moderate to high intensity during the first one to three years following the fire (USDA 2023). The BAER team believed it was likely that recovery of vegetation to pre-fire levels would occur rapidly in areas of low to moderate burn severity, where fire-adapted non-native grasses were present (USDA 2023). They noted that increased flood flows were predicted to be minimal at the watershed scale due to the relatively small proportion of total watershed acreage that was burned and the generally low burn severity in undeveloped areas. A 113-acre catchment located between Crater Reservoir and Lāhainā was noted as the greatest concern for runoff from undeveloped lands within the Lāhainā fire perimeter (USDA 2023). The BAER team concluded that this catchment has a greater risk of increased runoff (estimated to be 180% greater volume than pre-fire conditions) during intense rain events, although it was noted that extensive drainage modifications in this area associated with historical agricultural activities may serve to at least partially disperse flood flows. The team suggested that a measurable reduction in groundwater recharge is unlikely since the burned areas comprise a relatively small proportion of the overall groundwater recharge area and any reductions in water infiltration within burned areas are likely to be temporary (USDA 2023).

Potential future wildfire within the mountainous areas in the upper reaches of the Kahoma and Kauaʻula watersheds would pose a particularly high threat to the freshwater and marine ecosystems of the Lāhainā area. These areas, which have very steep slopes and annual rainfall totals that range from roughly 50 inches to 300 inches, periodically generate flood and debris flows even in the absence of wildfire impacts (Stock and Cerovski-Darriau 2021). Large acreage fires in these areas would increase the risk of catastrophic flood flows and debris flows contributing to additional long-term threats to affected streams, the nearshore marine ecosystem, and the community of Lāhainā.

4.2.1.11.2 Urban Lands

Within the town of Lāhainā, a wide variety of materials associated with residences, commercial buildings, and vehicles were incinerated. Wildfire ash can be delivered to water bodies through surface runoff, percolation through soils, and wind erosion, which may increase turbidity, and deliver heavy metals and POCs.

EPA and the U.S. Coast Guard worked with FEMA to mitigate the risk of harm to humans and ecosystems from hazardous materials in ash and debris. As part of the clean-up, approximately 1,390 residential lots and 148 commercial properties were cleared of over 400,000 tons ash and debris in Lāhainā (County of Maui 2025b). A soil stabilizer (SoilTac®) was applied to the burned properties within and around Lāhainā and absorbent materials and other pollution controls were installed around Lāhainā storm drains and along Front Street to trap solids and reduce pollutant delivery to coastal waters (Hawaiʻi DOH 2025a).

DOH sampling of the wildfire ash in the Lāhainā urban area in November 2023 evaluated concentrations of heavy metals, organochlorine pesticides, PAHs, and TEQ Dioxins (Hawaiʻi DOH 2025b). Three composite samples of ash were collected from 100 home sites. DOH compared individual pollutants in the ash with site specific screening values derived from DOH Exposure Action Levels (EALs) for contaminated soils (Hawaiʻi DOH 2024b). The EALs for soils are benchmarks used to indicate a level of soil contamination that may pose a health risk to humans. Some of the soil EALs (e.g., As, Co) were modified to reflect differences in contaminant bioavailability between ash and soil. Additionally, the USACE debris removal program included sampling of soil to at least 6 inches deep and in some cases to 12 inches deep. Metals levels in soils were generally low. However, some As and Pb sample values exceeded the soil EALs at the 12-inch depth, which was attributed to contamination that occurred prior to the wildfire (Hawaiʻi DOH 2025a).

DOH determined that levels of PAHs, pesticides, and PCBs in the ash were either not detected or below screening thresholds established to protect human health (Hawaiʻi DOH 2025a, 2025b). Concentrations of TEQ Dioxins in the ash in all three composite samples were below the DOH human health screening value (2.4E-4ppm) for unrestricted use of soils (Table 21). The primary environmental source of dioxins is the combustion of organic materials in the presence of chlorinated materials (CIDFS 2003). The presence of Dioxins in the wildfire ash indicate that it is a potential source of the apparently elevated TEQ Dioxins concentrations observed in Lāhainā Harbor. The values in the harbor sediment were all below the human health EAL of 1.5E-3ppm for commercial/industrial sites, although several sample values slightly exceeded the aquatic life PEL of 2.15E-5 ppm. When the harbor burned during the wildfire, ash containing dioxins may have settled into the sediments, which are considerably more sheltered than sites outside the harbor where TEQ Dioxins concentrations were much lower. Additionally, ash may may have been delivered into the harbor via urban runoff. Soil samples collected from Lāhainā area county parks indicates that windblown ash did not increase levels of contaminants in soils (Hawaiʻi DOH 2025b), which suggests that deposition of ash in nearshore marine waters may have been minimal.

As noted in Section 4.1.2.4, the harbor sediment samples collected by DLNR consisted of sediment cores with maximum depths ranging from of one-half to four feet below the surface. TEQ Dioxins concentrations in the DLNR samples may therefore reflect long-term deposition that occurred prior to the fire. The USGS samples were grab samples of surficial sediments that may have limited spatial representativeness. Both sets of samples, however, indicate that TEQ Dioxins in the harbor are a potential cause of impairment. Although the wildfire can be considered a probable contributor to the TEQ Dioxins concentrations in the harbor, there is no conclusive evidence that points to the wildfire as the primary source. It seems more likely that the majority of the concentrations in sediment reflect long-term accumulation associated with sources such as automobile and boat engine exhaust.

Several heavy metals in the ash exceeded the screening thresholds by significant margins. These metals include An, As, Co, Cu, and Pb. Table 21 below displays the level of these metals from three composite samples, as well as the respective screening thresholds to which the sample results were compared.

Table 21. Metal and TEQ Dioxins concentrations observed in ash samples from the Lāhainā fire.

Parameter	Screening Threshold Values (mg/kg)[1]	Composite Sample 1 Values (mg/kg)	Composite Sample 2 Values (mg/kg)	Composite Sample 3 Values (mg/kg)
Antimony	6.3	26	24	26
Arsenic[2]	23	69	62	64
Cobalt	4.7	27.4	23	25.7
Copper	630	1400	1970	1630
Lead	200	383	416	431
TEQ Dioxins	0.00024	0.0000939	0.000103	0.0001

Source: Hawaiʻi DOH (2025b)
Notes:
[1] Screening threshold values represent action levels for unrestricted current or future land use that address direct exposure to humans. The EALs are based on Table I-1 of DOH's TGM EAL Surfer (found here: Environmental Hazard Evaluation and Environmental Action Levels – HEER Office (Hawaiʻi.gov)) at the time of data release (December 2023). These EALs are toxicity-based and consider bioavailability of substance but do not account for natural background levels.
[2] Bioaccessible forms.

DOH and USACE have also collected over 1,000 air quality samples across multiple locations in Lāhainā since January 2024. DOH has determined that levels of particulates, heavy metals, and asbestos in the air are at levels that protect public health (Hawaiʻi DOH 2025b). Contributions of pollutants from atmospheric deposition of ash into fresh and nearshore marine waters is likely to be low, in large part due to the efforts to stabilize ash and dust immediately following the wildfire.

Pre- and post-fire monitoring of sites by HOKWO within the Kahoma nearshore marine AU, the Kauaʻula nearshore marine AU, and Lāhainā Harbor AU (Callender et al. 2024) show no apparent changes in averages for pH, turbidity, TN, nitrate + nitrite, ammonia, total phosphorus (TP) and phosphate during either dry (May 1–October 31) or wet (November 1–April 30) seasons. High outlier values of TP (ranging from 179 µg/L to 217 µg/L) on 4/26/24 for all seven sites across the three AUs were excluded from the evaluation; these values were excluded because they appear to be in error based on a lack of corroborating elevated values of turbidity and phosphate on that date, which would be expected if TP were actually at the reported levels. Despite no apparent change in monitored conventional pollutant parameters, it is not possible to exclude the fire as being a contributor to turbidity, nitrogen, and phosphorus based on the available data and information, e.g., there is no- data addressing how pollutant contributions from other sources may have changed over the same period. Nevertheless, it appears that any contributions resulting from the effects of the fire are minimal relative to other ongoing watershed sources.

In conclusion, the prompt and extensive clean-up effort following the wildfire likely prevented significant increases in loading of nutrients, metals, sediment, and POCs to inland and marine waters associated with the Kahoma and Kauaʻula watersheds. As described elsewhere in Section 4.2, the primary sources of these pollutants appear to be historical agricultural land grading/uses and associated erosion (nutrients, metals, sediment), ongoing urban runoff (nutrients, metals, sediment, POCs), and ongoing boat and harbor maintenance (metals, POCs). Lingering effects of the fire (e.g., burning of soil organic matter, which impacts soil health) may exacerbate surface runoff and loading of nutrients, metals, sediment, and POCs associated with existing land uses and legacy land use impacts. However, any ongoing contributions of nutrients, metals, sediment, and POCs to fresh and marine waters associated with the effects of the wildfire would likely be indistinguishable from the pre-fire pollutant loading given the general absence of practices to protect water quality from pollutants associated with urban stormwater and historical agricultural land management.

Regardless of whether the fire is a significant source of additional pollutant loading, there remains an immediate need to improve soil health, re-establish vegetation, and implement stormwater practices to protect water quality within the Kahoma and Kauaʻula watersheds. For example, some vegetation burned by the fire is growing back naturally, yet there is a need for additional revegetation efforts to strengthen the role of vegetation communities in regulating hydrology and protecting water quality at the watershed scale (e.g., by increasing precipitation interception, increasing evapotranspiration, increasing soil organic matter levels, reducing surface runoff, inhibiting erosion of soils and streambank sediments, and uptake of nutrients).

4.2.1.12 Unimproved Roads

There are no available data and information evaluating dirt roads as a source of sediment within the Kahoma and Kauaʻula watersheds. However, observations of dirt roads in the agricultural district of the Wahikuli and Honokōwai watersheds (north of Lāhainā) have documented that a lack of BMPs for runoff and sediment control along many sections of road result in an ongoing source of sediment eroded from road surfaces and fill material at stream and gulch crossings (SRGI 2012a). “Push piles” are commonly found on the edges of dirt roads and consist of sediments that were scraped to the side of roads during road construction and maintenance (Group 70 and SRGI 2016). When left unvegetated, sediments can erode and enter drainageways and streams. It is likely that similar conditions occur for dirt roads in Kahoma and Kauaʻula watersheds, which can therefore be considered a probable source of sediment.

4.2.1.13 Urban Runoff

Urban stormwater management is a major concern for Lāhainā. The Town of Lāhainā's drainage management plan was developed in 1988 and updated in 2005, to address frequent flooding of streets and buildings by stormwater (Belt Collins 2005). The plan is currently being updated to more fully address stormwater infrastructure needs. Urban runoff in Lāhainā is exacerbated by surface runoff from former agricultural fields upslope of Lāhainā, which is conveyed through small drainage ways into the urbanized area. Water quality practices for urban stormwater are of limited extent in Lāhainā. Although some stormwater infiltrates into the ground (e.g., in detention or retention basins) or evaporates, much of the stormwater drains through short, limited capacity culverts that outlet to the ocean, with no treatment prior to discharging (Belt Collins 2005). A map contained within Lāhainā's 2005 Drainage Master Plan displays stormwater outfalls to Kahoma stream AU (four, including a diversion ditch) and the Kahoma (four outfalls) and Kauaʻula (eight outfalls) nearshore marine AUs (Belt Collins 2005).

There are limited data and information associated with urban runoff water quality for Lāhainā. However, urban runoff has been identified as a source of sediment, nutrients, metals (including Cu, Pb, and Zn), and *Enterococci* bacteria (e.g., from pet waste) in other Maui watersheds (Group 70 and SRGI 2016, Reyes 2019, SRGI 2012a). Urban runoff can be a source of chemicals such as PAHs, pesticides (Burant et al. 2018), and Dioxins (CIDFS 2003).

Urban runoff often contains heavy metals derived from building materials (Hawaiʻi DOH 2018b) and automobile traffic (Hédouin et al. 2011). Inorganic As was used as an insecticide in "canec" board, which was made out of waste sugar cane fiber and widely used for ceilings or walls in home or commercial construction in Hawaiʻi during the 1930s through the 1950s (Hawaiʻi DOH 2018b). Additionally, CCA was a common wood preservative (e.g., pressure-treated lumber) for many years. Automobile exhaust and wear of vehicle parts such as brake pads and tires releases metals into the environment including Cd, Cr, Cu, Hg, Pb, Ni, Se, and Zn (Ozaki et al. 2004). Asphalt pavement can be a source of Ni and V. The metals leached from building materials and emitted by automobiles can contaminate soils and sediments and be transported in storm runoff.

In September 2023 and January 2024, USGS collected terrestrial sediment and soil samples for analysis of metals and organic contaminants, including some from urban stormwater conveyances and outfalls in Lāhainā (Hawaiʻi DOH 2025b). Although these samples were not collected according to DOH protocols, they are useful as an indicator of contamination. These data can help interpret and evaluate the marine water and sediment data. For example, it may be useful in identifying causes, sources, and potential critical source areas for potentially elevated heavy metals levels observed in nearshore marine waters. Sediment in a culvert at Punakea Loop (based on the station coordinates, the USGS dataset appears to incorrectly assign the station as being located along Pualea Loop), located in an unburned area, had values for An, As, Cd, and Pb that were below the method detection limit, while Cu, Hg, and Zn were below the 95^{th} percentile of background levels of metals in Hawaiian soils (AECOM 2012). At the Wahikuli culvert site (near the intersection of Leialii Pkwy. and Hwy. 30), all metals concentrations in sediment were below the 95^{th} percentile of background levels. Sediment metals at the Outfall I site (near the intersection of Front St. and Kauaʻula Rd) were above the 95^{th} percentile of background for the following metals: Ag, An, As, Cu, Pb, and Zn. Sediment metals at the Outfall J site (near Front St., north of the mouth of Kauaʻula stream) were above the 95th percentile of background for the following metals: An, As, Cu, and Zn. PAHs were below the method detection limit at Wahikuli culvert, Outfall I, and Outfall J. Comparison of observed TEQ Dioxins/Furans values in sediment to the DOH natural background level of TEQ Dioxins (2.0E-5ppm) (Hawaiʻi DOH 2019) provides a reasonable benchmark for assessing the relative degree of contamination in sediment since the purpose of this evaluation is to identify probable sources of TEQ Dioxins observed in marine waters rather than indicate whether the sediments pose a risk to human health. The concentration of TEQ Dioxins and Furans at the Outfall I site (4.0E-4ppm) and Outfall J site (9.1E-5ppm) exceed the background level value while the concentration at the Wahikuli culvert site (4.4E-6ppm) did not exceed. In summary, the available data for sediment in stormwater conveyances indicates that stormwater runoff is a probable source of heavy metals and TEQ Dioxins to the Kahoma and Kauaʻula nearshore marine AUs.

Studies have linked urban runoff on the Hawaiian Islands to elevated heavy metals concentrations in freshwater sediment. Hédouin et al (2011) noted that "in the Hawaiian Islands, a combination of basaltic rocks and large human populations with high traffic densities have led to elevated concentrations of copper, chromium, lead and zinc in streambed sediments (Andrews and Sutherland 2004, McMurtry et al. 1995), which in some cases, exceed the aquatic-life guidelines (De Carlo et al. 2005)." On Oahu, Andrews and Sutherland (2004) found evidence that Cu, Pb, and Zn were increasingly enriched in stream sediment in a downstream direction, corresponding to an increasing gradient of urban land use. In an urban canal on Oahu, De Carlo and Spencer (1997) found that Pb levels in the layers of freshwater sediment cores reflected a chronological history of deposition. The oldest sediment layers contained the least amount of Pb (<10 ppm), followed by a peak (750 ppm) corresponding to the 1970s before the use of alkyl-lead fuel additives was phased out, with a subsequent decline (100 ppm– 300 ppm) in the most recent layers. Cd, Cu, and Zn were also enriched in more recent sediment layers, although there was no apparent peak in concentrations associated with a specific period. The findings from these studies support a conclusion that urban runoff (in addition to sediment loads associated with historical agriculture) is a source of elevated metals (including As, Co, Cr, Cu, Pb, Ni, V, and Zn) in sediments observed in USGS samples in stormwater conveyances and below stormwater outfalls (Hawaiʻi DOH 2025b).

4.2.2 Unlikely Sources

The following potential sources are considered unlikely to contribute to observed pollutant levels in the Kahoma and Kauaʻula nearshore marines AUs based on the available data and information. They are included here to document that they were considered as potential sources and that the available data and information did not support a conclusion that they are probable sources of water quality degradation in the Kahoma and Kauaʻula nearshore marines AUs.

4.2.2.1 Coastal Erosion

The *West Maui Watershed Management Plan* noted that erosion of clay and silt banks along the shoreline could contribute to turbidity impacts upon coral reefs, but that no information was available linking shoreline erosion to coral reef health (USACE 2023). The USACE also noted that the West Maui coastline is considered sand-starved, which suggests that coastal erosion of sand banks is irrelevant. The University of Hawaiʻi at Mānoa's Coastal Geology Group concluded that West Maui shorelines have experienced light to moderate erosion (averages of -0.3 ft/yr to -1.0 ft/yr) based on analyzing historical shoreline positions from 1912 to 1997 (Romine and Fletcher 2013). At face value this suggests that coastal erosion within the Kahoma and Kauaʻula nearshore marine AUs is not a major source of turbidity and sedimentation in nearshore marine waters.

4.2.2.2 Wastewater Treatment Plant Discharge

The LWRF was identified in the 2012 *Wahikuli-Honokōwai Watershed Management Plan* (SRGI 2012a) and the 2023 USACE West Maui Watershed Study (USACE 2023) as an ongoing source of nitrogen loading (i.e., nitrate + nitrite) to the nearshore marine ecosystem north of Lāhainā. The LWRF facility and its injection wells are located roughly four miles north of the Kahoma Stream mouth. The facility injects treated wastewater into groundwater, which over time seeps into the nearshore marine ecosystem. There is also evidence that the Kahekili reef is being impacted by chronic exposure to low-pH groundwater, causing erosion of corals at eight times the rate of corals in unaffected areas (Prouty et. al. 2017). Process upgrades at the wastewater treatment facility appear to be reducing nitrate + nitrite concentrations in the injected wastewater (USACE 2023). In 2025 federal funding was awarded for expansion of the facility, including additional upgrades that will increase the capacity for recycling up to 3,472 acre-feet of water for non-potable uses (County of Maui 2025a).

In addition to nutrients, wastewater treatment plant effluent commonly contains heavy metals (Karvelas et al. 2003) and synthetic chemicals such as pharmaceuticals (Khasawneh and Palaniandy 2021), PCBs (Balasubramani et al. 2014), and PFAS (Lenka et al. 2021). USGS documented the presence of pharmaceuticals (e.g., carbamazepine and sulfamethoxazole), two synthetic musk fragrances, a fire retardant (tris(dichloroisopropyl) phosphate), and a plasticizer compound ((tris(2-butoxyethyl)) phosphate) in water discharged from submarine springs associated with the LWRF wastewater plume (Hunt and Rosa 2009).

At this time, the LWRF is not considered to be a probable source of water quality degradation to the Kahoma and Kauaʻula nearshore marine AUs due to a lack of evidence that pollutants in its effluent are impacting, or even being transported to these waterbodies.

4.3 SUMMARY OF THE CAUSES AND SOURCES OF WATER QUALITY DEGRADATION

The causes and sources of water quality degradation in fresh and marine waters can be categorized according to parameter (sediment, nutrients, bacteria, etc.) and the geographic or type/classification of source (eroding streambanks, cesspools, urban stormwater, etc.). Sources are often grouped by those requiring short-term remedial actions and sources that require longer-term restoration/protection actions. The Lāhainā wildfire is a source whose effects upon water quality requires an immediate response to prevent pollutant contributions, while the other sources will generally necessitate longer-term planning and implementation activities. Most of the causes of impairment (e.g., turbidity) overlap among sources and will require both short and long-term responses to address.

Table 22 summarizes documented and potential causes of water quality degradation associated with the Lāhainā wildfire. Linkage in the table of documented or potential causes to the wildfire is not intended to imply that the wildfire is the primary or only source (see also Table 22 for additional probable sources).

Table 23 summarizes the documented and potential causes of water quality degradation and corresponding probable sources associated with both historical and ongoing long-term land use.

Table 22. Causes of Water Quality Degradation Requiring Immediate Response.

Waterbody	AU ID	Designated Use	Cause of Impairment	Cause Status	Probable Source
Kahoma Stream	6-1-05	Aquatic Life; Recreation	Turbidity	Documented	Wildfire
		Aquatic Life	Sediment	Potential	Wildfire
		Aquatic Life; Recreation	TN, $NO_2 + NO_3$	Potential	Wildfire
		Aquatic Life	Metals (Cr, Co, Cu, Ni, V)	Potential	Wildfire
Kauaʻula Stream	6-1-04	Aquatic Life; Recreation	Turbidity	Potential	Wildfire
		Aquatic Life	Sediment	Potential	Wildfire
		Aquatic Life; Recreation	TN, $NO_2 + NO_3$	Potential	Wildfire
		Aquatic Life	Metals (Cr, Co, Cu, Ni, V)	Potential	Wildfire
Kahoma Nearshore Marine	HIW20009	Aquatic Life; Recreation	Chlorophyll-a[1]	Documented	Wildfire
		Aquatic Life; Recreation	$NO_2 + NO_3$, NH_4	Documented	Wildfire
		Aquatic Life; Recreation	Turbidity	Documented	Wildfire
		Aquatic Life	Metals (Cr, Co, Cu, Ni, Se, V)	Potential	Wildfire
		Aquatic Life	Sediment	Potential	Wildfire
Kauaʻula Nearshore Marine	HIW20012	Aquatic Life; Recreation	Chlorophyll-a[1]	Documented	Wildfire
		Aquatic Life; Recreation	$NO_2 + NO_3$, NH_4	Documented	Wildfire
		Aquatic Life; Recreation	Turbidity	Documented	Wildfire
		Aquatic Life	Metals (Cr, Co, Cu, Ni, Se, V)	Potential	Wildfire
		Aquatic Life	Sediment	Potential	Wildfire
Lāhainā Harbor	HIW00137	Aquatic Life	Metals (An, As, Cr, Co, Cu, Ni, V, Zn)	Potential	Wildfire
		Aquatic Life	TEQ Dioxins	Potential	Wildfire

Note:
Chlorophyll-a impairment (a measure of excessive algal growth) in the Kahoma and Kauaʻula nearshore marine AUs is an established impairment as identified in Hawaiʻi's 303(d) list. Although chlorophyll-a data was not evaluated in this plan, the wildfire is a potential source of $NO_2 + NO_3$ and NH_4 **which contributes to excessive algal growth.**

Table 23. Causes and Sources of Water Quality Degradation Requiring a Long-Term Response

Waterbody	AU ID	Designated Use	Cause of Impairment	Cause Status	Probable Source
Kahoma Stream	6-1-05	Aquatic Life; Recreation	Turbidity	Documented	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Sediment	Potential	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Recreation	*Enterococci*	Potential	• Non-native species • Urban runoff
		Aquatic Life	NO_2 + NO3, TN,	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Loss of coastal estuaries, ponds, wetlands • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Metals (Cr, Co, Cu, Ni, V)	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Natural Sources • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
Kauaʻula Stream	6-1-04	Aquatic Life; Recreation	Turbidity	Potential	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff

Waterbody	AU ID	Designated Use	Cause of Impairment	Cause Status	Probable Source
		Aquatic Life	Sediment	Potential	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Recreation	*Enterococci*	Potential	• Cesspools and septic systems • Non-native species • Urban runoff
		Aquatic Life	TN, NO_2 + NO_3	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Metals (Cr, Co, Cu, Ni, V)	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Natural sources • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
Kahoma Nearshore Marine	HIW20009	Aquatic life; Recreation	Chlorophyll-a, NO_3 + NO_2, NH_4	Documented	• Agricultural land management • Cesspools and septic systems • Climate variability • Commercial and residential landscaping management • Loss of coastal estuaries, ponds, wetlands • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff

Waterbody	AU ID	Designated Use	Cause of Impairment	Cause Status	Probable Source
		Aquatic life; Recreation	Turbidity	Documented	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Sediment	Potential	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Metals (Cr, Co, Cu, Ni, Se, V)	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Natural sources • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Recreation	*Enterococci*	Potential[1]	• Cesspools and septic systems • Non-native species • Urban runoff
Kauaʻula Nearshore Marine	HIW20012	Aquatic life; Recreation	$NO_3 + NO_2$, NH_4	Documented	• Agricultural land management • Cesspools and septic systems • Climate variability • Commercial and residential landscaping management • Loss of coastal estuaries, ponds, wetlands • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic life; Recreation	Turbidity	Documented	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff

Waterbody	AU ID	Designated Use	Cause of Impairment	Cause Status	Probable Source
			Sediment	Potential	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
			Metals (An, As, Cr, Co, Cu, Pb, Ni, Se, V, Zn)	Potential	• Agricultural land management • Climate variability • Commercial and residential landscaping management • Natural sources • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Recreation	*Enterococci*	Potential[1]	• Cesspools and septic systems • Non-native species • Urban runoff
Lāhainā Harbor	HIW00137	Aquatic Life; Recreation	Turbidity	Documented	• Agricultural land management • Climate variability • Loss of coastal estuaries, ponds, wetlands • Non-native species • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	Metals (An, As, Cr, Co, Cu, Ni, V, Zn)	Potential	• Agricultural land management • Boat and harbor maintenance • Climate variability • Commercial and residential landscaping management • Natural sources • Streambank erosion • Stream channel modification • Unimproved roads • Urban runoff
		Aquatic Life	TEQ Dioxins	Potential	• Boat and harbor maintenance • Urban Runoff

Note:
[1] DOH has determined that *Enterococci* in the Kahoma and Kauaʻula nearshore marine AUs meet water quality criteria; however, infrequent high values of *Enterococci* in the Kahoma and Kauaʻula nearshore marine AUs indicates that there is a need for measures and practices designed to protect marine waters from *Enterococci* loading so that the Recreation designated uses do not become impaired in the future.

4.4 DATA AND INFORMATION GAPS

This section identifies key data and information gaps associated with the identification of causes and sources of water quality degradation. It is anticipated that additional monitoring and assessment would be able to fill the gaps identified below. Filling the gaps will not only help with cause/source verification but will also help with the identification of critical source areas, estimating pollutant loads to waterbodies, and estimating potential load reductions resulting from pollutant control measures and practices.

4.4.1 Sediment and Turbidity

- Turbidity/TSS/SSC monitoring data for Kahoma and Kauaʻula streams
- Sediment loads to Kahoma and Kauaʻula streams from sources on conservation, agricultural lands and urban lands
- Location of eroding stream banks
- Instream sedimentation data/information for Kahoma and Kauaʻula streams to address if fine sediment impairs aquatic life
- Sediment loads contributed from Kahoma and Kauaʻula streams and stormwater outfalls to nearshore marine AUs
- Sediment loads to nearshore marine AUs from each probable source, including loads associated with wildfire effects
- Marine sedimentation related data to address if fine sediment impairs aquatic life.

4.4.2 Nutrients

- TN, NO_2+NO_3, NH_4, and TP monitoring data for Kahoma and Kauaʻula streams
- TN, NO_2+NO_3, NH_4, and TP loads to Kahoma and Kauaʻula streams from probable sources on conservation, agricultural, and urban lands
- Nutrient related conditions in Kahoma and Kauaʻula streams (e.g., do TN, NO_2+NO_3, NH_4, or TP impair aquatic life?)
- TN, NO_2+NO_3, NH_4, and TP loads contributed from Kahoma and Kauaʻula streams and stormwater outfalls to nearshore marine AUs
- TN, NO_2+NO_3, NH_4, and TP loads to nearshore marine AUs from each probable source, including loads associated with wildfire effects

4.4.3 Enterococci

- *Enterococci* monitoring data for Kahoma and Kauaʻula streams

- *Enterococci* loads to Kahoma and Kauaʻula streams from probable sources on conservation, agricultural, and urban lands
- *Enterococci* conditions in Kahoma and Kauaʻula streams (e.g., is recreation use impaired?)
- *Enterococci* loads contributed from Kahoma and Kauaʻula streams and stormwater outfalls to nearshore marine AUs
- *Enterococci* loads to nearshore marine AUs from each probable source, including loads associated with wildfire effects

4.4.4 Metals

- Metals monitoring data for Kahoma and Kauaʻula streams
- Metals loads to Kahoma and Kauaʻula streams from sources on conservation, agricultural, and urban lands
- Instream metals conditions for Kahoma and Kauaʻula streams to address if metals impair aquatic life
- Metals loads contributed from Kahoma and Kauaʻula streams and stormwater outfalls to nearshore marine AUs
- Metals loads to nearshore marine AUs from each probable source, including loads associated with wildfire effects
- Marine metals related data to address potential aquatic life impairment, including:
    - More rigorous characterization of metals in water/sediment of stormwater conveyances and below stormwater outfalls
    - Additional data for dissolved copper in water
    - Biological/ecological data to assess potential metals effects

4.4.5 POCs

- Marine TEQ Dioxins data to address potential impairment to aquatic life in Lāhainā Harbor
    - Verification of TEQ Dioxins in sediment within Lāhainā Harbor
    - Biological/ecological data to assess potential effects of TEQ Dioxins within the harbor
- TEQ Dioxins loads to nearshore marine AUs from each probable source, including loads associated with wildfire effects
- More rigorous characterization of TEQ Dioxins in water/sediment in stormwater conveyances, below stormwater outfalls, and from atmospheric deposition.

5.0 WATER QUALITY PROTECTION MEASURES AND PRACTICES

Protection and restoration of fresh and marine water quality in the Lāhainā area requires both immediate and long-term implementation of water quality protection measures and practices. Accordingly, both short- and long-term goals have been developed to guide watershed protection efforts. The short-term goal is ***to protect fresh and marine water quality from the effects of the Lāhainā wildfire***. Two long-term goals have been identified to guide watershed protection efforts. The first long-term goal is ***to reduce the risk of future impacts to fresh and marine water quality from wildfire.*** The second long-term goal is ***to restore and protect fresh and marine water quality from pollutants generated by historic and current land uses.*** The overarching strategy that these goals have in common is to reduce sediment, nutrients, metals, fecal bacteria (*Enterococci*), and POC loads to nearshore marine waters by reducing surface runoff to streams, drainageways, and storm water conveyances. This section identifies the following water quality protection measures and practices:

- Water quality-related measures and practices that have been completed or are underway.
- Measures and practices to address wildfire effects and whose implementation can begin within two years of alternative watershed management plan completion.
- Measures and practices to reduce the risk of water quality impacts from future wildfire.
- Measures and practices to protect water quality from the effects of historical and current land uses.
- Organizations and funding resources for planning and implementing water quality protection efforts.

This Preliminary Planning Framework focuses on measures and practices whose implementation can begin within two years of completion of an alternative watershed plan. Some actions identified under this goal can be completed within two years of plan completion, such as removal of sediment and debris from culverts. Other actions should be initiated within two years of plan completion, yet are part of longer-term water quality protection strategy, such as actions to reduce soil erosion, improve soil health, and restore native vegetation communities.

This framework also identifies potential measures and practices that support the long-term water quality protection goals; however, these measures and practices are not addressed in detail because they will be more appropriately addressed in a full EPA nine-element watershed management plan. For example, existing sediment loads from streambank erosion and pollutant load reductions associated with erosion control practices are not estimated in this plan but instead are to be estimated as part of the development of a nine-element plan.

The management measures and practices identified in this section represent a variety of options intended for consideration by stakeholders. It is anticipated that the final selection of specific measures and practices for both the immediate implementation phase and the long-term implementation phase will be conducted through processes that involve public engagement, discussion, and input.

As stated in Section 1, it is imperative that Native Hawaiian frameworks and knowledge systems inform water quality protection and wildfire recovery efforts. This plan acknowledges the traditional ahupuaʻa system as a guiding framework in recommended planning measures. The ahupuaʻa system takes a holistic watershed management approach that recognizes the connection between natural systems from mauka to makai. Within this framework, resources are managed with the understanding that the management of forestry and agricultural uses in upland areas can affect the quality of streams and coastal waters (NSSCP 2011). The ahupuaʻa system was taken into consideration when identifying BMPs in the Kahoma and Kauaʻula watersheds. This is reflected in the selection of measures and practices that prioritize the repair of ecological processes supporting water quality and hydrologic function, rather than relying solely on structural mitigation approaches designed to treat symptoms without addressing the root causes.

5.1 MEASURES AND PRACTICES COMPLETED OR UNDERWAY

The community of Lāhainā, County of Maui, DOH, EPA, FEMA, and the Army Corps of Engineers have been working together diligently on wildfire recovery efforts in Lāhainā. Water quality related measures and practices that have been implemented since the 2023 wildfire or are currently underway are listed in Table 24 below (note that this list may not be comprehensively identify all water quality related implemented or planned activities).

Table 24. Measures and Practices Completed, Ongoing, or Planned.

Measure/Practice	Lead(s)	Status
Removal of over 400,000 tons of ash and debris from burned properties (County of Maui 2025b).	County of Maui, U.S. Army Corps of Engineers, DOH	Completed.
Emergency temporary soil/ash stabilization chemical soil stabilizer upon approximately 1,390 burned residential lots and 148 commercial properties (County of Maui 2025b).	County of Maui, EPA, DOH	Completed.
Installation of filter socks at storm drains to prevent fire-related pollutants from entering stormwater conveyances.	County of Maui, DOH	Completed.
Demolition of the remaining harbor infrastructure (not including the seawalls) (County of Maui 2025b).	County of Maui	Completed in 2024.
Dredging of the harbor (County of Maui 2025b). This is expected to decrease the levels of metals and dioxins in the sediments of the harbor.	County of Maui	Ongoing, beginning in March 2025, with estimated completion by September 2025.
Reconstruction of the Lāhainā harbor infrastructure (County of Maui 2025b).	County of Maui	Ongoing, anticipated to be completed by the fall of 2026.
Establishing sewer connections for approximately 231 of the single-family home lots in the Wahikuli subdivision (AECOM 2025).	County of Maui, EPA, DOH	Ongoing, financing and design anticipated to be completed in 2025 (Hawaiʻi DOH 2025a). Construction anticipated to begin in 2025.

Measure/Practice	Lead(s)	Status
Updating the Lāhainā Drainage Master Plan, (County of Maui 2025b). The updated plan will better address localized flooding in urbanized areas of Lāhainā and will identify structural and non-structural practices for reducing stormwater volumes and protecting water quality.	County of Maui	Ongoing, with expected completion in 2025.
Updating the Environmental Impact Study on a project to divert a portion of floodwaters from Kahoma stream to Kaua'ula stream and a nearby secondary outlet to marine waters. Project would include multiple settling basins in the diversion channel to reduce sediment and turbidity in waters discharged into the nearshore marine waters (County of Maui 2025b).	USDA NRCS	Ongoing.
Development of Advisory Base Flood Elevation (ABFE) data for Lāhainā and North Lāhainā areas.	FEMA	Ongoing.
Reforestation project around Lāhaināluna High School's agricultural lands; Re-Landscape Hawai'i (Native Nursery).	Living Pono Project	Ongoing.
Emergency Watershed Protection Projects: sediment and debris removal, fencing, flood mitigation.	West Maui Soil and Water Conservation District	Canceled due to low landowner engagement.
Planting in Kahoma neighborhood to support recovery and growth.	Maui Nui Marine Resource Council	Ongoing.
Providing trees for Lāhainā recovery.	Treecovery Hawai'i	Ongoing.
Fencing to control feral ungulates, invasive weed control, monitoring of watershed health, and conducting public education to protect the native forests and watersheds of Mauna Kahālāwai, the West Maui Mountains.	Mauna Kahālāwai Watershed Partnership	Ongoing.
12 National Science Foundation (NSF) Rapid Response Research (RAPID) funded projects in progress since Fall 2023 to address the impacts to air and water quality, public health, ecosystem resilience and community evacuation responses.	University of Hawai'i Manoa	Ongoing.
Planting native species on over 300 acres in the middle watershed area (border of Kahoma and Kaua'ula watersheds) between Ku'ia Agricultural Education Center and DLNR land.	Kaiāulu Initiatives	Ongoing.
Education on principles of Mauka to Makai.	Hui o Wa'a Kaulua	Ongoing.
Community place-based, cultural foodscapes restoration, activism and learning.	Hawai'i Farmers Union Foundation, Ku'ia Ag Education Center (KAEC)	Ongoing.
Native forest restoration, urban planning, freshwater ecosystem restoration, agroforestry.	Kamehameha Schools	Planned.
Restoration of Moku'ula and Loko o Mokuhinia.	Maui County Department of 'Ōiwi Resources	Planned.

5.2 PROTECTING WATER QUALITY FROM LĀHAINĀ WILDFIRE EFFECTS

This section identifies measures and practices for immediate implementation (within two years of plan completion) on agricultural lands, urban lands, and the drainageways and stream gulches that connect these lands, per EPA guidance on the development of alternative watershed management plans (EPA 2024). The primary objective that will be used to guide the achievement of the goal to protect water quality from the Lāhainā wildfire effects are:

- Reduce the generation and transport of nutrient, sediment, metal, and POC loads in surface runoff from burned agricultural and urban lands.

Two overarching strategies that should be immediately initiated are the hiring of a watershed coordinator and establishment of a non-governmental Wai and Watershed partnership. These strategies are critical for ensuring successful coordination of planning and implementation efforts (both short and long term) among stakeholders including watershed residents, landowners, the business community, and federal/state/local agencies. A third overarching strategy for implementation in the near-term is to establish a native plant nursery to support native plant community restoration, as described in the *Lāhainā Long-Term Recovery Plan* (County of Maui 2024).

5.2.1 Agricultural Lands

This section addresses measures and practices for which implementation can begin within two years of completion of an alternative watershed management plan to address the wildfire effects upon agricultural lands. Measures and practices requiring long-term planning and implementation are to be addressed in a full EPA nine element watershed management plan. Five key near-term strategies that have been identified for agricultural lands are:

- Initiate soil health improvement.
- Facilitate re-vegetation of burned lands.
- Reduce runoff and erosion along unimproved roads.
- Reduce runoff and erosion along irrigation ditches.
- Reduce runoff and erosion along firebreaks.

5.2.1.1 Soil Health

As discussed in Section 4.2.1.1, it appears that historic land management practices have resulted in a soil organic matter deficit that has significant consequences for watershed hydrology and water quality. It is recommended that a soil health improvement initiative be undertaken on agricultural lands to improve watershed scale hydrologic functioning of soils in the Kahoma and Kauaʻula watersheds. Improvement of soil health is a long-term process requiring ongoing implementation of restorative practices to increase organic matter, enhance natural biota, improve water infiltration, and reduce erosion.

However, actions can be initiated in the near-term that will help protect water quality from wildfire effects and will also help provide a foundation for long-term watershed protection efforts.

The use of compost-based practices can serve as a cornerstone strategy for achieving soil health improvement. Compost applications can improve soil health in many ways, including, but not limited to improved soil structure, increased water infiltration into soils, and enhancement of a soil's water-holding capacity (EPA 2025). The soil health benefits of compost use often translate into decreased surface runoff, decreased soil erosion, improved plant establishment and growth, immobilization and degradation of soil contaminants, and reduced surface water and groundwater pollution (EPA 2025). Studies of compost use following wildfire have found significant reductions in the amount of surface runoff as well as reductions in suspended sediment and metals loads in runoff (Meyer 2001, Crohn 2013).

It is recommended that compost be applied at a rate of 8.5 to 17 tons/acre dry wt. (equivalent to 0.25-to-0.50-inch depth) (Stover et al. 2018) and a frequency of once every three years—subject to adjustment based on monitoring results—as surface applied compost degrades more quickly in warmer climates (Ozores-Hampton et al. 2022). The long-term objective should be to achieve and maintain a soil organic matter content of at least 5%, by mass (EPA 2025). The critical source areas are agricultural lands within the watersheds that are also within the wildfire burn perimeter (estimated to comprise roughly 450 acres), where higher priority should be placed on applications to lands that experienced moderate to high severity burning. Compost should be seeded for applications to lands in which natural recovery is lagging. Ground application methods are recommended where lands are accessible by vehicles while aerial application is recommended for less accessible areas. It is suggested that compost can be manufactured from food waste, food processing waste, landscaping residues, or agricultural residues (plant materials and livestock manure) originating on Maui. This practice should be initiated during the short term, although multiple compost applications across large acreages under multiple ownerships will require an extended implementation schedule.

The potential cumulative water holding capacity benefit of compost use on the agricultural lands can be conceptualized by the following example. According to USDA (2023), there are 1,436 acres of undeveloped land within the Lāhainā wildfire burn perimeter. A 0.25-inch application of compost to this acreage (equivalent to 8.5 tons per acre dry weight, assuming a bulk density of 1,000 lbs per cubic yard and a moisture content of 50%) is equivalent to 12,206 tons of compost. Since compost can hold five times its weight in water (Faucette 2012), the cumulative compost application has the potential to hold 61,030 tons of water, which is equivalent to approximately 14.6 million gallons of water, or roughly 180 acres covered by three inches of water.

5.2.1.2 Revegetation

NRCS (2023) recommended re-vegetation activities on approximately 1,200 acres of agricultural lands. It appears that non-native buffelgrass cover is naturally reestablishing on much of this agricultural acreage. Revegetating areas where natural recovery is slower will help to control surface runoff and sediment load generation and transport into fresh and marine waters. Seeding/planting of native plant species such as Pili grass (*Heteropogon contortus*) and other native grass, shrub, and tree species is preferable. However, NRCS (2023) noted that the availability of native plant materials is uncertain, as is the ability of native plantings to compete with buffelgrass without intensive management involving site preparation, temporary irrigation, and ongoing control of competing non-native vegetation. For this reason, NRCS recommended seeding with buffelgrass (*Cenchrus ciliaris*), potentially supplemented by additional non-native, non-invasive species that are used in erosion control, such as annual rye grass (*Lolium multiflorum*) or perennial rye grass (*Lolium perenne*). Although not preferable, re-seeding with non-native grasses is a practical option given its value for erosion control and the high likelihood that buffelgrass will eventually dominate any agricultural acreage that is not intensively managed to control its spread. However, it should be noted that buffelgrass and rye grasses are flammable when dry; annual rye grass experiences a mass-die off yearly, which may create large fuel sources for wildfire.

Aerial broadcast seeding was recommended by NRCS (2023) for most of the burned area, supplemented by hydroseeding of more severely burned areas (on terrain that ground vehicles an access) and temporary irrigation along gulches to accelerate recovery. Feral ungulate removal or fencing has been recommended in other Maui watersheds where grazing and browsing may impede revegetation efforts (MEC 2019). Ungulate removal or fencing should be considered on agricultural lands in the Kahoma and Kauaʻula watersheds where ungulate impacts are known or anticipated to occur.

5.2.1.3 Unimproved Roads

Measures and practices are needed to reduce runoff and erosion associated with the network of unimproved roads in the watersheds. During the short-term implementation phase, non-structural practices that require limited planning can be implemented to address wildfire effects such as low to moderate erosion associated with increased runoff and erosion due to loss of adjacent vegetation. One-to-two-inch-deep seeded compost-blankets can be used to reduce erosion along road shoulders where soil health is poor; compost filter socks and compost berms can be used to filter sediment and other contaminants from road runoff (EPA 2025). Ditch erosion in areas that can sustain vegetation can be mitigated with the use of temporary erosion control blankets or permanent turf reinforcement mats. Implementation of structural practices may need to be reserved for the long-term implementation phase due to planning requirements. On sites where erosion is moderate to severe, additional structural practices may include grade breaks, dips and low water crossings, water bars, cross-drains and culverts, ditches, turnouts, sediment traps, geosynthetics, soil and/or aggregate stabilization, slope stabilization, and water bars (MEC 2023). Also, wherever feasible, measures should be taken to hydrologically disconnect unimproved roads from streams and drainageways. For example, low-water crossings of stream channels by unimproved roads convey runoff and sediment directly into streams. Hydrologic disconnection of roads from waterways is also likely to be more feasible during the long-term implementation phase rather than during the short-term phase.

5.2.1.4 Irrigation Ditches

NRCS (2023) indicated that most irrigation ditches on agricultural lands appear to route water away from the stream gulches. Only one location was identified where field runoff is routed to Kauaʻula stream, although there may be additional locations. Treatment of ditches that discharge to the stream gulches will help reduce erosion and sediment loading to streams; reductions in sediment loading will also reduce metals and nutrient loading. Hydrologic disconnection of abandoned irrigation ditches from streams and other drainageways is recommended where possible. Another alternative is to establish vegetation in ditches within 200 ft of outlets, with a rock check dam placed where runoff discharges into the stream and rock riprap placed along the streambank where erosion is evident (NRCS 2023). Assuming the irrigation ditches are to remain unused for the foreseeable future, it is suggested that soil health and hydrologic functioning in the watersheds would benefit from native tree/shrub planting or grass seeding throughout the length of the abandoned ditches, along with berms to inhibit the flow of runoff, and compost mulch around tree/shrub plantings.

5.2.1.5 Firebreaks

USDA (2023) recommended rehabilitation of firebreaks not needed as a future road or firebreak. This typically consists of de-compacting the soil, increasing soil surface roughness and applying woody material (e.g., mulch) to impede runoff, and seeding. Where a firebreak needs to be maintained or is needed as a future road, USDA recommended installing drainage features such as water bars to prevent erosion and gully formation and potentially seeding with native grass; steep firebreaks should be rehabilitated rather than used as a road due to their maintenance difficulty. Some emergency firebreaks created by bulldozers crossed drainageways and gulches in multiple locations, resulting in soil being deposited in the channels. In these locations, soil deposits should be removed from the channels, damaged channel banks should be repaired, and woody debris or mulch should be spread adjacent to the channel to inhibit erosion and sediment transport.

5.2.2 Drainageways and Stream Gulches

This section addresses measures and practices to address the wildfire effects upon drainageways and stream gulches that can be implemented within two years of completion of an alternative watershed management plan. Two key near-term strategies for addressing water quality concerns related to drainageways and stream gulches include the following:

- Address the functional integrity of flood control embankments.
- Address fire-related sediment and debris deposits in drainageways and streams gulches.

The primary source of sediment, turbidity, and potentially other pollutants such as metals and nutrients appears to be streambank erosion, as described in Section 4: Causes and Sources of Water Quality Degradation. Although reducing sediment loads from streambank erosion is critical to the protection of fresh and marine water quality, measures and practices that can be implemented in the short term are limited due to a lack of available data on the location and extent of streambank erosion as well as the planning effort and resources that will be required to address this source. Although it has been deemed infeasible to remove similar anthropogenic sediment deposits along streams in other Maui watersheds (USACE 2023), it is uncertain if there are other approaches that would be as effective at achieving reductions in sediment and turbidity in the nearshore marine waters. Furthermore, it is unlikely that streambank stabilization practices that can be readily implemented within the next two years (such as streambank vegetation planting) will result in significant reductions in sediment loading associated with streambank erosion. This is due to the high erosive power of the streams originating in steep mountainous lands that receive large annual rainfall amounts. In the short term it is recommended that assessment work be completed to characterize and prioritize streambank erosion as well as monitoring of sediment loads (and associated loads of pollutants, such as TN and TP) in Kahoma and Kauaʻula watersheds to characterize sediment loads (described further in Section 7: Monitoring and Assessment). These actions will lay the foundation for addressing streambank erosion in a full EPA nine element watershed management plan.

Site specific practices identified below were recommended by NRCS (2023) for short-term implementation to reduce erosion and sediment loads associated with drainageways and stream gulches. Measures and practices requiring long-term planning and implementation are to be developed in a full EPA nine element watershed management plan.

5.2.2.1 Flood Embankments

NRCS (2023) noted potential problems with multiple embankments during their field survey. In one location, a portion of a flood control embankment was removed during the fire response in August 2023. The agency recommended that the removed section of embankment be replaced and constructed to the same shape as the existing embankment. At the same location it was recommended that the 8 ft high silt fence at the same location be moved to allow the proper function of the flood control embankment.

South of Lāhainā, NRCS (2023) noted that four embankments have been created, apparently to impound water, yet do not appear to be designed or constructed to any standards for water impoundment. A map is provided in the report showing the locations of the embankments. The main concern is that the embankments appear to be constructed of materials that are expansive, dispersive, or highly erodible. These conditions are associated with an increased risk of structural failure, which could result in property damage or impacts to water quality from sediment. If the embankments are needed to help control runoff, it is recommended that they be reconstructed according to NRCS standards.

5.2.2.2 Sediment and Debris Management

NRCS (2023) and USDA (2023) recommended several types of sediment and debris removal activities practices as a result of a post-fire survey of burned agricultural lands. NRCS observed several culverts where deposited sediments reduce culvert hydraulic capacity and potentially serve as a source for sediment loading to surface waterbodies. It is recommended that sediment be removed from all affected culverts to restore hydraulic function and reduce the risk of the sediments being delivered to marine waters during runoff events. USDA (2023) recommended removal of sediment and debris from existing sediment basins. This will help to ensure that these structures have the capacity to trap sediment during storm events.

NRCS (2023) observed a location along the Lāhainā Bypass (just south of Lāhaināluna Road overpass) where there is a risk of sediment being transported onto the road. It is recommended that mitigation measures be evaluated for preventing surface runoff from transporting sediment onto the road (NRCS 2023).

NRCS (2023) recommended removal of fallen trees within gulches, followed by mulch application to the top of banks within areas susceptible to overland flow. This would help to prevent the risk of debris blockages of bridges and culverts and prevent localized sediment delivery from the uplands into gulches and drainageways.

During the fire response efforts, 500 ft of fill material was placed in a section of a concrete-lined drainageway that connects to the concrete-lined reach of Kahoma stream to facilitate movement of large equipment to access a debris removal site. NRCS (2023) recommended removal of this fill material to prevent erosion and sediment delivery to Kahoma stream.

5.2.3 Urban Lands

State HAR for Water Pollution Control, County of Maui stormwater management requirements and soil erosion and sedimentation control requirements for construction, and the forthcoming updated Lāhainā Drainage Master Plan provide a foundation for controlling pollutant loading in urban stormwater. Additional options for implementing new measures and practices to address the wildfire effects upon urban stormwater are limited to those that do not require extensive planning efforts and implementation timelines. This is because implementation of measures and practices under an alternative watershed management plan are intended to begin within two years of plan completion per EPA's *Nonpoint Source Program and Grants Guidelines for States and Territories* (EPA 2024). Within this context, measures and practices for immediate implementation can be categorized into five key urban strategies that will help build momentum for undertaking long-term efforts to reduce stormwater volumes and pollutant loads (sediment, metals, nutrients, *Enterococci*, and POCs):

- Initiate soil health improvement.
- Initiate urban agroforestry.
- Incentivize green infrastructure.
- Acquire properties of importance to water quality protection.
- Monitor stormwater measures/practices and stormwater quality.

Additional resource intensive measures and practices will be needed to more fully address urban stormwater effects upon marine and fresh water. For example, implementation of many green infrastructure projects or restoration of historic wetlands would require considerable planning and implementation resources. Long-term measures and practices for protecting water quality will be the focus of a watershed plan that addresses all of EPA's nine minimum elements. However, consideration of potential urban stormwater related measures and practices should begin now. To this end, a preliminary list of potential stormwater related measures and practices in provided in Section 5.4.

5.2.3.1 Soil Health Improvement

Soil health improvement is a key strategy for reducing stormwater runoff and protecting water quality.

The use of compost in wildfire recovery efforts was identified as a priority strategy in the *Lāhainā Long-Term Recovery Plan* (County of Maui 2024). Compost-based landscaping practices can be used on urban residential and commercial properties to improve soil health, reduce stormwater runoff volumes, and protect water quality. The benefits of compost use are outlined in the section above on agricultural lands measures and practices and described in detail in the EPA report *Environmental Value of Applying Compost: Improving Soil Health for Stormwater Management, Contaminated Site Remediation, Ecosystem Restoration, Landscaping and Agriculture* (EPA 2025).

One-to-two-inch (e.g., 67–134 tons per acre wet weight) seeded compost blankets (i.e., grass seed mixed with compost and applied in a thin layer on soils) are recommended as an initial application for exposed soils where ground cover is sparse or not actively re-establishing (EPA 2025). For unburned turfgrass and turfgrass cover that is actively recovering, a 0.25-inch compost topdressing is recommended. The objective is to attain and maintain a soil organic matter content of at least 5%, by mass (EPA 2025). Periodic additional topdressing of compost to turfgrass will be required to achieve this objective, however, the required frequency of applications is uncertain. Following the initial application of compost, a suggested schedule is for annual topdressing to occur during the first two to three years, followed by reapplication every three years—with adjustments to the schedule informed by monitoring of soil organic matter content at several long-term monitoring sites. A 2-inch layer of compost mulch applied every two years is recommended for application to existing and new ornamental landscaping and around trees and shrubs, with adjustments made to the rate and frequency based on monitoring of compost degradation. Compost can also be applied to edible gardens, with the rates and frequency based on soil texture, existing organic matter content, and types of plants grown (EPA 2025).

5.2.3.2 Green Infrastructure

Stormwater measures and practices that promote infiltration of precipitation into soils should be implemented during the redevelopment of residential and commercial parcels within two years of the completion of this plan. Redevelopment of parcels is already occurring in Lāhainā. Where site conditions permit, low maintenance practices that promote infiltration of water into soils (such as rain gardens that can capture and infiltrate runoff from roofs and pavement) should be included in redevelopment of both commercial and residential properties. Additionally, efforts to minimize the area of impervious surfaces during property redevelopment should be implemented. A key near-term strategy is to incentivize the implementation of green infrastructure principles and practices into redevelopment and new development.

Maui County Code requires that the impervious surface area of lots within residential districts must not exceed 65% of the total zoning lot area for dwellings constructed under building permits applied for after January 1, 2023. There are no impervious cover limitations pertaining to other zone districts. Degradation of surface water bodies has been linked to impervious surface area of as little as 10% at the watershed scale; watersheds with impervious cover exceeding 25% experience are associated with severe aquatic habitat and water quality impairment (NHEP 2007). It is therefore important to find ways to encourage property owners to further reduce their stormwater runoff. Many states have created incentives for property owners to reduce stormwater runoff associated with impervious surfaces (EPA 2009). For residential and commercial properties being redeveloped or newly developed, incentives such as expedited construction permitting, discounts on stormwater fees or property taxes, or free rain garden installation may encourage property owners to reduce the area of impervious cover beyond that required in the Maui County Code. Incentives can vary based on whether they target residential or commercial properties. For long-term implementation, incentives could be expanded to encourage existing developed parcels to reduce impervious cover. Incentivizing additional limits on impervious cover area should incorporate a sliding scale based on parcel size, as the feasibility of limiting impervious cover area generally increases as parcel size increases. An example structure for residential lot incentive eligibility that accounts for increased practicality of additional limits on impervious cover as parcel size increases is provided below:

- <60% impervious cover for parcel sizes less than one-eighth of an acre
- <55% impervious cover for parcel sizes of one-eighth up to one-quarter of an acre
- <45% impervious cover for parcels of one-quarter up to one-half of an acre
- <25% impervious cover for parcels greater than one-half of an acre

Green infrastructure such as bioretention units, bioswales, green roofs, rooftop gardens, and rain gardens can play an important role in reducing stormwater runoff and improving the quality of runoff discharging to streams and marine waters. In the near-term, incentives can be created to encourage property owners to incorporate green infrastructure into re-development and new development. Common incentives for green infrastructure include (EPA 2009):

- **Stormwater Fee Discounts**: Stormwater fees are adjusted based on impervious surface area. If property owners reduce need for stormwater management services by reducing impervious area and the volume of runoff discharged from a property, the municipality reduces the fee.
- **Development Incentives**: Offered to developers during the process of applying for development permits. Examples include zoning upgrades, expedited permitting, reduced stormwater control requirements, and increases in floor area ratios.
- **Grants**: Can be used to provide direct funding to property owners and/or community groups for implementing a range of green infrastructure projects and practices.
- **Rebates and Installation Financing**: Can be used to provide funding, tax credits, or reimbursements to property owners who install specific practices. Often focused on practices needed in certain areas or neighborhoods.

- **Awards and Recognition Programs**: Provides marketing opportunities and public outreach for exemplary projects. May include monetary awards.

Compost-based practices are recommended for stormwater control and green infrastructure (EPA 2025). Compost-based practices such as compost blankets, compost filter socks, and compost berms have been found to be more effective at reducing runoff and protecting water quality from sediment, metals, PAHs, and sometimes nutrients (e.g., depending on the nitrogen and phosphorus content of the compost) than traditional stormwater practices such as topsoil and straw placement, hydroseeding, silt fencing, or straw bales. One-to-two-inch compost blankets can be applied either during and after construction sites to reduce runoff and prevent soil erosion and pollutant transport. Compost filter socks or compost filter berms can be installed on the perimeter of construction sites and at storm drain inlets; the filter berms can also be used as check dams in small drainage ditches. Compost feedstocks or amendments high in iron or aluminum (e.g., water treatment residuals) can be used to immobilize dissolved phosphorus in runoff. Where green stormwater infrastructure is being installed, it is recommended that compost be incorporated into the plant growing media at a volume of 10% to 30%; compost is also recommended for use in permeable pavement (e.g., as grout material between pavers) (EPA 2025).

5.2.3.3 Urban Agroforestry

Urban agroforestry has the potential to provide significant hydrologic, water quality, and microclimate benefits (Favor 2023). It helps reduce runoff and protect water quality by increasing precipitation interception, evapotranspiration, and soil organic matter levels, while reducing surface runoff, soil erosion, and loads of sediment and other pollutants in stormwater transport (Delgado-Lemus and Moreno-Calles 2022, Zhu et al. 2020). Urban agroforestry also has the potential to provide significant benefits to the community of Lāhainā, as an opportunity to select and steward plants that are important to them. An urban agroforestry initiative (i.e., extensive planting of fire-resilient native plants and canoe plants in Lāhainā) was identified as a key practice in the *Lāhainā Long-Term Recovery Plan* (County of Maui 2024). The recommended goal for an alternative watershed management plan is to establish an average of 100 trees per acre within the Town of Lāhainā, which in the long term can be anticipated to result in 25% shading, on average, within Lāhainā (NCAT 2025).

5.2.3.4 Property Acquisition

The *Lāhainā Long-Term Recovery Plan* identifies acquisition of real property as a strategy for improving the resiliency and livability of Lāhainā (County of Maui 2024). This strategy can also serve as an important means for achieving water quality protection goals. As noted by the County of Maui (2024), shoreline property can be acquired and converted to park lands to help address sea level rise and coastal erosion. Additionally, parcels along Kahoma and Kauaʻula streams within the urban area (and potentially extending up into the agricultural lands) can be acquired to help address flooding issues and protect water quality. For example, riparian corridors could be revegetated with native plant communities to help prevent streambank erosion and sediment loading. Property acquisition and conversion to open space is another means of achieving the preliminary objective to reduce the total impervious cover within Lāhainā to less than 50%. Furthermore, establishing public lands in the riparian corridor has the potential be used as future locations for the restoration of traditional loʻi kalo (irrigated terraces in stream valleys for growing taro), of important cultural significance to Native Hawaiians.

5.2.3.5 Monitoring

The final urban strategy for immediate implementation is stormwater-related monitoring. Continued inspections of stormwater measures and practices required under Maui County Code and surveillance of stormwater conditions will contribute towards the control of runoff volumes and pollutant loads during construction activities. Monitoring in the near-term will also include urban storm water conveyance water quality sampling and assessment as well as implementation monitoring to track the stormwater measures and practices. Monitoring of discharge, sediment, nutrients, metals, *Enterococci*, POCs will facilitate stormwater infrastructure planning in a full EPA nine element watershed management plan; it will enable estimation of pollutant loads in stormwater delivered to nearshore marine waters as well as estimation of reductions in pollutants loads resulting from proposed measures and practices. Water quality and soil health monitoring will also be used to gage the effectiveness of systems and practices implemented to reduce urban stormwater runoff volumes and pollutant loads. Additional detail on monitoring is provided in Section 7: Monitoring and Assessment.

5.2.4 Summary of Measures and Practices for Immediate Implementation

Table 25 below summarizes immediate measures and practices to address the effects of wildfire on water quality. The table also identifies the implementation priority for a given measure/practice, the pollutants/parameters addressed by a given measure or practice, and the critical source areas where implementation should be focused. During the immediate implementation phase, an adaptive management approach will be applied for individual measures and practices as well as for the overall suite of measures and practices as challenges arise (e.g., implementation resource constraints) or new data and information becomes available (e.g., through monitoring). It should be recognized that factors beyond control, such as technical and financial resource availability and implementation planning requirements, may result in the delay of measures and practices beyond a two-year implementation timeframe.

Table 25. Summary of Measures and Practices for Immediate Implementation

Applicable Setting	Measure/Practice	Priority	Pollutants/Parameters Addressed	Critical Source Area for Implementation
All	Hiring a watershed coordinator and establishment of a Wai and Watershed Partnership	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A

Applicable Setting	Measure/Practice	Priority	Pollutants/Parameters Addressed	Critical Source Area for Implementation
All	Monitoring and assessment per Section 7: implementation monitoring, practice effectiveness monitoring, pollutant source monitoring, status and trend monitoring	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	Kahoma and Kauaʻula streams, nearshore marine waters, stormwater sewers outlets to the Pacific Ocean; urban and agricultural lands where water quality measures and practices are implemented
All	Establish a local native plant nursery to support urban agroforestry and native plant community restoration on agricultural and conservation lands	Medium	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	N/A
Agricultural Lands	Compost application to agricultural lands to initiate soil health improvement	High	Sediment, Turbidity, Nutrients, Metals, POCs	Burned agricultural lands within the Kahoma and Kauaʻula watersheds, with precedence for acreage that experienced moderate to high severity burning
Agricultural Lands	Revegetation of agricultural lands where needed: seeding with grass species to stabilize soils, preferably native species	Medium	Sediment, Turbidity, Nutrients, Metals, POCs	Burned agricultural lands within the Kahoma and Kauaʻula watersheds, with precedence for acreage that experienced moderate to high severity burning
Agricultural Lands	Non-structural erosion control practices along unimproved roads: seeded compost blankets, compost filter socks, compost berms	Medium	Sediment, Turbidity, Nutrients, Metals	Sites along unimproved roads with low to moderate erosion and a direct hydrologic connection to drainageways and stream gulches
Agricultural Lands	Disconnection of abandoned irrigation ditches from drainageways and streams (preferred), or treatments of ditch outlets: riprap, check dams, and vegetation establishment	Medium	Sediment, Turbidity, Nutrients, Metals, POCs	Irrigation ditches that route water to drainageways and stream gulches, focusing on the area within 200 ft of ditch outlets

Applicable Setting	Measure/Practice	Priority	Pollutants/Parameters Addressed	Critical Source Area for Implementation
Agricultural Lands	Native tree/shrub planting and compost application throughout unused irrigation ditches	Low	Sediment, Turbidity, Nutrients, Metals, POCs	Irrigation ditches that route water to drainageways and stream gulches
Agricultural Lands	Rehabilitate unneeded or steep firebreaks: soil decompaction, increasing soil roughness, applying woody material, seeding	Medium	Sediment, Turbidity, Nutrients, Metals	Firebreaks with steep slopes (e.g., > 2% slope), with priority for slopes > 10%
Agricultural Lands	Erosion control practices on firebreaks to be maintained as firebreaks or roads: drainage features such as water bars	Medium	Sediment, Turbidity, Nutrients, Metals	Firebreaks with steep slopes (e.g., > 2% slope)
Agricultural Lands/ Drainageways and Stream Gulches	Rehabilitate firebreak crossings of drainageways and gulches: remove soil deposits from channels, repair channel banks, spread woody debris or mulch on firebreak path and banks adjacent to channels	Medium	Sediment, Turbidity, Nutrients, Metals	All crossings
Agricultural Lands/ Drainageways and Stream Gulches	Routine removal of sediment and debris deposits from culverts	Medium	Sediment, Turbidity, Nutrients, Metals	All culverts
Agricultural Lands/ Drainageways and Stream Gulches	Removal of downed trees from drainageways and gulches, followed by mulching and mulch application on banks adjacent to channels	High	Sediment, Turbidity, Nutrients, Metals	Drainageways and gulches that intersect roadways downstream

Applicable Setting	Measure/Practice	Priority	Pollutants/Parameters Addressed	Critical Source Area for Implementation
Drainageways and Stream Gulches	Repair flood control embankments removed or modified during fire response, remove any temporary silt fencing	High	Sediment, Turbidity, Nutrients, Metals	All locations where flood control embankments were removed or modified
Drainageways and Stream Gulches	Upgrade flood control embankments not constructed to NRCS standards	Medium	Sediment, Turbidity, Nutrients, Metals	Four embankments south of Lāhainā (and potentially additional locations)
Drainageways and Stream Gulches	Mitigate potential for sediment transport onto Lāhainā Bypass through non-structural or structural means	Medium	Sediment, Turbidity, Nutrients, Metals	All locations along the bypass where there is evidence that large quantities of sediment may impact roadway travel in response to storm events
Drainageways and Stream Gulches	Remove 500 ft of fill material from concrete-lined drainageway that connects to the concrete-lined reach of Kahoma stream	High	Sediment, Turbidity, Nutrients, Metals	Not applicable
Urban Lands	Continue to implement County of Maui stormwater requirements during construction activities. Continue associated stormwater surveillance, inspections, and compliance assurance	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Burned urban parcels
Urban Lands	Implement the Lāhainā Drainage Master Plan, once complete	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers
Urban Lands	Incorporate green infrastructure principles into property re-development and new development: establish incentives to limit impervious cover below the 65% limitation in Maui County Code.	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Burned urban parcels

Applicable Setting	Measure/Practice	Priority	Pollutants/Parameters Addressed	Critical Source Area for Implementation
Urban Lands	Compost-based landscaping practices: seeded compost blankets where revegetation is needed, compost topdressing of turf where revegetation is not needed, compost mulch around new and existing trees/shrubs, compost applications to ornamental and edible gardens	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers
Urban Lands	Compost-based stormwater practices: compost filter socks, compost berms, compost blankets, compost incorporated into green infrastructure projects including bioretention units, bioswales, green roofs, rooftop gardens, rain gardens	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Urban parcels and roadways located within the contributing area of flood-prone areas and stormwater sewers, with priority for parcels undergoing construction and around storm drains
Urban Lands	Urban agroforestry: Planting of fire-resilient native plants and canoe plants	High	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers
Urban Lands	Acquisition of private parcels for conversion to public open space with water quality benefits: riparian and floodplain lands, historical wetland locations, portions of critical source areas, lands for firebreaks	Medium	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Urban parcels within 300 feet of Kahoma and Kauaʻula streams, within 100 ft of the marine shoreline, within the contributing area of flood-prone areas and stormwater sewers, and in the vicinity of historical wetlands and ponds.

5.3 REDUCING THE RISK OF FUTURE WATER QUALITY IMPACTS FROM WILDFIRE

Two key objectives that can be used to guide achievement of the goal to reduce the risk of future water quality impacts from wildfire are:

- Implement measures and practices that prevent wildfire impacts.
- Implement measures and practices that build resilience against future wildfire effects.

Table 26 below summarizes potential measures and practices for reducing the risk of future water quality impacts from wildfire. The measures and practices listed in the table were mostly derived from recommendations within wildfire impact assessment reports by the Forest Service (USDA 2023) and NRCS (2023), as well as the Maʻalaea Bay Watershed Management Plan (MEC 2023) and West Maui Watershed Management Plan (USACE 2023). Other potential measures and practices included in the table were generated as professional opinions during the review of data and information used to develop this Preliminary Planning Framework.

Table 26. Potential Measures and Practices for Preventing Wildfire Impacts to Water Quality and Building Watershed Resilience to Wildfire.

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Critical Source Area for Implementation
All lands	Continue implementation of measures and practices identified in the Western Maui Community Wildfire Protection Plan for fire pre-suppression, update plan with specific post-fire response actions for water quality protection.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A
Agricultural/ Urban Lands	Establish a multi-purpose urban boundary firebreak: Establish a wide firebreak (e.g., 100 ft to 300 ft) that also serves as community open space, planted with native vegetation, irrigated with recycled water, with a road (having a permeable, yet erosion resistant surface) that can provide access to maintenance and emergency vehicles and also serve as a recreational trail.	Sediment, Turbidity, Nutrients, Metals	Adjacent to the perimeter of the urban growth boundary
Agricultural Lands	Establish an irrigation system for firebreaks, including tanks that can be used for fire suppression.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	Firebreaks within ¼ mile of Lāhainā
Agricultural Lands	Establish a network of planned firebreaks on agricultural lands. See NRCS (2023) and MEC (2023) for implementation recommendations.	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
All Lands	Convert overhead powerlines to underground lines within the urban growth boundary.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	All lands within the urban growth boundary

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Critical Source Area for Implementation
All Lands	Maintain powerline corridors as firebreaks.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	Overhead power line corridors on undeveloped lands
All Lands	Utilize roadside fuel breaks.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	Requires further assessment
All Lands	Seek grants and cost-share awards associated with wildfire prevention and defense.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A
All Lands	Establish a community watershed protection and restoration fund.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A
All Lands	Implement practices identified in Table 27 improve soil health, reduce stormwater runoff, and reduce soil erosion.	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A

5.4 RESTORATION AND PROTECTION OF WATER QUALITY FROM POLLUTANTS GENERATED BY HISTORICAL AND CURRENT LAND USES

The two key objectives that can be used to protect water quality from pollutants generated by historical and current land uses represent a continuation and expansion of efforts to protect water quality from the wildfire effects:

- Improve soil health and vegetation communities on agricultural and urban lands.
- Reduce the generation and transport of nutrients, sediment, metals, *Enterococci*, and POC loads in surface runoff and groundwater flow from agricultural and urban lands.

Table 27 below summarizes potential measures and practices for achieving the two objectives listed above. These measures and practices were derived from the *Lāhainā Long-term Recovery Plan* (County of Maui 2024), other Maui Watershed Plans (SRGI 2012b, Group 70 and SRGI 2016, USACE 2023, MEC 2023, MEC 2019), and through potential opportunities identified through analysis of pollutant causes and sources and associated land use information during development of this Preliminary Planning Framework.

Many of the listed potential measures and practices represent a continuation of efforts to be implemented within the first two years following alternative watershed plan completion (e.g., soil health improvement); they are included to signify that reducing the risk of future water quality impacts from wildfire requires ongoing efforts. Ultimately, the process of developing a watershed-based plan that addresses all of EPA’s nine minimum elements will refine the list of potential measures and practices into a final set of strategic measures and practices that can be used to achieve pollutant load reductions necessary to protect and restore water quality in the Kahoma and Kauaʻula watersheds and associated nearshore marine waterbodies.

Table 27. Potential Measures and Practices to Address Historical and Current Land Uses.

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
New Measures and Practices[1]			
All Lands	Integrated watershed plan that addresses County of Maui's One Water principles, EPA's nine minimum elements for watershed-based plans, and FEMA's watershed master plan criteria	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, *Enterococci*, POCs	N/A
Agricultural Lands/ Conservation Lands	Wild ungulate management: ungulate removal and fencing along boundary between agricultural lands and conservation lands	Sediment, Turbidity, Nutrients, Metals, *Enterococci*	Boundary between agricultural lands and conservation lands
Agricultural Lands	Improved livestock grazing management	Sediment, Turbidity, Nutrients, Metals, *Enterococci*	Grazing lands with sub-optimal soil health and vegetation community health
Agricultural Lands	Conservation plans based on soil health principles	Sediment, Turbidity, Nutrients, Metals, *Enterococci*	All agricultural parcels
Agricultural Lands	Structural erosion control for unimproved roads: grade breaks, dips and low water crossings, water bars, cross-drains and culverts, ditches, turnouts, sediment traps, geosynthetics, soil and/or aggregate stabilization, slope stabilization, water bars	Sediment, Turbidity, Nutrients, Metals	Sections of unimproved roads that contribute measurable loads of sediment to drainageways and streams
Agricultural Lands	Native forest restoration—follows improvement of soil health	Sediment, Turbidity, Nutrients, Metals	Mid-elevation (e.g., wetter) agricultural lands owned by the State of Hawaiʻi and Kamehameha Schools that were historically de-forested
Drainageways and Stream Gulches	"Push pile" assessment: includes identification and mapping of sediment terraces	Sediment, Turbidity, Nutrients, Metals	Actively eroding terraces along reaches of Kahoma, Kanahā, and Kauaʻula streams and other gulches/drainageways within agricultural lands

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
Drainageways and Stream Gulches	"Push pile" mitigation: stabilization of sediment terraces, with preference for vegetative techniques	Sediment, Turbidity, Nutrients, Metals	Actively eroding terraces along reaches of Kahoma, Kanahā, and Kauaʻula streams and other gulches/drainageways within agricultural lands
Drainageways and Stream Gulches	"Push pile" mitigation: incremental removal of sediment terraces- explore options for removal and disposal, e.g., sediment hauling by helicopter and buckets and disposal of sediments in abandoned irrigation ditches	Sediment, Turbidity, Nutrients, Metals	Actively eroding terraces along reaches of Kahoma, Kanahā, and Kauaʻula streams and other gulches/drainageways within agricultural lands
Drainageways and Stream Gulches	Hydrologic disconnection of unimproved road crossings from streams and drainageways	Sediment, Turbidity, Nutrients, Metals	All unimproved road crossings of streams and drainageways
Drainageways and Stream Gulches	Eliminate surface water diversions from streams to support ecosystem health and cultural practices	Requires further assessment	Requires further assessment
Drainageways and Stream Gulches	Restoration of traditional loʻi kalo (irrigated terraces in stream valleys for growing taro)	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
Drainageways and Stream Gulches	Micro basins in stream valleys	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
Drainageways and Stream Gulches	Riparian buffer practices: stacked practices including ripping, terraforming, micro-basins, key lining/ripping on contour, vetiver eyebrows in kickouts, contour planting vetiver, native plant establishment, hydro-mulching and check dams	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
Drainageways and Stream Gulches	Desilting/detention basins: maintenance of existing basins; retrofits to improve existing sediment basins; new basins; monitoring/assessment of sediment loads	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
Drainageways and Stream Gulches	NRCS Kahoma floodwater diversion project	Sediment, Turbidity, Nutrients, Chlorophyll-a Metals	N/A

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
Drainageways and Stream Gulches	Groundwater recharge basins	Sediment, Turbidity, Nutrients, Chlorophyll-a Metals	Requires further assessment
Agricultural/ Urban Lands	Agricultural planning: Create a plan to develop and prioritize agriculture initiatives for Lāhainā moku's agriculture, farms, food systems, and ecosystems (building off the County of Maui Department of Agriculture 2024–2028 Strategic Plan)	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	All agricultural lands
Agricultural/ Urban Lands	Construction/ development BMPs to reduce runoff and soil erosion; BMP enforcement	Sediment, Turbidity, Nutrients, Metals	Areas prone to surface runoff
Agricultural/ Urban Lands	Invasive weed management	Sediment, Turbidity, Nutrients, Metals	Requires further assessment
Agricultural/ Urban Lands	Establish a community composting facility: for waste diversion and generation of compost for agriculture, soil health improvement, re-vegetation, and erosion control	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban/ Agricultural Lands	Cesspool conversion: conversion of the estimated 70 remaining cesspool to sewer connections	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	All remaining cesspools in the Kahoma and Kauaʻula watersheds
Urban/ Agricultural Lands	Expansion of recycled water use: for agriculture, landscaping irrigation, re-vegetation, irrigated firebreaks	Nutrients, Chlorophyll-a	Requires further assessment
Urban/ Agricultural Lands	Use of non-toxic flocculants (e.g., chitosan from shellfish exoskeletons or alginates from seaweed) to reduce turbidity in surface runoff	Sediment, Turbidity, Nutrients, Chlorophyll-a	Requires further assessment: potential implementation sites include the Kahoma stream sediment basin and within the contributing area of flood-prone areas and existing stormwater sewers
Urban Lands	Restoration of coastal ponds and wetlands	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals	Loko o Mokuhinia Loko o Nalehu Loko o Kaluaʻehu
Urban Lands	Low impact development requirements	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	All urban parcels
Urban Lands	Update Drainage Master Plan for Lāhainā: in progress	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
Urban Lands	Post construction stormwater ordinance: Drainage Master Plan requirement	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban Lands	Ocean-friendly landscaper outreach program	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban Lands	Landscaping management plans	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	Commercial parcels
Urban Lands	Pool and vehicle wash discharge policy	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban Lands	Green stormwater infrastructure such as bioretention basins, rain gardens, green roofs, infiltration trenches, permeable pavement, low impact development retrofits for areas with extensive impervious surface	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	Within the contributing area of flood-prone areas and existing stormwater sewers
Urban Lands	Traditional stormwater mgmt. infrastructure: baffle boxes, infiltration wells, water and sediment control basins in stormwater conveyances and ditches	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	Within the contributing area of flood-prone areas and existing stormwater sewers where green stormwater infrastructure is infeasible
Urban Lands	Stormwater management parks (see Māʻalaea Bay Watersheds Management Plan (MEC 2023))	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	Requires further assessment
Urban Lands	Stormwater management fees	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban Lands	Stormwater management asset mapping	Sediment, Turbidity, Nutrients, Metals, Chlorophyll-a, POCs	N/A
Urban Lands	Stream restoration: removal of concrete lined reaches of Kahoma and Kauaʻula streams	Sediment, Turbidity, Nutrients	Lower reaches of Kahoma and Kauaʻula streams
Urban Lands	Flood control levees: set back from Kahoma and Kauaʻula streams stream channels; requires property acquisition, assumes stream restoration of concrete-lined channels	Sediment, Turbidity, Nutrients	Lower reaches of Kahoma and Kauaʻula streams

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
Nearshore Marine Waters	Oyster seeding—to help reduce nearshore marine turbidity	Sediment, Turbidity, Nutrients, Chlorophyll-a	Nearshore marine waters within ½ mile of Kahoma and Kauaʻula stream outlets to the Pacific Ocean
Measures and Practices Continued from the Immediate Implementation Phase			
All Lands	Continue employment of a watershed coordinator and administration of a Wai and Watershed Partnership	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	N/A
All Lands	Continue monitoring per Section 7: implementation monitoring, effectiveness monitoring, status and trend monitoring	Sediment, Turbidity, Nutrients, Chlorophyll-a, Metals, POCs	Kahoma and Kauaʻula Streams; stormwater sewer outlets to the Pacific Ocean
Agricultural Lands	Continue revegetation of agricultural lands	Sediment, Turbidity, Nutrients, Metals, POCs	Burned agricultural lands within the Kahoma and Kauaʻula watersheds
Agricultural Lands	Continue periodic compost applications to agricultural lands to improve soil health	Sediment, Turbidity, Nutrients, Metals, POCs	All agricultural lands within the Kahoma and Kauaʻula watersheds
Agricultural Lands	Maintain erosion control practices along unimproved roads	Sediment, Turbidity, Nutrients, Metals	Sites along unimproved roads with moderate to severe erosion and a direct hydrologic connection to drainageways and stream gulches
Agricultural Lands	Measures to hydrologically disconnect unimproved roads from drainageways and streams	Sediment, Turbidity, Nutrients, Metals	All low-water crossings of drainageways and stream gulches
Agricultural Lands	Treatment of abandoned irrigation ditch outlets: rip-rap, check dams, and vegetation establishment	Sediment, Turbidity, Nutrients, Metals, POCs	Irrigation ditches that route water to drainageways and stream gulches, focusing on the area within 200 ft of ditch outlets
Agricultural Lands	Continue native tree/shrub planting throughout irrigation ditches	Sediment, Turbidity, Nutrients, Metals, POCs	Irrigation ditches that route water to drainageways and stream gulches
Agricultural Lands	Maintain erosion control practices on firebreaks to be maintained as firebreak or road: drainage features such as water bars	Sediment, Turbidity, Nutrients, Metals	Firebreaks with steep slopes (e.g., > 2% slope)

Applicable Setting	Measure/Practice	Pollutants/Parameters Addressed	Apparent Critical Source Area for Implementation
Urban Lands	Incentivize incorporation of green infrastructure principles into re-development, new development, and existing development: implement incentives to attain a preliminary goal of achieving and maintaining the total area of impervious cover within the Lāhainā Town boundary below 50%.	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels
Urban Lands	Continue compost-based landscaping practices: compost topdressing of turf, compost mulch around new and existing trees/shrubs, compost applications to ornamental and edible gardens	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers
Urban Lands	Continue implementation of green stormwater infrastructure and compost-based stormwater practices: bioretention units, bioswales, green roofs, rooftop gardens, rain gardens, compost filter socks, compost berms	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Urban parcels and roadways located within the contributing area of flood-prone areas and stormwater sewers, with priority for parcels undergoing construction and around storm drains
Urban Lands	Continue urban agroforestry: Planting of fire-resilient native plants and canoe plants	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	All urban parcels, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers
Urban Lands	Continue acquisition of private parcels for conversion to public open space	Sediment, Turbidity, Nutrients, Chlorophyll-a, *Enterococci*, Metals, POCs	Urban parcels along Kahoma and Kauaʻula streams (e.g., within 300 ft of channels) the marine shoreline (e.g., within 100 ft of the high tide line), within the contributing area of flood-prone areas and stormwater sewers, and in the vicinity of historical wetlands and ponds

5.5 IMPLEMENTATION RESOURCES

Protecting water quality in the Kahoma and Kauaʻula watersheds and associated nearshore marine waterbodies will require effective long-term partnerships among water quality stakeholders and continual efforts to identify and secure funding for implementation of water quality protection measures and practices. This section provides non-exhaustive lists of stakeholder organizations and potential funding sources that may support the achievement of the water quality protection goals and objectives outlined in this plan.

5.5.1 Stakeholder Organizations

The following include stakeholder organizations could support implementation of the watershed plan.

- County of Maui https://www.mauicounty.gov/
- Farm Service Agency https://www.fsa.usda.gov/state-offices/hawaii-and-pacific-islands
- Hawaiʻi Farmers Union United, Lāhainā Chapter https://hfuuhi.org/chapters/maui-lahaina-chapter/
- Kaiāulu Initiatives https://www.kaiauluinitiatives.org/
- Kamehameha Schools https://kaiaulu.ksbe.edu/
- Kuʻia Agricultural Education Center https://www.facebook.com/people/Ku%CA%BBia-Agricultural-Education-Center/100034198646441/
- Lāhainā Town Action Committee https://visitlahaina.com/about/
- Maui Nui Marine Resource Council https://www.mauireefs.org/
- Mauna Kahālāwai Watershed Partnership https://www.maunakahalawai.org/
- State of Hawaiʻi, Department of Agriculture https://hdoa.hawaii.gov/
- State of Hawaiʻi, Department of Health https://health.hawaii.gov/
- State of Hawaiʻi, Department of Land and Natural Resources https://dlnr.hawaii.gov/
- Surfrider Foundation, Maui Chapter https://maui.surfrider.org/
- Treecovery Hawaiʻi https://treecoveryhawaii.org/
- University of Hawaiʻi at Mānoa, Water Resources Research Center https://www.wrrc.hawaii.edu/
- University of Hawaiʻi at Mānoa, College of Tropical Agriculture and Human Resilience, Cooperative Extension Program https://cms.ctahr.hawaii.edu/ce
- USDA Natural Resources Conservation Service, Kahului Service Center https://www.nrcs.usda.gov/state-offices/pacific-islands-area
- U.S. Environmental Protection Agency, Region 9 https://www.epa.gov/aboutepa/epa-region-9-pacific-southwest
- West Maui Ridge to Reef Initiative https://www.westmauir2r.com/

- West Maui Soil and Water Conservation District https://www.mauicountysoilandwater.org/west-maui

5.5.2 Funding Sources

The following funding sources could be considered to support implementation of the watershed plan.

Business Sponsorships, e.g., banks, hotels, restaurants, recreation-based companies—contributions towards funding nonpoint source pollution control activities.

Federal Emergency Management Agency— grants to address hazard mitigation and recovery.

- Assistance to Firefighters Grant Program https://www.fema.gov/grants/preparedness/firefighters/assistance-grants
- Fire Prevention and Safety Grant Program https://www.fema.gov/grants/preparedness/firefighters/safety-awards
- Hazard Mitigation Grant Program https://www.fema.gov/grants/mitigation/learn/hazard-mitigation
- Hazard Mitigation Post Fire Grant Program https://www.fema.gov/grants/mitigation/learn/post-fire
- Building Resilient Infrastructure and Communities https://www.fema.gov/grants/mitigation/learn/building-resilient-infrastructure-communities

State of Hawaiʻi, Dept of Health—point and nonpoint pollution control grants and loans.

- CWA State Revolving Fund https://health.hawaii.gov/wastewater/home/cwsrf/
- CWA Section 319 grants https://health.hawaii.gov/cwb/clean-water-branch-home-page/polluted-runoff-control-program/319-grant-program/

U.S. Department of Agriculture—agriculture, natural resource conservation, wildfire prevention, and recovery cost-share, loans, grants, and special initiative funding.

- Farm Service Agency Programs https://www.fsa.usda.gov/resources/programs
- Community Wildfire Defense Grant Program https://www.fs.usda.gov/managing-land/fire/grants
- Wildland Urban Interface Grant Program, administered through the Council of Western State Foresters https://www.westernforesters.org/wui-grants#:~:text=The%20Wildland%20Urban%20Interface%20%28WUI%29%20Grant%20Program%20is,Plan%20through%20the%20State%20and%20Private%20Forestry%20Branch
- Landscape Scale Restoration Program https://www.fs.usda.gov/managing-land/private-land/landscape-scale-restoration

- Environmental Quality Incentives Program https://www.nrcs.usda.gov/programs-initiatives/eqip-environmental-quality-incentives/pacific-islands-area/environmental
- Conservation Reserve Enhancement Program https://www.fsa.usda.gov/resources/programs/conservation-reserve-enhancement-program-crep
- Conservation Reserve Program https://www.nrcs.usda.gov/programs-initiatives/crp-conservation-reserve-program
- Conservation Stewardship Program https://www.nrcs.usda.gov/programs-initiatives/csp-conservation-stewardship-program/pacific-islands-area/conservation
- Conservation Innovation Grants https://www.nrcs.usda.gov/programs-initiatives/cig-conservation-innovation-grants
- Regional Conservation Partnership Program https://www.nrcs.usda.gov/programs-initiatives/rcpp-regional-conservation-partnership-program/pacific-islands-area/regional

6.0 SCHEDULE AND MILESTONES

Table 28 below outlines a draft implementation schedule and milestones that can be used to guide the implementation phase of water quality measures and practices. The draft implementation schedule is subject to revision based on stakeholder feedback that may be received during development of an alternative watershed management plan as well as the availability of technical and financial resources associated with the identified measures and practices. The lead entity that will be responsible for implementation of each measure or practice will also be determined by requirements of the entity providing funding or other support, and through the stakeholder engagement process. Funding, technical assistance, and other resources required for implementation will be provided by the DOH nonpoint source pollution control program, USDA NRCS, the county, volunteer groups, and local sources, as appropriate and available.

The measures and practices in Table 28 are grouped by priority for implementation. Within each group, measures and practices are listed in order of when the measure or practice is proposed to be initiated. Most of the schedules and milestones are linked to the implementation of water quality measures and practices in critical source areas as identified in Section 5: Water Quality Protection Measures and Practices. The schedule and milestones for practices whose implementation may be expanded into non-critical source areas during the long-term implementation phase will be identified in a future full nine element watershed restoration plan.

Table 28. Implementation Schedule and Milestones

Applicable Setting	Measure/Practice	Schedule	Milestones
High Priority Measures and Practices			
Urban Lands	Continue to implement County of Maui's stormwater requirements during construction activities. Continue associated stormwater surveillance, inspections, and compliance assurance.	Implementation of stormwater requirements is already ongoing.	As tracked by the county stormwater management program.
Drainageways and Stream Gulches	Remove 500 ft of fill material from concrete-lined drainageway that connects to the concrete-lined reach of Kahoma stream.	Removal completed for critical source areas within six months of alternative watershed plan completion.	Practice implementation for critical source areas to begin within three months of alternative watershed plan completion.
All	Hiring a watershed coordinator and establishment of a Wai and Watershed Partnership.	Recruitment of a watershed coordinator within one year of alternative watershed plan completion.	Recruitment planning to begin within six months of alternative watershed plan completion.
Agricultural Lands/ Drainageways and Stream Gulches	Removal of downed trees from drainageways and gulches, followed by targeted stabilization, mulching, and mulch application on banks adjacent to channels.	Practices completed for critical source areas within one year of alternative watershed plan completion.	Practice implementation for critical source areas to begin within six months of alternative watershed plan completion.
Drainageways and Stream Gulches	Repair flood control embankments removed or modified during fire response, remove any temporary silt fencing, and stabilize upslope areas.	Practices completed for critical source areas within one year of alternative watershed plan completion.	Practice implementation for critical source areas to begin within six months of alternative watershed plan completion.
Urban Lands	Incorporate green infrastructure principles into property re-development and new development; establish incentives to limit impervious cover below the 65% limitation in Maui County Code.	Ongoing.	Implementation for critical source areas to begin within six months of alternative watershed plan completion.
Urban Lands	Compost-based stormwater practices: compost filter socks, compost berms, compost blankets, compost incorporated into green infrastructure projects including bioretention units, bioswales, green roofs, rooftop gardens, rain gardens.	Ongoing.	Practice implementation for critical source areas to begin within six months of alternative watershed plan completion.

Applicable Setting	Measure/Practice	Schedule	Milestones
Urban Lands	Urban agroforestry: Planting of fire-resilient native plants and canoe plants.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within six months of alternative watershed plan completion.
Urban Lands	Implement the Lāhainā Drainage Master Plan.	Ongoing, implementation to be initiated immediately upon plan completion.	The Drainage Master Plan is anticipated to be completed within six months of alternative watershed plan completion; the Plan will identify a schedule and milestones for water quality-related measures and practices.
All	Monitoring: implementation monitoring, effectiveness monitoring, pollutant source monitoring, status and trend monitoring.	Ongoing, based on resource availability; monitoring of nearshore marine water quality is already ongoing.	Initiation of new monitoring varies from six months to two years of alternative watershed plan completion, based on monitoring type. See Table 29 in Section 7: Monitoring and Assessment for milestones associated with the initiation of specific monitoring types.
Agricultural Lands	Compost application to agricultural lands to initiate soil health improvement; use of native vegetation and reestablishment of natural areas where possible.	Initial applications to all critical source areas accomplished within one year of alternative watershed plan completion; re-applications ongoing, estimated to be needed once every three years.	Initial applications to critical source areas to begin within six to nine months of alternative watershed plan completion.
Urban Lands	Compost-based landscaping practices: seeded compost blankets where revegetation is needed, compost topdressing of turf where revegetation is not needed, compost mulch around new and existing trees/shrubs, compost applications to ornamental and edible gardens.	Initial applications to critical source areas accomplished within one year of alternative watershed plan completion; re-applications ongoing, starting with re-application annually for two to three years after the initial application, followed by re-application estimated to be needed once every three years.	Initial applications to critical source areas to begin within six to nine months of alternative watershed plan completion.

Applicable Setting	Measure/Practice	Schedule	Milestones
Medium Priority Measures and Practices			
Urban Lands	Acquisition of private parcels for conversion to public open space with water quality benefits: riparian and floodplain lands, historical wetland locations, portions of critical source areas, lands for firebreaks.	Ongoing, implementation has already begun.	Milestones to be determined based on evaluation of potential acquisitions by the Town of Lāhainā and County of Maui.
Agricultural Lands/ Drainageways and Stream Gulches	Routine removal of sediment and debris deposits from culverts.	Ongoing, as needed.	Practice implementation for critical source areas to begin within six months of alternative watershed plan completion.
Agricultural Lands	Revegetation of agricultural lands where needed: seeding with grass species to stabilize soils, preferably native species.	Seeding of critical source areas accomplished within one year of alternative watershed plan completion.	Seeding of critical source areas to begin within six to nine months of alternative watershed plan completion.
Agricultural Lands	Non-structural erosion control practices along unimproved roads: seeded compost blankets, compost filter socks, compost berms.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
Agricultural Lands	Treatment of abandoned irrigation ditch outlets: riprap, check dams, and vegetation establishment.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
Agricultural Lands	Rehabilitate unneeded or steep firebreaks: soil decompaction, increasing soil roughness, applying woody material, seeding.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
Agricultural Lands	Erosion control practices on firebreaks to be maintained as firebreaks or roads: drainage features such as water bars.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
Agricultural Lands/ Drainageways and Stream Gulches	Rehabilitate firebreak crossings of drainageways and gulches: remove soil deposits from channels, repair channel banks, spread woody debris or mulch on firebreak path and banks adjacent to channels.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
Drainageways and Stream Gulches	Upgrade flood control embankments not constructed to NRCS standards.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.

Applicable Setting	Measure/Practice	Schedule	Milestones
Drainageways and Stream Gulches	Mitigate potential for sediment transport onto Lāhainā Bypass through non-structural or structural means.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.
All	Establish a local native plant nursery to support ongoing urban agroforestry and native plant community restoration on agricultural and conservation lands.	Ongoing.	Start-up of nursery within two years of alternative watershed plan completion.
Low Priority Measures and Practices			
Agricultural Lands	Native tree/shrub planting and compost application throughout unused irrigation ditches.	Practices completed for critical source areas within two years of alternative watershed plan completion.	Practice implementation for critical source areas to begin within one year of alternative watershed plan completion.

7.0 MONITORING AND ASSESSMENT

As noted previously, this plan addresses water quality management activities associated with the immediate aftermath of the 2023 fire, with longer term restoration and protection actions serving as the focus of a more comprehensive plan. Water quality monitoring and assessment is a critical component of an adaptive management framework for watershed protection and restoration. Water quality monitoring is the process of collecting measurements and observations. Water quality assessment is the process of evaluating and analyzing monitoring data and information to develop science-based findings that can be used to inform watershed planning and implementation of water quality protection measures and practices. For the sake of simplicity, the term "monitoring" is used in this section to describe the combined processes of monitoring and assessment. This section addresses four categories of monitoring activities that could be performed to support both short and long-term water quality protection efforts in the Kahoma and Kauaʻula watersheds and associated nearshore marine waters:

- BMP implementation monitoring
- BMP effectiveness monitoring
- Pollutant source monitoring
- Status and trend monitoring

BMP implementation monitoring is the process of tracking the progress of water quality protection measures and practices relative to an implementation schedule and milestones that serve as markers of significant progress. This category of monitoring is used to evaluate if activities were carried out as planned and determine the reasons for any necessary deviations in the schedule.

BMP effectiveness monitoring is the process of collecting and evaluating environmental data to determine if an individual or group of implemented measures and practices have the intended effect on water quality. For example, discharge and sediment can be monitored at a stormwater outfall to determine if stormwater practices are reducing runoff volumes and sediment loads. Quantitative objectives established prior to implementation are a critical component of an effectiveness assessment. The objectives serve as the benchmark by which to evaluate effectiveness.

Pollutant source monitoring is important for watershed planning purposes. The associated monitoring data is used to estimate pollutant loads from different land uses or portions of a watershed. Based on the pollutant loading estimates, watershed models can be used to determine the types, numbers, and locations of management practices needed to reduce pollutant loads to levels that support designated uses of waterbodies such as water contact recreation and aquatic life habitat.

Status and trend monitoring is intended to collect data that can be used to evaluate the attainment of water quality standards in discrete units of waterbodies referred to as AUs (e.g., a stream reach) during a specific time period. Samples typically consist of a routine set of parameters corresponding to established water quality criteria, and are often, but not always collected at a fixed station. Trend monitoring is used to evaluate general changes in water quality parameters over time and is conceptually similar to status monitoring. Sites and parameters used in status monitoring can often be used in trend monitoring, although trend monitoring is typically conducted more frequently and outside of typical assessment periods than routine monitoring for CWA water quality assessments. An example of this is the ongoing marine water quality monitoring that is conducted by DOH and partners as discussed in Sections 3 and 4.

The discussion in this section focuses on BMP implementation and effectiveness monitoring since these two monitoring categories are directly related to the short-term implementation plan for an alternative watershed management plan. However, pollutant source monitoring and status and trend monitoring are also partially addressed. Pollutant source monitoring needs to be initiated in the near-term to supply data necessary to develop a full watershed plan that addresses EPA's nine minimum elements for watershed-based plans. Status and trend monitoring is addressed because (1) datasets collected for other monitoring needs may also have utility for evaluating water quality criteria attainment or long-term trends and vice versa and (2) as identified in Section 4: Causes and Sources of Water Quality Degradation, there are unresolved questions about specific potential water quality impairments that need to be addressed in support of full nine element watershed plan development.

7.1 IMPLEMENTATION MONITORING

In the context of this Preliminary Planning Framework, implementation monitoring is described as a tool to support future efforts to ensure that the selected management measures and practices for immediate implementation identified in Section 5: Water Quality Protection Measures and Practices are being addressed in alignment with the implementation schedule and milestones presented in Section 6: Implementation Schedule and Milestones. Implementation monitoring supports adaptive management of watershed protection efforts by providing feedback that stakeholders can use to adapt plans as needed to help ensure the achievement of water quality measures and practices.

Implementation monitoring could include “desktop” administrative review by a designated entity (e.g., watershed coordinator or watershed partnership) involved in coordinating implementation. Reviews would ideally occur no less than quarterly and be documented in an implementation activities spreadsheet. Information for these reviews would be gathered through ongoing communication with stakeholders involved in planning and implementation of water quality measures and practices.

During each review, progress on implementation of measures and practices could be categorized as either “not started”, “in progress”, or “completed”. Challenges that arise during the implementation of measures and practices would also be identified and tracked along with associated remedies. Additionally, any necessary modifications to schedules or estimated completion dates will be made. Tracking of measures or practices that consist of multiple tasks to be completed over an extended period will be monitored at the task level, as well as the overall measure or practice level.

Implementation monitoring could also include field inspections of individual measures/practices. Field inspection could occur during and immediately after measure/practice implementation on a schedule/frequency that is appropriate for ensuring that implementation occurs according to plans. Field inspection monitoring parameters will be specific to an individual measure/practice or site. For example, if a planned practice consists of a one-inch seeded compost application to a one-quarter acre parcel of land, the inspection will be used to verify that the planned amount of seeded compost was applied to the planned area of land.

7.2 BMP EFFECTIVENESS MONITORING

Various types of effectiveness monitoring would be needed to evaluate the success of water quality protection measures and practices identified in Section 5: Water Quality Protection Measures and Practices. Table 2929 outlines effectiveness monitoring needs (in addition to other monitoring needs) including monitoring parameters, sampling design, and monitoring locations. The application of many measures and practices initiated during the immediate implementation phase may extend into the long-term implementation phase following development of a full EPA nine-element watershed restoration plan. Effectiveness monitoring for these measures and practices should therefore be conducted during the immediate and long-term implementation phases. The subsections below focus on summarizing effectiveness monitoring needs that have a nexus with evaluating the success of measures/practices applied during the immediate implementation phase. The monitoring schemes described below are subject to modification based on consideration of new data and information (e.g., monitoring results) and availability of resources.

For large-scale implementation projects (e.g., acres of upland vegetation restoration), a project specific monitoring plan should be developed to quantify and evaluate the effects of measures or practices. Specifics are not outlined here but should be developed by DOH staff to meet the project needs. Effectiveness monitoring projects should generally align with before/after or upstream/downstream monitoring designs, although a before-after-control impact design may be implemented as resources allow. Components for effectiveness monitoring may include select water quality and quantity parameters but may also include visual assessments, public perception surveys, or before and after photography for a project specific website or other public communications and community engagement.

It is important for effectiveness monitoring efforts to characterize baseline conditions prior to the implementation of water quality measures and practices, and for the same monitoring parameters and procedures to be used both before and after practice implementation. Although many repeated measures should be collected under similar conditions (e.g., observations of vegetation communities same time of year), it is not always necessary to sample the same sites during every sampling event. For example, in a rotating sampling design, a subset of sites can be sampled during each sampling event such that sampling of each subset of sites is staggered in time; this type of monitoring design is useful when there are resource constraints to monitoring a large number of sites.

7.3 SUGGESTED MONITORING PARAMETERS

This section lists and describes a full range of monitoring parameters appropriate for the management practices in Section 5: Water Quality Protection Measures and Practices. The exact configuration of the monitoring program would be based on the resources available, the watershed protection and restoration objectives, and how they are prioritized by staff, volunteers, and others involved in data collection. The information in the subsections below is intended to inform decisions regarding the monitoring program and plan.

7.3.1 Weather

USDA (2023) recommended monitoring of precipitation to help understand what events trigger surface runoff, floods, and sediment transport. This type of monitoring would also be useful for evaluating watershed responses to implementation efforts such as activities to improve soil health and vegetation communities. At minimum, precipitation monitoring should occur within the Town of Lāhainā near sea level and near the upper boundary of the agricultural lands around 1,500 ft above sea level. If resources allow, additional weather parameters such as temperature, humidity, and wind speed could be monitored; monitoring precipitation in the upper elevations of the watersheds would be valuable in characterizing streamflow patterns. These additional monitoring components would support full watershed plan development (e.g., characterizing how precipitation variations affect pollutant loading and stormwater volumes).

7.3.2 Erosion and Sedimentation

The immediate implementation phase will likely involve various erosion and sedimentation control measures and practices for unimproved roads, irrigation ditches, firebreaks, drainageways, culverts, and flood embankments affected by the wildfire. Field monitoring surveys should be used to:

- Inventory locations where measures and practices are to be implemented during the immediate implementation phase.
- Provide information about the effectiveness of implementation of erosion and sedimentation control measures and practices.
- Support adaptive management. For example, monitoring may reveal that additional, more intensive practices are needed to adequately control erosion at a given site.
- Identify non-fire related erosion and sedimentation control issues that will be addressed in more detail during the full watershed restoration planning process and subsequent long-term implementation phase.

Monitoring resources should be focused upon the critical source areas identified in Sections 4 and 5 of this Preliminary Planning Framework. Monitoring surveys should largely consist of standardized visual assessments that include qualitative ratings of erosion and sedimentation conditions (e.g., rating erosional features as absent, slight, moderate, or severe). They should also qualitatively characterize apparent hydrologic connections between source areas and waterbodies (e.g., evidence of sediment delivery from a road to a stream); these characterizations should be supplemented by digital photographs taken at benchmarked locations. Repeat performance of erosion and sedimentation ratings and characterization of apparent pollutant delivery to waterbodies at individual sites should be used to evaluate effectiveness through time. It is anticipated that monitoring of treatment effectiveness during the immediate implementation phase should continue into the long-term implementation phase to ensure ongoing control of sediment sources.

Monitoring surveys to inventory treatment sites and complete initial assessments should begin prior to the onset of the wet season (i.e., during the period of lowest vegetative control of erosion and sediment transport) preceding implementation of measures and practices. Monitoring should continue once per year thereafter at the onset of the wet season.

7.3.3 Vegetation Communities

Vegetation communities on burned agricultural and urban lands should be monitored to:

- Identify and characterize locations needing treatment during the immediate and long-term implementation phases.
- Evaluate effectiveness of treatments applied during the immediate and long-term implementation phases.

- Support adaptive management of revegetation efforts during both immediate and long-term implementation phases.

During the immediate implementation phase, vegetation community monitoring should focus upon the critical source areas:

- Burned agricultural lands within the Kahoma and Kauaʻula watersheds, with precedence for acreage that experienced moderate to high severity burning.
- All urban parcels on which grass seeding and urban agroforestry are initiated, with priority for parcels located within the contributing area of flood-prone areas and stormwater sewers.

Monitoring surveys consist of systematic observations at the parcel scale, as well as at a broader scale, such as the entire contributing area for a specific storm sewer. The standard monitoring protocol should involve standardized visual assessments that include qualitative ratings of vegetation community health indicators (such as relative amounts of ground and canopy cover, relative plant cover/density by plant type or species (e.g., native vs. non-native grass, forbs, weeds, shrubs, trees, canoe plants), plant health, and plant vigor). Monitoring may also include repeat photo-points at individual sites and public perception surveys regarding the effectiveness of revegetation efforts. Repeat performance of these protocols should be used to evaluate effectiveness through time. It is anticipated that monitoring of treatment effectiveness during the immediate implementation phase should continue into the long-term implementation phase to ensure ongoing control of sediment sources.

Monitoring surveys to inventory treatment sites and complete initial assessments should begin prior to the onset of the wet season (preceding implementation of measures and practices). Monitoring should continue at least once per year thereafter at the onset of the wet season. Monitoring during the period of lowest vegetative influence over water quality in each year (prior to the onset of the wet season) should support adaptive management of revegetation efforts, as it will increase the likelihood that any identified revegetation problems at a site can be addressed prior to the onset of the next dry season (e.g., through supplemental seeding/planting).

7.3.4 Soil Health

Soil health monitoring is recommended to evaluate the effectiveness of compost application and vegetation plantings on soil organic matter content. This monitoring component can facilitate evaluation of hydrologic functioning of soils in the two watersheds. As identified in Section 5, the soil health objective for both agricultural and urban lands is to achieve and maintain a soil organic matter (SOM) content ≥ 5%. At minimum, monitoring should consist of measuring SOM content in composited soil samples from the upper eight-inches of the soil profile at ≥ 12 sites on urban and ≥ 12 sites on agricultural lands distributed both the Kahoma and Kauaʻula watersheds; methods should roughly follow the sampling protocol used by the University of Hawaiʻi's College of Tropical Agriculture and Human Resources, Agricultural Diagnostic Service Center (ADSC) and their Cooperative Extension Service. The urban sites should be randomly located on parcels within the critical source areas for addressing stormwater and should consist of a mixture of burned/non-burned and compost treatment/no-compost treatment. Similarly, the agricultural sites should be randomly located on burned lands treated with compost. Monitoring may also include public perception surveys of effectiveness of soil health improvement efforts (e.g., whether residents are observing any positive outcomes resulting from compost applications, such as reducing stormwater runoff).

The accumulation of SOM is a long-term process that should require repeated applications of compost, therefore long-term monitoring is necessary to facilitate ongoing adaptive management of soil health. Baseline monitoring needs to be initiated during the immediate implementation phase so that the effectiveness of soil health practices can be evaluated in the future. Following the collection of baseline samples, repeat measures of SOM should occur every two years; repeat measures should be performed at least six months after a compost application and preceding any additional compost application so that the results are not skewed by the presence of fresh compost.

7.3.5 Stormwater Volume

Effectiveness for urban stormwater quantity should be initiated during the immediate implementation phase and extend through the long-term implementation phase. Effectiveness monitoring should occur within the critical source areas for urban stormwater control—the contributing area for flood-prone areas and storm sewers. The methodology should consist of standardized visual assessments of stormwater runoff and flooding for specific storm events. Monitoring may also include additional components such as geospatial mapping of flooding, public perception surveys regarding the effectiveness of efforts to reduce stormwater volumes, and photographic monitoring at fixed locations.

Stormwater quantity effectiveness monitoring should begin within one year of alternative watershed plan completion at the onset of the wet season and be conducted immediately following significant rain events (e.g., ≥ 0.1-inch of precipitation) during each wet season.

7.3.6 Stormwater Quality

Effectiveness monitoring for collective urban stormwater quality management actions should be initiated during the immediate implementation phase and extend through the long-term implementation phase. Monitoring sites should include the four stormwater outfalls to Kahoma stream (including the outfall associated with the diversion ditch on Princess Nāhiʻenaʻena Elementary School) and the approximately 12 stormwater outfalls to nearshore marine waters.

Parameters recommended for measurement include: discharge, TSS/SSC (see footnote in Table 29), TN, TP, total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb Se, V, Zn), *Enterococci*, organochlorine compounds (total PCBs, total dioxins, total furans, individual pesticides such as Fipronil, Imidacloprid, Bifenthrin), and organoflourine compounds (total PFAS). Methods should be consistent with DOH Clean Water Branch protocols. Parameters to be monitored should be adjusted based on an adaptive management process that considers new information including the initial results of monitoring. For example, a parameter may be excluded from further monitoring if results indicate that it is likely to consistently be non-detect. It is particularly important that repeatable methods for measuring stormwater outfall discharge is employed so that pollutant loads can be estimated.

Sampling should begin within one year of alternative watershed plan completion. To establish characterize baseline conditions, all outfalls should initially be sampled prior to widespread implementation of stormwater, soil, health, and vegetation practices. Once widespread implementation of stormwater measures and practices begins, four to eight randomly selected outfalls should be sampled per qualifying storm event. Samples should be collected during "first flush" conditions (within one hour of a storm event onset) of at least three storm events per year forecast to have a precipitation total ≥ 0.1-inch. Ensuring that all samples are collected during the first flush should facilitate evaluation of changes in discharge and pollutant loads through time.

Monitoring should occur for a given outfall even if implementation is not occurring in the contributing area of that outfall; in this case, the results should provide another point of comparison by which to evaluate effectiveness of treatments.

7.3.7 Stream Water Quality

Stream water quality should be monitored during the immediate and long-term implementation phases. Changes in stream water quality are not expected to be observed as a result of the immediate implementation phase, which should not substantially reduce pollutant loading from streambank erosion—the apparent primary source of sediment and potentially nutrients and metals as well. However, initiating monitoring during the immediate implementation phase should provide baseline data for evaluating the effectiveness of measures and practices applied during the long-term implementation phase, data for characterizing pollutant loading for full watershed plan development, and data for evaluating water quality status and trends.

Monitoring at the following approximate locations is recommended:

- Kahoma stream above high tide line
- Kahoma stream just above confluence with Kanahā stream
- Kanahā stream just above confluence with Kahoma stream
- Kahoma stream at conservation lands boundary
- Kanahā stream at conservation lands boundary
- Kauaʻula stream above high tide line
- Kauaʻula stream at the urban/agricultural lands boundary
- Kauaʻula stream at the conservation lands boundary

Monitoring parameters should include discharge, TSS/SSC (see footnote for Table 29), turbidity, TN, TP, total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb Se, V, Zn), and *Enterococci*. Sampling methods should be consistent with DOH Clean Water Branch protocols.

Monitoring of stream water quality should be ongoing, with sampling to begin within one year of alternative watershed plan completion and coordinated with BMP implementation. Multiple samples should be collected per year from a range of stream flows, with the sample number (≥ 10 samples per site per year is preferable), and scheduled to be determined based on available resources and the specific parameter. No samples should be collected when flow at a site is below 0.5 cfs.

7.3.8 Streambank Erosion

The immediate implementation phase is not expected to significantly reduce streambank erosion. However, effectiveness monitoring related to streambank erosion should be initiated within two years of alternative watershed plan completion to:

- Identify and characterize sites needing treatment during the long-term implementation phase.
- Provide baseline erosion data prior to the application of streambank erosion measures and practices during the long-term implementation phase.
- Estimate sediment, nutrient, and metal loads needed for full watershed plan development.

The monitoring locations should include eroding streambanks along Kahoma, Kanahā, and Kaua'ula streams on agricultural lands. The monitoring parameters include:

- Length and height of eroding streambanks.
- Streambank erosion rate using erosion pins.
- Particle size distribution and bulk density of streambank sediments.
- Nutrient (TN, TP) concentrations in streambank sediments.
- Total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb, Se, V, Zn) concentrations in streambank sediment.

Particle size distribution, bulk density, nutrients, and metals samples should be collected once during initial visits (at a minimum of two sites per stream), with each sample to consist of 10 composited subsamples. The length and height of eroding streambanks should be measured once during initial visit, with follow-up measurement to be determined, based on long-term implementation treatments. Streambank erosion rates should be measured one year after erosion pin installation involving at least two sites per stream, with 10 erosion pins installed in a grid pattern per site. The schedule for follow-up measurement of streambank erosion rates should be determined based on the type of long-term implementation treatments.

7.3.9 Marine Water Quality

Ongoing marine water quality monitoring is conducted by DOH and partner organizations such as the Surfriders Foundation and HOKWO. Marine water quality should continue to be monitored during the immediate and long-term implementation phases. Changes in marine water quality are not expected to be observed because of the immediate implementation phase. However, initiating monitoring during the immediate implementation phase should provide baseline data for evaluating the effectiveness of measures and practices applied during the long-term implementation phase as well as evaluating water quality status and trends.

Monitoring should consist of systematic observations at sites where ongoing water quality monitoring is being conducted in the Kahoma nearshore AU, Kauaʻula nearshore AU, and Lāhainā Harbor AU. Sampling methods should be consistent with DOH Clean Water Branch protocols. At minimum, monitoring parameters should include:

- pH, dissolved oxygen (DO), and salinity
- Nitrogen parameters: TN as N, Nitrate + Nitrite as N, Ammonia as N
- Phosphorus parameters: TP as P, Phosphate as P
- Chlorophyl-a
- *Enterococci*
- Turbidity
- Dissolved Cu (to verify Hawaiʻi water quality criterion exceedances observed in the Kahoma nearshore AU and Lāhainā harbor AU—see Section 4.1.2.4.2)

Multiple samples per year should be collected during wet and dry seasons. The schedule and number of sites and samples (≥ 10 samples per site per year is preferable) should be determined based on available resources, the specific parameter, and sample results (e.g., for dissolved Cu).

7.3.10 Marine Sediment Quality

The immediate implementation phase is not expected to significantly affect marine sediment quality. However, marine sediment quality monitoring is needed to:

- Determine status and trends (e.g., to provide data to evaluate attainment of state water quality standards).
- Support development of a full watershed plan.
- Evaluate the effectiveness of pollutant control measures and practices during the long-term implementation phase at preventing impairment of marine areas from the accumulation metals and POCs.

As discussed in Sections 3 and 4, marine sediment monitoring has been conducted in response to the Lāhainā wildfire and serves as a baseline for future sediment monitoring. Monitoring should consist of systematic observations at sites within the Kahoma nearshore AU, Kauaʻula nearshore AU, and Lāhainā Harbor AU—including sites within and not within the vicinity of stormwater outfalls. Sampling methods should be consistent with DOH Clean Water Branch protocols and/or related DOH protocols, which includes the collection of composited samples. The monitoring schedule—including when monitoring will be initiated, the number of sites, and the sampling frequency—are to be determined based on available resources, with adaptive management to be applied based on monitoring results.

At minimum, monitoring parameters should include:

- Total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb, Se, V, Zn)
- Organochlorine compounds (total PCBs, total dioxins, total furans, individual pesticides of concern)
- Organoflourine compounds (total PFAS)

7.4 SUMMARY OF MONITORING NEEDS

Table 29 outlines monitoring needs associated with all four categories of monitoring. This table serves two purposes: (1) to identify implementation and effectiveness monitoring needs associated with the immediate implementation phase and (2) to identify effectiveness, pollutant sources, and status and trend monitoring needed to support full watershed plan development and the subsequent implementation of the plan.

The table identifies where datasets associated with the different categories of monitoring can serve multiple purposes (e.g., stream water quality datasets will have utility for evaluating the effectiveness of water quality protection measures and practices, for estimating pollutant loading for watershed planning purposes, and for evaluating water quality standards attainment). For each monitoring type, details on the monitoring purpose(s), parameters, sampling design, and locations are provided. In accordance with adaptive management principles, the monitoring schemes outlined in Table 29 are subject to modification based on consideration of new data and information (e.g., monitoring results) and availability of resources.

Table 29. Recommended Lāhainā Watersheds Monitoring Parameters and Approach.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Adaptive management	BMP Implementation	To track progress of water quality measures and practices relative to an implementation schedule and milestones.	*Administrative review:* measures and practices not yet started, in progress, or completed. *Field inspection:* project/site specific inspection parameters.	Systematic observations. Administrative review schedule/frequency: at least quarterly. Feld inspection schedule/review: during and immediately after measure/practice completion as appropriate to ensure correct implementation.	Administrative review: N/A Field inspection: all implementation sites/areas.
Weather	Pollutant Source BMP Effectiveness (immediate and long-term implementation phases)	To develop an understanding of how variation in precipitation amounts affect pollutant loading and stormwater volumes for full watershed plan development. To assist with evaluating the effectiveness of stormwater control practices implemented during both the immediate and long-term implementation phases.	*Minimum*: precipitation measurements (hourly).	Systematic observations of precipitation. Schedule/frequency: To begin within one year of alternative watershed plan completion.	Minimum: One site located in Lāhainā near sea level, one site located in the agricultural lands around 1,500 ft elevation. If resources allow, add a high elevation site (≥ 3,000 ft).
Erosion and sedimentation associated with irrigation ditches, unimproved roads, culverts, firebreaks, flood embankments, upland drainageways	Pollutant Source BMP Effectiveness (immediate and long-term implementation phases)	To identify sites needing immediate treatment. To evaluate effectiveness of treatments and support adaptive management during both the immediate and long-term implementation phases.	Standardized visual assessments/rating of erosion and sediment conditions.	Systematic observations at fixed locations. Schedule/frequency: to begin within one year of alternative watershed plan completion, prior to measure/practice implementation and prior to the onset of the wet season; once per year thereafter prior to the onset of the wet season.	Critical source areas identified in Section 5.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Vegetation communities on burned agricultural and urban lands	Pollutant Source BMP Effectiveness (immediate and long-term implementation phases)	To identify sites needing immediate treatment. To evaluate effectiveness of treatments and support adaptive management during both the immediate and long-term implementation phases.	Standardized visual assessment/ratings of vegetation community conditions (e.g., percent cover, density, vigor, health); may include repeat photo-points and public perception surveys of effectiveness.	Systematic observations at fixed locations. Schedule/frequency: to begin within one year of alternative watershed plan completion, prior measure/practice implementation and prior to the onset of the wet season; once per year thereafter at the onset of the wet season.	Critical source areas identified in Section 5.
Urban soil health	BMP Effectiveness (immediate and long-term implementation phases)	To evaluate effectiveness of soil health measures and practices and support adaptive management during both the immediate and long-term implementation phases.	Soil organic matter content in upper 8-inches of the soil profile. May also include public perception surveys of effectiveness.	Before-after-control impact (BACI) design: ≥ 12 randomly selected sites—replicate combinations of burned/non-burned, treated/non-treated. Each sample at a site to consist of 10 composited soil subsamples, with any above ground live vegetation removed. Schedule/frequency: to begin within one year of alternative watershed plan completion, prior to initial implementation of soil health practices; sites monitored every two years after initial implementation, at least six months after any compost application and preceding any additional compost application.	Within critical source areas for stormwater control—parcels within the contributing area of flood-prone areas and storm sewers. Non-treated sites and non-burned sites may be omitted if resources are inadequate for BACI design.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Agricultural soil health	BMP Effectiveness (immediate and long-term implementation phases)	To evaluate effectiveness of soil health measures and practices and support adaptive management during both the immediate and long-term implementation phases.	Soil organic matter content in upper 8-inches of the soil profile. May also include public perception surveys of effectiveness.	BACI design: ≥ 12 randomly selected sites—replicate combinations of burned/non-burned, treated/non-treated. Each sample at a site to consist of 10 composited subsamples, with any above ground live vegetation removed. Schedule/frequency: to begin within one year of alternative watershed plan completion, prior to initial implementation of soil health practices; sites monitored every two years after initial implementation, at least six months after any compost application and preceding any additional compost application.	Burned and non-burned agricultural lands. Non-treated sites and non-burned sites may be omitted if resources are inadequate for BACI design.
Urban stormwater quantity	Pollutant Source BMP Effectiveness (immediate and long-term implementation phases)	To evaluate effectiveness of stormwater control measures and practices during both the immediate and long-term implementation phases	Standardized visual assessments/ratings of flooding for specific events; may also include geospatial mapping, public perception surveys of effectiveness, and repeat photo-points.	Systematic observations at fixed locations. Schedule/frequency: to begin within one year of alternative watershed plan completion at the onset of the wet season; conducted immediately following significant rain events (e.g., ≥ 0.1 inch of precipitation) during each wet season.	Within critical source areas for stormwater control—within the contributing area of flood-prone areas and storm sewers.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Urban stormwater quality	Pollutant Source BMP Effectiveness (immediate and long-term implementation phases)	To evaluate effectiveness of stormwater control measures and practices during both the immediate and long-term implementation phases. To provide estimates of stormwater pollutant loading to nearshore marine waters for full watershed plan development.	Discharge, TSS/SSC, TN, TP, total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb Se, V, Zn), *Enterococci*, organochlorine compounds (total PCBs, total dioxins, total furans, individual pesticides of concern), organoflourine compounds (total PFAS). Methods need to be devised to measure discharge.	Methods should be consistent with DOH Clean Water Branch protocols. Schedule/frequency: to begin within one year of alternative watershed plan completion—all outfalls sampled prior to widespread implementation of stormwater, soil, health, and vegetation practices; four to eight randomly selected outfalls sampled per qualifying storm event after widespread implementation begins. Samples to be collected during "first flush" conditions (within one hour of a storm event onset) of at least three storm events per year forecast to have a precipitation total ≥ 0.1 inch.	Four stormwater outfalls to Kahoma stream (including the diversion ditch on Princess Nahienaena Elementary School). Approximately 12 stormwater outfalls to nearshore marine waters.
Stream water quality	Pollutant Source Status and Trend BMP Effectiveness (immediate and long-term implementation phase)	To provide estimates of pollutant loading to nearshore marine waters for full watershed plan development. To evaluate the effectiveness of pollutant control measures and practices during both the immediate and long-term implementation phases. To provide data to evaluate attainment of state water quality criteria.	Discharge, TSS/SSC, turbidity, TN, TP, total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb Se, V, Zn), *Enterococci.*	Systematic measurements at fixed locations. Methods should be consistent with DOH Clean Water Branch protocols. Schedule/frequency: ongoing sampling, with baseline sampling to begin within one year of alternative watershed plan completion—multiple samples per year representing a range of stream flows, with sample number and schedule to be determined based on available resources and specific parameter; ≥ 10 samples per site per year is preferable. No samples collected when flow at a site is below 1.0 cfs.	Kahoma stream*:* above high tide line; Kahoma stream just above confluence with Kanahā stream; Kanahā stream just above confluence with Kahoma stream; Kahoma stream at conservation lands boundary; Kanahā stream at conservation lands boundary. Kauaʻula stream: above high tide line; at the urban/agricultural lands boundary; at the conservation lands boundary.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Streambank erosion	Pollutant Source BMP Effectiveness (long-term implementation phase)	To identify and characterize sites needing treatment. To provide estimates of pollutant loading to support full watershed plan development. To evaluate the effectiveness of pollutant control measures and practices during the long-term implementation phase.	Location, length, and height of eroding streambanks; streambank erosion rate using erosion pins; particle size distribution and bulk density of streambank sediments; nutrients (TN, TP) and total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb, Se, V, Zn) concentrations in streambank sediments.	Systematic measurements at fixed locations. Particle size distribution, bulk density, nutrients, and metals: collected once during initial visit at two sites per stream; each sample at a site to consist of 10 composited subsamples. Schedule/frequency: to begin within two years of alternative watershed plan completion. Length and height of eroding streambanks measured once during initial visit, follow-up measurement TBD, based on long-term implementation treatments. Erosion rate: measured one year after erosion pin installation; follow-up measurement TBD, based on long-term implementation treatments.	Eroding streambanks along Kahoma, Kanahā, and Kauaʻula streams on agricultural lands.
Marine water quality	Status and Trend BMP Effectiveness (long-term implementation phases)	To evaluate the effectiveness of pollutant control measures and practices during the long-term implementation phase. To provide data to evaluate attainment of state water quality criteria.	Turbidity, TN, Nitrate + Nitrite, Ammonia, TP, Chlorophyl-a, *Enterococci*, DO, pH, salinity. Dissolved Cu only in Kahoma nearshore marine AU and Lāhainā Harbor AU.	Systematic measurements at fixed locations. Methods should be consistent with DOH Clean Water Branch protocols. Schedule/frequency: continue ongoing sampling efforts—multiple samples per year during wet and dry seasons, with number of sites/samples and schedule to be determined based on available resources, specific parameter, and sample results (e.g., for dissolved Cu); ≥ 10 samples per site per year is preferable.	Kahoma nearshore marine AU. Kauaʻula nearshore marine AU.

Monitoring Type	Associated Monitoring Categories	Purpose	Parameters	Sampling Design	Location
Marine sediment quality	Status and Trend BMP Effectiveness (long-term implementation phase)	To support development of full watershed plan development. To provide data to evaluate attainment of state water quality standards. To evaluate the effectiveness of pollutant control measures and practices during the long-term implementation phase.	Total recoverable metals (As, Cr, Cu, Hg, Pb, Ni, Sb, Se, V, Zn); organochlorine compounds (total PCBs, total dioxins, total furans, individual pesticides of concern); organoflourine compounds (total PFAS).	Systematic measurements at fixed locations. One composite sample collected from each site. Methods should be consistent with DOH Clean Water Branch protocols. Schedule/frequency: initiation of monitoring TBD; number of sites TBD based on available resources; frequency to be determined based on available resources and monitoring results.	Kahoma nearshore marine AU: sites within/not within the vicinity of stormwater outfalls. Kauaʻula nearshore marine AU: sites within/not within the vicinity of stormwater outfalls. Lāhainā Harbor AU: sites within/not within the vicinity of stormwater outfalls.

Notes:
N/A = not applicable; TBD = to be determined.
Associated monitoring categories are those discussed in Section 7.1: BMP implementation monitoring, BMP effectiveness monitoring, pollutant source monitoring, and status and trend monitoring.
TSS/SSC: Hawaiʻi has water quality criteria for total suspended solids (TSS). Although Hawaiʻi does not have criteria for suspended sediment concentration (SSC), this parameter is often preferable for quantifying ambient sediment concentrations in waterbodies. The TSS analysis method was developed for wastewater and may underestimate total sediment concentrations when ambient samples contain significant levels of sand (Gray et al. 2000). This is because the TSS analysis method estimates solids based on a subsample (an aliquot) from the water sample whereas the SSC analysis method uses the entire water sample. Using the entire water sample provides a more accurate estimate of the content of sand, which tends to rapidly sink to the bottom of a sample bottle following agitation; therefore, the sand content may not be adequately represented by an aliquot used to analyze TSS.

QUALITY ASSURANCE

To support the development of an alternative watershed plan and future watershed-based plans for the Kahoma and Kauaʻula watersheds, several quality control checks were performed during development of this preliminary watershed planning framework. Quality control checks included reviews of data transfers from individual data sets into data compilations, evaluations of data values for correctness/reasonableness, reviews of geospatial data for accuracy and metadata completeness, as well as editorial reviews. All identified errors were corrected before finalizing this document.

REFERENCES

AECOM. 2012. *Hawaiian Islands Soil Metal Background Evaluation Report.* Prepared for Hawaiʻi Dept. of Health, Hazard Evaluation and Emergency Response, Honolulu, HI, by AECOM, Honolulu, HI.

AECOM. 2025. *Draft Environmental Assessment for the Wahikuli Subdivision Gravity Sewer System*. Volume 1. Lāhainā, District of West Maui, County of Maui, HI.

Allan, J.D., M.M. Castillo, and K.A. Capps. 2021. *Stream Ecology: Structure and Function of Running Waters*. Springer Nature, Berlin, Germany.

Andrews, S., and R.A. Sutherland. 2004. Cu, Pb and Zn contamination in Nuuanu watershed, Oahu, Hawaiʻi. *Science of the Total Environment* 324(1-3):173–182.

Balasubramani, A., N.L. Howell, and H.S. Rifai. 2014. Polychlorinated biphenyls (PCBs) in industrial and municipal effluents: concentrations, congener profiles, and partitioning onto particulates and organic carbon. *Science of the Total Environment* 473:702–713.

Belt Collins (Belt Collins Hawaii, Ltd). 2005. *Final Lāhainā drainage master plan*. Prepared for County of Maui, Department of Public Works and Environmental Management, Maui, HI.

Brown, S., and M. Cotton. 2011. Changes in soil properties and carbon content following compost application: results of on-farm sampling. *Compost Science and Utilization* 19:87–96.

Brown, S., K. Kurtz, A. Bary, and C. Cogger. 2011. Quantifying benefits associated with land application of organic residuals in Washington State. *Environmental Science & Technology* 45:7451–7458.

Buchman, M.F. 2008. *NOAA screening quick reference tables*. NOAA OR&R report 08-1. National Oceanic and Atmospheric Administration, Office of Response and Restoration Division, Seattle, WA.

Burant, A., W. Selbig, E.T. Furlong, and C.P. Higgins. 2018. Trace organic contaminants in urban runoff: Associations with urban land-use. *Environmental Pollution* 242:2068–2077.

Callender, T., K. Falinski, C. Keyhani, L. Yannell, and A. Yurkanin. 2024. *Hui O Ka Wai Ola Data Set*. Accessed April 28, 2025. https://www.huiokawaiola.com/data.html.

Campbell, P.L., N.G. Prouty, C.D. Storlazzi, and N.L. D'Antonio. 2017. *The Use of Passive Membrane Samplers to Assess Organic Contaminant Inputs at Five Coastal Sites in West Maui, Hawaiʻi*. U.S. Geological Survey Open-File Report 2017-1097. https://doi.org/10.3133/ofr20171097.

CCME (Canadian Council of Ministers of the Environment). 2012. *Glyphosate Canadian Water Quality Guidelines for the Protection of Aquatic Life.* Canadian Environmental Quality Guidelines.

CCME (Canadian Council of Ministers of the Environment). 2025. *Canadian Environmental Quality Guidelines*. https://ccme.ca/en/current-activities/canadian-environmental-quality-guidelines.

Cannarella, R. 2010. *Appendix F: Timeline of forest history in Hawaiʻi*. https://dlnr.hawaii.gov/forestry/files/2013/09/Appendix-F-Forest-History.pdf.

CH2MHILL. 2013. *Integrated Feasibility Report and Environmental Assessment. Mokuhinia Ecosystem Restoration Report*. Draft. Prepared for U.S. Army Corps of Engineers, Honolulu District and the County of Maui, Maui, HI.

CIDFS (Committee on the Implications of Dioxin in the Food Supply). 2003. *Dioxins and Dioxin-Like Compounds in the Food Supply: Strategies to Decrease Exposure*. National Academies Press, Washington, DC.

County of Maui. 2024. *Lāhainā Long-Term Recovery Plan*.

County of Maui. 2025a. *Federal government awards $15.6M to County of Maui for Lāhainā Water Recycling Project*. Accessed January 16, 2025. https://www.mauirecovers.org/news/federal-government-awards-15-6m-to-county-of-maui-for-lahaina-water-recycling-project.

County of Maui. 2025b. *County of Maui's Website for Recovery Efforts for Maui Wildfire Survivors*. https://www.mauirecovers.org/.

County of Maui Department of Fire and Public Safety. 2024. *Origin and Cause Report Wildfire Lāhainā, HI*. County of Maui Department of Fire and Public Safety. https://www.mauicounty.gov/DocumentCenter/View/149693/FI23-0012446-Lahaina-Origin-and-Cause-Report_Plus-Appendix-A-B-C-Redacted

Crohn, D.M., V.N. Chaganti, and N. Reddy. 2013. Composts as post-fire erosion control treatments and their effect on runoff water quality. *Transactions of the ASABE* 56(2):423–435.

Dal Pizzol, J.L., J.A. Marques, J. da Silva Fonseca, P.G. Costa, and A. Bianchini. 2022. Metal accumulation induces oxidative stress and alters carbonic anhydrase activity in corals and symbionts from the largest reef complex in the South Atlantic ocean. *Chemosphere* 290:133216.

De Carlo, E.H., and K.J. Spencer. 1997. Retrospective analysis of anthropogenic inputs of lead and other heavy metals to the Hawaiian sedimentary environment. *Applied Organometallic Chemistry* 11(5):415–437.

De Carlo, E.H., M.S. Tomlinson, and S.S. Anthony. 2005. Trace elements in streambed sediments of small subtropical streams on O ʻahu, Hawai ʻi: Results from the USGS NAWQA program. *Applied Geochemistry* 20(12):2157–2188.

Delgado-Lemus, T.S., and A.I. Moreno-Calles. 2022. *Agroforestry Contributions to Urban River Rehabilitation*. Sustainability, 14(13):7657.

EPA (U.S. Environmental Protection Agency). 2001. *National Management Measures Guidance to Control Nonpoint Source Pollution from Marinas and Recreational Boating*. EPA 841-B-01-005. EPA, Office of Water, Washington, DC.

EPA (U.S. Environmental Protection Agency). 2009. *Managing Wet Weather with Green Infrastructure Municipal Handbook Incentive Mechanism*. EPA-833-F-09-001.

EPA (U.S. Environmental Protection Agency). 2024. *Nonpoint Source Program and Grants Guidelines for States and Territories*. EPA 841-R-24-009.

EPA (U.S. Environmental Protection Agency). 2025. *Environmental Value of Applying Compost: Improving Soil Health for Stormwater Management, Contaminated Site Remediation, Ecosystem Restoration, Landscaping and Agriculture*. EPA/600/X-25/015. EPA, Office of Research and Development, Washington, DC.

Evanylo, G., C. Sherony, J. Spargo, D. Starner, M. Brosius, and K. Haering. 2008. Soil and water environmental effects of fertilizer-, manure-, and compost-based fertility practices in an organic vegetable cropping system. *Agriculture, Ecosystems and Environment* 127:50–58.

Faucette, L.B. 2012. Compost in the green infrastructure tool box. *BioCycle* 53(10):33–36.

Favor, K. 2023. *Urban Agroforestry*. National Center for Appropriate Technology.

FDEP (Florida Department of Environmental Protection). 2025. *Sediment Guidelines*. https://floridadep.gov/dear/watershed-monitoring-section/content/sediment-guidelines.

FEMA (Federal Emergency Management Agency). 2024. *FEMA Flood Advisory Maps for Post-Fire Conditions in Lāhainā*. FEMA Region 9, Mitigation Division. https://waihalana.hawaii.gov/wp-content/uploads/2024/11/05-Simmons_Lahaina-ABFEs_Simmons_Nov2024-1.pdf.

Ferreira, S. 2024. *Reviving the Ahupua'a System in Lāhainā*. Ka Wai Ola. https://kawaiola.news/oha/ceo/reviving-the-ahupuaa-system-in-lahaina/.

Giambelluca, T.W., X. Shuai, M.L. Barnes, R.J. Alliss, R.J. Longman, T. Miura, Q. Chen, A.G. Frazier, R.G. Mudd, L. Cuo, and A.D. Businger. 2014. *Evapotranspiration of Hawaiʻi.* Final report submitted to the U.S. Army Corps of Engineers—Honolulu District, and the Commission on Water Resource Management, State of Hawaiʻi.

Gilbert, J., M. Ricci-Jurgensen, and A. Ramola. 2020. *Quantifying the benefits of applying quality compost to soil*. Rotterdam: International Solid Waste Association.

Glenn, C.R., R.B. Whittier, M.L. Dailer, H. Dulaiova, A.I. El-Kadi, J. Fackrell, J.L. Kelly, C.A. Waters, and J. Sevadjian. 2013. *Lāhainā groundwater tracer study. Lāhainā, Maui, Hawai`i. Final report*. Prepared for State of Hawaiʻi Department of Health, U.S. Environmental Protection Agency, and U.S. Army Engineer Research and Development Center.

Gravuer, K., S. Gennet, and H.L. Throop. 2019. Organic amendment additions to rangelands: a meta-analysis of multiple ecosystem outcomes. *Global Change Biology* 25:1152–1170.

Gray, J.R., G.D. Glysson, L.M. Turcios, and G.E. Schwarz. 2000. *Comparability of suspended-sediment concentration and total suspended solids data (No. 4191).* U.S. Department of the Interior, U.S. Geological Survey, Reston, VA.

Griffith, E.M. 1902. General description of the Hawaiian forests, a report of U.S. Forester E. M. Griffith on Hawaiian forests presented at Yokohama, Japan, 8 pp. (transcribed). (ms. preserved in headquarters office, State of Hawaiʻi Department of Land and Natural Resources, Division of Forestry and Wildlife, Honolulu).

Group 70 (Group 70 International) and SRGI (Sustainable Resources Group International, Inc.). 2016. *West Maui Watershed Plan*. *Kahana, Honokahua, and Honolua Watersheds Characterization Report*.

Prepared for U.S. Army Corps of Engineers and State of Hawai`i Dept. of Land and Natural Resources.

Hawaiʻi Department of Taxation. 2025. *Migration Effects of the Maui Wildfires*. https://tax.hawaii.gov/blog/blog18-migration-effects-maui-wildfires-moore-karacaovali/#:~:text=Migration%20Impact%20Analysis&text=%3EOur%20estimates%20reveal%20that%20relocations,by%20at%20least%201000%20people.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2017. *Report to the Twenty-Ninth Legislature State of Hawaiʻi 2018 Regular Session: Relating to Cesspools and Prioritization for Replacement*. Hawaiʻi DOH, Environmental Management Division, Pearl City, HI.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2018a. *Arsenic in Soil Fact Sheet*.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2018b. *Arsenic in Canec Fact Sheet.*

Hawaiʻi DOH (Hawaiʻi Department of Health). 2019. *Hazard Evaluation and Emergency Response Office Technical Guidance Manual*.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2021. *Hawaiʻi Administrative Rules (HAR).* https://health.hawaii.gov/cwb/files/2022/01/HAR-11-54-October-22-2021.pdf.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2024a. *State of Hawaiʻi Water Quality Monitoring and Assessment Report*. Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to §303(d) and §305(b), Clean Water Act (P.L. 97-117). Hawaiʻi DOH, Honolulu, Hawaiʻi. https://health.hawaii.gov/cwb/files/2024/09/IR-2024-final-draft.pdf.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2024b. *Evaluation of Environmental Hazards at Sites with Contaminated Soil and Groundwater Volume 2: Background Documentation for the Development of Tier 1 Environmental Action Levels Appendix 1: Detailed Lookup Tables Hawaiʻi Edition*.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2025a. Personal communication, Nancy Convard, Strategic Program Development Manager, Environmental Management Infrastructure Project.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2025b. *Environmental Monitoring Data Portal*. https://health.hawaii.gov/environmental-data/.

Hawaiʻi DOH (Hawaiʻi Department of Health). 2025c. *Enterococci Monitoring Results for Kahoma and Kauaʻula Nearshore Marine Assessment Units*.

Hawaiʻi Statewide GIS Program. 2025. *GIS Data*. Hawaiʻi Office of Planning and Sustainable Development. https://planning.hawaii.gov/gis/download-gis-data-expanded/.

Hédouin, L., A.J. Reichelt-Brushett, and R.D. Gates. 2009. Assessment of metals and a metalloid in sediments from Hawaiʻian coral reef ecosystems. *Marine Pollution Bulletin* 58(11):1759–1765.

Hédouin, L., M. Metian, and R.D. Gates. 2011. Ecotoxicological approach for assessing the contamination of a Hawaiian coral reef ecosystem (Honolua Bay, Maui) by metals and a metalloid. *Marine Environmental Research* 71(3):149–161.

Henshaw, J., and J. Lewis. 2011. *The Lessons of History. Making A Case for a National Forest in Hawaiʻi*. Forest History Today.

Hester, E.T., K.E. Brooks, and D.T. Scott. 2018. Comparing reach scale hyporheic exchange and denitrification induced by instream restoration structures and natural streambed morphology. *Ecological Engineering* 115:105–121.

Hunt, C.D. Jr., and S.N. Rosa. 2009. *A Multitracer Approach to Detecting Wastewater Plumes from Municipal Injection Wells in Nearshore Marine Waters at Kihei and Lāhainā, Maui, Hawaiʻi*. U.S. Geological Survey Scientific Investigations Report 2009–5253.

Kamehameha Schools. 2025. *KS Maui haumāna and community boost restoration vision for Ka Malu site in Lāhainā*. https://www.ksbe.edu/article/ks-maui-haumana-and-community-boost-restoration-vision-for-ka-malu-site-in-lahaina.

Karvelas, M., A. Katsoyiannis, and C. Samara. 2003. *Occurrence and fate of heavy metals in the wastewater treatment process*. *Chemosphere* 53(10):1201–1210.

Khasawneh, O.F.S., and P. Palaniandy. 2021. Occurrence and removal of pharmaceuticals in wastewater treatment plants. *Process Safety and Environmental Protection* 150:532–556.

Kriebel, D., J. Tickner, P. Epstein, J. Lemons, R. Levins, E.L. Loechler, M. Quinn, R. Rudel, T. Schettler, and M. Stoto. 2001. The precautionary principle in environmental science. *Environmental Health Perspectives* 109(9)L871–876.

Kumu Pono Associates LLC. 2025. *Lāhainā: An Overview of Native History*. Kumu Pono Associates LLC. https://www.kumupono.com/lahaina/

Lal, R. 2020. Soil organic matter and water retention. *Agronomy Journal* 112(5):3265–3277.

Lenka, S., M. Kah, and L. Padhye. 2021. A review of the occurrence, transformation, and removal of poly- and perfluoroalkyl substances (PFAS) in wastewater treatment plants. *Water Research* 199:117187.

Madson, A., M. Dimson, L.B. Fortini, K. Kawelo, T. Ticktin, M. Keir, C. Dong, Z. Ma, D.W. Beilman, K. Kay, and J. Ocón. 2023. A near four-decade time series shows the Hawaiian Islands have been browning since the 1980s. *Environmental Management* 71(5):965–980.

Maui Recovers. 2024. *Ola Lāhainā – Shaping Lāhainā's Future*. https://www.mauirecovers.org/lahaina.

McMurtry, G.M., J.C. Wiltshire, and J.P. Kauahikaua. 1995. *Heavy Metal Anomalies in Coastal Sediments of O'ahu, Hawai'i*.

MEC (Maui Environmental Consulting). 2019. *Southwest Maui Watershed Management Plan*.

MEC (Maui Environmental Consulting). 2023. *Ma`alaea Bay Watershed Management Plan*. Prepared for Maui County, Office of Innovation and Sustainability and State of Hawaiʻi, Department of Health, Surface Water Protection Branch, Maui, HI, by MES, Paia, HI.

Merill, L., and D. Tonjes. 2014. A review of the hyporheic zone, stream restoration, and means to enhance denitrification. *Critical Reviews in Environmental Science and Technology* 44(21):2337–2379.

MES (MacDonald Environmental Services). 1994. *Approach to the Assessment Sediment Quality in Florida Coastal Waters. Volume 1 - Development And Evaluation of Sediment Quality Assessment*

Guidelines. Prepared for: Florida Department of Environmental Protection, Office of Water Policy, Tallahassee, FL, by MES, Ladysmith, British Columbia.

Meyer, V.F., E.F. Redente, R. Barbarick, and R. Brobst. 2001. Biosolids (compost) Application Affect Runoff Water Quality Following Forest Fire. *Journal of Environmental Quality* 30:1528–1532.

Mezzacapo, M., and C. Shuler. 2022. *Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool*. Updated Report & Technical Appendices. Special report WRRC-SR-2022-02 (Revised). Prepared For: State of Hawaiʻi Department of Health Wastewater Branch State of Hawaiʻi Cesspool Conversion Working Group.

Mohammadi, M. 2005. The initiation of sediment motion in fixed bed channels. *Iranian Journal of Science & Technology, Transaction B, Engineering* 29(B3):365–372.

Munekiyo and Hirage, Inc. 2003. *Final Environmental Impact Statement. Lāhainā Flood Control Project*. Prepared for U.S. Dept. of Agriculture, Natural Resource Conservation Service, West Maui Soil and Water Conservation District and County of Maui, Department of Public Works and Environmental Management.

NCAT (National Center for Appropriate Technology). 2025. *Quick Tips for Agroforestry*. https://attra.ncat.org/.

Neff, J. 1997. Ecotoxicology of arsenic in the marine environment. *Environmental Toxicology and Chemistry* 16(5):917–927.

NHEP (New Hampshire Estuaries Project). 2007. *The Impacts of Impervious Surfaces on Water Resources, NHEP*. PREP Reports & Publications 236. https://scholars.unh.edu/prep/236.

NOAA (National Oceanic and Atmospheric Administration). 2015. *Coastal Change Analysis Program (C-CAP) High-Resolution Land Cover*. https://coast.noaa.gov/digitalcoast/data/ccaphighres.html.

NOAA (National Oceanic and Atmospheric Administration). 2024. *U.S. Climate Normals Quick Access.* NOAA, National Centers for Environmental Information, Asheville, NC. https://www.ncei.noaa.gov/access/monitoring/climate-at-a-glance/county/time-series.

NRCS (Natural Resources Conservation Service). 2023. *Emergency Watershed Protection Maui, Hawaiʻi-Lāhainā Fire*. U.S. Department of Agriculture, NRCS, Washington, DC.

NRCS (Natural Resources Conservation Service). 2024. *Soil Survey Geographic Database (SSURGO)*. U.S. Department of Agriculture, NRCS, Washington, DC. https://www.nrcs.usda.gov/resources/data-and-reports/soil-survey-geographic-database-ssurgo.

NRCS (Natural Resources Conservation Service). 2025. *Web Soil Survey*. U.S. Department of Agriculture, NRCS, Washington, DC. https://websoilsurvey.nrcs.usda.gov/app/

NSSCP (North Shore Sustainable Communities Plan). 2025. *Adapt the Ahupua'a Concept as a Framework for Land Use and Natural Resource Management*. North Shore Sustainable Communities Plan https://northshorescp.com/adapt-ahupuaa-concept-framework-land-use-and-natural-resource-management

O'Connor, T. 2004. The sediment quality guideline, ERL, is not a chemical concentration at the threshold of sediment toxicity. *Marine Pollution Bulletin* 49(5–6):383–385.

Ozaki, H., I. Watanabe, and K. Kuno. 2004. Investigation of the heavy metal sources in relation to automobiles. *Water, Air, and Soil Pollution* 157:209–223.

Ozores-Hampton, M., J. Biala, G. Evanylo, B. Faucette, L. Cooperband, N. Roe, J.A. Creque, and D. Sullivan. 2022. Compost Use. Chapter 16 in *The Composting Handbook*, *ed. R.Rynk,* pp. 777–846. Academic Press.

Parrish, J, J.A. Maciolek, A.S. Timbol, C.B. Hathaway, Jr., and S.E. Norton. 1978. *Stream Channel Modification in Hawaiʻi: Part D, Summary Report*. U.S. Department of the Interior, US. Fish and Wildlife Service, Biological Services Program.

Perkins, K., J. Nimmo, and A. Medeiros. 2012. Effects of native forest restoration on soil hydraulic properties, Auwahi, Maui, Hawaiian Islands. *Geophysical Research Letters* 39:L05405.

Prouty, N., A. Cohen, K. Yates, C. Storlazzi, P. Swarzenski, and D. White. 2017. Vulnerability of coral reefs to bioerosion from land-based sources of pollution. *Journal of Geophysical Research, Oceans* 122(12):9319–9331.

Rafferty, J.P. 2025. *Maui Wildfires of 2023*. Encyclopedia Britannica. https://www.britannica.com/event/Maui-wildfires-of-2023

Reyes, M. 2019. *Southwest Maui watershed management plan*. Prepared for Hawaiʻi Department of Health, Clean Water Branch and U.S. Environmental Protection Agency, by Maui Environmental Consulting, LLC.

Romine, B.M., and C.H. Fletcher. 2013. A Summary of Historical Shoreline Changes on Beaches of Kauai, Oahu, and Maui, Hawaiʻi. *Journal of Coastal Research* 29(3):605–614. https://doi.org/10.2112/JCOASTRES-D-11-00202.1

Rumpel, C., and I. Kögel-Knabner. 2011. *Deep soil organic matter—a key but poorly understood component of terrestrial C cycle*. *Plant and Soil* 338:143–158.

Sherrod, D.R., J.M. Sinton, S.E. Watkins, S. E., and K.M. Brunt. 2007. *Geological Map of the State of Hawaiʻi: U.S. Geological Survey Open-File Report 2007-1089*. 83 p., 8 plates, scales 1:100,000 and 1:250,000, with GIS database. U.S. Geological Survey.

Shuler, C., Renteria, A., Mezzacapo, M., Allen, K., Whittier, R. 2021. *2021 Hawaiʻi Cesspool Hazard Assessment & Prioritization Tool: Web Application*. Available online at: https://seagrant.soest.hawaii.edu/cesspools-tool/

SRGI (Sustainable Resources Group International, Inc.). 2012a. *Wahikuli-Honokōwai Watershed Management Plan Volume I: Watershed Characterization*. Prepared for National Oceanic and Atmospheric Administration, Office of Ocean and Coastal Resource Management, Coral Reef Conservation Program.

SRGI (Sustainable Resources Group International, Inc.). 2012b. *Wahikuli-Honokōwai Watershed Management Plan Volume II Strategies and Implementation*. Prepared for National Oceanic and

Atmospheric Administration, Office of Ocean and Coastal Resource Management, Coral Reef Conservation Program

State of Hawaiʻi. 2017. *Instream Flow Standard Assessment Report: Island of Maui Hydrologic Unit 6007: Kauaʻula*. https://files.hawaii.gov/dlnr/cwrm/ifsar/PR201704-KauaulaDraft.pdf.

State of Hawaiʻi. 2018a. *Instream Flow Standard Assessment Report: Island of Maui Hydrologic Unit 6007: Kauaʻula*. https://files.hawaii.gov/dlnr/cwrm/ifsar/PR201804-6007-Kauaula.pdf.

State of Hawaiʻi. 2018b. *Instream Flow Standard Assessment Report: Island of Maui Hydrologic Unit 6008: Kahoma*. https://files.hawaii.gov/dlnr/cwrm/ifsar/PR201808-6008-Kahoma.pdf.

Stock, J.D., K.A. Falinksi, T. Callender. 2016. *Reconnaissance Sediment Budget for Selected Watersheds of West Maui, Hawaiʻl*. U.S. Geological Survey Open-File Report 2015–1190. http://www.dx.doi.org/10.3133/ofr20151190.

Stock, J., and C. Cerovski-Darriau. 2021. *Sediment Budget for Watersheds of West Maui, Hawaiʻi*. U.S. Geological Survey Scientific Investigations Report 2020–5133.

Storlazzi, C.D., O.M. Cheriton, K.M. Cronin, L.H. van der Heijden, G. Winter, K.J. Rosenberger, J.B. Logan, and R.T. McCall. 2023. *Observations of coastal circulation, waves, and sediment transport along West Maui, Hawaiʻi (November 2017–March 2018), and modeling effects of potential watershed restoration on decreasing sediment loads to adjacent coral reefs*. Open-File Report 2022-1121. U.S. Geological Survey, Reston, VA.

Stover, H., J.J. James, and W. Silver. 2018. *Compost on Rangeland*. University of California, Agriculture and Natural Resources, Davis, CA.

TNC (The Nature Conservancy of Hawai`i) and the East Moloka`I Watershed Partnership. 2019. *Alternative Watershed-Based Plan for the Kawela Watershed, Moloka`I, Hawai`i*. Prepared for the State of Hawai`i Department of Health.

Trask, H. 2010. *The Struggle for Hawaiian Sovereignty – Introduction*. Cultural Survival.

UH News (University of Hawaiʻi News). 2020. *UH Team to Develop Wildfire Risk System*. https://www.hawaii.edu/news/2020/09/22/wildfire-risk-system/.

U.S. Census Bureau. 2022a. *American Community Survey (ACS), Narrative Profiles: 2018-2022 ACS 5-Year Narrative Profile Lāhainā CDP, Hawaiʻi.* https://www.census.gov/acs/www/data/data-tables-and-tools/narrative-profiles/2022/report.php?geotype=place&state=15&place=42950.

U.S. Census Bureau. 2022b. *Lāhainā CDP, Hawaiʻi QuickFacts.* https://www.census.gov/quickfacts/fact/table/lahainacdphawaii/PST045224.

U.S. Census Bureau. 2022c. *Lāhainā, Hawaiʻi Decennial Census.* https://data.census.gov/table/DECENNIALPL2020.P1?q=lahaina.

U.S. Climate Data. 2025. *Climate Lāhainā – Hawaiʻi.* https://www.usclimatedata.com/climate/lahaina/hawaii/united-states/ushi0055.

USACE (U.S. Army Corps of Engineers). 2023. *West Maui Watershed Study*. USACE, West Maui, HI.

USDA (U.S. Department of Agriculture). 2022a. *Land Resource Regions and Major Land Resource Areas of the United States, the Caribbean, and the Pacific Basin: United States Department of Agriculture, Agriculture Handbook 296*. https://www.nrcs.usda.gov/sites/default/files/2022-10/AgHandbook296_text_low-res.pdf

USDA (U.S. Department of Agriculture). 2022b. *Major Land Resource Areas (MLRA) Geographic Database, version 5.2*. https://catalog.data.gov/dataset/major-land-resource-areas-mlra.

USDA (U.S. Department of Agriculture). 2023. *ESF4 Burned Area Emergency Response Assessment Technical Report. Hawaiʻi Wildfires*. CA-FE9-000005.

USDA Forest Service (U.S. Department of Agriculture Forest Service). 2025. *Wildfire Risk to Communities*. https://wildfirerisk.org/.

USGS (U.S. Geological Survey). 2018. *The National Elevation Dataset*. https://www.usgs.gov/publications/national-elevation-dataset.

USGS (U.S. Geological Survey). 2019. *The National Water Information System (NWIS) Mapper*. https://www.usgs.gov/tools/national-water-information-system-nwis-mapper.

USGS (U.S. Geological Survey). 2025. *USGS Water Data for the Nation*. http://waterdata.usgs.gov/nwis/.

Yang, F., G.L. Zhang, J.L. Yang, D.C. Li, Y.G. Zhao, F. Liu, R.M. Yang, and F. Yang. 2014. Organic matter controls of soil water retention in an alpine grassland and its significance for hydrological processes. *Journal of Hydrology* 519:3086–3093.

Zhu, X., W. Liu, J. Chen, L. Bruijnzeel, Z. Mao, X. Yang, R. Cardinael, F. Meng, R. Sidle, S. Seitz, and V. Nair. 2020. *Reductions in water, soil and nutrient losses and pesticide pollution in agroforestry practices: a review of evidence and processes*. *Plant and Soil* 453:45–86.